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BALLISTICALLY OPERATED WATER CANNON

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AAI Corporation

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A test program was conducted to determine and document the water pulse performance characteristics of the Portable Pumping System (P.P.S.) and the Ballistically-Actuated Water Cannon (B.W.C.). Dynamic testing utilizing a pendulum, physiological testing using animal targets, accuracy test against still and moving targets and impact type tests utilizing targets which simulated human motive characteristics were conducted to determine the terminal energy and hazard of the water pulse as a function of range.

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20. ABSTRACT CON'T

The performance characteristics of the water pulse as a function of range for total energy at impact, velocity, area of impact, dangerous and innocuous effects to humans were determined and documented.

SUMMARY

Target impact energy, accuracy, simulated man knockdown and physiological testing was conducted to determine the impact energy and hazard of the water pulse projected by the Portable Pumping System and the Ballistically-Actuated Water Cannon.

The energy test results indicate that the 2.9 gallon water pulse of the Portable Pumping System at all ranges imparts more energy to a 4 feet x 5 feet target than the Ballistically-Actuated Water Cannon. However, against man size targets, the Ballistically-Actuated Water Cannon is more effective. The firing accuracy of both units appeared to be acceptable for non-moving targets. For moving targets the Portable Pumping System test data appeared satisfactory and the Ballistically-Actuated Water Cannon was not tested.

With regard to knockdown target performance, both units were about equal in that they consistently upset the man simulated target at all ranges out to 70 feet.

The physiological damage assessment, with regard to the hazard of the water pulse, is that from the standpoint of a direct water impact on a human body, the resultant physiological damage is range independent up to the range tested - 45 feet.

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PREFACE

A ballistically-operated water cannon intended for evaluation as an aid in riot control was developed by the AAI Corporation for the US Army Land Warfare Laboratory under Contract No. DAAD05-72-C-0153.[1] Concurrent with development of the Ballistically-Operated Water Cannon, a portable pumping system, also intended for evaluation as an aid in riot control, was developed by LWL.[2] Under a modification to the contract, AAI conducted a testing program to determine the performance characteristics of the Portable Pumping System and the Ballistically-Operated Water Cannon. This Technical Report, prepared by AAI Corporation under the terms of the contract modification, describes and documents the results of the test program, and provides a record of the performance characteristics of the two riot control systems.

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[1] Ballistically Operated Water Cannon, Technical Report No. LWL-CR-04M72, prepared by AAI Corporation for USA Land Warfare Laboratory, March 1974.

[2] Portable Pumping System, Technical Report No. 74-22, USA Land Warfare Laboratory, May 1974.

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I. INTRODUCTION

This report covers the test of two riot control devices, a Ballistically-Actuated Water Cannon and a Portable Pumping System. The purpose of the test was to determine and document the performance of the above units with regard to the hazard and terminal effectiveness of the water output from these devices impacting on a target. The test approach that was used for this performance determination, consisted of designing and conducting a series of tests that would yield sufficient and pertinent data in the following areas of inquiry to permit a meaningful overall evaluation of the units.

- Energy (PPS and BWC)

  Utilizing pendulum type target tests, determine impact conditions of water output as a function of range, where impact conditions include area impacted, velocity at impact, total energy at impact and energy concentration over the impacted area. The purpose of these tests were to derive test data that could be utilized to establish the regions of dangerous and innocuous effects to humans.

- Correlation of Impact Energy with Physical Effect on Man-Simulated Target (PPS and BWC)

  Conduct dynamic tests against mock-ups simulating the weight, balance and surface friction of humans to establish stopping and knockdown capabilities of the output water.

- Accuracy (PPS and BWC)

  Utilizing man-silhouette type targets, conduct a series of accuracy tests to determine first and subsequent round accuracy for the water output. The tests were varied over range and some moving targets were used.

- Physiology (PPS)

  Conduct a series of impact tests with animal targets to verify with some precision the change in hazard as a function of range as the animal is moved from the dangerous region to the region of innocuous effects. These tests were conducted with Government furnished facilities at Aberdeen Proving Ground, Maryland. This report contains a description of the test items, the test and test findings, the assessment of effectiveness and the conclusions.

II. DESCRIPTION OF THE TEST ITEMS

A. Ballistically Actuated Water Cannon

1. Description of Unit

The Ballistically Actuated Water Cannon as shown in Figures 1 and 2 is a cartridge actuated water pumping device that was designed primarily for a truck installation. It can be operated and fired by a single operator and has the per shot capability of projecting (pumping) 1.5 gallons of water through a 1.375 inch diameter nozzle at a muzzle velocity of 161 fps. The unit is self-contained in that it requires no auxiliary power services other than the cartridge for operation and all firing and operating controls are located conveniently to the operator.

Essentially, the Ballistically Actuated Water Cannon as shown in Figure 1 consists of the following major assemblies.

- Water Expulsion Cylinder/Hot Gas Chamber

This assembly is essentially a pneumatic/hydraulic linear actuator consisting of two different size cylinders integrally mounted in series with the pistons of both cylinders mounted to a common shaft. The configuration of the cylinders provides this device with the capability of reducing a given input pressure (1800 psi - hot gas) in the 2.5-inch diameter hot gas chamber to the desired output pressure (175 psi-water) in the water expulsion cylinder. The water expulsion cylinder contains the two primary vent valves which have to be opened during the priming sequence to permit the air in the system to be removed during water fill.

- Receiver Assembly

The receiver assembly is mounted in series with the hot gas chamber and utilizes the housing and action from a 12-gauge Ithaca pump shotgun action for the firing chamber and the cartridge feed and ejection mechanism.

- Trunnion Assembly

This assembly is a universal type hydraulic trunnion which is utilized for mounting the cannon to its support structure and enables the cannon to be manually aimed and controlled in azimuth and elevation.

- Nozzle Assembly

The Stand nozzle assembly which consists of nozzle, flow straightener and nozzle control valve is mounted in series with the water expulsion cylinder and provides the orifice for determining the diameter of the water pulse. During this test program, the nozzle control valve (for automatic operation) was removed to prevent inadvertent interruption

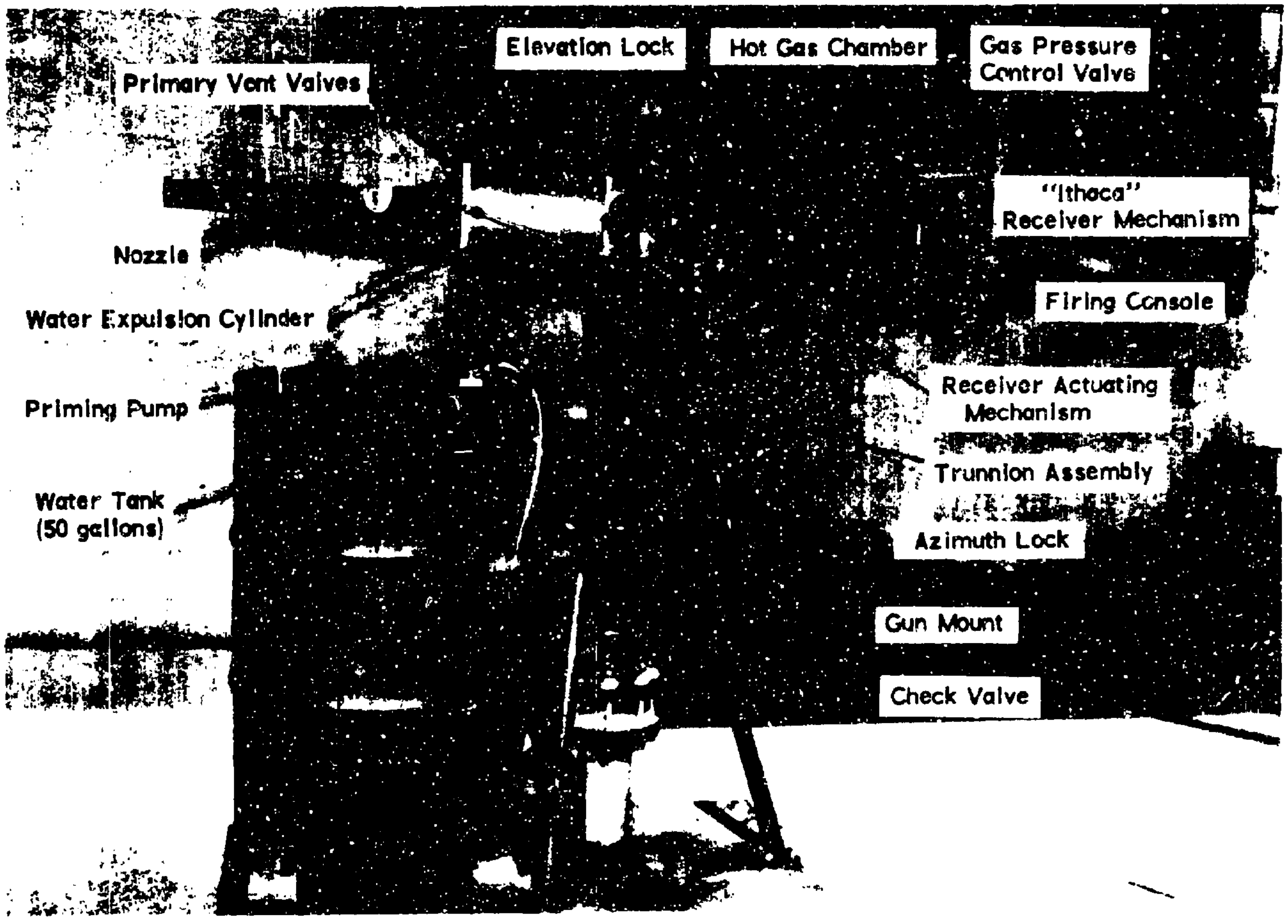


FIGURE 1. BALLISTIC WATER CANNON - SIDE VIEW

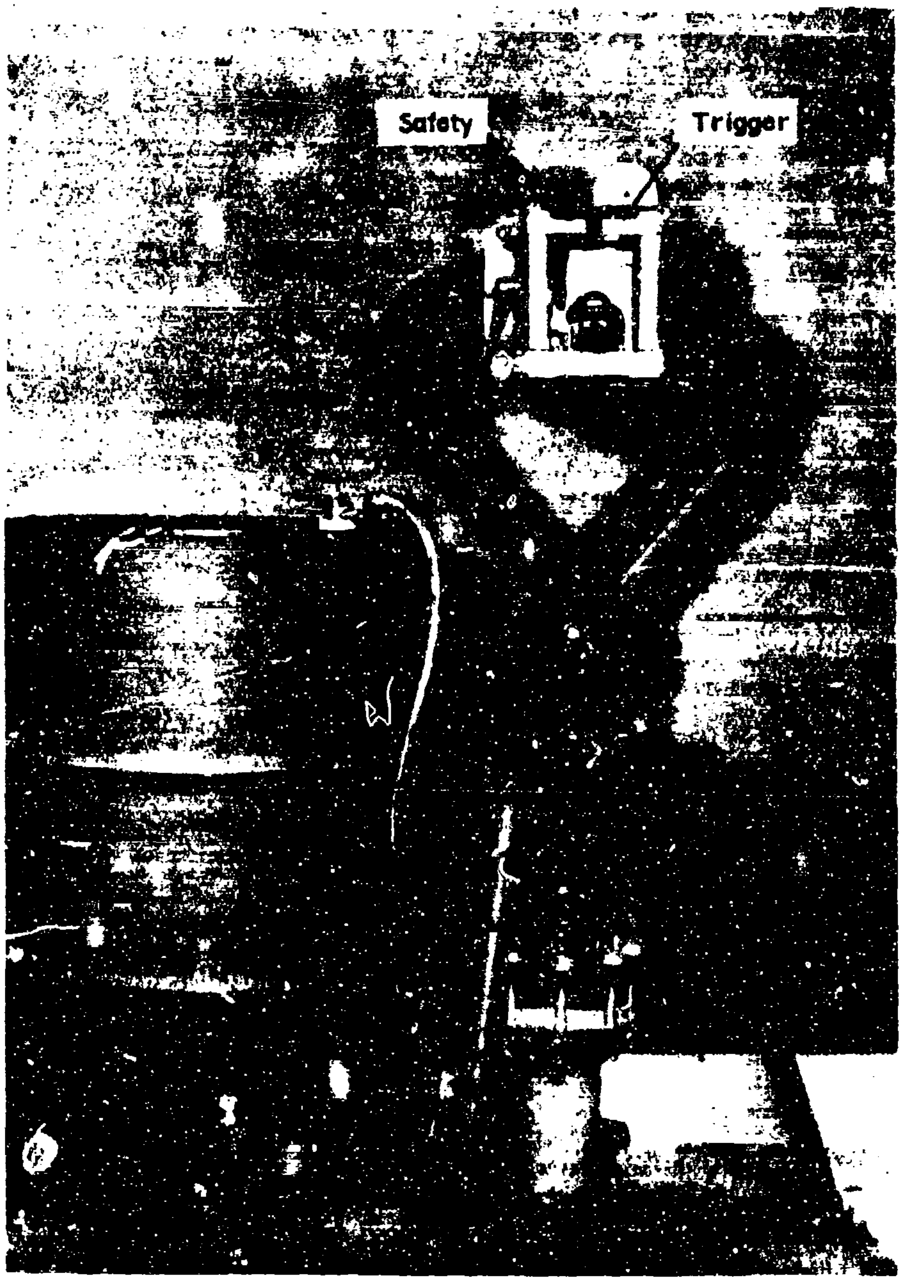


FIGURE 2. BALLISTIC WATER CANNON - REAR VIEW

of the water pulse. The removal of this valve required the use of a cylindrical aluminum plug which was fastened internally in the end of the nozzle with .032 inch diameter shear pins to act as a water stopper. This improvisation required the unit to be operated in the single shot mode and was used to prevent water flowing from the cannon while preparing to fire and during firing to provide the necessary hydraulic restraint for an efficient cartridge ignition.

- Water Tank

The water tank is a 50-gallon drum that is interconnected in series to the piping and check valve of the water cannon mount. Mounted internally on the side of the tank is a priming pump which during the test was used for filling the cannon with water for each firing.

- Cartridge

The Olin gas cartridge is a standard percussion fired 12-gauge shot gun case with primer which houses the slow burning propellant grain. The hot gaseous output of this cartridge provides the primary motive energy for the operation of the water cannon.

2. Operation of Unit

The unit was designed to be magazine fed and to operate in either the single shot or semi-automatic firing mode. During this test program, however, only the single shot mode which is described below was employed because of difficulties experienced with the nozzle control valve.

- Water Fill

The firing of the water cannon without the nozzle control valve installed requires the use of a plug or stopper in the nozzle and the refilling of the cannon after each firing. During this test a cylindrical plug with an "O" ring installed on the periphery was mounted in the nozzle and fastened in place with two .040 inch diameter aluminum shear pins. One end of a ten-foot flexible cord lanyard was connected to the plug and the other end attached to the cannon to prevent the plug from traveling down range during the firing of the cannon. With the plug installed and the water tank full, the water fill sequence is as follows:

- After aiming the unit, tighten locks in both azimuth and elevation.

- Open both air vent valves on the water expulsion cylinder to permit air to bleed from the system during water fill.

- Open globe valve which is located between priming pump output and main piping to cannon.

- Stroke priming pump until water pours from vent valves which indicates unit is full.

- Close vent valve and globe valve.

- Retract firing mechanism until it is locked in the open bolt position and place the safety of the finger trigger in the "safe" position.

- Insert cartridge into firing chamber.

- When ready to fire, place the safety in the "fire" position and pull the firing lanyard which fires the device.

B. Portable Pumping System

1. Description of Unit

The Portable pumping System shown in Figure 3 is an integral skid mounted pumping system which can be mounted in the cargo bed of a military truck. It is operated and controlled by two operators and can be actuated in a continuous stream of water firing mode or a pulsed water firing mode. The water flow rate of both modes can be varied by changing the nozzle size and the output water pressure at the pump. The water gun is the primary unit for disbursing the water. It is mounted on a platform over the engine and pumps and provides complete 360-degree rotation in azimuth as well as vertical up and down travel. An electronically controlled ball type valve is located at the tip of the gun and provides the operator with the capability of firing continuous stream water or of firing water pulses of various lengths. Through a trigger and controls, the operator has either a manual or an automated ON and OFF sequence control of the valve. The unit is self contained in that it requires no auxiliary power services other than the gasoline or battery for the internal combustion engine which drives the centrifugal type water pump.

The skid mounted pumping system shown in Figure 4 is 120 inches long, 82 inches wide and approximately 72 inches high to the top of the boarding ladder. It consists of a skid and a structural frame which provides the mounting provisions for the following primary components.

- Pump and Engine

The pump is a centrifugal type, single stage with a single suction impeller. A Ford 250 cubic inch, six cylinder industrial engine provides power for the pump.

- Water Tank

An 800-gallon capacity, steel tank of welded construction is the largest component. The inside and outside of the tank is coated with epoxy for rust prevention. A screened 6" fill stack is located in the left hand front corner. An overflow pipe is located in the center rear as a safety precaution in case of overfilling.

Figure 3. Portable Pumping System

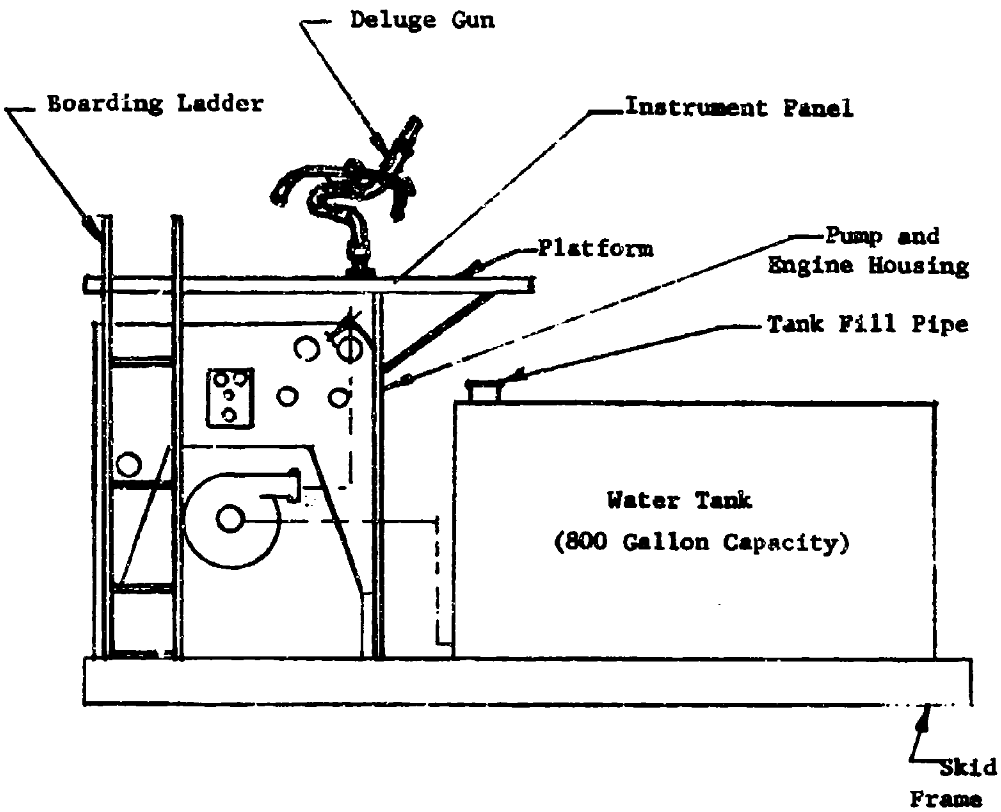


Figure 4. Skid Mounted Portable Pumping System

- o <u>Priming System</u>

This system is used to prime the main pump when operating from draft. It consists of an electric motor driven positive displacement pump connected to the main pump suction through a hand operated priming valve. A primer tank oil reservoir completes the system.

- o <u>Instrument panel and controls</u>

All gauges and engine controls are mounted on the face of the engine housing.

- o <u>Platform</u>

The platform is mounted directly over the pump and engine compartment. It is used to support the man operating the deluge gun and related equipment. Access to the platform is provided by the boarding ladder.

- o <u>Deluge gun</u>

The deluge gun is the primary piece of apparatus used to disburse the water. It is mounted on the platform and provides complete 360 degree rotation as well as vertical up and down travel through a bicycle type handle bar control.

- o <u>Automatic shut-off valve and control</u>

An electronically controlled ball type shut off valve is located at the tip of the deluge gun and provides the operator with the capability of firing water pulses of various lengths. Through a trigger and controls, the operator has either a manual or an automated on and off sequence control of the valve.

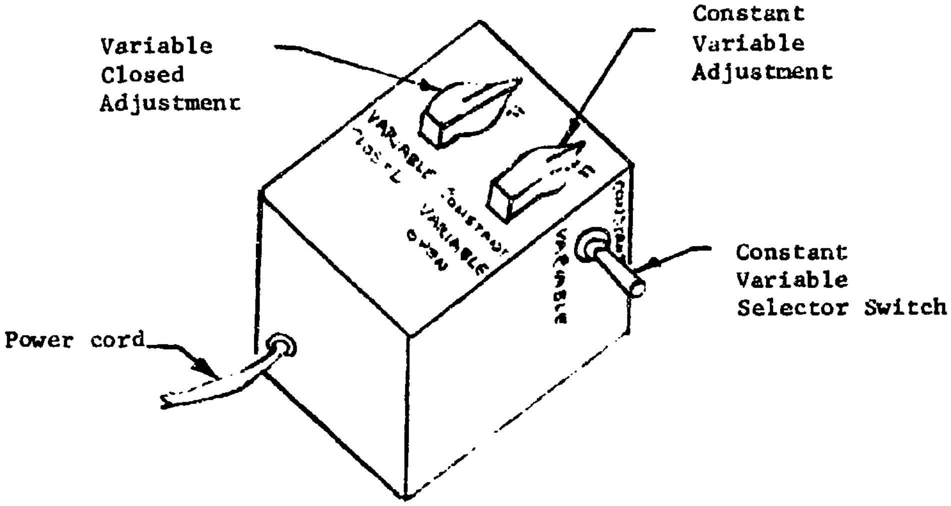
2. <u>Operation of Unit</u>

When the pumping unit has been primed, started and the desired pump pressure reached, the deluge gun is ready for operation. The entire discharge line is now pressurized to the ball valve at the nozzle. The nozzle valve control mechanism is turned on through the ON-OFF switch located at the handle bar mounted trigger box. The red light indicates the power is ON. With the selector switch in manual - the opening and closing of the valve only responds through the trigger mechanism. A small touch is enough to depress the trigger. As long as the trigger is depressed, the valve stays open. Upon releasing the trigger the valve closes. Through the use of the trigger, the operator has complete control of the firing cycle. With both hands on the handle bar the gun can be aimed at any target desired. A moving target can be followed through the transverse and vertical movement of the deluge gun. To switch the operation to a completely automated cycle, the selector switch located at the trigger box is set to the automatic position (up). The switching can be made at any time during the cycle without damaging any components.

As described earlier, the operator has a choice of either operating the automatic cycle in a constant sequence or a variable on-off relationship cycle through the selector switch located at the master control box. To turn the nozzle off for shutdown, switch the system to the manual operation. This automatically closes the valve. Always leave the switch in the manual operation during the shutdown period.

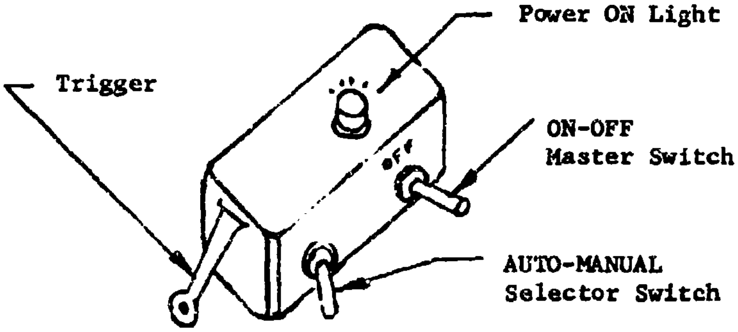
Operation of Gun Control Valve

To make the operation of the deluge gun serve similar to a water cannon, an electronically controlled ball valve shutoff system has been designed for this unit. The primary components are the motor and gear mechanism at the nozzle tip, the main frequency cycle control box, and the trigger switch box.



Master Control Box

The operator can select either a complete manual trigger actuated system or an automated frequency controlled cycle to turn the ball valve on and off. The automatic cycle further provides options of a constant or variable sequence frequency operation through selector and adjustable switches and controls. Each system is described in the following paragraphs.



Trigger and Switch Box

The preceding figure shows the trigger and switch box. This box is located on the handle bar control near the right grip. Two toggle switches appear on the side of the box. One is the master power ON and OFF switch. The light on top of the box indicates red when the power is ON. The second switch is the auto-manual selector switch. The down position places the system in a manual operation. Depressing the trigger down opens the valve. The valve remains open as long as the trigger is depressed. Upon releasing the trigger, the valve automatically closes. Through this control, the operator can open and close the valve at his discretion.

The up position of the selector switch places the system in the automatic cycle sequence of opening and closing the valve. The valve at the nozzle tip automatically closes and opens on a preset cycle as determined by the frequency setting on the master control box.

The master control box is located at the deluge nozzle strapped to the pipe elbow to rotate with the gun. The heart of the electronic system is located in this box. The two knobs on the front face of the box are the frequency cycle controls while the selector switch located in the side of the box lets the operator choose the mode of automation he desires. The automatic options available are as follows:

Constant frequency control - Placing the constant - variable switch in the constant position (up) switches the automatic control of the valve operation to a constant frequency of opening and closing cycles. That is, the open duration of time of the valve is the same as the closed duration. The cycle cycle of opening and closing continues at the rate set on the constant -

variable adjustment control. Turning the control adjustment clockwise speeds up the frequency rate of opening and closing - that is the valve opens and closes more times per minute automatically. Turning the adjustment counter clockwise slows down the frequency of opening and closing. Keep in mind that a constant frequency (open time is the same as the closed time) is only regulated by this control, hence the name constant.

Variable frequency control - While the selector switch is in the Constant (up) position, the variable closed time adjustment is not in the circuit, therefore, it is not functioning. Only the constant-variable adjustment provides the control stated above. When the selector switch is placed in the variable position (down) the variable closed time adjustment is activated providing one more option for the operator. The operator, through the adjustment of both controls now has the option of controlling the duration of open time of the valve as well as the closed time. The open time can be made longer or shorter than the closed time, depending on the adjustable switch positions. Each adjustment control is marked S for SHORT and L for LONG - The variable closed time control permits adjustments between long and short periods of valve closed time - while the variable open time adjustment allows the operator to select periods of valve open time. The maximum closed time with minimum of open valve time occurs with variable open time control in the S (short) position while the variable closed time adjustment is in the extreme L (long) position. Conversely, the maximum open time occurs when the variable open control is set in the L (long) position and the variable closed time control is in the S (short) position. Adjustment between these two extreme settings allows the operator a wide latitude of ON - OFF relationships. With experimentation, the operator can select the best sequence producing the maximum desired effect.

III. DESCRIPTION OF THE TEST

A. Test Objectives

The overall objective of the test was to determine and document the waterpulse performance characteristics of the Portable Pumping System and the Ballistically Actuated Water Cannon. The detail test objectives included the following determinations.

1. Area of impact as a function of range.
2. Velocity of impact as a function of range.
3. Total energy at impact as a function of range.
4. Impact force as a function of range.
5. Dangerous and innocuous effects to humans as a function of range.
6. Accuracy of first and subsequent water slug bursts as a function of range, on both fixed and moving targets.
7. Stopping and knockdown capabilities as a function of range, using mock-up targets which simulate weight, balance and surface friction of humans.
8. Lethality to animal targets as a function of range, and the change in hazard as a function of range, when the animal target is moved from the dangerous region to the region of innocuous effects.

B. Test Theory and Principles Involved

The principle device used to gather data in this test was a vertically hung pendulum. This pendulum had a plywood face normal to the water stream and a parallelogram suspension such that this face remained normal to the stream when the pendulum swung about its pivot. Water impinging on the flat face will change velocity and therefore momentum, transferring the change in momentum to the pendulum. The momentum transfer, neglecting energy lost in destroying the impact face of the target, changed the momentum of the pendulum, giving it a rearward velocity. Since the suspension of the pendulum constrained it to follow a circular path, the rearward velocity caused the mass of the pendulum to rise. The pendulum rises, continuously changing the kinetic energy imparted to it by the water to gravitational potential energy. The change in gravitational potential is quite easy to obtain by measuring the stroke of the pendulum and through the geometry of the pendulum, calculating the change in vertical height. It is assumed in this system that there is sufficient friction so that a light pendulum follower will not grossly overshoot the end of the pendulum swing but an amount insufficient to dissipate a significant amount of energy.

The order of magnitude of the energy loss to aerodynamic drag may be assessed analytically. An accepted drag coefficient for flat plates at low velocity is 1.0. Using the 4-foot by 5-foot target face area and a velocity of 3 in/sec, a force of 1.2 pounds is obtained. A conservative approach is to assume that this force decreases linearly throughout the stroke of 12 inches and therefore the energy dissipated is 1/2 x 1.2 x 12 = 7.2 in./lb., or 0.6 ft/lbs. Since a stroke of twelve inches is equivalent to 40.2 ft/lbs, the aerodynamic friction loss is negligible.

A pendulum weight of approximately 450 pounds was chosen to keep the pendulum swing within the physical bounds of the support frame. For direct comparison of the two water cannon systems under study this pendulum is satisfactory. However, it was quite obvious that the energy transfer information derived from the tests with the 450 pound pendulum would not apply directly to the energy transferred by the same water pulse to swine in the medical tests. This is due primarily to the large mass differential. It was therefore determined that the forces acting on the pendulum would be analyzed and a computer program would be written which could be used as a tool to determine the effect of pendulum mass on the amount of energy transferred during the impact of a pulse of water.

The following schematic, shown in Figure 5 is a free body representation of the test pendulum.

There are four basic equations which completely define this system, namely the three equations of dynamic equilibrium consisting of the sum of the forces in the X and Y directions and the sum of the moments in the X-Y plane and a fourth equation describing the geometric displacement path. This will yield the following set of four equations in five unknowns:

Free Body Representation of Test Pendulum

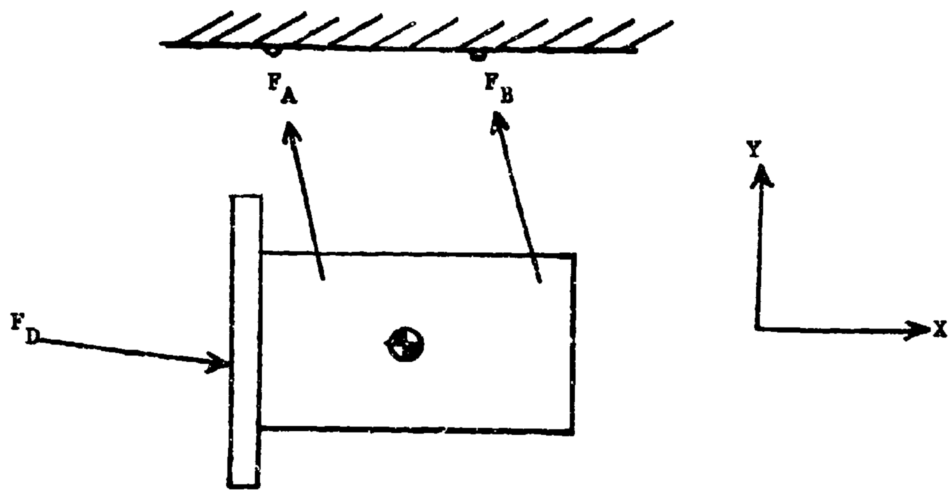


Figure 5. Test Pendulum

$$B(1) = A(1,1)\ \ddot{X} + A\ (1,2)\ \ddot{Y} + A(1,3)\ F_A + A(1,4)F_D + A(1,5)F_B$$

$$\vdots$$

$$B(4) = A(4,1)\ \ddot{X} + A\ (4,2)\ \ddot{Y} + A\ (4,3)\ F_A + A\ (4,4)F_D + A(4,5)F_B$$

Using the above system of equations, if any one of the unknown forces or displacements can be determined experimentally or can be approximated, the remaining forces and displacements can be calculated. The above set of equations have been programmed for two solutions, The first solution assumes the X displacement is known and solves for Y displacement and all the forces. This solution is used for the 450 pound pendulum where the displacement is known and it is desirable to know the forces acting on the pendulum. The second solution assumes the impact force of the water, F_D, is known and the remaining forces and displacements are calculated. This solution can be used to predict the resulting displacement vs. time for variations in pendulum mass or geometry by estimating the force on the pendulum based on test results combined with the results from solution one.

The force of the water impacting the pendulum is defined using the principle of impulse and momentum,

$$F_D = \frac{\dot{w}}{g}\ (V_1 - V_2)$$

where: $\dot{w}/g$ = mass rate of flow
V_1 = water velocity before impact
V_2 = water velocity after impact (assumed equal to pendulum velocity based on movies of the impact)

From this equation it can readily be deduced that as long as the velocity of the pendulum is small compared to the velocity of the water stream the force on the pendulum for a given water pulse will for all practical purposes be independent of the physical characteristics of the pendulum. The same statement cannot however be made for energy transfer.

In summary, two computer programs were written. The first program was used in conjunction with experimentally determined displacement vs. time for a particular water pulse and pendulum to give the impact force of the water. Since, as described in the preceding paragraph, the impact force does not change appreciably for changes in the physical characteristics of the pendulum, the forces from this analysis can be used as input to a second program to predict the displacement and therefore the energy of a modified pendulum. Both programs output the energy transferred to the pendulum as a function of time.

C. Test Instrumentation

1. Pendulum Test Fixture - The test fixture shown in Figure 6 consisted of the pendulum with its attached target, the swine silhouette target, the man silhouette target, witness screen and the various scales and grid board for measuring the pendulum's displacement and acceleration. This fixture was used to determine the kinetic energy imparted to the pendulum by the impacting of the water pulse. The use of the masking shield silhouette target in series with the pendulum provided a method and a test fixture for determining the impact energy of a water pulse impinging on a pendulum that is representative in size to the surface area of a man or a swine.

2. Man area target - This target as shown in Figure 7 is a .5-inch thick plywood sheet and is utilized to assess the energy imparted by a given water pulse impacting on a simulated man. For this test a masking shield mounted independently of the pendulum is utilized which permits only the cross sectional area (highest concentration of energy) of the water pulse corresponding to the silhouette area of a man to impact the pendulum.

3. Swine area target - This target as shown in Figure 8 is a .5-inch thick plywood sheet and is utilized to assess the energy imparted by a given water pulse impacting on a simulated swine. For this test a masking shield mounted independently of the pendulum is utilized which permits only the cross sectional area (highest concentration of energy) of the water pulse corresponding to the silhouette area of a swine to impact the pendulum.

4. Witness Screen - The witness screen shown in Figure 9 is a wire mesh screen mounted in a wood frame and covered with a thin tissue paper. When impacted with a water pulse the fractured area of paper approximately displays the cross section intensity (energy concentration) of the water pulse at time of impact and records the accuracy of the shot.

5. Knockdown Test Fixture - The fixture shown in Figure 10 consists of a man size silhouette target attached to a pendulum type structure that is hinged to a solid base structure. The pendulum type structure simulates the stability (weight, C.G., balance and surface friction) of a man in a normal erect stance.

6. Physiological Test Fixture - The fixture shown in Figure 11 is the Knockdown Test Fixture that has been modified to permit the mounting of the swine in place of the man type silhouette. During the test, this fixture was modified by cutting large slots in the animal/ mounting panel so that the water pulse impinged only on the swine and not on the mounting panel.

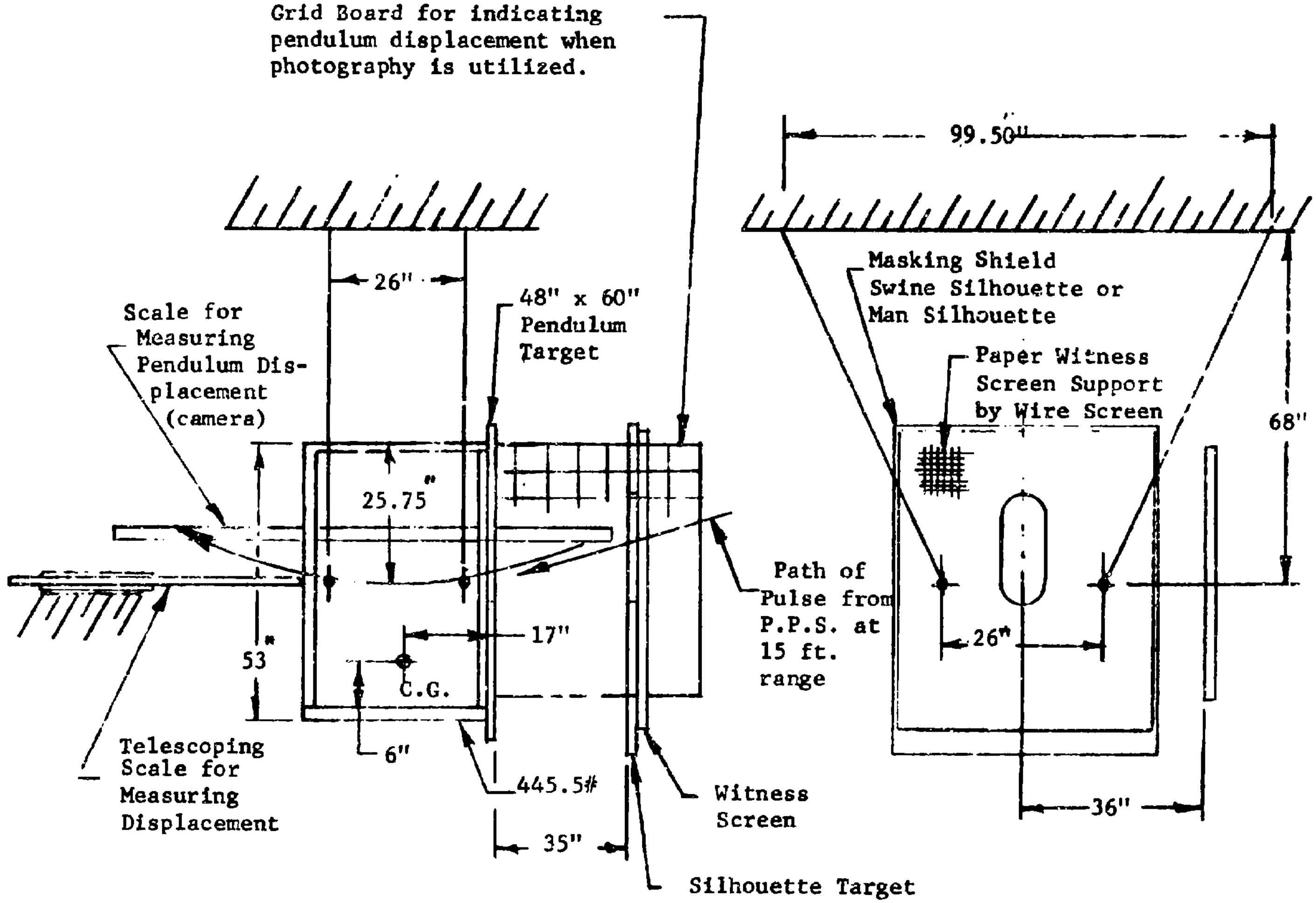


Figure 6. Pendulum Test Fixture

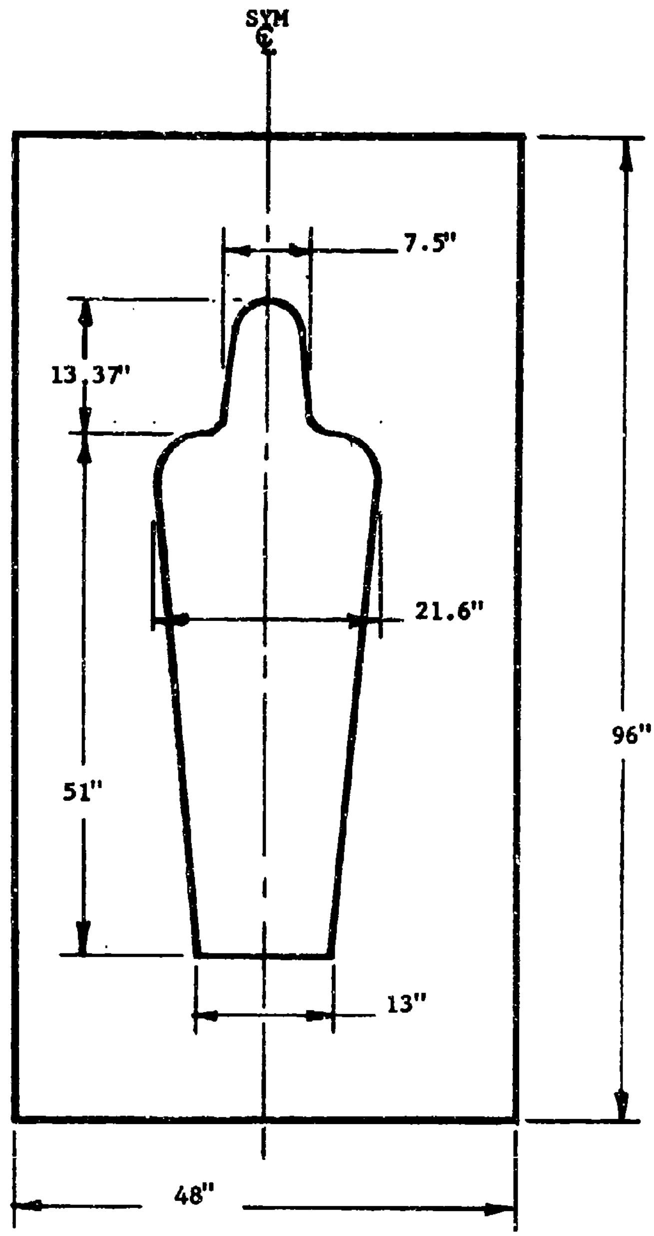


Figure 7. Man Area Target

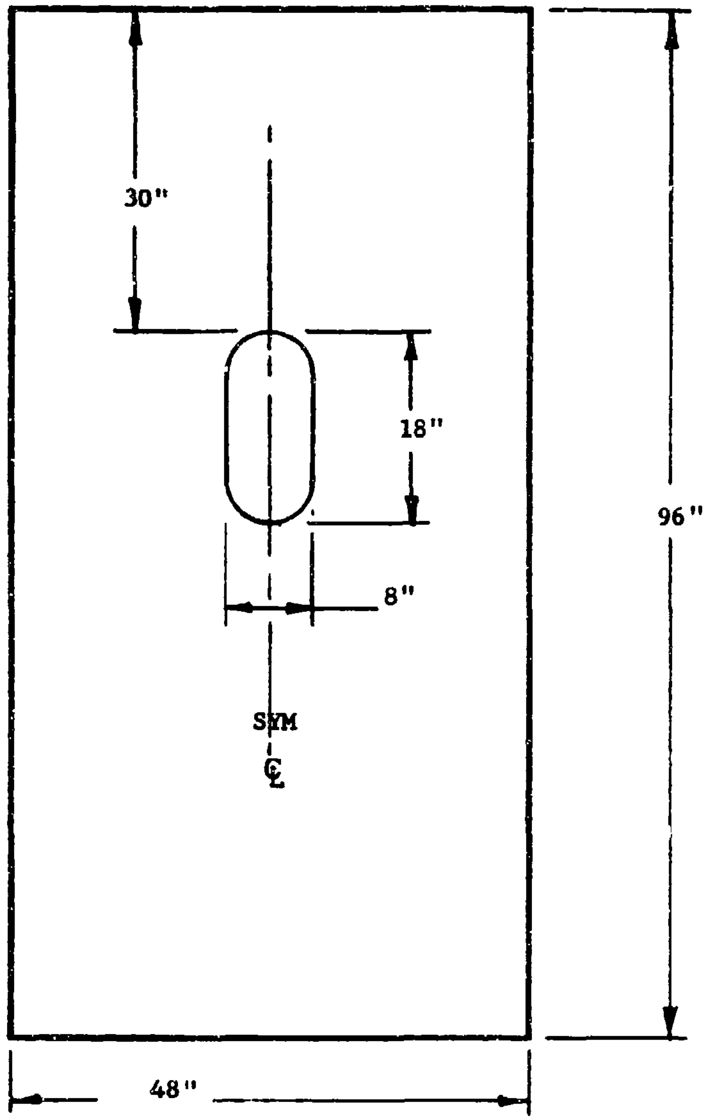


Figure 8. Swine Area Target

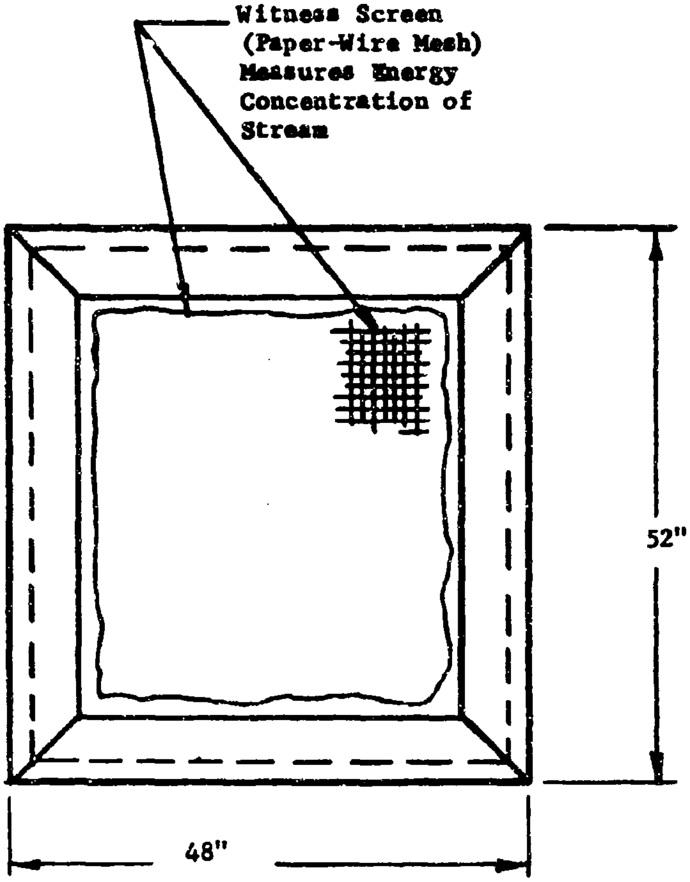


Figure 9. Witness Screen

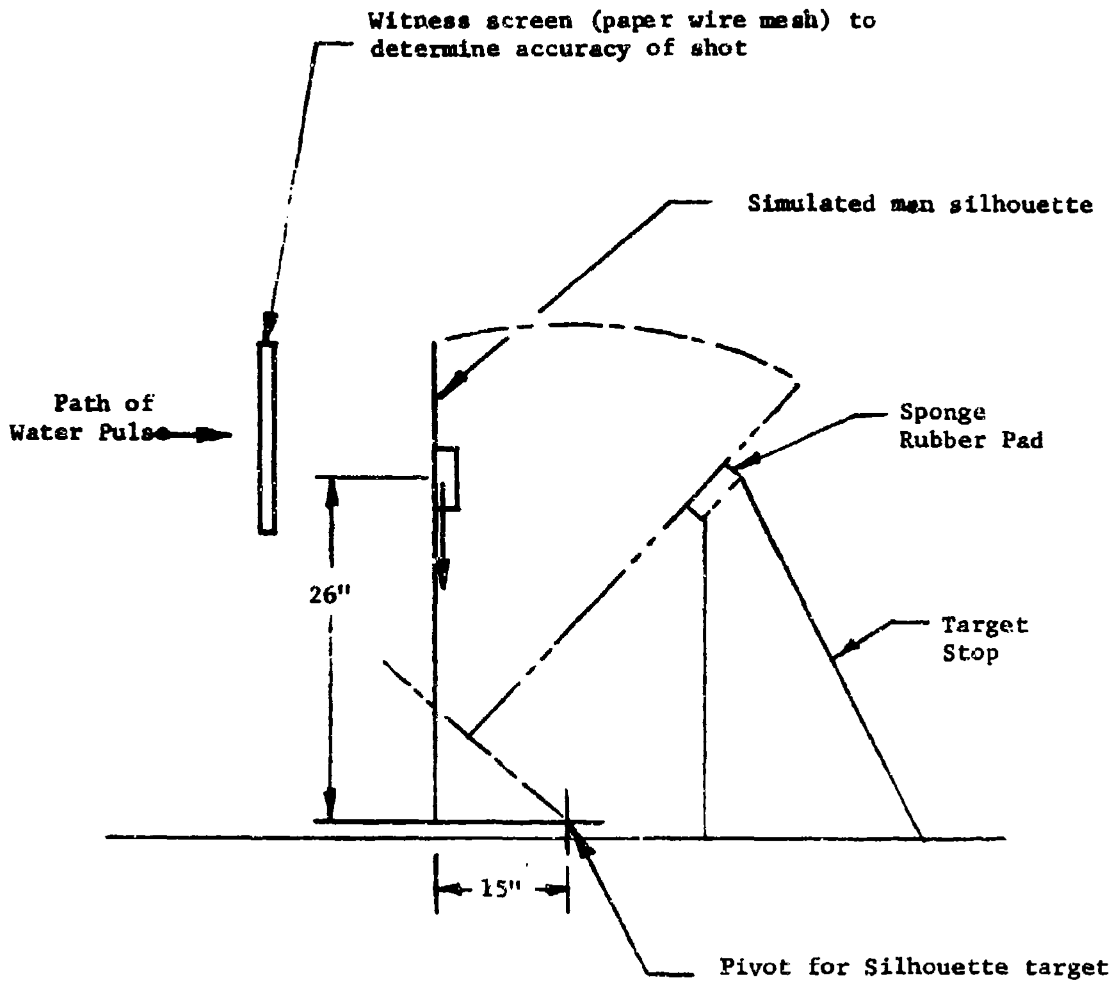


Figure 10. Test Fixture for Correlating Impact Energy with Human Knockdown Capability

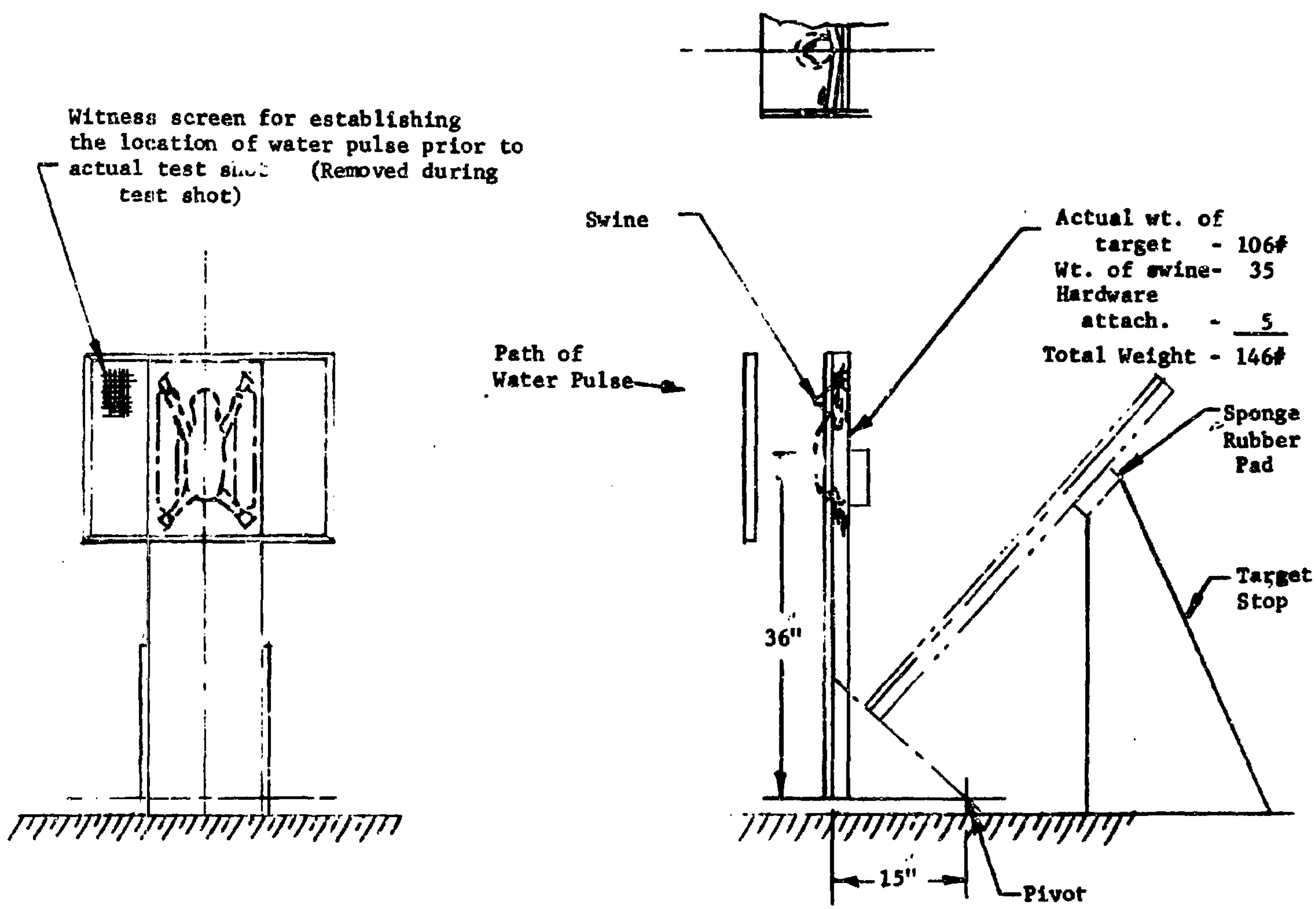


Figure 11. Physiological Test Fixture

D. Test Methods and Procedures

1. General

The test methods and procedures which are described in this section define and comprise the test activity that was performed during this program. Essentially, the test activity consisted of conducting a series of energy, accuracy, target-knockdown and physiological tests to determine the water impact on target performance of the PPS and BWC with respect to the following detail test objectives.

a. Area of impact as a function of range.
b. Velocity of impact as a function of range.
c. Total energy at impact as a function of range.
d. Impact force as a function of range.
e. Dangerous and innocuous effects to humans as a function of range.
f. Accuracy of first and subsequent water slug bursts as a function of range, on both fixed and moving targets.
g. Stopping and knockdown capabilities as a function of range, using mock-up targets which simulate weight, balance and surface friction of humans.
h. Lethality to animal targets as a function of range and the change in hazard as a function of range, when the animal target is moved from the dangerous region to the region of innocuous effects.

The following paragraphs identify the tests and give a description of the methods and procedures that were utilized during the conduct of the test.

2. Energy Test (Portable Pumping System)

o Continuous Stream Firing Mode Test (Approximately 1 minute continuous firing)

Purpose: Determine impact conditions on pendulum shown in Figure 6 as a function of 70-foot range for various combinations of nozzles and pressures in order to expedite selection of candidate nozzle/pressure configuration for pulse testing.

Test Method

With the selected nozzle/pressure configuration, fire a continuous stream of water at 70-foot range as shown in Figure 12 so that it impinges on a given spot long enough to achieve a steady displacement of the target. Measure displacement of pendulum when subjected to the force of the continuous impinging on the pendulum target. In this test no man-swine silhouette targets on witness screens were used.

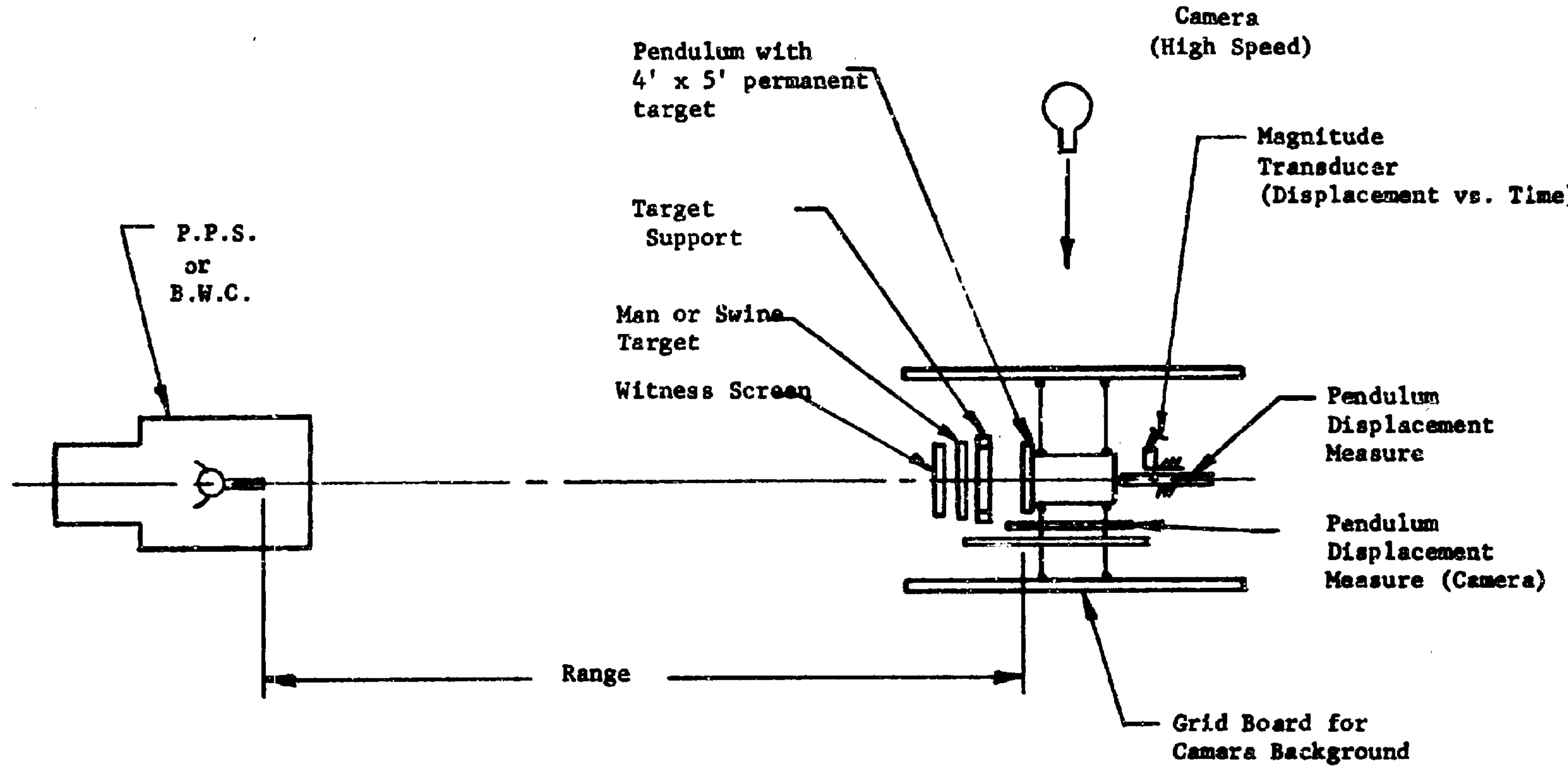


Figure 12.Test and Equipment Layout
for Energy Test

o <u>Pulse Firing Mode - PORTABLE PUMPING SYSTEM</u>

<u>Purpose</u>: To establish the impact conditions produced on various size targets with respect to range when targets are impacted with pulses of water fired from the PPS at various energy levels. The impact data thus derived will be the basis for formulating the physiological test plan and will provide the basic energy performance data for the unit.

<u>Test Method</u>

1. Selection of Optimum Nozzle Size and Pressure

At prescribed ranges conducted a series of firings of water pulses (various intensities and length of burst) from the PPS to impact on the pendulum test fixture shown in Figure 6 in order to select the optimum nozzle/pressure/burst length configuration for further test. The pendulum test fixture was utilized to measure the kinetic energy that was imparted to the pendulum by the impact of the water pulse with the pendulum.

2. Acquisition of Impact Data for the Selected Nozzle Size/Pressure Configuration with Respect to Target (4' x 5'), Man Size Target and Swine Size Target

To provide the desired impact data with respect to target size (man and swine silhouette), masking shields (targets) containing cutout silhouettes of appropriate size were mounted in front of the pendulum which permitted only that portion of the stream defined by the cutout to impact on the pendulum.

During these tests, paper witness screen shown in Figure 9 were mounted directly in front of the pendulum in order to attest to the accuracy of the impact and to provide the area data with regard to energy concentration of the water pulse on the pendulum.

For this test, the impact conditions of the water striking the target/pendulum were defined in terms of pendulum displacement with respect to time for an approximate energy concentration per unit area and for a given target size. This data in turn yielded the following physical characteristics for the impact of the water pulse.

Man or Swine Target Size

1. K.E. imparted to the pendulum
2. Force on the pendulum
3. Impulse on the pendulum
4. Energy concentration per unit area

Large Target (4' x 5')

1. K.E. imparted to the pendulum
2. Force on the pendulum
3. Impulse on the pendulum
4. Energy concentration per unit area

3. Energy Test (BALLISTICALLY ACTUATED WATER CANNON)

Purpose: To establish the impact conditions produced on various size targets with respect to range when targets are impacted with pulses of water fired from the BWC. The impact data thus derived was in part the basis for formulating the physiological test plan and provided the basic performance data for comparing the PPS with the BWC.

Test Method: At prescribed ranges a series of firings of water pulses from the PPS to impact on the pendulum test fixture shown in Figure 6 was conducted. The pendulum test fixture was utilized to measure the kinetic energy of the pulse with respect to time.

During these tests, paper witness screen shown in Figure 9 was mounted directly in front of the pendulum in order to attest to the accuracy of the impact and to provide the area data with regard to energy concentration of the water pulse on the pendulum.

To provide the desired impact data with respect to target size (man and swine silhouette), masking shields (targets) containing cut-out silhouette of proper size were mounted in front of the pendulum which permitted only that portion of the stream defined by the cutout to impact on the pendulum.

For this method, the impact conditions of the water striking the target/pendulum were defined in terms of pendulum displacement with respect to time for an approximate energy concentration per unit area and for a given target size. This data yielded the following physical characteristics for the impact of the water pulse.

Man or Swine Target Size

1. K.E. imparted to the pendulum

2. Force on the pendulum

3. Impulse on the pendulum

4. Energy concentration per unit area

Large Target (4' x 5')

1. K.E. imparted to the pendulum

2. Force on the pendulum

3. Impulse on the pendulum

4. Energy concentration per unit area

4. Tests to Correlate Impact Energy with Physical Effects on Man Simulated Target

o Pulse Firing Mode - P.P.S. and B.W.C.

Purpose: Utilizing the energy impact data derived during the Energy Test, establish against a mock-up simulating the weight, C.G., balance, surface friction of a man, the knockdown capabilities of the water pulse.

Test Method: At prescribed ranges, a series of test firings of single water pulses (selected nozzle/pressure and length of burst) from the P.P.S. to impact at various heights on the simulated man silhouette test fixture shown in Figure 10 was conducted. The test fixture consisted of a silhouette target which simulated the stability (weight, C.G., balance and surface friction) of a man in a normal erect stable stance. The knockdown capability of the water pulse was expressed in terms of range, angle of impact and length of burst with respect to the upsetting of the target from its original position. Witness screens were utilized to assess accuracy and energy concentration.

5. Accuracy Tests

o Pulse Firing Mode - P.P.S. and B.W.C.

Purpose: To determine first and subsequent round accuracy for the water pulse as a function of range and time on target when utilizing a simple iron sight with both systems.

Test Method: At prescribed ranges, a series of accuracy tests to verify the sighting system and to establish the innate repeatability of the systems was conducted. This portion of the accuracy test (Figure 13) consisted of firing a series of 5 water pulses with a rigid gun at a target of set range with witness screens utilized to record the area of impact on the target.

At prescribed ranges and for a 45° gun movement, a series of aimed shots at a knockdown type target (Figure 14) to establish the time and number of shots required to upset the target was conducted.

At prescribed ranges, a series of accuracy tests at a moving target (approximately 10 fps) per Figure 15 , was conducted. Hits were determined by fracturing area of human silhouette on witness screen.

6. Physiological Tests

Purpose: To determine physiological damage produced in the test animals as a function of range and the terminal impact energy derived from the preselected water bursts fired from the Portable Pumping System.

a. To investigate the hazard of the water impact by arranging to provide impact energies of 15, 30 and 90 ft-lb, and in addition to investigate the hazard of impacting the target at the close range of 6.6 feet. The energy levels are used to provide correlation with other hazard studies. This test will consider only the physiological damage involved in water impacting the subject and not secondary damage due to the subject falling or tumbling against a hard surface.

b. Assess physiological damage due to impact of water pulse.

c. Establish estimates of the water pulse's physiological desirable and undesirable effects by medical team.

Test Method

Conducted 20 firings with the Portable Pumping System at ranges of 6.6 feet, 15 feet (90 ft-lbs), 35.5 feet (30 ft-lbs) and 45 feet (15 ft-lbs). For these tests a .75 inch diameter nozzle was used and a nozzle pressure of 300 psi and a 2.90 pm pulse were maintained throughout the tests. In each test the water stream from a single pulse was directed at the test animal (swine). The test subject was harnessed and located in the test fixture shown in Figure 11 which simulates the physical and stability characteristics (CG location, moments and friction) of a man in an erect stable position. The animal was then removed, observed by a veterinarian, after which the animal was sacrificed and a gross necropsy performed. Figure 16 is a photograph of a test firing at 15 feet range.

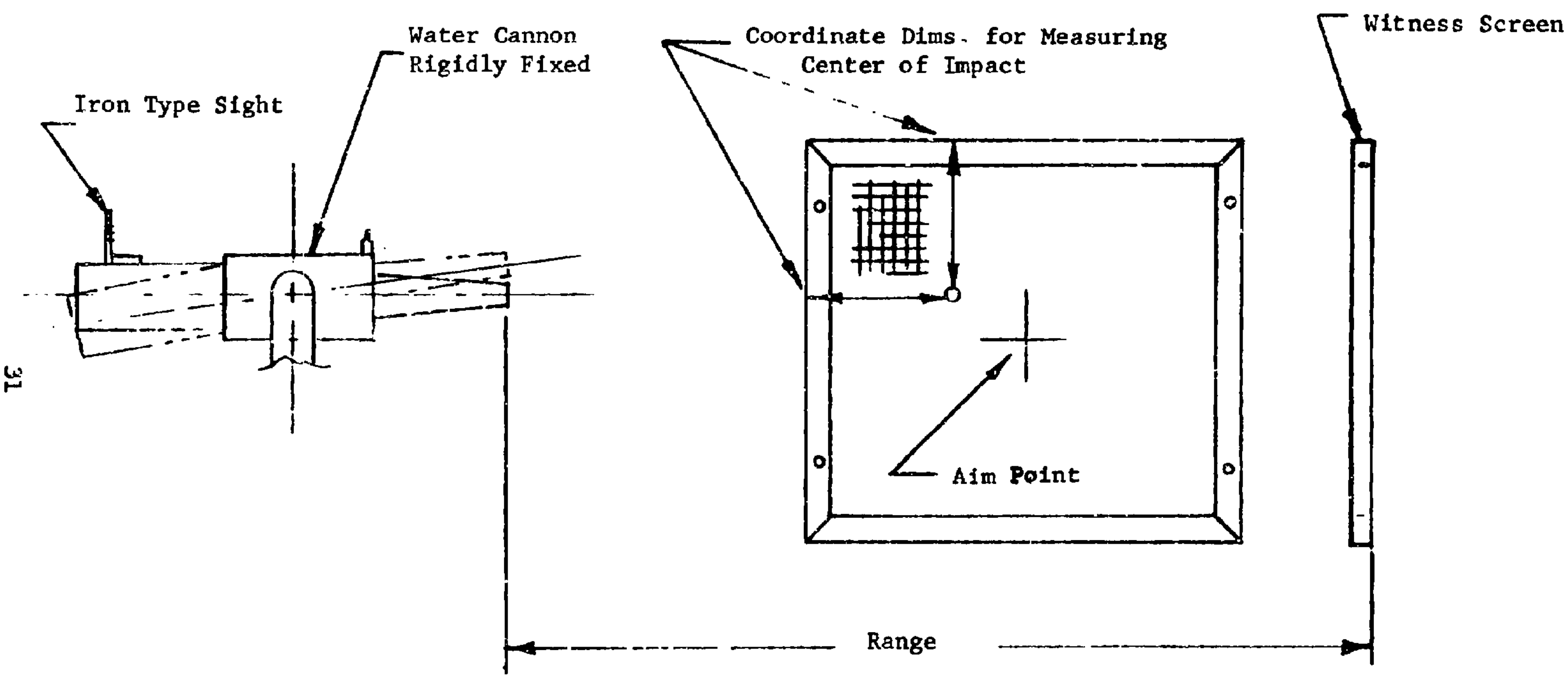


Figure 13. Accuracy Test Fixture to Verify Sights and Establish Repeatability Accuracy of System

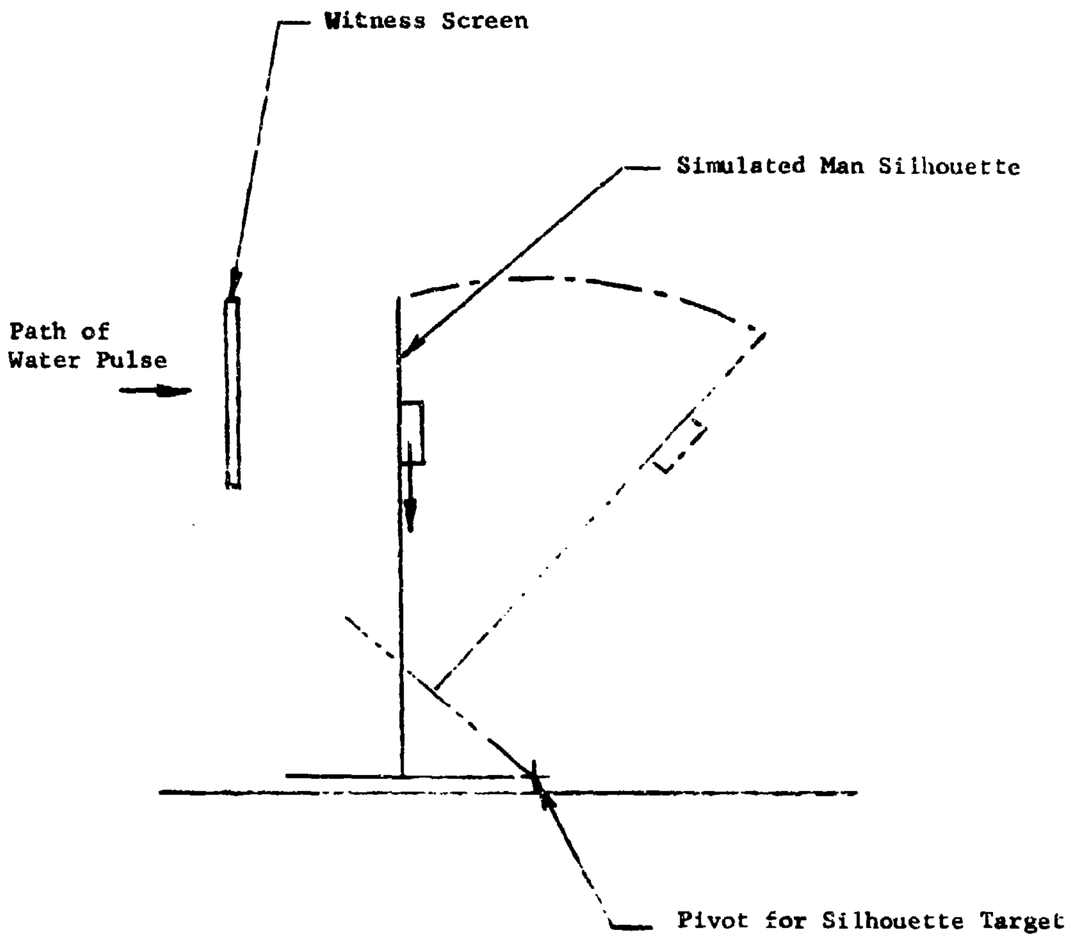


Figure 14. Test Fixture for Accuracy Test
(Knockdown Target)

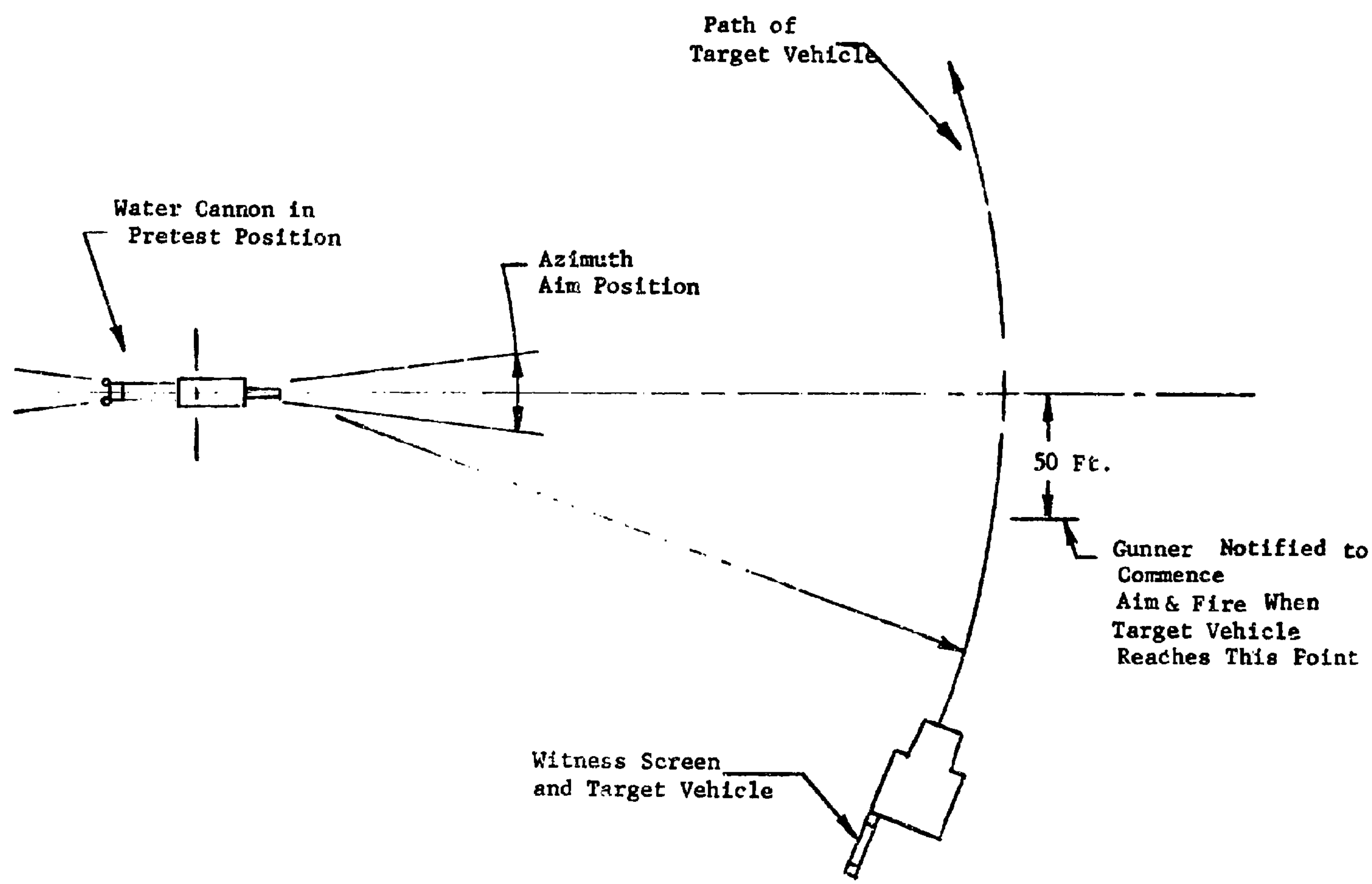


Figure 15. Accuracy Test with Moving Target

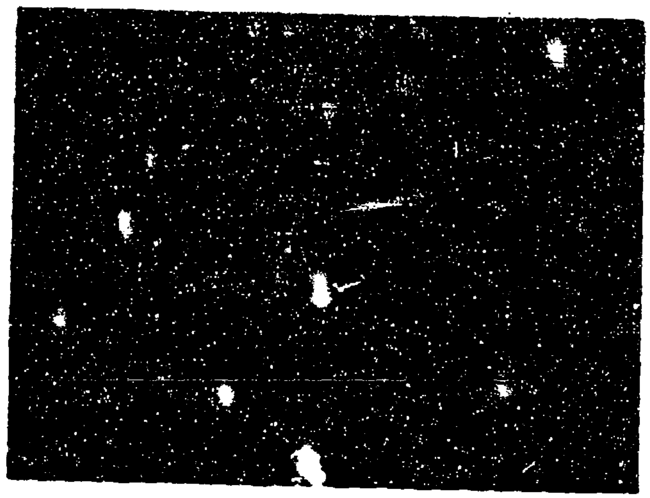


Figure 16. Water Pulse Impacting Swine
Range - 15 Feet

Physical Test Data Taken

1. Physical characteristics of water cannon's impact energy for each test shot.

   a. Nozzle size

   b. Pressure (static) and nozzle

   c. Volume of water pulse (time)

   d. Range and energy level

2. Photograph (still) of animal in test harness after test. (Test No. for identification).

3. Camera coverage of test (high speed or 65 fpm)

Medical Data Taken

1. EKG monitor of subject before and after test.

2. Pathology

The veterinarian performed gross necropsies at LWL Bldg. No. 2420 and microscopic examinations with corresponding histopathology at his facility. Major tissue samples/organs associated with damaged area(s) were taken at the time gross necropsies were performed. The physiological damage produced as a result of each water impact was graded in accordance with damage grade levels described in Appendix C.

IV. TEST RESULTS

A. Portable Pumping System

1. Energy Test

The tabular results of the energy test, the dynamic test, and the accuracy test are shown in Appendix A .

Preliminary to the actual energy testing, some testing to obtain an optimum configuration for the portable pumping system was required. For this testing a water pulse time length of 0.6 seconds was arbitrarily selected. Candidate nozzle diameters of 5/8, 3/4, 7/8, and 1 inch were tested. Initial tests showed that the 5/8 and 1-inch nozzle performance were markedly inferior in performance to the 3/4 and 7/8-inch nozzle and were eliminated from the selection. Figures 17, 18, 19 and 20 illustrate the range of energies obtained versus pump pressure for the 3/4 and 7/8-inch nozzles at both 70 and 40-foot ranges. The pressure shown is gage pressure from the pump control panel gage which was subsequently found to read 20 psi low for the pressure range shown. Since this is the gage that is used to control the pump, however, the uncorrected pressure appears throughout this report in the pressure, P, column. The figures show that the 3/4-inch nozzle showed marked superiority to the 7/8-inch nozzle at the 70-foot range and had commensurate performance at the 40-foot range. Also, a reading of 300 psi on the pump gage appeared to give the highest energies at the target.

For those reasons, the 3/4-nozzle operating at a gage reading of 300 psi was selected to perform the bulk of the tests, although other combinations were utilized to gain a wider basis of data in some tests. The combination also offered the advantage of being more conservative of water than the 7/8-inch nozzle for equal energies. The 3/4-inch-0.6 sec-300 psi configuration used 2.9 gallons per burst and the 7/8 nozzle uses 3.2 gallons. These water quantities were used to explore the high energy water effects but it was felt necessary to obtain a water quantity that would offer a basis of comparison between the Ballistic Water Cannon, with its non-variable 1.5 gallon per burst capability, and the Portable Pumping System. Consequently, it was found that a pulse time length of 0.3 seconds with the 3/4-inch nozzle at a pump gage reading of 300 psi used 1.6 gallons and this combination was used in tests for comparison.

Table I presents the average energies measured for various ranges and masking screens. The screens are detailed in Section III.D Test Methods and Procedures.

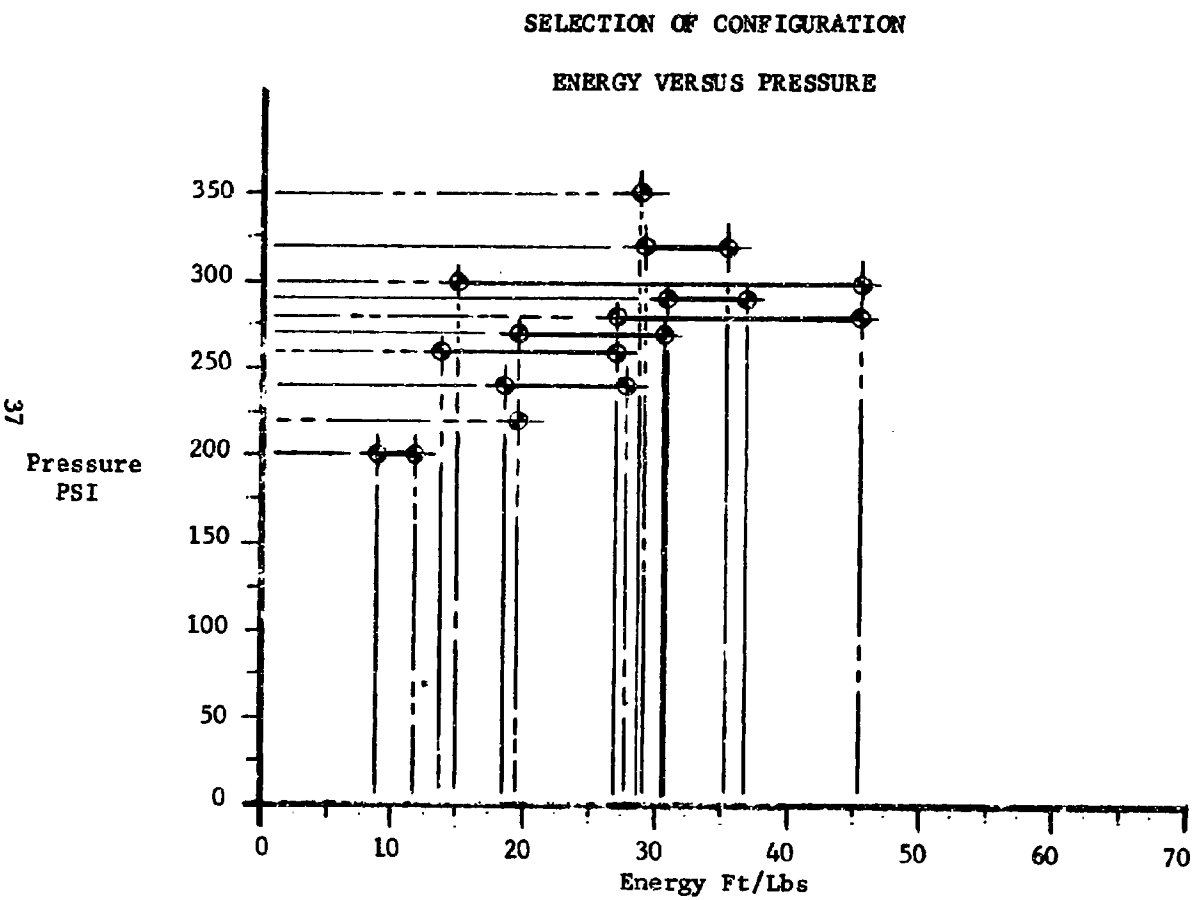


Figure 17. Configuration, 3/4-In. Nozzle - 2.9 Gallons - 70' Range

SELECTION OF CONFIGURATION

ENERGY VERSUS PRESSURE

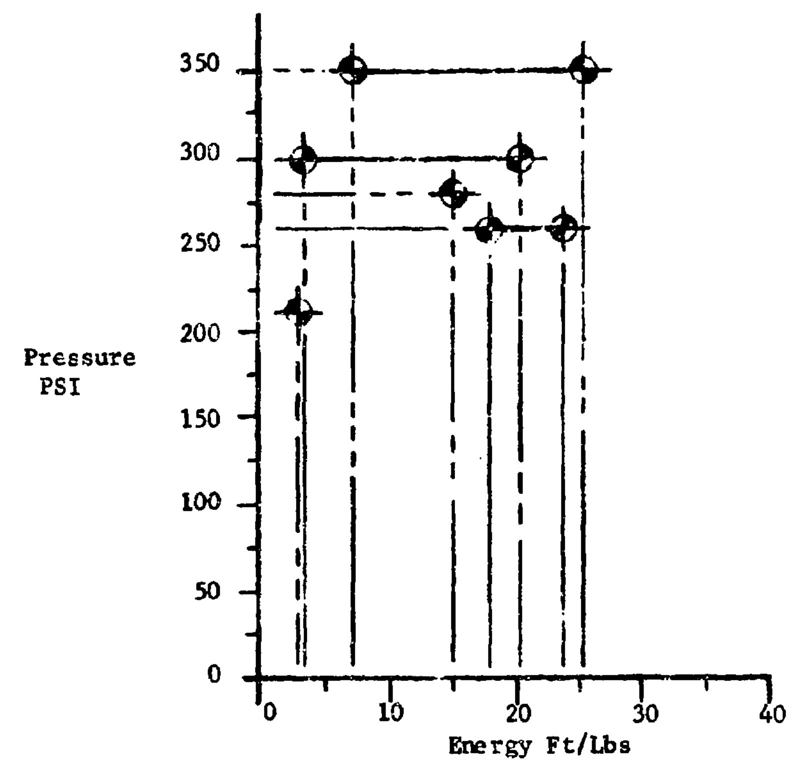


Figure 18. Configuration, 7/8-In. Nozzle - 3.2 Gallons - 70' Range

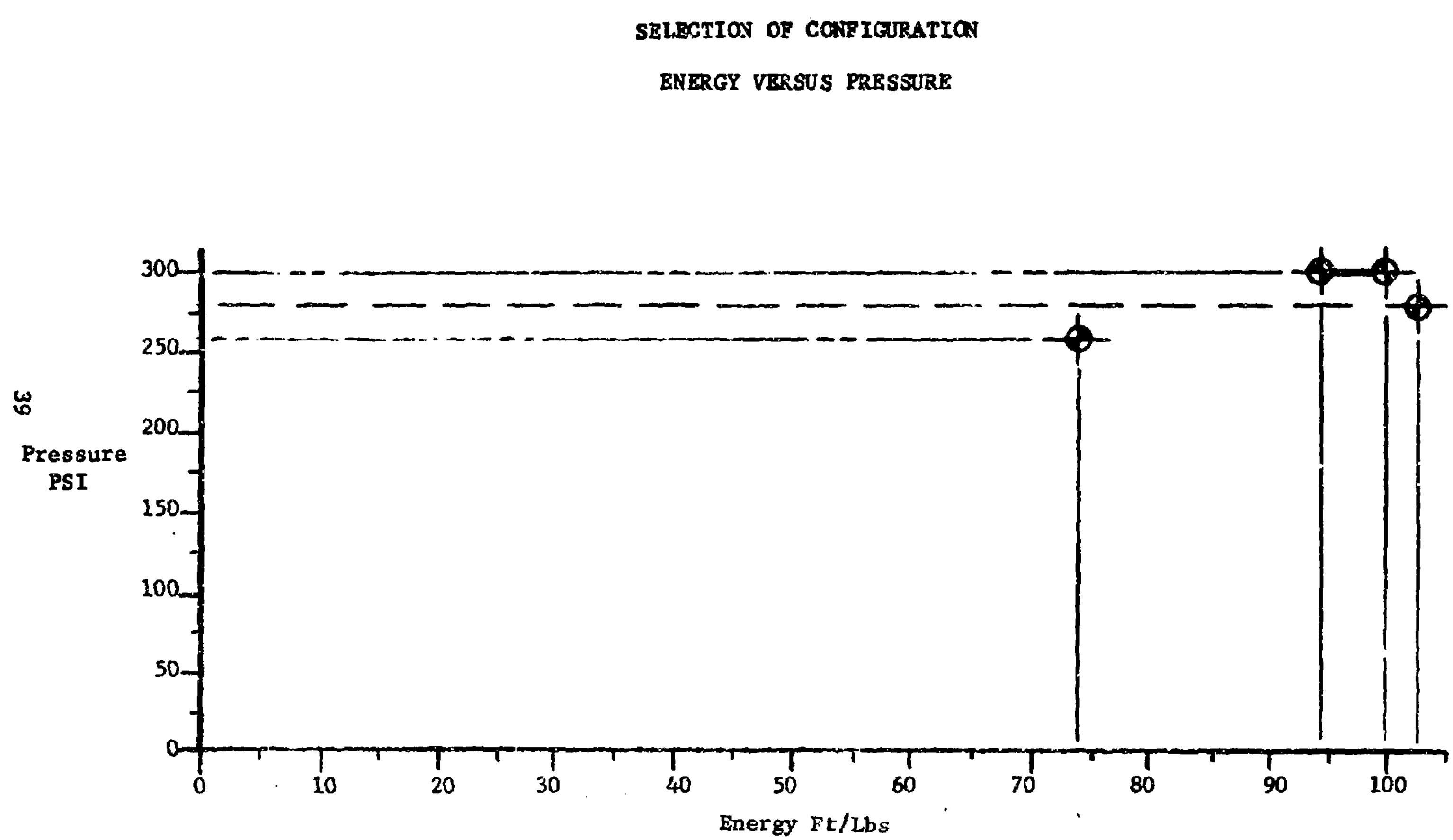


Figure 19. Configuration, 3/4-In. Nozzle - 2.9 Gallons - 40' Range

SELECTION OF CONFIGURATION

ENERGY VERSUS PRESSURE

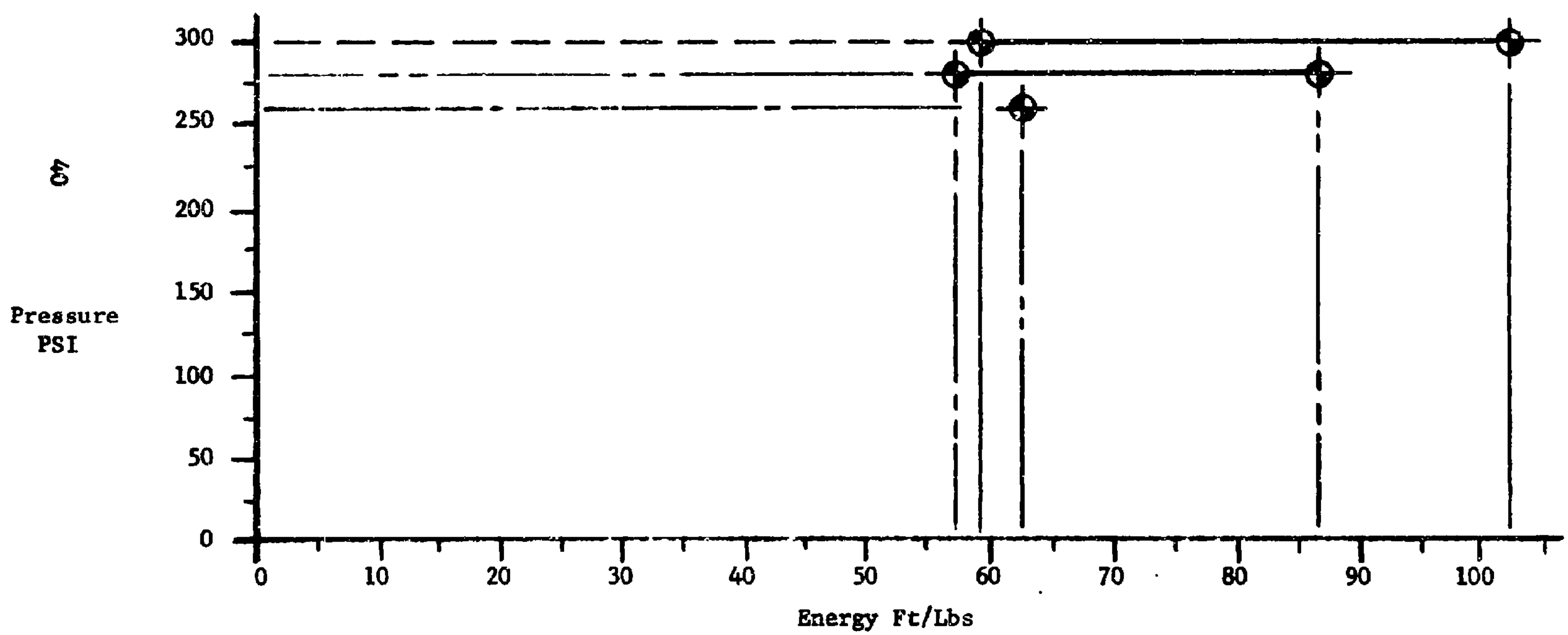


Figure 20. Configuration, 7/8-In. Nozzle - 3.2 Gallons - 40' Range

TABLE I. - ENERGIES IN FOOT-POUNDS

Range, Ft.	15	40	70
PPS, 2.9 gal.			
No screen	179	132	61
Man screen	138	57	2.0
Pig screen	116	24	3.2
PPS, 1.6			
No screen	91	36	6.4
Man screen	63	8.4	0.0

Characteristics to be noted are that while there is a large proportion of energy available at longer ranges, it is only available for a large target. Importantly, a man sized target experiences a rapid and large decrease in energy with increasing range. Such energies and time of impact would suggest more of a shower bath than an impact at a range of 70 feet. This effect also suggests more effective tactical employment against closely packed crowds as opposed to individuals. Figures 21, 22, and 23 show graphically the range of energies obtained during the test. The large variations noted are attributed to variations in the winds at the test site, pump efficiency, inaccuracies in measurement, and other, unknown factors. These variations are important in that they are the same kinds of variations that may be expected in the tactical use of the device.

The velocities of the water streams, taken from the high speed motion pictures, substantiate the energy loss with increasing range, in that stream velocity decreases from approximately 175 feet per second at a range of 6.5 feet to about 100 feet per second at 70 feet range. The films also show that the time of the pulse, measured at the target, decreases substantially with increasing range from 0.73 seconds at 6.5 feet range to 0.44 seconds at 70 feet range. This shortening does not appear to be attributable to water loss but to the condition that the front of the water mass experiences more air drag than the water in the latter part of the pulse. This condition, however, would lead one to expect a gradient of velocities in the water stream but the velocities obtained were very consistent throughout a given pulse.

The areas of high energy obtained with the paper screen substantiate the energy distributions obtained from the use of the various masking screens in that the energy becomes distributed over an increasing area with increasing range.

Figures 24, 25, 26, 27 & 28 consist of plots of displacement, force, and energy versus time for selected pendulum tests conducted at AAI using the portable pumping system. The test procedure and description of the test set-up is included in Section III of this report. The circled points on the displacement curve represent actual data points as determined from high speed movies of the tests. The solid displacement

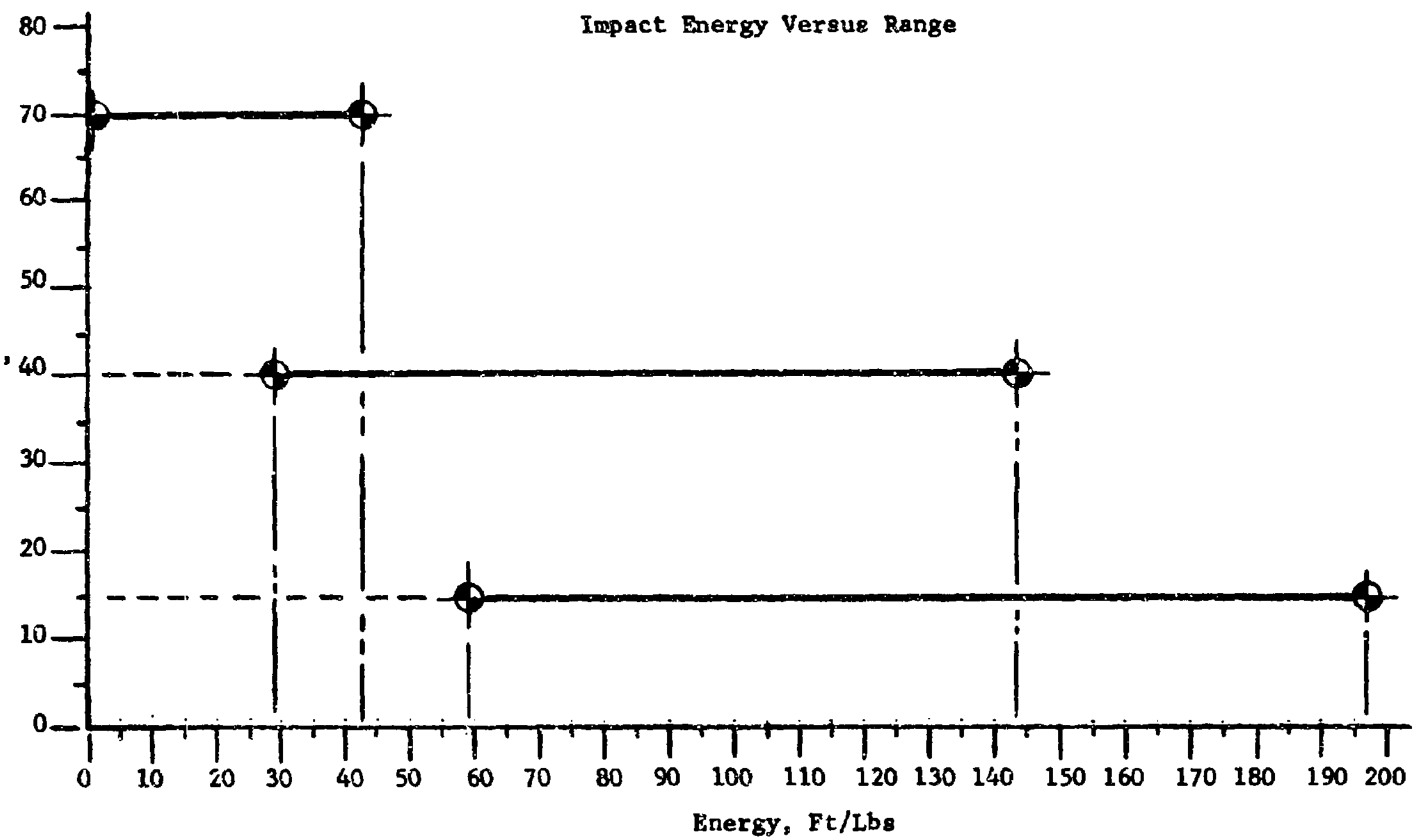


Figure 21. Portable Pumping System
Large Target

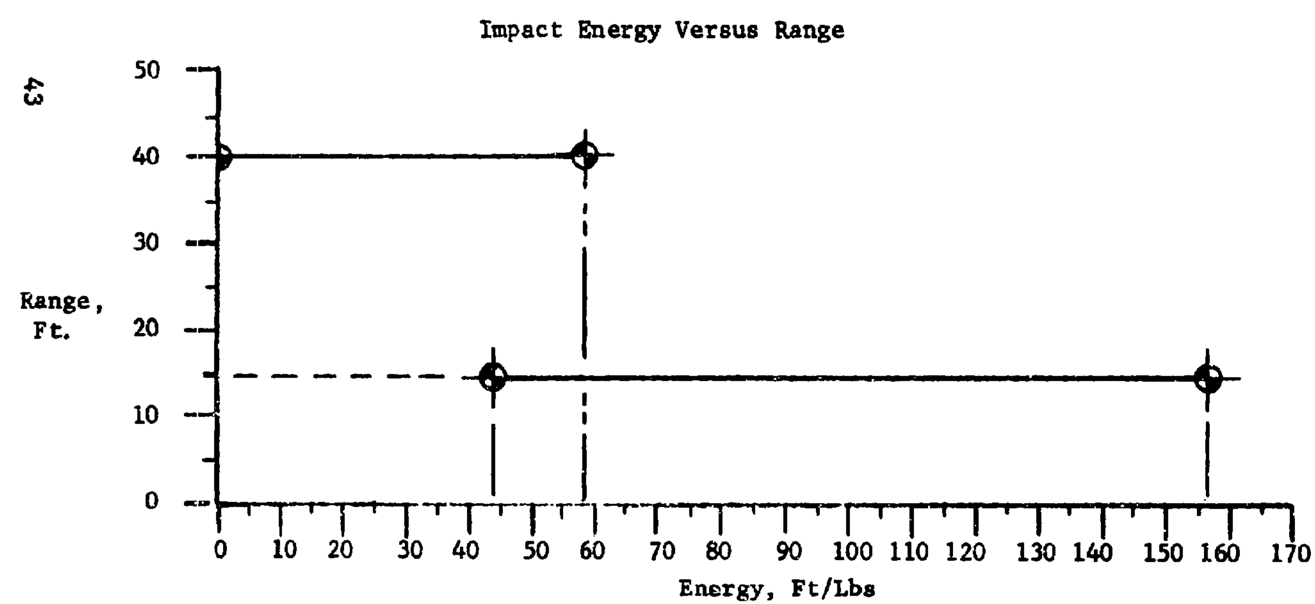


Figure 22. Portable Pumping System
Man Area Target

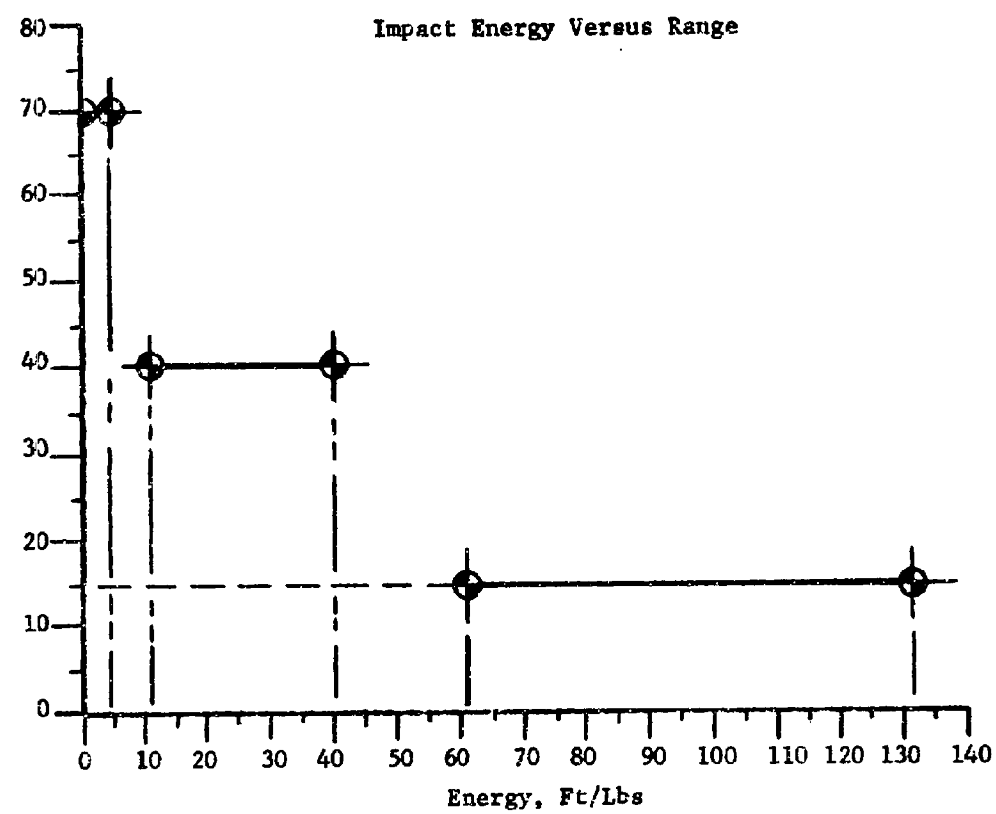


Figure 23. Portable Pumping System

Swine Area Target

Portable Pumping System

Pendulum Test No. 415

Range - 15 Feet
Average Water Velocity = 149.6 fps
No Silhouette

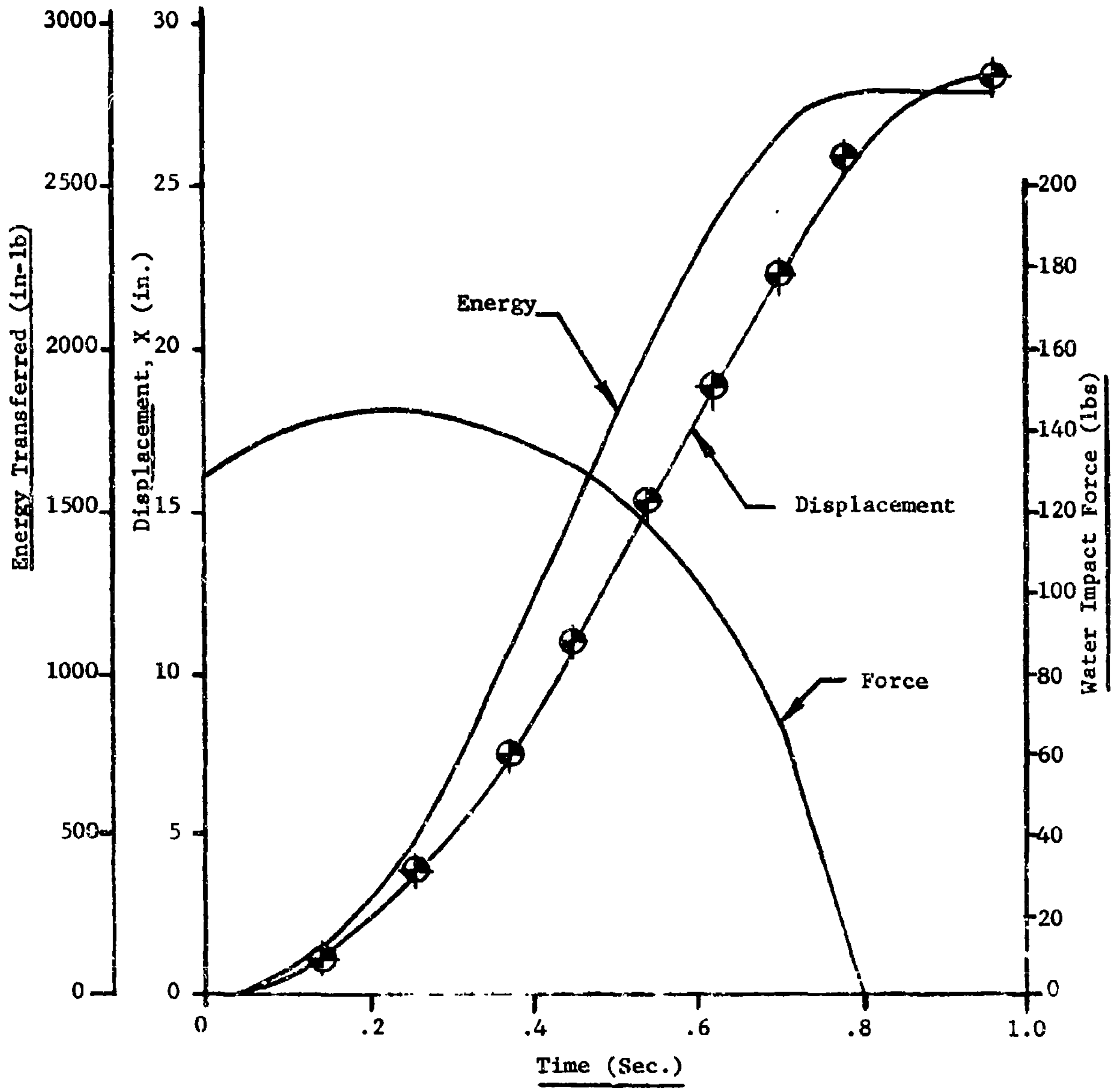


Figure 24

Portable Pumping System

Pendulum Test No. 429

Range - 15 Feet
Water Velocity = 160 fps
Pig Silhouette

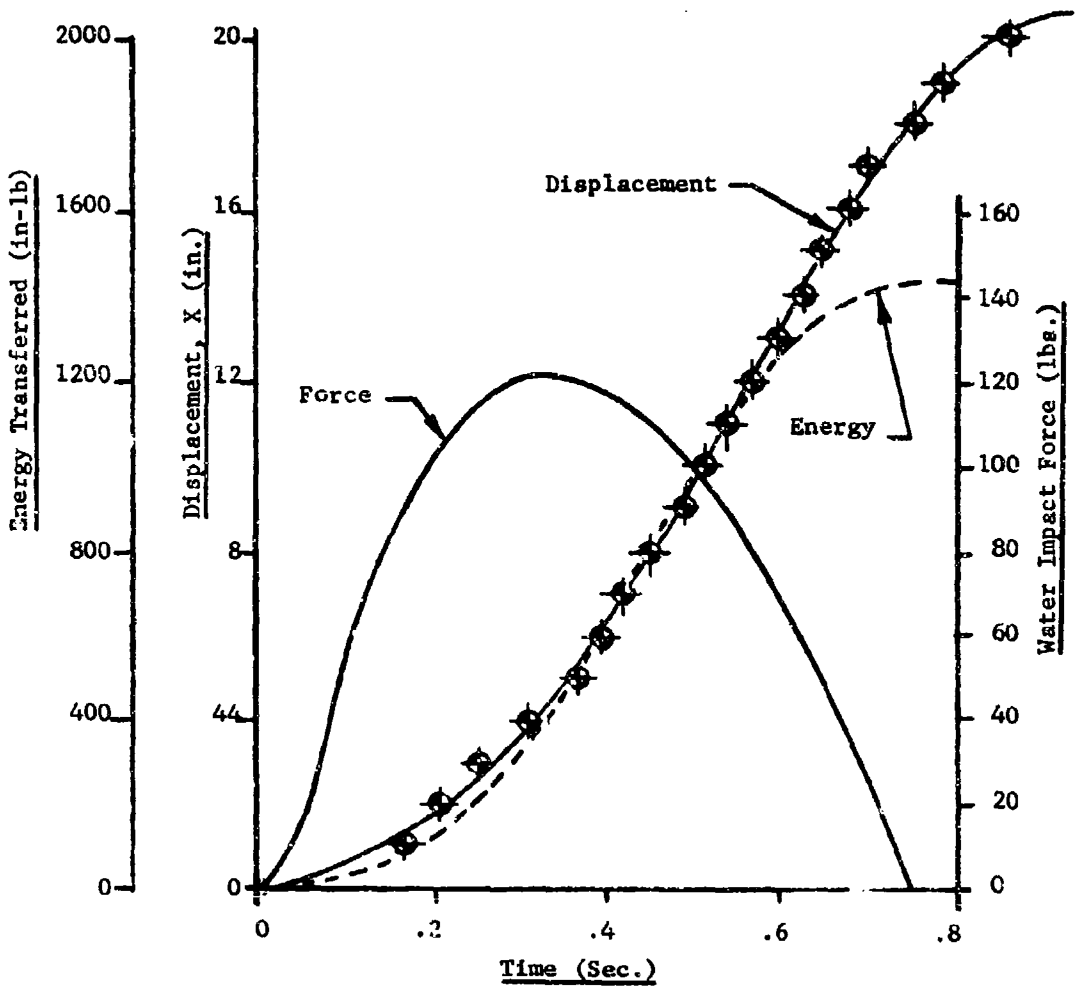


Figure 25

Portable Pumping System

Pendulum Test No. 414

Range - 40 Feet
Average Water Velocity = 164 fps
No Silhouette

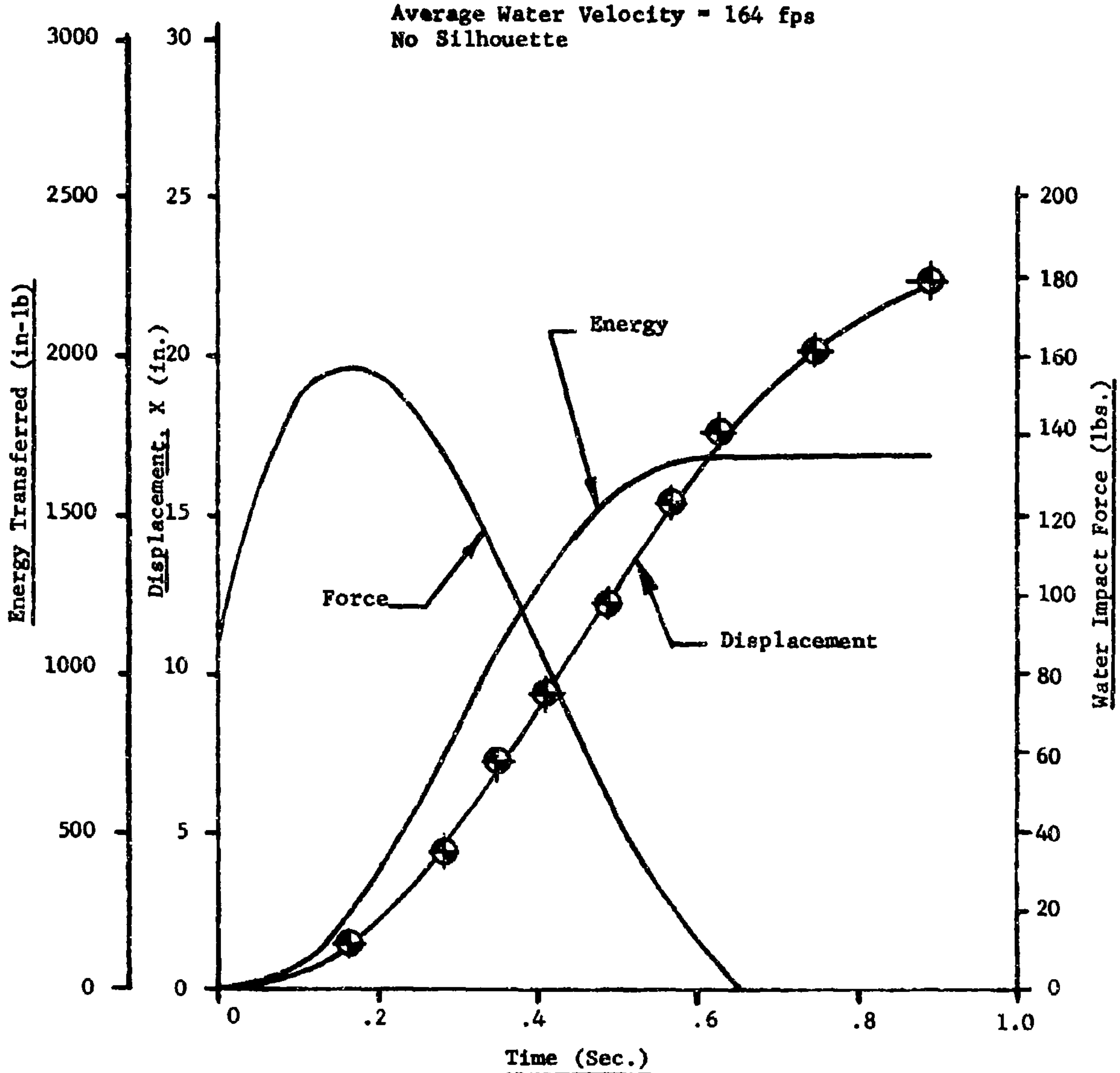


Figure 26

Portable Pumping System

Pendulum Test No. 427

Range - 40 Feet
Water Velocity = 140 fps
No Silhouette - 1.6 gallon burst

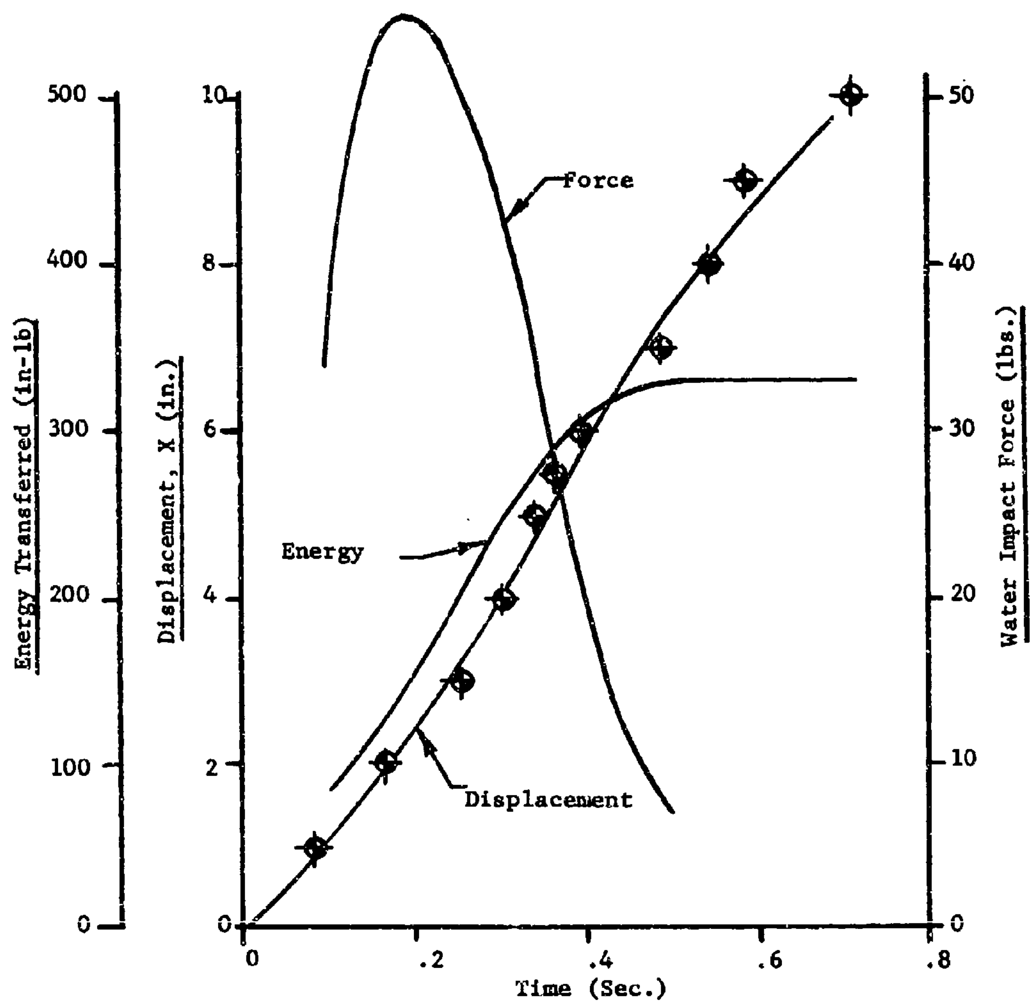


Figure 27

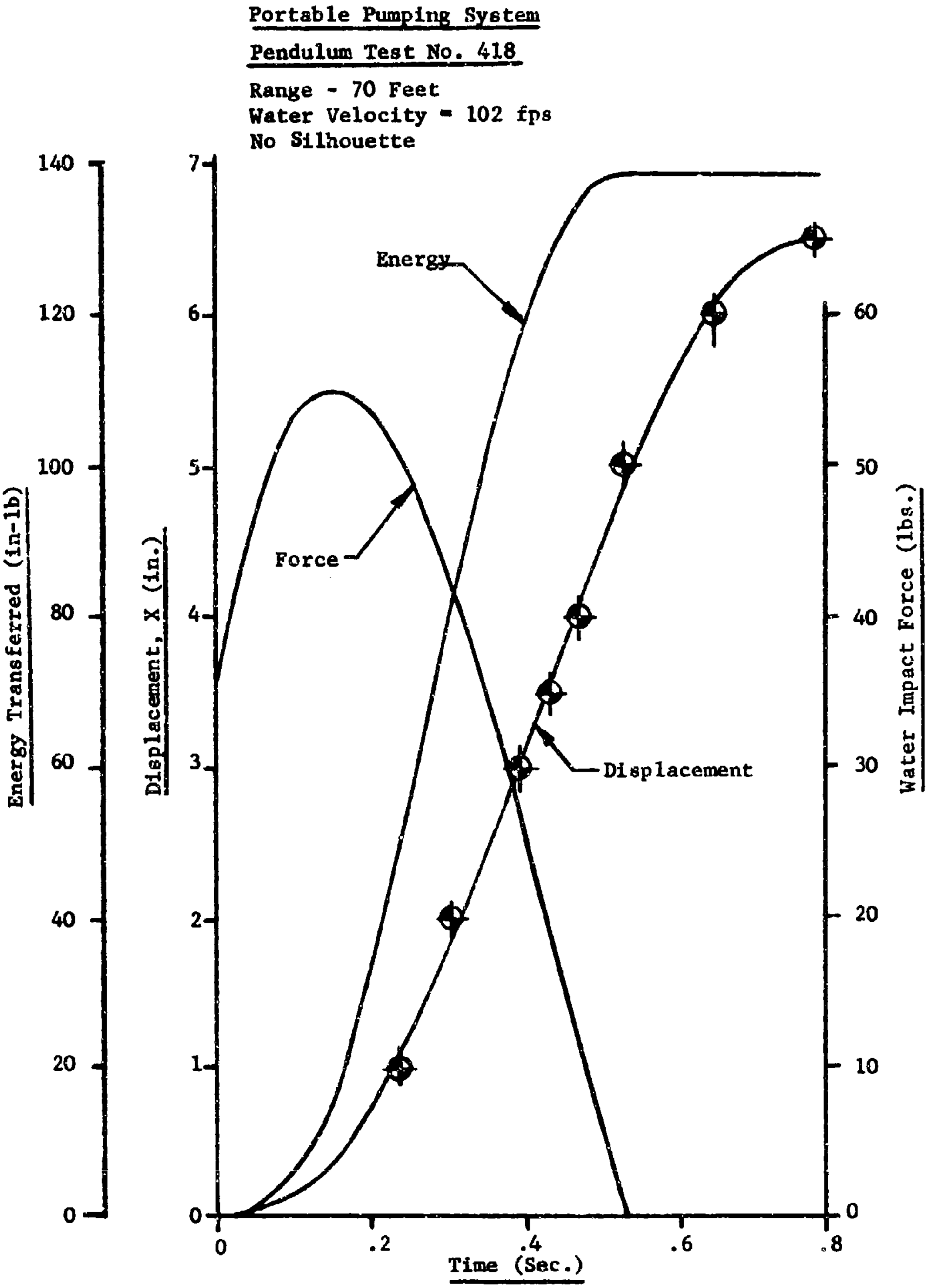
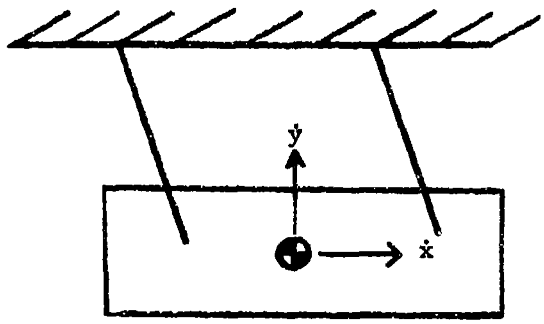

Portable Pumping System
Pendulum Test No. 418
Range - 70 Feet
Water Velocity = 102 fps
No Silhouette
Energy
Force
Displacement
Energy Transferred (in-lb)
Displacement, X (in.)
Water Impact Force (lbs.)
Time (Sec.)
0
20
40
60
80
100
120
140
1
2
3
4
5
6
7
10
30
50
.2
.4
.6
.8

Figure 28

curve is a fifth-order polynomial approximation of the displacement data points.

The displacement equation was used as input to the computer model which computes the impact force along with the energy transferred to the pendulum.



By design, all points on the pendulum have the same $\dot{x}$ and $\dot{y}$ displacements and velocities. Therefore the total energy of the pendulum at any given time is,

$$E = \frac{W}{2g} (\dot{x}^2 + \dot{y}^2) + W (y - y_o)$$

where: W = Total Pendulum Weight.

2. Accuracy Tests

The accuracy tests indicate that the Portable Pumping System is very consistent and inherently accurate. The fixed mount results show all shot centers within a 3-inch circle at 15-feet range,with the circle regularly increasing in diameter to 7 inches at 70-feet range.

In the free mount mode of operation, the decrease in number of shots required for hitting and knockdown with decreasing range was due in large part to increased operator familiarity and practice. Even at 70-feet range at the beginning of the test, the operator was able to wet the target in one shot and achieve knockdown in one or two more shots.

In the moving target portion of the test, the operator experienced some difficulty in target acquisition corrections due to the large spray of water and the necessity for a considerable amount of lead. Even with these handicaps, operator proficiency increased rapidly and in no case were more than 3 pulses required to get on target.

3. Physical Effects

The results of the test of physical effects show that the 2.9-gallon water pulse is effective to ranges beyond 70 feet when aimed at the high chest and effective to 70-feet range when aimed at the low abdomen. When using the 1.6-gallon pulse however, effectiveness is limited to somewhat less than 70 feet range for either aim point.

4. Physiological Test

Test Findings

A general description of the medical findings is given below. The detailed description of each necropsy, summary of damage levels, results and conclusions are contained in the Medical Report[3]. Appendix D contains plots of displacement and energy versus time for the Physiological Test Ranges.

Gross and microscopic examination of the pigs impacted at various ranges indicated a general reduction in the severity of damage as the range was increased. Reddening of the skin was characteristically seen immediately following impact and in some instances persisted until the animals were necropsied. A moderate degree of liver damage was seen in Pig No. 902 (range 15 feet) and Pig No. 916 (range 6.5 feet). Pig No. 902 died shortly after impact. In general, the data indicate that the front of the pig is somewhat more sensitive to the impact than the back. However, subepidural hemorrhage was seen grossly in three of the six pigs impacted in the back. A summary of the gross damage resulting from impacting the front and back of the pig is found in Table II.

Assessment of Effectiveness

The following estimates were taken from the Minutes of the Medical Meeting (Appendix B) and are for the undesirable effects and the desirable effects for the Moving-H, Army Scenario II (Annex to Appendix B). The probabilities of effects cited in Table III have the following interpretation.

- P_{ue} a .10 probability means that out of 100 people sustaining the impact, 10 will be expected to experience the effect of interest and 90 will not.

In the Moving-H Scenario, the desirable effect probability is composed of the following elements.

- P_{de} = a .10 probability means that out of 100 people sustaining the impact, 10 will be expected to experience the effect of interest and 90 will not.
- Column heading "P cannot leave" = P_{cl}

  a .10 probability means that out of 100 people sustaining the impact, 10 will not be expected to be able to leave the area (physical damage excessive, cannot even crawl away).
- Column heading "P will not leave" = P_{wnl}

  a .10 probability means that out of 100 people sustaining the impact, 10 will not be expected to leave (stubborn, martyr, willing and able to participate, etc.).

[3]William M. Busey, "Tissue Damage in Experimental Animals Resulting from the Impact of Water Fired from a Portable Pumping System," prepared for USA Land Warfare Laboratory, April 1974, (unpublished).

The desirable effect probabilities cited for any one animal are subject to the constraint:

$$\sum i = 1$$

where $i = P_{de}, P_{cannot\ leave}, P_{will\ not\ leave}$.

TABLE II

DAMAGE LEVELS RESULTING FROM IMPACTING VARIOUS ORGANS OF PIGS WITH WATER FROM THE PORTABLE PUMPING SYSTEM FIRED AT VARIOUS RANGES

Shot No.	Animal No.	Range Ft.	Target	Damage Levels: Skin	Liver	Kidney	Lung	Heart	Spleen	Other	Remarks
3	902-S	15	Front of Pig		3		2	2			Died
17	916-S	6.5	Front of Pig		3					2	Serosal hemorrhage of colon
16	915-S	6.5	Front of Pig	2							
15	914-S	6.5	Front of Pig	2							
7	906-S	6.6	Front of Pig	1							
8	907-S	6.6	Front of Pig	1					5	2	Fractured rib
1	900-S	15.	Front of Pig	1							
2	901-S	15	Front of Pig	1			1				
9	908-S	35.5	Front of Pig	1							
11	910-S	35.5	Front of Pig	1							
10	909-S	35.5	Front of Pig	1							
18	917-S	45	Front of Pig				2				
19	918-S	45	Front of Pig	2			3				
20	919-S	45	Front of Pig	0				2			
4	903-S	15	Back of Pig	1						2	Epidural hemorrhage
5	904-S	15	Back of Pig	2							
6	905-S	15	Back of Pig	0(3)			2				Sub.cut.hem.pig hitting board
12	911-S	35.5	Back of Pig	1						2	Epidural hemorrhage
13	912-S	35.5	Back of Pig	0						2	Epidural hemorrhage
14	913-S	35.5	Back of Pig	0							Died-marked pneumonia

TABLE III

PROVISIONAL ESTIMATES OF UNDESIRABLE EFFECTS, P_{ue}, AND DESIRABLE EFFECTS, P_{de}, FOR THE PORTABLE PUMPING SYSTEM

Swine Shot Number	Animal Number	P_{ue}	P_{de}*	P_{cl}	P_{wnl}	Remarks **
3	902-S	1.00	0	1.00	0	Liver lesion. EKG-chaotic rhythm, fatal arrhythmia.
17	916-S	.25	0	0	1.00	Similar liver lesion as 902-S. Peritoneal irritation would be uncomfortable.
16	915-S	0	0	0	1.00	Reddening of skin. No gross lesions.
15	914-S	0	0	0	1.00	Similar to 915-S
7	906-S	0	0	0	1.00	Animal almost dead before shot. No gross lusions.
8	907-S	.25	.50	0	.50	Redness in belly wall; fractured rib, ruptured spleen.
1	900-S	0	0	0	1.00	No gross lesions.
2	901-S	0	0	0	1.00	No gross lesions.
9	908-S	0	0	0	1.00	No gross lesions.
11	910-S	0	0	0	1.00	No gross lesions.
10	909-S	0	0	0	1.00	No gross lesions.
18	917-S	.10	0	0	1.00	Some lung injury.
19	918-S	1.00	.50	0	.50	Hemothorax, chest pain.
20	919-S	1.00	0	1.00	0	EKG-Chaotic rhythm, died in 5 minutes.
4	903-S	.50	.10	0	.90	The group speculated on the mechanism of damage. Possible first stage rebound injury. If we eliminate the rebound, probably not much damage was done.

TABLE III (Cont'd)

Swine Shot Number	Animal Number	P_{ue}	P_{de}*	P_{cl}	P_{wnl}	Remarks**
5	904-S	0	0	0	1.00	Reddening of skin, epidural hemorrhage.
6	905-S	.25	0	0	1.00	Subcutaneous hemorrhage; lung lesion.
12	911-S	.50	.50	0	.50	Epidural hemorrhage. Assume a significant lesion accompanied by backache.
13	912-S	.50	.25	0	.75	Some would have posterior nerve root irritation pain and/or sensory disturbance.
14	913-S	0	0	0	1.00	Not much physical damage. Animal died from marked pneumonia and anesthetic.

*Moving-H, Army Scenario II (Annex to Appendix B)

**Patho-physiological damage grades are given in Appendix C. EKG commentary and grading are given in Appendix B. EKG's are entered in the above table only when they contribute to the effects estimates.

For obvious reasons all physiological data was obtained against non-human targets (swine). The previous programs conducted by AAI under LWL technical direction, medical assessment of blunt trauma (non-penetrating) wounds produced in swine have been evaluated to determine the extent to which these data may be applied to humans. Results of these assessments indicated a reasonable degree of correlation which would justify concluding that the degree of physiological effect produced in this test series (Reference 3) would be observed in human subjects under similar conditions.

The test results indicated that the physiological damage from impact of water fired from the Portable Pumping System at the ranges tested is relatively range independent.

During the animal test phase of this program all tests were conducted with the Portable Pumping System. In order to extend the predicted effect upon human targets to the Ballistic Water Cannon a comparison of energy versus range obtained with both devices is shown in Figure 29. A comparison of equivalent energies at impact indicated that a degree of safety equal to that produced by the Portable Pumping System at 15-feet range is produced by the Ballistic Water Cannon at 15 feet range.

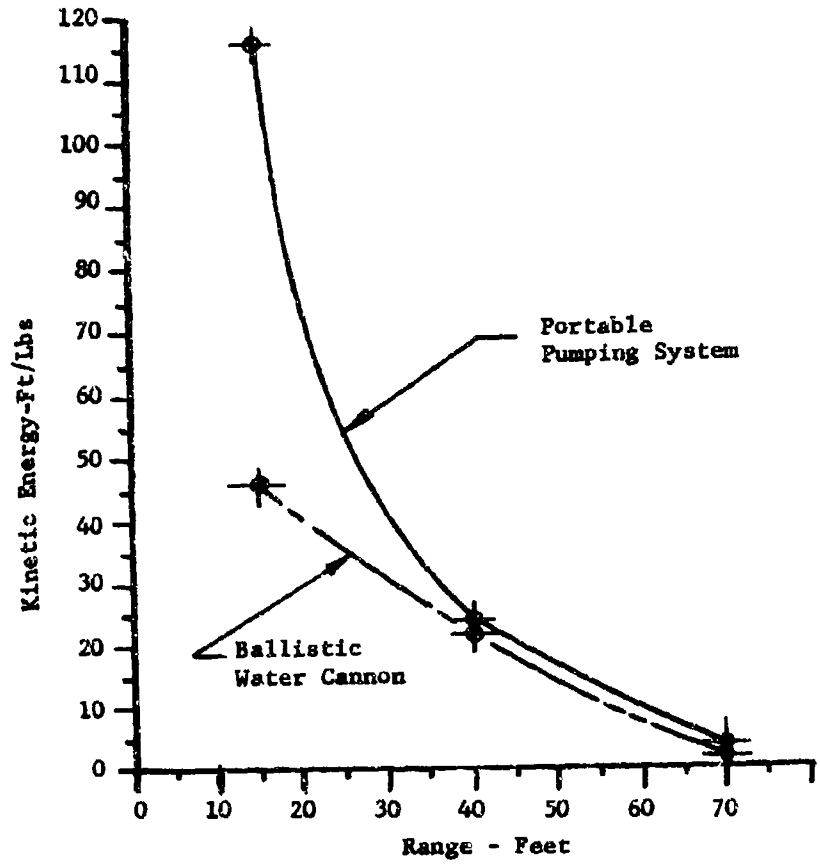


Figure 29 Kinetic Energy Imparted to Pendulum by Water Pulse from Portable Pumping System and Ballistic Water Cannon during Energy Tests.

B. Ballistic Water Cannon

1. Energy

Table IV shows the average energies obtained at the various ranges.

TABLE IV

ENERGY VERSUS RANGE, BALLISTIC WATER CANNON

Range, Feet	15	40	70
Masking Screen	Energies in Ft-lbs		
No screen	40	34.2	14
Man screen	36	35	12
Pig screen	46	22	1.2

Notable in the table is that the Ballistic Water Cannon suffers very little decrease in energy when the target is masked to man size, indicating that it may be effectively employed against individual targets. This concentration is further demonstrated at nearer ranges by the small decrease in energy when the target is masked by the swine silhouette. Figures 30,31, and 32 Impact Energy versus Range, continue to substantiate this performance, as the range of energies is changed very little with the addition of masking screens.

The velocity of the streams has a small range, 160 feet per second at 15 feet range to 115 feet per second at 70 feet, which would also indicate better consolidation at longer ranges. The timelengths of impact would also indicate good consolidation as it ranges from .29 seconds at 15 feet to .2 seconds at 70 feet.

The energy distributions calculated from the paper screen areas continue to agree with the above data decreasing from 0.35 foot pounds of energy per square inch at 15 feet range to 0.16 foot pounds per square inch at 70 feet range.

2. Accuracy

Tests of inherent accuracy show that the Ballistic Water Cannon has excellent inherent accuracy. At both 40-feet range and 70-feet range, all centers of water burst were within a two-inch diameter circle, demonstrating clearly the consistency of the weapon.

The Ballistic Water Cannon, a developmental model, was not capable of repeating operation which rendered it unsuitable for further accuracy testing in either the free mount or moving target tests.

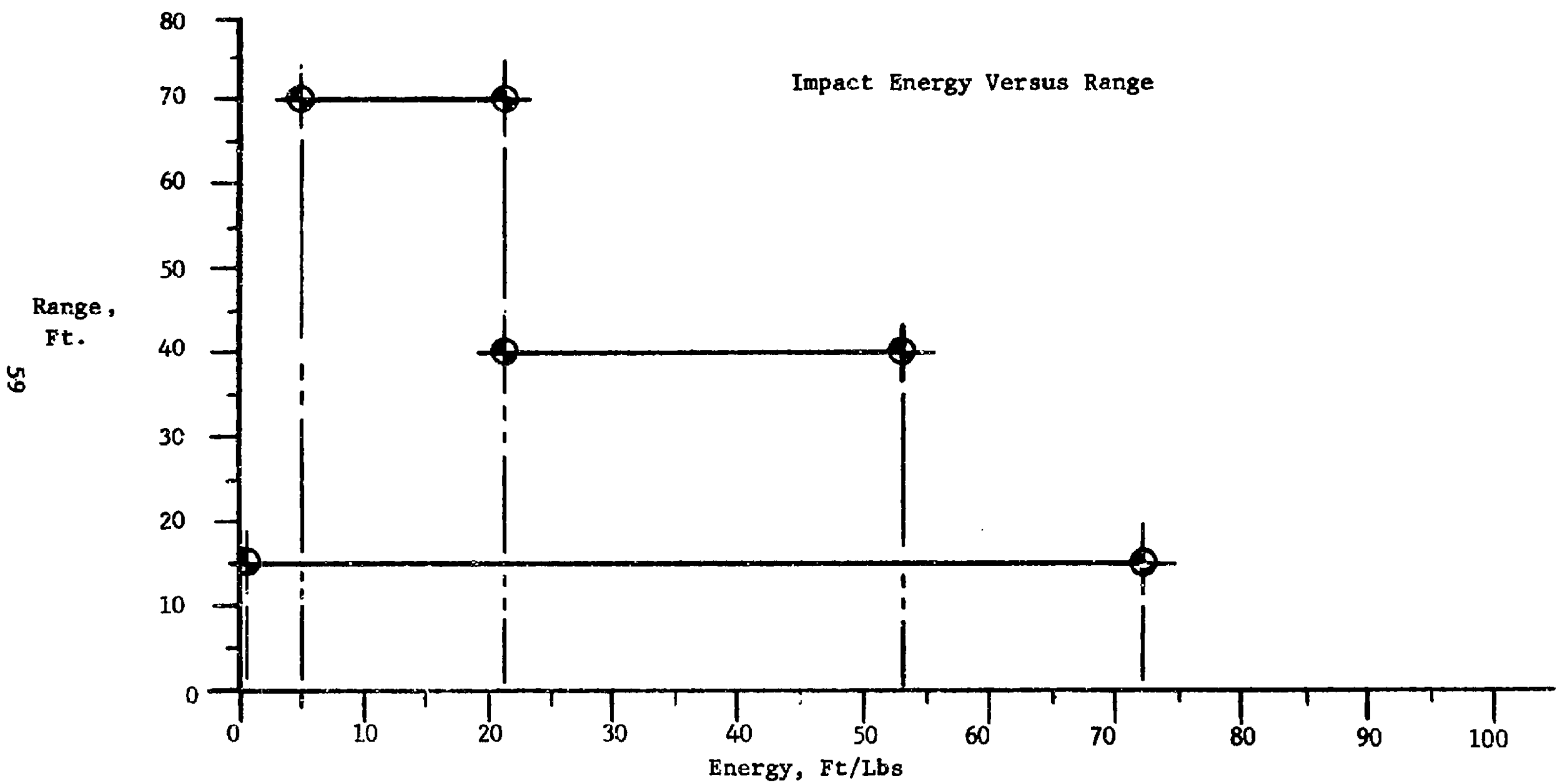


Figure 30. Ballistic Water Cannon
Large Target

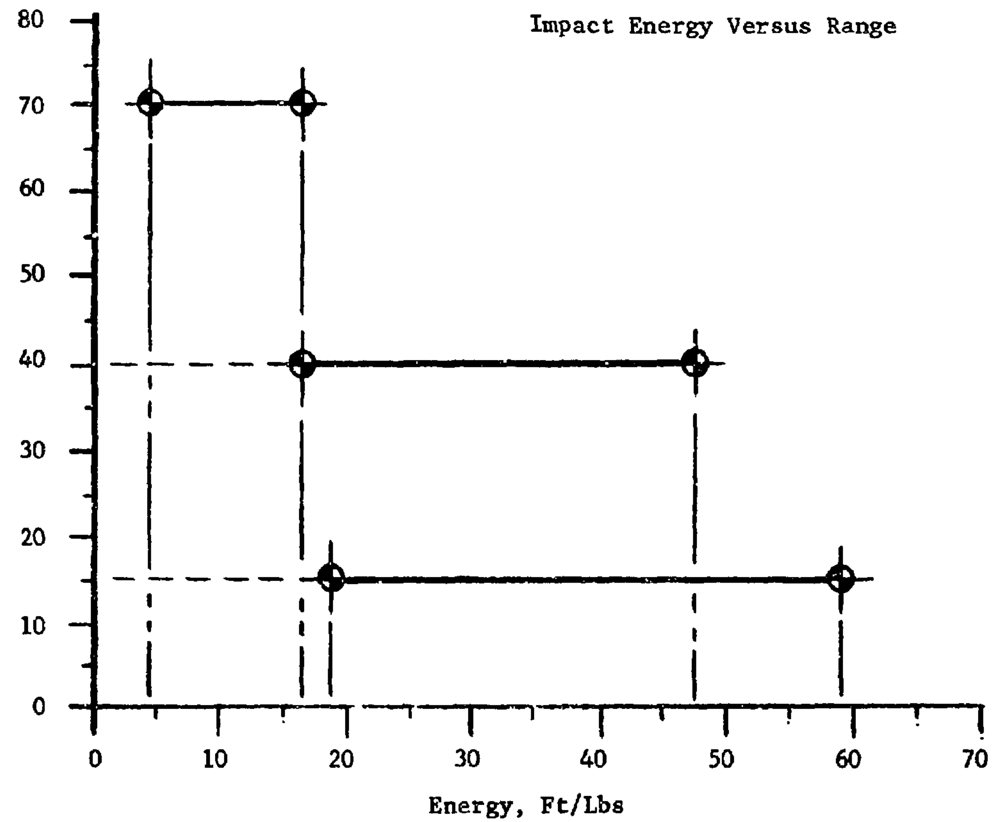


Figure 31. Ballistic Water Cannon Man Area Target

Impact Energy Versus Range

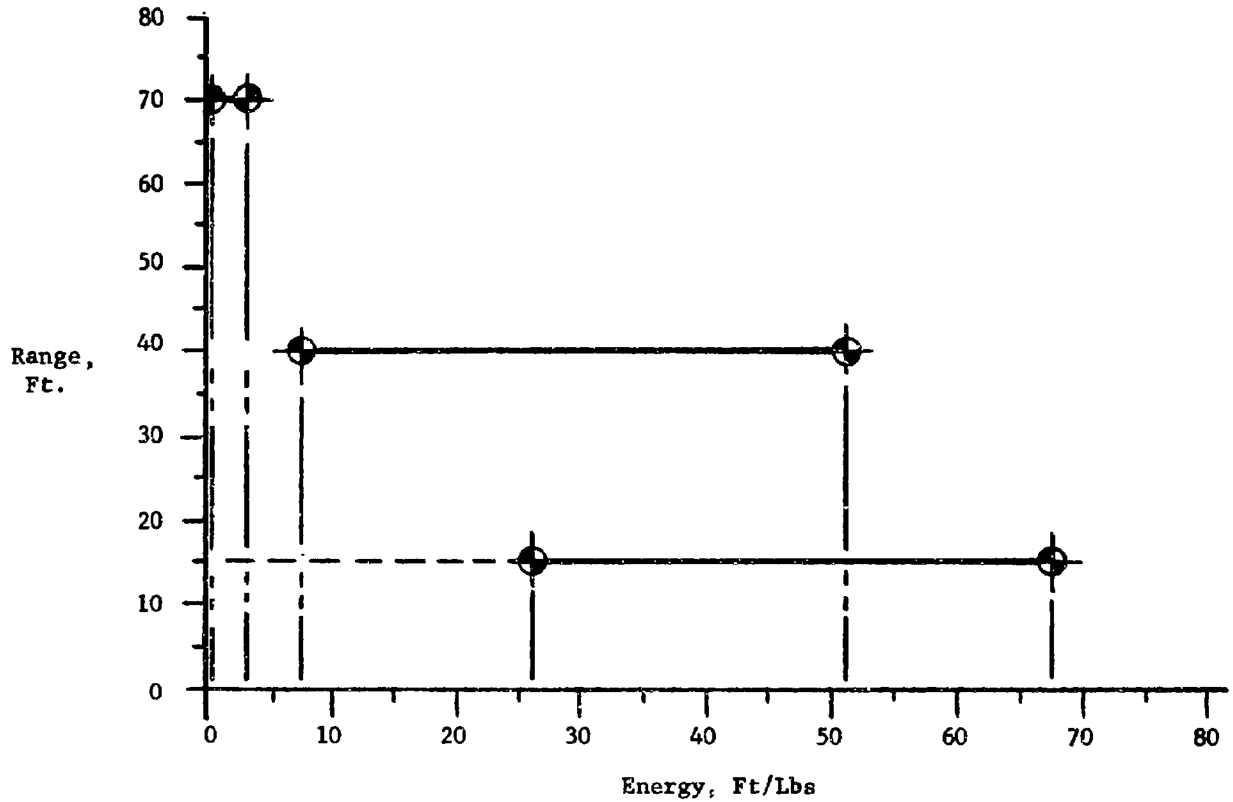


Figure 32. Ballistic Water Cannon Swine Area Target

3. Physical Effects

In the tests of physical effects the Ballistic Water Cannon again demonstrated good longer range characteristics by being able to achieve knock-down of the test target at ranges exceeding 70 feet when aimed at the high chest of the target. Low abdomen-aimed shots were effective beyond 40 feet.

V. CONCLUSIONS

The data collected in the test program provides a determination of the target impact performance of the PPS and BWC water pulse with regard to hazard and terminal effectiveness of the water pulse.

The energy type test data derived during this program indicates that a nozzle size of .75 inch diameter and a pump pressure of 300 PSI provides the optimum water output configuration for the PPS water pulsing mode of operation. For this nozzle/pump pressure configuration two water pulse lengths were selected for study of the Portable Pumping System, one that allowed water volumes of 2.9 gallons to be ejected in each pulse and one that allowed 1.6 gallons. The larger water volume was used to study high impact energy effects and the smaller volume was selected to achieve a basis of comparison with the Ballistically Actuated Water Cannon (1.37 inch diameter nozzle/175 PSI), which has a non-variable 1.5 gallon capacity.

The following tabulation presents the average energies in foot-pounds measured for various ranges and masking screens for the PPS (2.9 gallon and 1.6 gallon water pulse) and the BWC (1.5 gallon water pulse).

Range, Ft.	15	40	70
PPS, 2.9 gal.			
No Screen	179	132	61
Man Screen	138	57	2.0 (wind)
Pig Screen	116	24	3.2
PPS, 1.6 gal.			
No Screen	91	36	6.4
Man Screen	63	8.4	0.0
BWC, 1.5 gal.			
No Screen	40	34.2	14
Man Screen	36	35	12
Pig Screen	46	22	1.2

Characteristics to be noted are that there is a large decrease in energy of the Portable Pumping System with placement of the man silhouette screen while such a decrease is not noted in the energies of the Ballistic Water Cannon. This indicates that the effective portion of the water jet is larger than a man for the Portable Pumping System, but smaller than a man for the Ballistic Actuated Cannon. Another characteristic of note is the large proportional decrease in energy with increasing range exhibited by the Portable Pumping System while the Ballistic Water Cannon shows much less decrease.

The study of the cross-sectional areas of the water rods and a calculation of an energy concentration shows that the Portable Pumping System has a drastic decrease in energy concentration when projecting 1.6 gallons of water, but has a much better performance with the 2.9 gallon pulse. From a review of the photographic data, both the PPS and the BWC exhibit similar water velocities and velocity decays with distance. However, the PPS exhibits more shortening of water impact time with increasing range than the BWC, which indicates shortening and thickening of the water pulse.

In summary, it appears that the 2.9 gallon water pulse of the PPS imparts more energy to the large target (4 x 5 feet) at all ranges than the BWC. However, with respect to the energy imparted to a man size or pig size target, the BWC appears to be more effective than the PPS since the rate of energy decay with range is less and the conservation of water is greater.

In the tests of physical effects on a knock down target, the Ballistic Water Cannon was as effective as the Portable Pumping System using water pulses twice as large (2.9 gallons). Both would knock over the test target at ranges of 70 feet while the Portable Pumping System using 1.6 gallon pulses would not.

Both systems gave very repeatable and good accuracy results when operated from a fixed mount. However, since the goal of semi-automatic fire was not achieved with the Ballistic Water Cannon, accuracy data for a free mount and moving target were not obtainable for that system. The Portable Pumping System operation in the free mount and moving target test suffered somewhat because the sights were not on the operator's eye level, but operators were still able to quickly adjust to the target in both the free mount and moving target tests and demonstrated effective accuracy of the unit.

From the data collected during the physiological testing and the assessment of this data with regard to human hazard, it appears that from the standpoint of a direct water impact on a human body, the resultant physiological damage from either unit is range independent up to the range tested - 45 feet. With regard to their effectiveness from a physiological damage standpoint, Appendix B, "Minutes of Medical Group Meeting," presents the estimates for the undesirable and the desirable effects in the context of a civil disturbance situation.

APPENDIX A

RECORD OF TEST RESULTS

Test results from tests 1 to 106 which are not reported were preliminary tests which were used for developing test techniques and checking out equipment.

TABLE A-1
SELECTION OF CONFIGURATION - 40' RANGE

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
-	-	3/4-.6	-	40							
296	11/23	3/4-.6	300	40	18-5/8	N	OK	OK	0-1	98.1	
297	11/23	3/4-.6	300	40	18-3/4	N	OK	OK	0-1	99.4	
298	11/23	3/4-.6	300	40	18-1/4	N	OK	OK	0-1	94.1	
299	11/23	3/4-.6	280	40	19	N	OK	OK	0-1	102.1	
300	11/23	3/4-.6	280	40	19	N	OK	OK	0-1	102.1	
301	11/23	3/4-.6	280	40	19	N	OK	OK	0-1	102.1	
302	11/23	3/4-.6	260	40	16-1/8	N	OK	OK	0-1	73.2	
303	11/23	3/4-.6	260	40	16-1/4	N	OK	OK	0-1	74.3	
304	11/23	3/4-.6	260	40	16-1/4	N	OK	OK	0-1	74.3	
-	-	3/4-.3	-	40	-	-	-	-	-	-	
283	11/21	3/4-.3	300	40	12-1/4	N	OK	OK	8-12 T	41.9	Pump ≤ 300 psi
284	11/21	3/4-.3	300	40	11	N	OK	OK	8-12 T	33.8	Pump ≤ 300 psi
285	11/21	3/4-.3	300	40	11	N	OK	OK	8-12 T	33.8	Pump ≤ 300 psi
286	11/21	3/4-.3	280	40	10-1/4	N	OK	OK	8-12 T	29.3	Pump ≤ 300 psi
287	11/21	3/4-.3	280	40	8-7/8	N	OK	OK	8-12 T	21.9	Pump ≤ 300 psi
288	11/21	3/4-.3	280	40	10-1/4	N	OK	OK	8-12 T	29.3	Pump ≤ 300 psi
289	11/21	3/4-.3	260	40	8-1/8	N	OK	OK	8-12 T	18.4	Pump ≤ 300 psi
290	11/21	3/4-.3	260	40	9-1/2	N	OK	OK	8-12 T	25.1	Pump ≤ 300 psi
291	11/21	3/4-.3	260	40	9-1/2	N	OK	OK	8-12 T	25.1	Pump ≤ 300 psi
-	-	7/8-.6	-	40	-	-	-	-	-	-	-
274	11/21	7/8-.6	300	40	16-1/4	N	OK	Fair	8-12 T	74.3	Pump ≤ 300 psi
275	11/21	7/8-.6	300	40	19	N	OK	Fair	8-12 T	102.1	Pump ≤ 300 psi
276	11/21	7/8-.6	300	40	14-1/2	N	OK	Fair	8-12 T	58.9	Pump ≤ 300 psi
277	11/21	7/8-.6	280	40	17-1/2	N	OK	Fair	8-12 T	86.3	Pump ≤ 300 psi
278	11/21	7/8-.6	280	40	14-1/4	N	OK	Fair	8-12 T	56.9	Pump ≤ 300 psi
279	11/21	7/8-.6	280	40	15	N	OK	Fair	8-12 T	63.1	Pump ≤ 300 psi
280	11/21	7/8-.6	260	40	15	N	OK	OK	8-12 T	63.1	Pump ≤ 300 psi
281	11/21	7/8-.6	260	40	14-3/4	N	OK	OK	8-12 T	61.0	Pump ≤ 300 psi
282	11/21	7/8-.6	260	40	15	N	OK	OK	8-12 T	63.1	Pump ≤ 300 psi
-	-	7/8-.3	-	40	-	-	-	-	-	-	-
305	11/23	7/8-.3	300	40	8-5/8	N	OK	OK	0-1	20.7	
306	11/23	7/8-.3	300	40	8-7/8	N	OK	OK	0-1	21.9	
307	11/23	7/8-.3	300	40	8-1/2	N	OK	OK	0-1	20.1	
308	11/23	7/8-.3	280	40	8-1/4	N	OK	OK	0-1	18.9	
309	11/23	7/8-.3	280	40	8-3/8	N	OK	OK	0-1	19.5	
310	11/23	7/8-.3	280	40	8-1/4	N	OK	OK	0-1	18.9	
311	11/23	7/8-.3	260	40	7-7/8	N	OK	OK	0-1	17.3	
312	11/23	7/8-.3	260	40	7-7/8	N	OK	OK	0-1	17.3	
313	11/23	7/8-.3	260	40	7-3/4	N	OK	OK	0-1	16.7	

TABLE A-1 (Cont'd)
SELECTION OF CONFIGURATION - 70' RANGE

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
-	-	3/4-.6	-	70	-	-	-	-	-	-	-
242	11/20	3/4-.6	200	70	6.5	N	OK	OK	0-1	11.7	150 Run. Press.
243	11/20	3/4-.6	200	70	5.5	N	OK	OK	0-1	8.4	160 Run. Press.
244	11/20	3/4-.6	220	70	8-1/4	N	OK	OK	0-1	18.9	170 Run. Press.
245	11/20	3/4-.6	220	70	8-3/8	N	OK	OK	0-1	19.5	175 Run. Press.
246	11/20	3/4-.6	240	70	8-1/8	N	OK	OK	0-1	18.4	180 Run. Press.
247	11/20	3/4-.6	240	70	10	N	OK	OK	0-1	27.9	180 Run. Press.
248	11/20	3/4-.6	240	70	10	N	OK	OK	0-1	27.9	180 Run. Press.
249	11/20	3/4-.6	260	70	8-1/8	N	OK	OK	0-1	18.4	180 Run. Press.
250	11/20	3/4-.6	260	70	9-7/8	N	OK	Bad	0-1	27.1	185 Run. Press.
251	11/20	3/4-.6	260	70	7	N	OK	Bad	0-1	13.6	185 Run. Press.
252	11/20	3/4-.6	270	70	8-3/8	N	OK	Bad	0-1	19.5	170 Run. Press.
253	11/20	3/4-.6	270	70	9	N	OK	Bad	0-1	22.5	180 Run. Press.
254	11/20	3/4-.6	270	70	10-1/2	N	OK	Bad	0-1	30.7	175 Run. Press.
255	11/20	3/4-.6	280	70	12-3/4	N	OK	OK	0-1	45.5	180 Run. Press.
256	11/20	3/4-.6	280	70	9-7/8	N	OK	Bad	0-1	27.1	170 Run. Press.
257	11/20	3/4-.6	290	70	10-1/2	N	OK	Fair	0-1	30.7	170 Run. Press.
258	11/20	3/4-.6	290	70	11-1/8	N	OK	OK	0-1	33.0	175 Run. Press.
259	11/20	3/4-.6	290	70	11-1/2	N	OK	OK	0-1	36.9	180 Run. Press.
260	11/20	3/4-.6	300	70	12	N	OK	OK	0-1	40.2	185 Run. Press.
261	11/20	3/4-.6	300	70	12-3/4	N	OK	OK	0-1	45.5	190 Run. Press.
262	11/20	3/4-.6	300	70	7-3/8	N	OK	Bad	0-1	15.1	150 Run. Press.
263	11/20	3/4-.6	320	70	11-1/4	N	OK	Fair	0-1	35.3	190 Run. Press.
264	11/20	3/4-.6	320	70	10-1/4	N	OK	OK	0-1	29.3	180 Run. Press.
265	11/20	3/4-.6	320	70	11	N	OK	OK	0-1	33.8	185 Run. Press.
266	11/20	3/4-.6	300	70	11	N	OK	OK	0-1	33.8	175 Run. Press.
267	11/20	3/4-.6	350	70	10-1/8	N	OK	OK	0-1	28.6	180 Run. Press.
-	-	7/8-.6	-	70	-	-	-	-	-	-	- -
268	11/20	7/8-.6	350	70	5	N	OK	OK	0-1	6.9	140 Run. Press.
269	11/20	7/8-.6	350	70	9-1/2	N	OK	OK	0-1	25.1	140 Run. Press.
270	11/20	7/8-.6	350	70	8-1/8	N	OK	OK	0-1	18.4	- -
271	11/20	7/8-.6	300	70	3-1/2	N	Bad	OK	0-1	3.4	140 Run. Press.
272	11/20	7/8-.6	300	70	5-7/8	N	OK	Bad	0-1	9.6	- -
273	11/20	7/8-.6	220	70	3-1/8	N	OK	Bad	0-1	2.7	60 Run. Press.
323	11/23	7/8-.6	300	70	7-7/8	N	OK	OK	0-1	17.3	
324	11/23	7/8-.6	300	70	7-3/4	N	OK	OK	0-1	16.7	
325	11/23	7/8-.6	300	70	8-1/2	N	OK	OK	0-1	20.1	GB Hot
326	11/23	7/8-.6	280	70	7-1/4	N	OK	OK	0-1	14.6	
327	11/23	7/8-.6	280	70	7-1/2	N	OK	OK	0-1	15.6	
328	11/23	7/8-.6	280	70	7-3/8	N	OK	OK	0-1	15.1	
329	11/23	7/8-16	260	70	9-1/4	N	OK	OK	0-1	23.8	
330	11/23	7/8-.6	260	70	8	N	OK	OK	0-1	17.8	
331	11/23	7/8-.6	260	70	8	N	OK	OK	0-1	17.8	

TABLE A-2
IMPACT ENERGY DATA - PORTABLE PUMPING SYSTEM

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
107	10/18	3/4-.6	300	15	27-1/2	N	OK	OK	8-C	187	
108	10/18	3/4-.6	300	15	26	N	OK	OK	8-C	166	
155	10/31	3/4-.6	300	15	25	N	OK	OK	0-1	179.6	N 320S - R
156	10/31	3/4-.6	300	15	25-1/4	N	OK	OK	0-1	183.4	N 320S 200R
157	10/31	3/4-.6	300	15	25-1/2	N	OK	OK	0-1	187.2	N 320S 205R
227	11/ 8	3/4-.6	300	15	24-1/2	N	OK	OK	2-4T	172.3	
106	10/18	3/4-.45	300	15	4-5/8	N	OK	OK	15H	-	Pendulum Struck Frame
158	10/31	3/4-.3	300	15	16-1/4	N	OK	OK	0-1	74.3	N 320S 200R
159	10/31	3/4-.3	300	15	19	N	OK	OK	0-1	102.1	N 320S 200R
105	10/ 8	7/8-.45		15	-	N	OK	OK	15H	-	Pendulum Struck Frame
111	10/18	7/8-.6	300	15	24	N	OK	OK	8-C	141	
112	10/18	7/8-.6	300	15	23.5	N	OK	OK	8-C	135	
152	10/31	7/8-.6	300	15	26-1/8	N	OK	OK	0-1	196.9	N 320S 140R
153	10/31	7/8-.6	300	15	26-1/8	N	OK	OK	0-1	196.9	N 320S 140R
154	10/31	7/8-.6	300	15	26-1/8	N	OK	OK	0-1	196.9	N 320S 140R
218	11/ 7	7/8-.6	300	13	20-3/8	N	OK	OK	6-8HG12	117.8	
219	11/ 7	7/8-.6	300	13	20-3/8	N	OK	OK	8-8HG12	117.8	
110	10/18	7/8-.45	300	15	23	N	OK	OK	8-C	129	
149	10/31	7/8-.3	300	15	17-1/4	N	OK	VF	0-1	83.9	N 320S 150R
150	10/31	7/8-.3	300	15	14-1/2	N	OK	OK	0-1	58.9	N 320S 150R
151	10/31	7/8-.3	300	15	17-5/8	N	OK	OK	0-1	87.6	N 320S 150R
164	10/31	3/4-.6	300	40	21-3/4	N	OK	OK	0-1	134.7	N 320S -
165	10/31	3/4-.6	300	40	22-3/8	N	OK	OK	0-1	142.9	N 320S 195R
166	10/31	3/4-.6	300	40	22	N	OK	OK	0-1	137.9	N 320S 200R
223	11/ 8	3/4-.6	300	40	19-3/4	N	OK	OK	2-4T	110.5	Mag Trans
161	10/31	3/4-.3	300	40	11	N	OK	OK	0-1	33.8	N 320S 200R
162	10/31	3/4-.3	300	40	11	N	OK	OK	0-1	33.8	N 320S 195R
163	10/31	3/4-.3	300	40	12-1/8	N	OK	OK	0-1	41.1	N 320S 195R
167	10/31	7/8-.6	300	40	20-1/4	N	Low	OK	0-1	116.3	N 320 125R
168	10/31	7/8-.6	300	40	17-3/4	N	OK	VF	0-1	88.9	N 320 140R
169	10/31	7/8-.6	300	40	15-1/8	N	RT	OK	0-1	64.2	N 320 135R
209	11/ 5	7/8-.6	300	40	14-1/2	N	OK	OK	6-8HG12	58.9	
210	11/ 5	7/8-.6	300	40	15-1/2	N	OK	OK	6-8HG12	67.5	
211	11/ 5	7/8-.6	300	40	13-1/2	N	OK	OK	6-8HG12	51.0	
217	11/ 7	7/8-.6	300	40	13	N	OK	OK	6-8HG12	47.3	Mag Trans.
170	10/31	7/8-.3	300	40	11-7/8	N	OK	OK	0-1	39.4	N 320S 145R
171	10/31	7/8-.3	300	40	10-1/8	N	OK	OK	0-1	28.6	N 320S 135R
172	10/31	7/8-.3	300	40	11-1/2	N	OK	OK	0-1	36.9	N 320S 135R

TABLE A-2 (Cont'd)
IMPACT ENERGY DATA - PORTABLE PUMPING SYSTEM

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
179	10/31	3/4-.6	300	70	12	N	OK	OK	5-8T	40.2	N 320 S 160 R
180	10/31	3/4-.6	300	70	12-3/8	N	OK	OK	5-8T	42.8	N 320 S 180 R
181	10/31	3/4-.6	300	70	11-3/8	N	OK	OK	5-8T	36.1	N 320 S 180 R
222	11/8	3/4-.6	300	70	10	N	OK	Good	2-4T	27.9	
182	10/31	3/4-.3	300	70	5-3/4	N	OK	OK	5-8T	9.2	N 320 S - R
183	10/31	3/4-.3	300	70	4-5/8	N	OK	OK	5-8T	5.9	N 320 S 170 R
184	10/31	3/4-.3	300	70	3-7/8	N	OK	OK	5-8T	4.2	N 320 S 170 R
176	10/31	7/8-.6	300	70	9-3/4	N	OK	OK	3-5	26.5	N 320 S 125 R
177	10/31	7/8-.6	300	70	9-3/8	N	Low	OK	3-5	24.5	N 320 S 125 R
178	10/31	7/8-.6	300	70	9-3/8	N	OK	OK	3-5	24.5	N 320 S 125 R
216	11/7	7/8-.6	300	70	1-1/2	N	OK	Good	6-8H G12	.6	Mag. Trans.
173	10/31	7/8-.6	300	70	3-1/4	N	OK	OK	3-5	2.9	N 320 S 135 R
174	10/31	7/8-.3	300	70	2-7/8	N	OK	OK	3-5	2.3	N 320 S 135 R
175	10/31	7/8-.3	300	70	4	N	OK	OK	3-5	4.4	N 320 S 135 R

TABLE A-2 (Cont'd)

IMPACT ENERGY DATA - PORTABLE PUMPING SYSTEM

Test No.	Date	Conf.	.P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
350	11/29	3/4-.6	300	15	20-3/4	M	OK	OK	15H 20G	122.3	
351	11/29	3/4-.6	300	15	22	M	OK	OK	15H 20G	137.9	
352	11/29	3/4-.6	300	15	22-3/8	M	OK	OK	15H 20G	156.3	
353	11/29	3/4-.6	300	15	21-7/8	M	OK	OK	15H 20G	136.3	
354	11/29	3/4-.3	300	15	12-1/2	M	OK	OK	15H 20G	43.7	
355	11/29	3/4-.3	300	15	16	M	OK	OK	15H 20G	72.0	
356	11/29	3/4-.3	300	15	16	M	OK	OK	15H 20G	72.0	
360	11/29	3/4-.6	300	40	14-1/4	M	OK	OK	15H 20G	56.9	
361	11/29	3/4-.6	300	40	14-3/8	M	Fair	OK	15H 20G	57.9	
362	11/29	3/4-.6	300	40	14-1/4	M	OK	OK	15H 20G	56.9	
357	11/29	3/4-.3	300	40	5-1/2	M	Fair	OK	15H 25G	8.4	
358	11/29	3/4-.3	300	40	5-1/2	M	OK	OK	15H 25G	8.4	
359	11/29	3/4-.3	300	40	5-1/2	M	OK	OK	15H 25G	8.4	
347	11/29	7/8-.6	300	15	21-1/8	M	OK	OK	15H 20G	126.9	
348	11/29	7/8-.6	300	15	18-1/4	M	OK	OK	15H 20G	94.1	
349	11/29	7/8-.6	300	15	19-3/4	M	OK	OK	15H 20G	110.5	
344	11/29	7/8-.3	300	15	12-3/4	M	OK	OK	15H 20G	45.5	
345	11/29	7/8-.3	300	15	14	M	OK	OK	15H 20G	54.9	
346	11/29	7/8-.3	300	15	14	M	OK	OK	15H 20G	54.9	
363	11/29	7/8-.6	300	40	9-5/8	M	OK	OK	15H 25G	25.8	
364	11/29	7/8-.6	300	40	5-1/4	M	OK	OK	15H 25G	7.7	
365	11/29	7/8-.6	300	40	5-1/4	M	Fair	OK	15H 25G	7.7	
366	11/29	7/8-.3	300	40	5-1/4	M	Fair	OK	15H 25G	7.7	
367	11/29	7/8-.3	300	40	5-1/4	M	Fair	OK	15H 25G	7.7	
368	11/29	7/8-.3	300	40	1-1/4	M	Fair	OK	15H 25G	0.4	

TABLE A-2 (Cont'd)
IMPACT ENERGY DATA - PORTABLE PUMPING SYSTEM

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
226	11/8	3/4-.6	300	15	21-1/2	P	OK	OK	2-4T	131.5	
113	10/25	3/4-.6	300	15	19-7/8	P	OK	OK	0 - 1	112.0	
114	10/25	3/4-.6	300	15	18-7/8	P	OK	OK	0 - 1	100.8	
115	10/25	3/4-.6	300	15	20-3/8	P	OK	OK	0 - 1	117.8	
143	10/31	3/4-.45	300	15	14-3/4	P	GOOD	OK	0 - 1	61.0	N 320S - R
144	10/31	3/4-.45	300	15	15-5/8	P	GOOD	OK	0 - 1	68.6	N 320S 210R
145	10/31	3/4-.45	300	15	15-1/4	P	GOOD	OK	2 - 1	65.3	N 320S 195R
224	11/8	3/4-.6	300	40	8-3/8	P	GOOD	GOOD	2 - 4T	19.5	
225	11/8	3/4-.6	300	40	12	P	LOW	GOOD	2 - 4T	40.2	
122	10/25	3/4-.6	300	40	7-1/2	P	OK	OK	0 - 1	15.6	
123	10/25	3/4-.6	300	40	8-1/2	P	OK	OK	0 - 1	20.1	
124	10/25	3/4-.6	300	40	9-1/8	P	OK	OK	0 - 1	23.2	
140	10/31	3/4-.45	300	40	6-3/8	P	HIGH	OK	0 - 1	11.3	N 320S 170R
141	10/31	3/4-.45	300	40	10-1/8	P	GOOD	OK	0 - 1	28.6	N 320S 180R
142	10/31	3/4-.45	300	40	9-1/2	P	GOOD	OK	0 - 1	25.1	N 320S 185R
221	11/8	3/4-.6	300	70	4	P	GOOD	GOOD	2 - 4T	4.4	
125	10/25	3/4-.6	300	70	3-1/2	P	OK	OK	0 - 1	3.4	
126	10/25	3/4-.6	300	70	3-5/8	P	OK	OK	0 - 1	3.7	
127	10/25	3/4-.6	300	70	2-1/8	P	OK	OK	0 - 1	1.3	
131	10/31	3/4-.45	300	70	1-1/8	P	FAIR	OK	0 - 1	0.3	N 320S - R
132	10/31	3/4-.45	300	70	7/8	P	HIGH	OK	0 - 1	0.2	N 320S 190R
133	10/31	3/4-.45	300	70	3/4	P	GOOD	OK	0 - 1	0.2	N 310S 190R

TABLE A-2 (Cont'd)
IMPACT ENERGY DATA - PORTABLE PUMPING SYSTEM

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
116	10/25	7/8-.6	300	15	14-3/8	P	OK	OK	1 - 2	57.9	
117	10/25	7/8-.6	300	15	16	P	OK	OK	1 - 2	72.0	
118	10/25	7/8-.6	300	15	18-1/2	P	OK	OK	1 - 2	96.7	
146	10/31	7/8-.45	300	15	14-1/8	P	Low	OK	0 - 1	55.9	N320S 150R
147	10/31	7/8-.45	300	15	14-7/8	P	OK	OK	0 - 1	62.1	N320S 145R
148	10/31	7/8-.45	300	15	13-1/8	P	OK	OK	0 - 1	48.2	N320S 150R
212	11/7	7/8-.6	300	40	6-1/2	P	OK	OK	6 - 8H	11.7	
213	11/7	7/8-.6	300	40	4-3/8	P	PART	OK	6 - 8H	5.3	
214	11/7	7/8-.6	300	40	6-5/8	P	OK	OK	6 - 8H	12.2	
217	11/7	7/8-.6	300	40	13	P	OK	OK	6 - 8H	47.3	
119	10/25	7/8-.6	300	40	8-5/8	P	OK	OK	1 - 2	20.7	
120	10/25	7/8-.6	300	40	8-5/8	P	OK	OK	1 - 2	20.7	
121	10/25	7/8-.6	300	40	7-1/2	P	OK	OK	1 - 2	15.6	
137	10/31	7/8-.4	300	40	6	P	OK	OK	0 - 1	10.0	N320S 145R
138	10/31	7/8-.45	300	40	6-5/8	P	OK	OK	0 - 1	12.2	N325S 145R
139	10/31	7/8-.45	300	40	5-1/8	P	OK	OK	0 - 1	7.3	N322S 145R
128	10/25	7/8-.6	300	70	2-5/8	P	OK	OK	1 - 2	1.9	
129	10/25	7/8-.6	300	70	3	P	OK	OK	1 - 2	2.5	
130	10/25	7/8-.6	300	70	2-5/8	P	OK	OK	1 - 2	1.9	
215	11/5	7/8-.6	300	70	1-1/2	P	OK	OK	6 - 8H	0.6	
134	10/31	7/8-.45	300	70	1/8	P	FAIR	OK	0 - 1	.01	
135	10/31	7/8-.45	300	70	1/2	P	OK	OK	0 - 1	.07	
136	10/31	7/8-.45	300	70	1/8	P	MISS-LEA	OK	0 - 1	.01	

TABLE A-3
IMPACT ENERGY DATA - BALLISTIC WATER CANNON

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
454	12/14	BWC	-	15	1-1/2	N	-	Very Slow	3-5C	0.6	
455	12/14	BWC	-	15	9-1/2	N	Good	Inc.Ret.	3-5C	25.1	
456	12/14	BWC	-	15	9	N	Good	No Cock	3-5C	22.5	
457	12/14	BWC	-	15	8-3/4	N	Good	No Cock	3-5C	21.3	
479	12/27	BWC	-	15	14-1/2	N	OK	OK	0-1	58.9	Cu.Wire
499	12/29	BWC	-	15	16	N	OK	OK	6-8H	72.0	HSMP
430	12/12	BWC	-	40	8-3/4	N	Good	Good	4-6H	21.3	
431	12/12	BWC	-	40	10-1/2	N	Good	No Cock	4-6H	30.7	
432	12/12	BWC	-	40	10-7/8	N	Good	No Cock	4-6H	33.0	
433	12/12	BWC	-	40	11-1/2	N	Good	Good	4-6H	36.9	
434	12/12	BWC	-	40	10-1/2	N	Good	No Cock	4-6H	30.7	
435	12/12	BWC	-	40	12	N	Good	No Cock	4-6H	40.2	
465	12/27	BWC	-	40	11	N	Good	Exc.	8-10H	33.8	
468	12/27	BWC	-	40	9-3/4	N	High	Exc.	8-10H	26.5	
469	12/27	BWC	-	40	10-1/2	N	OK	Exc.	8-10H	30.7	
470	12/27	BWC	-	40	13-3/4	N	OK	Exc.	8-10H	52.9	Cu. Wire
501	12/29	BWC	-	40	12	N	OK	No Cock	6-8H	40.2	HSMP
444	12/13	BWC	-	70	4-1/4	N	Good	No Latch	10-12T	5.0	
445	12/13	BWC	-	70	7-1/4	N	Good	Inc. Ret.	10-12T	14.6	
446	12/13	BWC	-	70	6	N	Good	Inc. Ret.	10-12T	10.0	
472	12/27	BWC	-	70	8-1/2	N	OK	Exc.	8-10H	20.1	
473	12/27	BWC	-	70	8-3/4	N	OK	Exc.	8-10H	21.3	
505	12/29	BWC	-	70	7	N	OK	OK	6-8H	13.6	HSMP
461	12/14	BWC	-	15	12-1/4	M	Good	Inc. Ret.	3-5C	41.9	
462	12/14	BWC	-	15	8-1/4	M	Good	No Cock	3-5C	18.9	
463	12/14	BWC	-	15	9-1/8	M	Good	No Cock	3-5C	23.2	
480	12/27	BWC	-	15	14-1/2	M	OK	OK	1-2C	58.9	
439	12/12	BWC	-	40	12-1/8	M	Good	Inc.Ret.	4-6H	41.4	
440	12/12	BWC	-	40	12	M	Good	Inc.Ret.	4-6H	40.2	
441	12/12	BWC	-	40	12	M	Good	Inc.Ret.	4-6H	40.2	
466	12/27	BWC	-	40	7-3/4	M	RT	Exc.	8-10H14G	16.7	
467	12/27	BWC	-	40	9-3/4	M	Good	Exc.	8-10H14G	26.5	
503	12/29	BWC	-	40	13	M	OK	No Cock	4-6C	47.3	HSMP
447	12/13	BWC	-	70	5-3/4	M	Good	Inc.Ret.	10-12T G15	9.2	
448	12/13	BWC	-	70	6-3/4	M	Good	Inc.Ret.	10-12T G15	12.7	
449	12/13	BWC	-	70	4	M	Good	No Cock	10-12T G15	4.4	

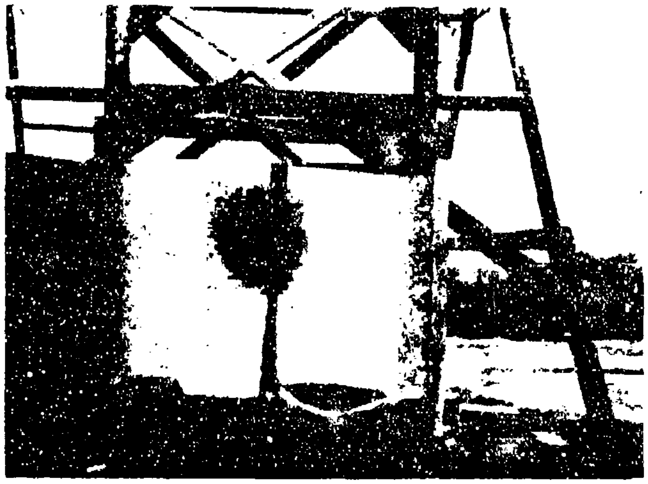
(CONTINUED)

TABLE A-3 (Cont'd)
IMPACT ENERGY DATA - BALLISTIC WATER CANNON

Test No.	Date	Conf.	P PSI	R Ft	Displ. In.	S	Acc	Function	Wind MPH	E Ft Lb	Remarks
474	12/27	BWC	-	70	7-1/2	M	OK	No Cock	8-10H G14	14.6	
475	12/27	BWC	-	70	7-3/4	M	OK	No Cock	8-10H G14	16.7	
504	12/29	BWC	-	70	7	M	OK	No Cock	4-6C	13.6	HSMP
458	12/13	BWC	-	15	9-7/8	P	Good	No Cock	3-5C	27.2	
459	12/13	BWC	-	15	9-3/4	P	Good	No Cock	3-5C	26.5	
460	12/13	BWC	-	15	13-1/4	P	Good	No Cock	3-5C	49.1	
481	12/27	BWC	-	15	14-1/2	P	OK	OK	1-2	58.9	
500	12/29	BWC	-	15	15-1/2	P	OK	OK	6-8H	67.5	HSMP
436	12/12	BWC	-	40	7-3/4	P	Good	No Cock	4-6H	16.7	
437	12/12	BWC	-	40	8-1/4	P	Good	No Cock	4-6H	18.9	
438	12/12	BWC	-	40	6-5/8	P	Good	Inc.Ret.	4-6H	12.2	
470	12/27	BWC	-	40	13-1/2	P	OK	Exc.	8-10H	51.0	
502	12/29	BWC	-	40	7	P	OK	OK	6-8H	13.6	
450	12/12	BWC	-	70	3-1/4	P	Good	Inc.Ret.	10-12T G15	2.9	
451	12/12	BWC	-	70	2	P	Good	Inc.Ret.	10-12T G15	1.1	
452	12/13	BWC	-	70	7/8	P	High	Inc.Ret.	10-12T G15	.2	
476	12/27	BWC	-	70	1	P	Left	OK	8-10H	.3	
477	12/27	BWC	-	70	2	P	Low	OK	8-10H	1.1	
478	12/27	BWC	-	70	2	P	Good	OK	8-10H	1.1	
506	12/29	BWC	-	70	2-1/2	P	OK	OK	4-6C	1.7	

FIGURE A-1

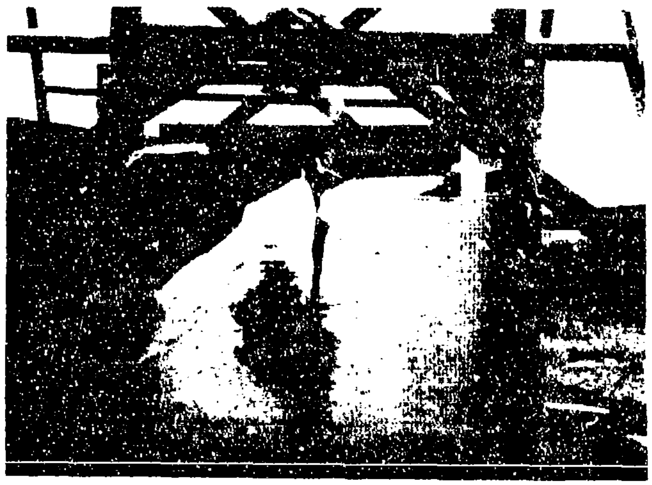
PAPER SCREEN (EA TESTS



Test No. 228

Portable Pumping System, 3/4" Nozzle - 2.9 gallons

Range - 15 Feet

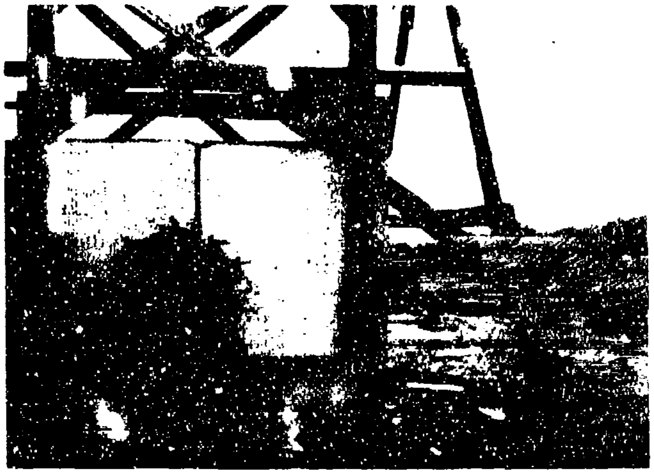


Test No. 220

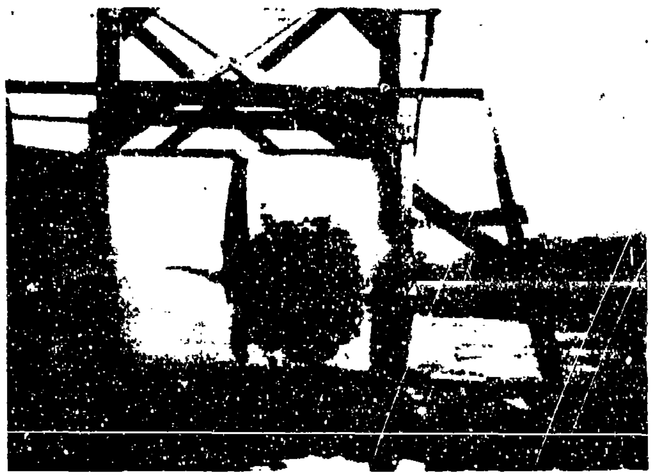
Portable Pumping System, 3/4" Nozzle- 2.9 gallons

Range - 40 Feet

FIGURE A-1 (Cont'd)
PAPER SCREEN AREA TESTS



Test No. 229
Portable Pumping System, 3/4" Nozzle - 2.9 gallons
Range - 40 Feet



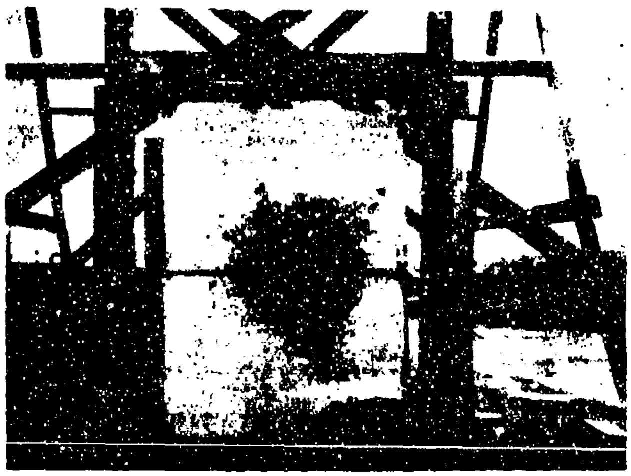
Test No. 230
Portable Pumping System, 3/4" Nozzle - 2.9 gallons
Range - 70 Feet

FIGURE A-1 (Cont'd)
PAPER SCREEN AREA TESTS

Test No. 241

Portable Pumping System, 3/4" Nozzle - 1.6 gallons

Range - 15 Feet



Test No. 340

Portable Pumping System, 3/4" Nozzle - 1.6 gallons

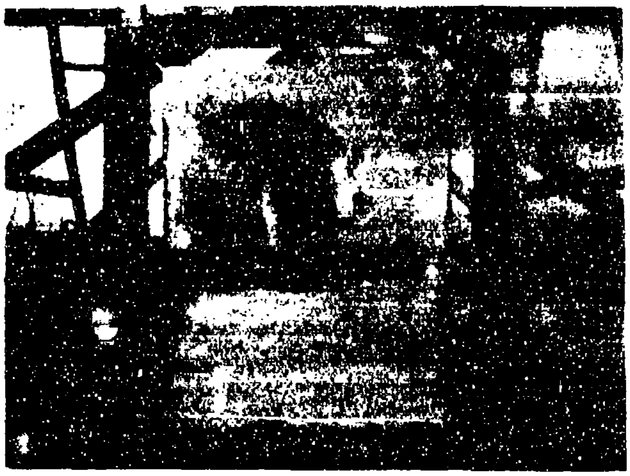
Range - 40 Feet

PAPER SCREEN AREA TESTS

Test No. 335
Portable Pumping System, 3/4" Nozzle - 1.6 gallons
Range - 70 Feet

Test No. 343
Portable Pumping System, 7/8" Nozzle - 3.2 gallons
Range - 15 Feet

FIGURE A-1 (Cont'd)
PAPER SCREEN AREA TESTS

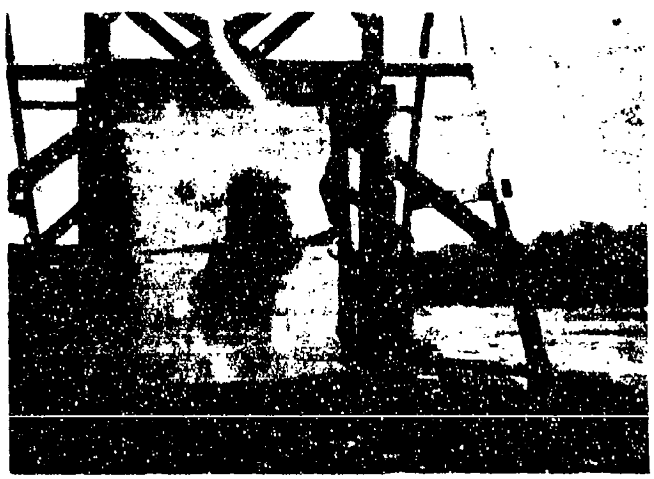


Test No. 338
Portable Pumping System, 7/8" Nozzle - 3.2 gallons
Range - 40 Feet

Test No. 337
Portable Pumping System, 7/8" Nozzle - 3.2 gallons
Range - 70 Feet

FIGURE A-1 (cont'd)
PAPER SCREEN AREA TESTS

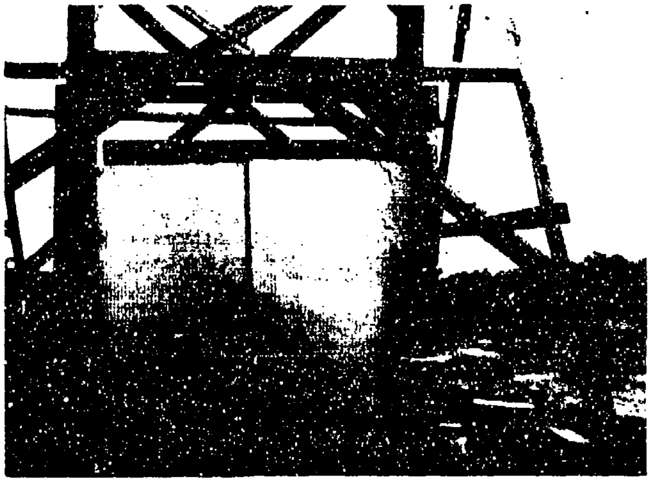
Test No. 342
Portable Pumping System, 7/8" Nozzle - 2.5 gallons
Range - 15 Feet



Test No. 337
Portable Pumping System,7/8" Nozzle - 2.5 gallons
Range - 40 Feet

FIGURE A-1 (cont'd)

PAPER SCREEN AREA TESTS



Test No. 336

Portable Pumping System, 7/8" Nozzle - 2.5 gallons
Range - 70 Feet

Test No. 464
Ballistic Water Cannon

Range - 15 Feet

FIGURE A-1 (cont'd)
PAPER SCREEN AREA TESTS

Test No. 443
Ballistic Water Cannon
Range - 40 Feet

Test No. 453

Ballistic Water Cannon
Range - 70 Feet

TABLE A-4

AREAS OF WATER ROD - FROM PHOTOGRAPHS

PPS - 2.9 gal. pulse

Range, ft.	Area, in^2	Energy, ft lbs/in^2	Test No.
15	125	1.4	228
40	159	.9	220 229
70	79	.8	230

PPS - 1.6 gal. pulse

Range, ft.	Area, in^2	Energy, ft lbs/in^2	Test No.
15	214	.43	341
40	297	.10	340
70	219	.03	335

BWC

Range, ft.	Area, in^2	Energy, ft lbs/in^2	Test No.
15	113	.35	464
40	203	.17	443
70	86.5	.16	453

TABLE A-5
VELOCITY OF WATER STREAM AND TIME OF PULSE AT TARGET

PPS - 2.9 gal. pulse

Range, Ft.	Vel., ft/sec	Test No.	t, sec
6.5	193.5	906	.722
6.5	151.3	914	.725
6.5	167.8	915	.753
6.5	150.9	916	.735
15	173	416	.673
15	145	429	.679
17	160.8	900	.752
17	159.1	901	.602
17	157.2	903	.700
17	148.8	904	.665
		905	.657
37.5	123.7	908	
37.5	134	909	.571
37.5	147	910	.523
37.5	133	911	.656
37.5	130	912	.555
37.5	120	913	.552
40	155.8	414	.570
40	156.2	427	.360
45	141.7	917	.484
45	149.5	918	.482
45	142	919	.455
70	104.6	418	.437

TABLE A-5 (Cont'd)
VELOCITY OF WATER STREAM AND TIME OF PULSE AT TARGET

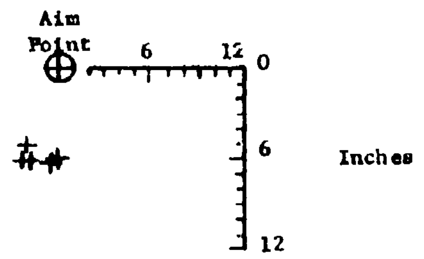
BWC Range, Ft.	Vel., ft/sec	Test No.	t, sec
15	140.3	499	.29
15	166.8	500	.26
40	157.2	501	.28
40	152.3	502	.248
40	150.8	503	.311
70	139.7	504	.236
70	115.5	505	.235
70	100.2	506	.145

TABLE A-6

ACCURACY TESTS

PORTABLE PUMPING SYSTEM

RANGE 15 Feet



RANGE 40 Feet

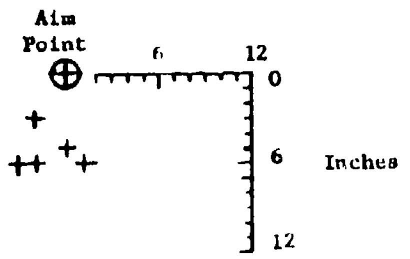
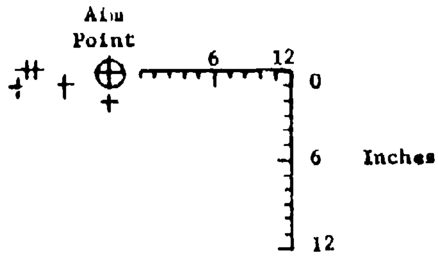


TABLE A-6 (Cont'd)
ACCURACY TESTS

PORTABLE PUMPING SYSTEM (CONT.)

RANGE 50 Feet



RANGE 70 Feet

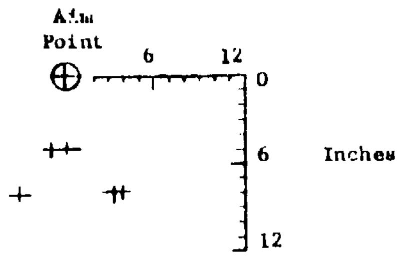
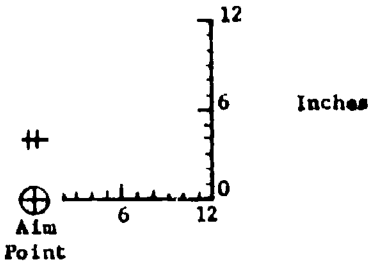


TABLE A-6 (Cont'd)

ACCURACY TEST

BALLISTIC WATER CANNON

RANGE 40 Feet



RANGE 70 Feet

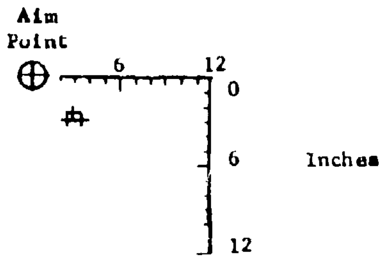


TABLE A-6 (Cont'd)

ACCURACY TESTS

FREE MOUNT

PORTABLE PUMPING SYSTEM

Test No.	Range (Feet)	Time to On Target (Minutes)	No. of Shots To On Target	Time to Knock Down (Minutes)	No. of Shots To Knock Down
403	70	.07	1	.14	3
404	70	.08	1	.11	2
405	70	.08	1	.12	3
406	50	-	-	.09	1
407	50	-	-	.12	1
408	50	.09	1	.12	2
409	30	-	-	.11	1
410	30	-	-	.06	1
411	30	-	-	.06	1
412	15	.06	1	.08	2
413	15	-	-	.06	1
413A	15	-	-	.06	1

TABLE A-6 (Cont'd)

ACCURACY TESTS

MOVING TARGET

PORTABLE PUMPING SYSTEM

Test No.	Range (Feet)	Time to On Target (Minutes)	No. of Shots to On Target
507	30	.08	2
508	30	.05	2
509	30	.025	1
510	70	.05	3
511	70	.03	2
512	70	.03	2

Table A-7

Test of Physical Effects

Portable Pumping System - 2.9 gal. pulse

Test Number	Date	Height of aim, Ft.	Range, Ft.	KD	Acc.	Func.	Wind
369	12/3	3	40	yes	good	OK	0-1 T
370	12/3	3	40	yes	good	OK	0-1 T
371	12/3	3	40	yes	good	OK	0-1 T
378	12/4	3	70	yes	good	OK	0
379	12/4	3	70	no	good	OK	0
380	12/4	3	70	no	good	OK	0
381	12/4	5	70	yes	good	OK	0
382	12/4	5	70	yes	good	OK	0
383	12/4	5	70	yes	good	OK	0
390	12/4	5	90	no	OK	OK	0
391	12/4	5	90	no	OK	OK	0
392	12/4	5	90	no	OK	OK	0

Table A-7 (Cont'd)
Test of Physical Effects

Portable Pumping System - 1.6 gal. pulse

Test Number	Date	Height of aim, Ft.	Range, Ft.	KD	Acc.	Func.	Wind
372	12/4	3	40	yes	good	OK	0-1 T
373	12/4	3	40	yes	good	OK	0-1 T
374	12/4	3	40	yes	good	OK	0-1 T
375	12/4	3	70	no	good	OK	0-1 T
376	12/4	3	70	no	good	OK	0-1 T
377	12/4	3	70	no	good	OK	0-1 T
384	12/4	5	70	no	good	OK	0
385	12/4	5	70	no	good	OK	0
386	12/4	5	70	no	good	OK	0
387	12/4	5	90	no	poor	OK	0
388	12/4	5	90	no	poor	OK	0
389	12/4	5	90	no	poor	OK	0

Table A-7 (Cont'd)
Test of Physical Effects

Ballistic Water Cannon

Test Number	Date	Height of aim, Ft.	Range, Ft.	KD	Acc.	Func.	Wind
495	12/28	3	15	yes	good	OK	6-8 H
496	12/28	3	40	yes	good	OK	6-8 H
497	12/28	3	70	no	good	OK	6-8 H
498	12/28	5	70	yes	good	OK	6-8 H

APPENDIX B

MINUTES OF MEDICAL GROUP MEETING

(Conducted at AAI 7 December 1973 to estimate the physiological undesirable and desirable effects resulting from impacting swine with the water pulse from the Portable Pumping System.)

MINUTES OF
FOURTEENTH MEDICAL GROUP MEETING - AAI

7 December 1973

ATTENDEES:
* M. J. Wargovich, Chairman-LWL
* E. B. Shank-LWL
B. Thein (Mrs.)-LWL
* W. M. Busey, D.V.M., Ph D
* R. S. Fisher, M.D.
* W. F. Renner, M.D.
* W. Gill, M.D.
J. Rush (Mrs.)-EPL
A. F. Tiedemann, Jr. -AAI

GENERAL

The attendees keyed on an agenda as follows:

1. Chairman's opening remarks; schedule meeting dates, review of minutes program forecast, etc.

2. High-speed film of Portable Pumping System test series.

3. Estimates of Physiological Undesirable and Desirable Effects for the Portable Pumping System.

    a. Review of slides of physical damage.

    b. Approve and/or modify and concur on damage level assigned.

    c. EKG commentary and grading

    d. Undesirable effect estimate with rationale.

    e. Desirable effect estimate with rationale Moving-H, Army Scenario II described in an Annex to these minutes.

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*Voting Members

DETAIL

In his opening remarks, the chairman introduced the new Medical Group member, Dr. William Gill. Dr. Gill is a general surgeon. He received his formal training in England and came to the U.S.A. about 18 months ago. Dr. Gill has worked with BRL in the wound ballistics area. At present Dr. Gill is the Clinical Director at the Maryland Institute for Emergency Medicine, University of Maryland, Baltimore, Maryland.

A review of the initial damage grade assessments was conducted. The standard procedure of viewing sequential slides of the wound tract was followed. In addition, an assessment of cardiac rhythm disturbances and injury was rendered according to a priori criteria established. Using all of this information, the group independently estimated undesirable effects and desirable effects for the Moving-H, Army Scenario II, concurrently.

Supporting rationale was given for each of the estimates rendered. Discussion continued until the group reached consensus on a probability estimate. This procedure was repeated for each wound in order to obtain first undesirable and second desirable effects estimates.

After completing these estimates, the group was shown a high-speed film from the Portable Pumping System test series.

After reviewing the film and discussing some of the experimental techniques and the design of the experimental equipment used for animal support, the group estimated the physiological undesirable and desirable effects.

The following estimates are for the undesirable effects and the desirable effects for the Moving-H, Army Scenario II. The probabilities of effects cited in Table B-1 have the following interpretation.

- o P_{ue} a .10 probability means that out of 100 people sustaining the impact, 10 will be expected to experience the effect of interest and 90 will not.

In the Moving-H Scenario, the desirable effect probability is composed of the following elements.

- o P_{de} = a .10 probability means that out of 100 people sustaining the impact, 10 will be expected to experience the effect of interest and 90 will not.

- o Column heading "P cannot leave" = P_{cl}

  a .10 probability means that out of 100 people sustaining the impact, 10 will not be expected to be able to leave the area (physical damage excessive, cannot even crawl away).

o Column heading "P will not leave" - P_{wnl}

a .10 probability means that out of 100 people sustaining the impact, 10 will not be expected to leave (stubborn, martyr, willing and able to participate, etc.).

The desirable effect probabilities cited for any one animal are subject to the constraint.

$$\sum i = 1$$

where $i = P_{de}, P_{cannot\ leave}, P_{will\ not\ leave}$.

Table B-1

Provisional Estimates of Undesirable Effects, P_{ue}, and Desirable Effects, P_{de}, for the Portable Pumping System

Swine Shot No.	Animal Number	P_{ue}	P^1_{de}	P_{ci}	P_{wnl}	Remarks 2, 3
3	902-S	1.00	0	1.00	0	Liver lesion. EKG-chaotic rhythm, fatal arrhythmia.
17	916-S	.25	0	0	1.00	Similar liver lesion as 902-S. Peritoneal irritation would be uncomfortable.
16	915-S	0	0	0	1.00	Reddening of skin. No gross lesions.
15	914-S	0	0	0	1.00	Similar to 915-S.
7	906-S	0	0	0	1.00	Animal almost dead before shot. No gross lesions.
8	907-S	.25	.50	0	.50	Redness in belly wall; fractured rib, ruptured spleen.
1	900-S	0	0	0	1.00	No gross lesions.
2	901-S	0	0	0	1 00	No gross lesions.
9	908-S	0	0	0	1.00	No gross lesions.
11	910-S	0	0	0	1.00	No gross lesions.
10	909-S	0	0	0	1.00	No gross lesions.
18	917-S	.10	0	0	1.00	Some lung injury.
19	918-S	1.00	.50	0	.50	Hemothorax, chest pain.
20	919-S	1.00	0	1.00	0	EKG-Chaotic rhythm; died in 5 minutes.

Table B-1 (Cont'd)

Swine Shot No.	Animal Number	P_{ue}	P^1_{de}	P_{cl}	P_{wnl}	Remarks[2, 3]
4	903-S	.50	.10	0	.90	The group speculated on the mechanism of damage. Possible first stage rebound injury. If we eliminate the rebound, probably not much damage was done.
5	904-S	0	0	0	1.00	Reddening of skin; epidural hemorrhage.
6	905-S	.25	0	0	1.00	Subcutaneous hemorrhage; lung lesion.
12	911-S	.50	.50	0	.50	Epidural hemorrhage; Assume a significant lesion accompanied by backache.
13	912-S	.50	.25	0	.75	Some would have posterior nerve root irritation pain and/or sensory disturbance.
14	913-S	0	0	0	1.00	Not much physical damage. Animal died from marked pneumonia and anesthetic.

[1] Moving-H, Army Scenario II is described in the Annex to this Appendix.

[2] Patho-physiological damage grades are given in Appendix C. EKG commentary and grading are given in Table B-3. EKG comments are entered in the above table only when they contribute to the effects estimates.

[3] Summary of physiological damage levels is given in Table B-2.

Table B-2
Summary Of Damage Levels Resulting From Impacting Various Organs
Of Pigs With Water From The Portable Pumping System Fired At Various Ranges

Shot No.	Animal No.	Range Ft.	Target	Damage Levels							Remarks
				Skin	Liver	Kidney	Lung	Heart	Spleen	Other	
3	902-S	-	Front of Pig		3		2	2			Died
17	916-S	6.5	Front of Pig		3					2	Serosal hemorrhage of colon
16	915-S	6.5	Front of Pig	2							
15	914-S	6.5	Front of Pig	2							
7	906-S	6.5	Front of Pig	1							
8	907-S	6.5	Front of Pig	1					5	2	Fractured rib
1	900-S	15	Front of Pig	1							
2	901-S	15	Front of Pig	1			1				
9	908-S	35.5	Front of Pig	1							
11	910-S	35.5	Front of Pig	1							
10	909-S	-	Front of Pig	1							
18	917-S	45	Front of Pig				2				
19	918-S	45	Front of Pig	2			3				
20	919-S	45	Front of Pig	0				2			
4	903-S	15	Back of Pig	1						2	Epidural hemorrhage
5	904-S	15	Back of Pig	2							
6	905-S	15	Back of Pig	0(3)			2			2	Epidural hemorrhage (Sub. cut.hem.pig hitting board)
12	911-S	35.5	Back of Pig	1						2	Epidural hemorrhage
13	912-S	35.5	Back of Pig	0						2	Epidural hemorrhage
14	913-S	35.5	Back of Pig	0							Died - marked pneumonia

Table B-3
Summary of Results of EKG Monitoring: 900 Series

Animal No.	C.D.	M.I.	Remarks	P.D.
906S	0	0	No recording for 5 sec. after hit; AV disassociation at time of sacrifice	
907S	0	0	T wanes and waxes posthit	
914S	0	0	Variable T-waves posthit	
915S	0	0		
916S	0	1	T inverts for 3 sec. posthit	
900S	0	0	Variable T posthit; T deeply inverted at sacrifice	
901S	0	0	Variable T-waves posthit	
902S	4	0	With hit ventricular tachycardia to ventricular flutter to chaotic rhythm; at 5 min. chaotic rhythm	
903S	0	0	AV disassociation pre- and post-hit	
904S	0	0		
905S	2	0	QRS changes configuration with hit; aberrant QRS conduction	
908S	0	0	At sacrifice small Q and T inversion in II, III, AVF	
909S	0	0		
910S	2	1	RS changes to tall R for 00 sec. with deep T inversion which persists beyond the 30 sec.	pig began to breathe abnormally at hit
911S	0	0		
912S	0	0	Q in II with T inversion at sacrifice	
913S	4	?	No change with hit; aberrant I.V. conduction and AV dissociation prior to hit; at 15 sec. rate speeds up with ST elevation; at 51 sec. atrial premature beats; at 120 sec. bundle branch block; at 126 sec. paroxyms of atrial fibrillation; at 180 sec. 3 to 1 block, then only P-waves to straight line	
917S	0	0		
918S	0	0		
919S	4	0	No change at either hit; no prehit arrhythmias; at 150 sec. AF disassociation develops, goes on to chaotic rhythm to straight line on tape marked "before hit."	

C.D. = Conduction Disturbance M.I. = Myocardial Injury
P.D. = Physical Damage

SUMMARY

- In the Portable Pumping System test series EKG changes are delayed and develop after the impact.

- In the Portable Pumping System test series, physical injuries may result from the impact, a second impact (rebound) and from tertiary effects peculiar to the animal restraint syutem.

ANNEX TO APPENDIX B

DESCRIPTION OF MOVING-H ARMY SCENARIO II

The abstracted information* presented below was used by the Methods Group and the Medical Group to render provisional percentage estimates of undesirable and desirable effects related to pain, various degrees of physiological damage, and nonphysiological phenomena.

The scenario discussed herein was constructed to depict a situation likely to confront military control forces during civil disturbances. It was the intent in establishing this scenario to identify factors which might help in establishing guidelines and standards for the evaluation of the purported less-lethal weapons.*

In the construction of this scenario, particular consideration was given to the constraints which the presence of bystanders, the level of threat to the officer, and general public reaction might impose upon the selection and employment of less-lethal weaponry.

Army Scenario II - The Moving "H"

The setting for Scenario II is a city street in the early stages of a disturbance or perhaps later when "hard-core" troublemakers try to provoke a re-escalation of tensions.

The tactic of the troublemakers is to block off a street in order to, first, present a challenge to the control forces and, second, provide an incident which will motivate bystanders to join in the troublemaking.

The typical scene involves the troublemakers in the middle of the street, a number of bystanders along the sidewalks, and the control forces confronting the troublemakers in the street. So long as the control forces maintain their distance, the troublemakers hold their ground and throw rocks, bottles, or other objects at control force personnel. It is estimated that a distance of 20-70 meters will generally separate the rock-throwers from the control forces, with the rock-throwers occasionally running forward out of the group blocking the street in order to get within range.

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*Draft report "A Multidisciplinary Technique for the Evaluation of Less-Lethal Weapons (Vol I)," Annex to Appendix C, Descriptions of Army Scenarios, July 1973, US Army Land Warfare Laboratory, Aberdeen Proving Ground, MD 21005

The control forces will be drawn up in standard crowd dispersal formations. After reading the riot act to either those persons blocking the street, or else to everyone on the scene, these formations advance to clear the street. As the control forces advance, the troublemakers will probably hold their ground initially in order to see how bystanders will react. The distance between the control forces and those blocking the street will therefore diminish and objects will be thrown at the control forces from the crowd blocking the street. As the control forces continue to advance, those blocking the street may retreat for a distance; but, if they at some point stand their ground until control forces are quite close, they will either disperse and try to escape (as the control forces hope) or else attack individual control force personnel.

The major aims of the control forces in this situation are to:

1. disperse the group blocking the street by motivating them to leave the area

2. avoid affecting bystanders or otherwise motivating onlookers to join the disturbance

Other aims include deterring the rock-throwers and perhaps apprehending individuals who run forward out of the crowd to throw things.

While the troublemakers and onlookers together might outnumber the control forces, the number of bystanders is not significant unless they join in for some reason. If the bystanders do not join in, the control forces may have numerical superiority over those blocking the street. Even if they are outnumbered, the control forces will have training and discipline on their side.

These types of confrontations normally occur in daylight or early evening hours. In some situations, as in certain ghetto areas, the crowd might contain children. If the confrontation is in connection with campus disorders, the crowd can be considered to consist of adults only.

APPENDIX C

PHYSIOLOGICAL DAMAGE GRADES

CRITERIA FOR THE EVALUATION OF DAMAGE
RESULTING FROM BLUNT TRAUMA*

I. SKIN, SUBCUTANEOUS TISSUE AND MUSCLE

Grade	Criteria
1	Superficial blemish or signature in skin
2	Grade 1 plus subcutaneous hemorrhage and/or edema
3	Grades 1 and 2 plus subcutaneous and/or intramuscular hematoma
4	Grades 1, 2 and 3 plus laceration of fascia
5	Grades 1, 2, 3 and 4 plus laceration of skin

II. KIDNEY

Grade	Criteria
1	Superficial contusion with subcapsular hemorrhage and/or perirenal hemorrhage
2	Grade 1 plus superficial laceration of cortex not penetrating more than 2-3 mm.
3	Grade 1 plus simple laceration of kidney penetrating to pelvis
4	Grades 1, 2 and 3 plus multiple lacerations
5	Grades 1, 2, 3 and 4 plus rupture of capsule and destruction of kidney

*Abstracted from draft report "A Multidisciplinary Technique for the Evaluation of Less-Lethal Weapons (Vol 1)," Appendix J, Physiological Damage Criteria, July 1973, US Army Land Warfare Laboratory, Aberdeen Proving Ground, MD 21005

III. LIVER

Grade	Criteria
1	Subcapsular hematoma with no visible fracture of liver
2	Grade 1 plus simple fracture of liver less than 1 cm. deep and/or less than 5 cm. long
3	Grades 1 and 2 plus rupture of capsule and fracture of liver 1-2 cm. deep and/or less than 10 cm. long
4	Grades 1, 2, and 3 plus fracture greater than 2 cm. and/or greater than 10 cm. long
5	Fragmentation of liver

IV. SPLEEN

Grade	Criteria
1	Subcapsular hematoma less than 5 cm. in diameter
2	Subcapsular hematoma greater than 5 cm. in diameter and/or minor intrasplenic hemorrhage
3	Grades 1 and 2 plus rupture of capsule less than 1 cm. long
4	Grades 1 and 2 plus capsular rupture greater than 1 cm. long
5	Disruption of spleen, laceration of substance of spleen - torn capsule

V. LUNG

Grade	Criteria
1	Small contusion of lung with subpleural hemorrhage less than 5 cm. in diameter and extending less than 1 cm. into lung
2	Subpleural hemorrhage greater than 5 cm. in diameter and/or multiple hemorrhages less than 5 cm. in diameter
3	Grades 1 or 2 with pleural rupture and pneumothorax
4	Grade 3 with bilateral pneumothorax
5	Deep tears in lung parenchyma with hemopneumothorax

VI. OTHER VISCERA

Grade	Criteria
1	Less than 1 cm. subserosal hemorrhage
2	Greater than 1 cm. subserosal hemorrhage
3	Grade 2 plus serosal laceration and/or mensenteric lacerations
4	Single rupture of viscera and/or diaphragm
5	Multiple rupture of one or more viscera

VII. BONE

Grade	Criteria
1	Periosteal hemorrhage without visible fracture
2	Simple fracture with no displacement
3	Fracture with lateral displacement without pleural perforation (rib)
4	Grade 3 plus perforation of pleura (rib) or multiple simple fractures or compound fracture of long bone
5	Fragmentation of bone

VIII. HEAD

Grade	Criteria
1	Linear fracture of skull and/or minor epidural or subdural hemorrhage and/or contusion of brain less than 2 mm. in diameter
2	Grade 1 plus subcritical intracranial hemorrhage *
3	Depressed fractures of skull with subcritical intracranial hemorrhage and/or limited brain contusion
4	Critical intracranial hemorrhage and/or multiple linear or depressed fractures of skull
5	Massive intracranial hemorrhage with extensive laceration and contusion of brain - immediate death or death prior to sacrifice

* Critical intracranial hemorrhage is defined as that volume of accumulated blood required to produce coma due to increased intracranial pressure.

IX. HEART

Grade	Criteria
1	Epicardial and/or myocardial hemorrhages 2 cm. or less in diameter with no electrocardiographic conduction or rhythm changes.
2	Epicardial and/or mycardial hemorrhages greater than 2 cm. in diameter and/or transient conduction or rhythm changes lasting 10 seconds or less.
3	Same as Grade 2 - or myocardial necrosis less than 2 cm. in diameter or electrocardiographic conduction or rhythm changes lasting longer than 10 seconds, but less than 1 minute.
4	Myocardial necrosis greater than 2 cm. in diameter or electrocardiographic conduction or rhythm changes lasting longer than 1 minute but survival for 24 hours.
5	Rupture of the heart with immediate death or electrocardiographic changes indicating fibrillation, other marked rhythm changes, or electrical conduction changes severe enough to cause death.

APPENDIX D

PHYSIOLOGICAL TEST RESULTS

Physiological Test Results

Figures D-1, -2, -3, and -4 consist of plots of displacement and energy versus time for selected physiological tests on swine conducted at LWL. The Portable Pumping System was used throughout this series of tests. The circled points on the displacement curves represent actual data points as determined from high speed motion pictures of the tests. The solid displacement curve is a fifth order approximation of the displacement data points.

The energy transferred to the knockdown target to which the pig was attached was calculated using the following equation.

$$E = \frac{W}{2g}\left(\dot{x}^2 + \dot{y}_B^2\right) + W\left(y_A - y_{Ao}\right)$$

Figure D-1

Swine Medical Test No. 901

Range - 15 Feet

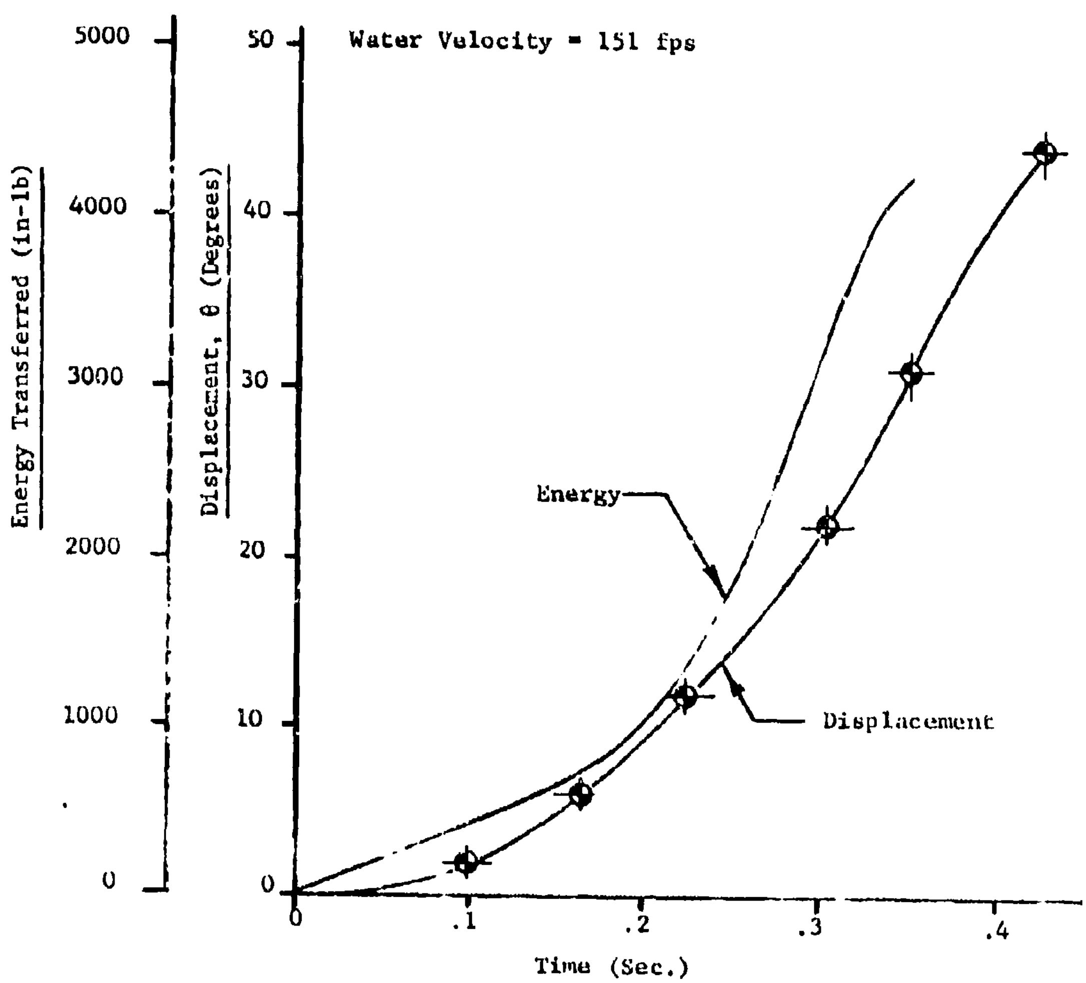


Figure D-2

Swine Medical Test No. 906

Range-6.5 Feet

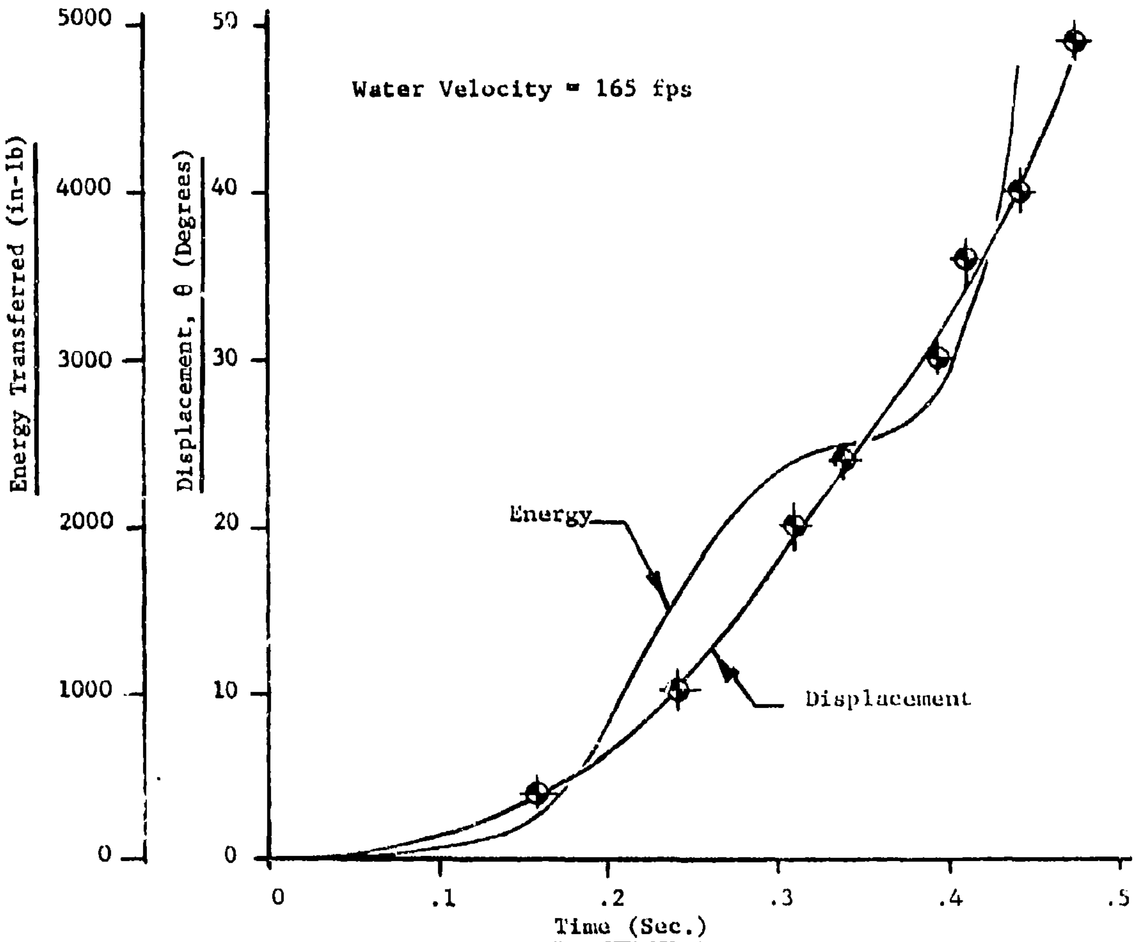


Figure D-3
Swine Medical Test No. 908
Range - 35.5 Feet

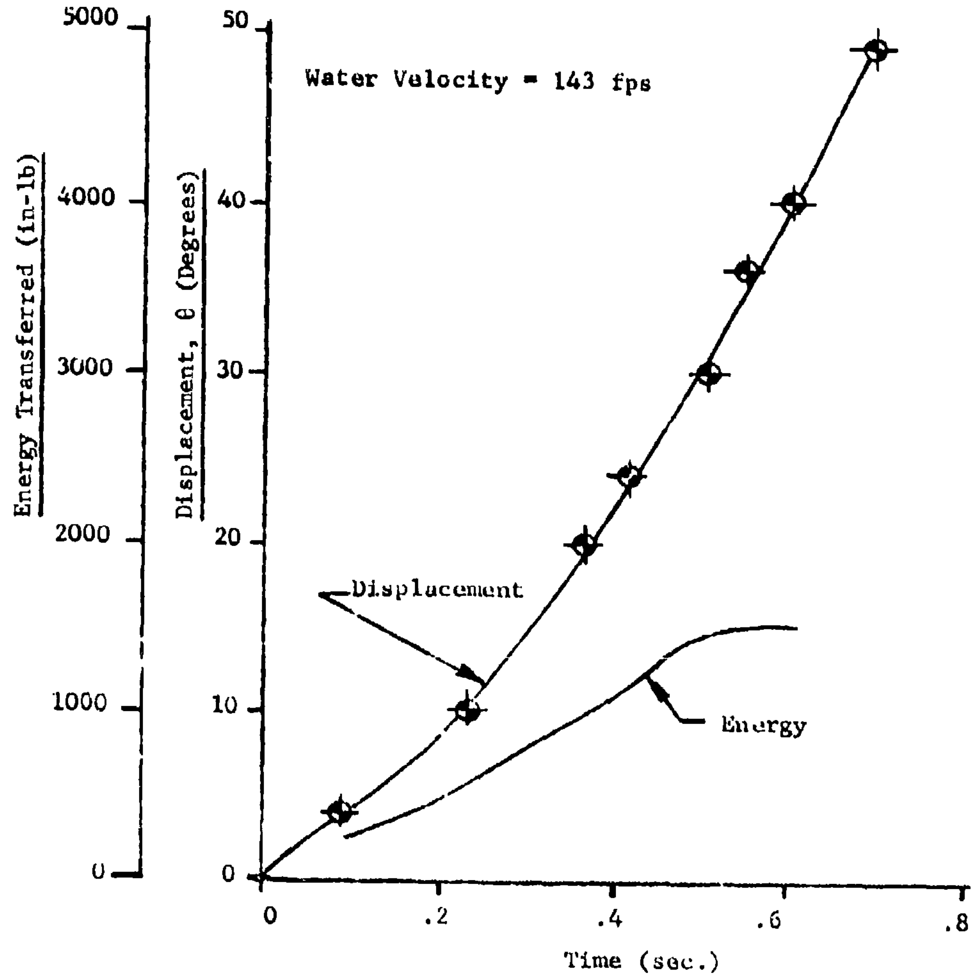
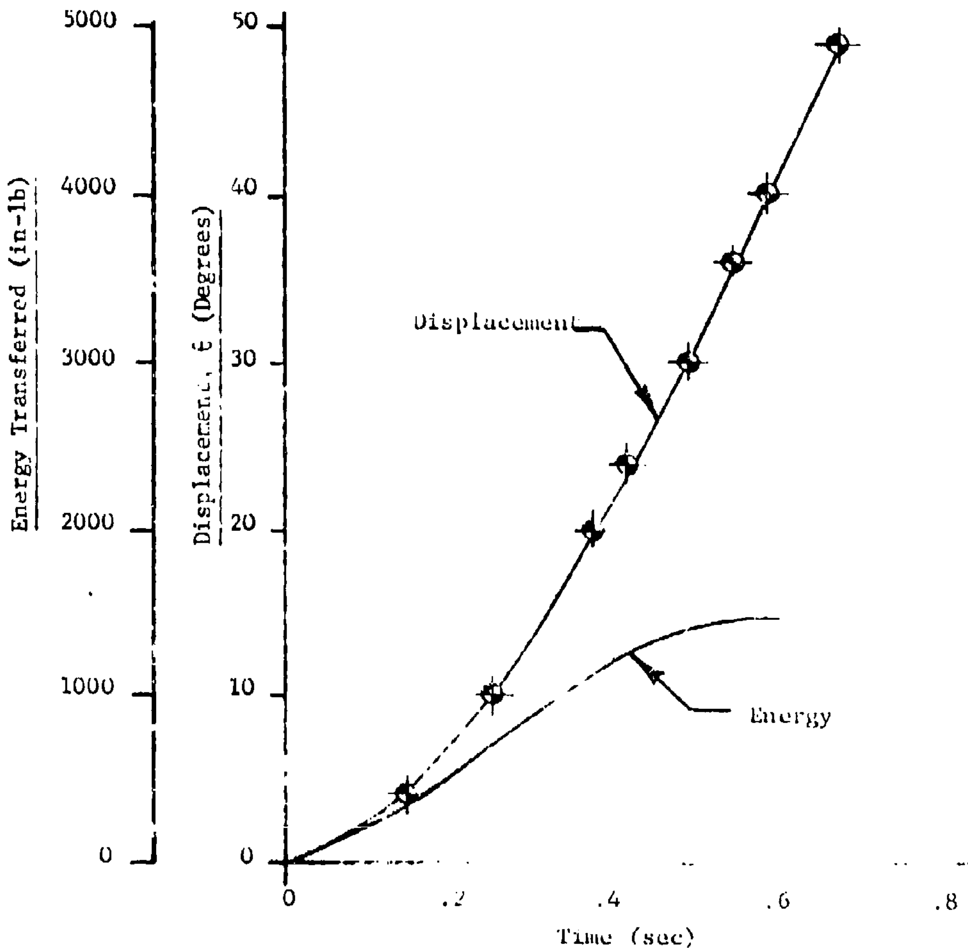


Figure D-4

Swine Medical Test No. 918

Range - 45 Ft.

Water Velocity = 144 FPS



List of Terms, Abbreviations and Symbols

PPS -- Portable Pumping System

BWC -- Ballistically-Actuated Water Cannon

Conf. -- Configuration being tested.

Fraction-Decimal - indicates Portable Pumping System, fraction is nozzle diameter in inches; decimal is length of pulse in seconds.

P -- Pressure of water at pump outlet gauge, pounds/inches^2. Not applicable to Ballistic Water Cannon.

R -- Range of test, Feet.

Displ.-- Displacement of Test Pendulum, inches.

S -- Masking screen used in test.

N - none
M - man silhouette
P - pig silhouette

Acc. -- Accuracy of shot

OK -- on target
Bad - miss
Low, High, Left, RT, Part - partial misses and direction.

Function- Mechanical System Function

Inc. Ret. - BWC, incomplete return to battery.
No cock - BWC, failed to achieve fully latched condition.

Wind -- Wind condition during test, mph

T - tail wind
H - head wind
C - cross wind
G - gusts

E -- Energy imparted to pendulum, ft-lbs

List of Terms, Abbreviations and Symbols (con't)

psi	--	Pounds per square inch
gpm	--	Gallons per minute
C.G.	--	Center of Gravity
ft-lbs	--	Foot-pounds
fps	--	Feet per second

Remarks -

Pump $\leq$ 300 psi	- Malfunction of pump, pressure is highest that could be achieved.
Run. Press.	- Running Pressure, psi
GB HOT	- Pump Gearbox overheated
N320S200R	- Nozzle pressure from nozzle pressure gage, psi, "S", static pressure, "R", running pressure.
Mag trans -	- Magnetic displacement transducer.
Cu Wire	- Copper Wire used to retain muzzle plug.
HSMP	- High Speed Motion Picture

Equations of Pendulum Equilibrium

A An array of coefficients of variables of the equations of equilibrium.

B An array of coefficients for the constants associated with the equations of equilibrium.