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SUMMARY REPORT

ON

TASK ORDER NO. MM

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May 31, 1960

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P. O. BOX 216 - STATION A

COLUMBUS, OHIO

25X1

May 31, 1960

BATTELLE MEMORIAL INST

Dear Sir:

This summary letter report describes the effort performed on Task Order No. MM, from October 14, 1959, through (THRU) May 31, 1960.

The objective of this program was to develop a powered hand tool which would facilitate the removal of dirt from the face of a small tunnel. During this program, a study of design parameters was made, the specifications for an experimental tunneling tool were formalized, and an experimental tunneling tool was designed and built. The tool was essentially comprised of a hydraulic-cylinder assembly, hydraulic-power-pack assembly, and electrical-transmission assembly. The operation of the equipment under limited test conditions was very satisfactory except for a few minor features. These features were modified, and the unit was returned to you on April 12, 1960, for further evaluation.

As discussed with you, the next step in the developmental program for the tunneling tool would be the incorporation of the operating features of the experimental tool into a prototype design.

Background Information

On June 22, 1959, Work Order No. XI, Task Order No. CC, was undertaken to investigate existing tools which could be used for or adapted to the removal of dirt from the face of a tunnel, to facilitate a tunneling operation. As a result of this research, a principle of tool operation was evolved that showed considerable promise. The principle involved a hydraulic cylinder with special working blades attached to the ram that could be used to cut slots in

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the face of the tunnel. The slots would make it possible for large chunks of dirt to be broken easily and quietly from the tunnel face. Preliminary tests with a modified automobile hydraulic jack were very encouraging. Subsequently, Task Order No. MM was originated with the objective of designing, building, and evaluating an experimental model of a hand-held power tool using the above-outlined principle.

Engineering Activity

Design Investigation

In the design investigation, a study of the design parameters was made and the tunneling-tool specifications were established. The standard components of the tunneling-tool package were then selected and the design of the experimental unit was completed.

Design Parameters. In connection with the design of the tunneling tool, the following parameters were selected for study: force, speed, size, and weight. A preliminary evaluation of these factors was made with the experimental tool which had been prepared under Work Order No. XI, Task Order No. CC. The most rigorous slotting was done with the modified hydraulic jack in hard clay; a maximum force of 2,000 pounds was required under the most severe conditions. The speed of movement of the slotting blade was varied over a very limited range. The general handling characteristics of the device were studied relative to size and weight.

Based on the results of the field test and evaluation of the modified hydraulic jack, the following specifications were tentatively established for the proposed tunneling tool. The maximum force at the working blade was set at 2,000 pounds. This force would be attained by the proper combination of operating pressure and hydraulic-cylinder-piston diameter. The maximum force would be required only on the advance or working part of the cycle. It was decided that the tool should operate at between 6 and 12 cycles per minute. A cycle of operation would consist of the advance of the blade to remove dirt by slotting and the retraction of the blade under no load. The speed of the blade would be determined primarily by the size of the hydraulic cylinder relative to the pump capacity.

As envisioned, the hand-held tool would be used to slot horizontal grooves in one half of the tunnel face from top to bottom. By reversal of the position of the tool, the other half of the face would be slotted. The hand-held tool, which basically would be a hydraulic cylinder with an 18-inch stroke, would be approximately 20 inches long with the piston rod retracted. The maximum weight of the unit was set at 35 pounds, but every effort was to be made to achieve a unit weighing less than 20 pounds.

The maximum weight of the power-pack assembly and electrical components was set at 100 pounds, unless a carrier vehicle could be provided for the transportation of these items. The components were to have a configuration such that they would not appreciably restrict the working width of the tunnel floor.

<u>Selection of Components</u>. Based on the specifications formalized for the tunneling tool, a survey was made of various commercial hydraulic components. These included hydraulic cylinders, power-pack units, pumps, motors, valves, and flexible hoses and fittings.

With a 1 to 1-1/4-inch-diameter piston in the hydraulic cylinder, the required pressure range would be about 2,540 to 1,640 psi, and the flow rates would range from about 150 to 432 cubic inches per minute. On consideration of the power-transmission problems and motor weight, it was deemed inadvisable to use a motor larger than 1 horsepower. However, with 100 per cent efficiency and no leakage in the pump, a 1-horsepower input to the pump would result in a flow rate of only 243 cubic inches per minute at 1,640 psi. It was decided that the normal operating pressure should be made lower than 1,640 psi, in order to provide the capacity for the desired speed. For maximum-pressure conditions, the pump relief valve could be adjusted and the motor could be overloaded for short periods of time.

A gear pump was selected because of the low first cost and low maintenance costs. A hydraulic cylinder with a piston diameter of 1-1/4 inches and a stroke of 18 inches was selected for incorporation in the hand tool. A three-way manually operated hydraulic valve was chosen to control the operation of the hydraulic cylinder. The three positions of the valve directed oil (1) so as to advance the piston, (2) so as to retract the piston, and (3) through the valve directly to the pump return line (in the neutral position).

The hydraulic power-pack unit was comprised of a gear pump rated at 1-1/2 gallons per minute, 1-horsepower motor, pressure gage, pressure-relief valve, and 2-gallon reservoir. Two flexible hydraulic hoses, each 15 feet long, approximately 3/16 inch in inside diameter, and rated at 3,000-psi working pressure, were selected to connect the hydraulic power-pack unit to the control valve of the hydraulic-cylinder assembly.

<u>Electrical Components</u>. As discussed previously, the selection of a 1-horsepower electric motor for the power-pack unit was based on the hydraulic requirements, limitations of size and weight, and electrical-transmission problems. The electric motor was a standard 115-volt, single-phase, 60-cycle,

flange-mounted unit. The current and allowable voltage drop in the equipment determined the size and allowable length of transmission wire. However, the wire size had to be kept small, to minimize the weight and bulk. As a result, the following electrical-transmission equipment was selected: two 1-KVA transformers (115/480 volts), 250-foot coil of No. 10 three-wire conductor, and suitable connectors.

Design of Tunneling Tool. In the contemplation of the design of the experimental tunneling tool, it was apparent that the use of standard components was desirable because the original cost would be less and the cost of modifications would undoubtedly be less. However, due to the ineffective use of materials as a result of combining commercial components, the resulting tool would be bulkier, heavier, and less finished looking than an original design. For the experimental tool, it was decided that the design should be based on the modification and adaptation of standard components wherever possible.

An order was placed for a 1-1/4-inch-diameter hydraulic cylinder with an effective piston area of 1.227 square inches for the advance or working cycle. The piston rod was 7/8 inch in diameter and had an effective area of 0.626 square inch for the return or no-load stroke. This combination of sizes was used to reduce the total volume of oil needed for each cycle, and to provide an extended rod with strength sufficient to eliminate the need for additional guides for normal operation of the equipment. Designs were prepared for a slotting-blade adapter, to attach to the threaded end of the piston-rod extension; a base plate, to bolt to the cylinder end cap with four machine screws; and an auxiliary piston-rod felt wiper and wiper housing, to mount on the front end cap. The control valve was modified, and a split-block mounting adapter was designed to facilitate the attachment of the valve to the cylinder. Also, designs were made up for a flat disc-shaped handle, to replace the rod-type handle of the valve; a hydraulic-cylinder assembly, to include the working blade, blade adapter, base plate, control valve, and suitable piping; and a power-pack unit, so as to be located within a maximum of 15 feet from the hydraulic-cylinder assembly with two flexible hydraulic hoses connected between the hydraulic-cylinder control valve and the power-pack unit.

Three types of working blades were designed for the tunneling tool: (1) a slotting blade, (2) a scraper blade, and (3) a spade blade. The slotting blade was designed so as to cut parallel grooves in the soil. The number of slotting teeth was varied from 1 to 4, on a base which was 4 to 12 inches wide. The teeth were spaced approximately 2-1/2 inches apart so that, during slotting, the soil between the teeth could crumble and fall, or, subsequently, could be easily removed with a simple hand tool. The scraper blade was designed to undercut the soil with a flat bar, thus causing it to crumble and fall. The scraper bar was located parallel to and approximately 2-3/4 inches from the blade base. The spade blade was a 1/4-inch-thick flat plate with a sharpened edge. All of these blades were designed to be attached to the blade adapter with six 1/4-20 NC flat-head machine screws.

The electrical-transmission components were standard parts which were partially redesigned in order to provide the following system. The 115-volt power supplied was to be increased to 480 volts at the first transformer, for transmission to the second transformer located near the power-pack unit; the voltage was then to be reduced from 480 to 115 volts. With suitable electrical connectors, this system provided a safe and convenient transmission arrangement using a 250-foot conductor of the smallest practical wire diameter. The electrical connectors were selected so as to prevent the possibility of improper connection that would result in damage to the equipment.

Fabrication and Assembly

The blades, blade adapter, base plate, valve adapter, and piston-rod-wiper housing were fabricated from aluminum alloys. Following fabrication of these parts and the modification of standard purchased parts, the experimental tunneling-tool components were assembled. The control valve, control-valve adapter, blade adapter, blade, base plate, piston-rod wiper, and stainless steel piping were mounted on the hydraulic cylinder; the hydraulic-cylinder assembly weighed approximately 15 pounds. The hydraulic-cylinder assembly was connected, through the control valve, to the power-pack unit with 15-foot-long flexible hydraulic lines. The power-pack assembly weighed approximately 75 pounds. The electric motor of the power-pack unit was arranged so as to plug directly into the output transformer. The two transformers can be grouped independently and weigh 22 pounds each. The 250-foot conductor coil was a separate component and weighed approximately 100 pounds; the transmission line can be lengthened by the addition of electrical conductors or shortened by the substitution of shorter electrical conductors with the proper electrical connectors. The assembled experimental tunneling tool is shown in Figure 1. The completed package could be transported on a medium-sized coaster wagon.

Evaluation of Tunneling Tool

The tunneling-tool package was tested and evaluated in the laboratory using various grades of fire brick as the work piece. In a representative test with a double slotting blade, a maximum pressure of 1,800 psi or 2,200 pounds of force on the blade was required to slot into and crumble the fire brick. The operation of the hydraulic equipment was satisfactory except that an excessive back pressure of approximately 500 psi was noted; this was attributed to

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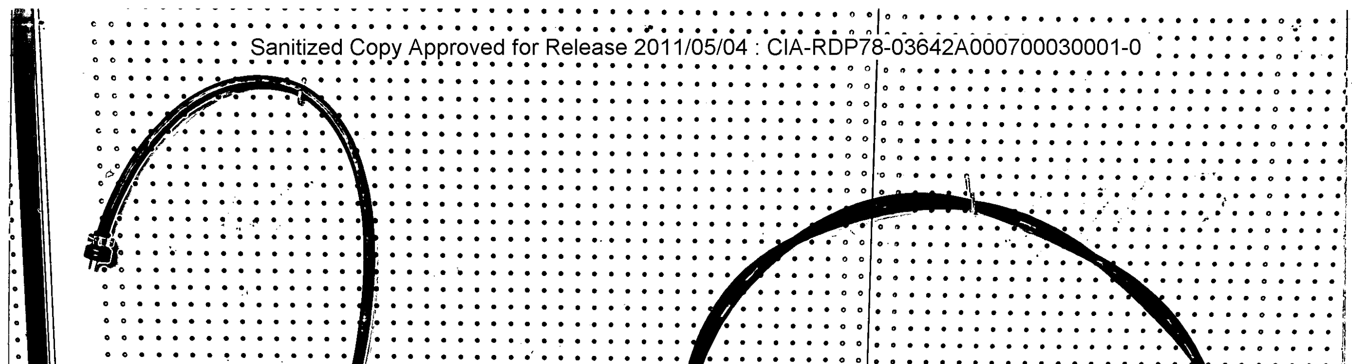

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Figure 1. Experimental Tunneling Tool

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resistance to fluid flow in the system. In an attempt to alleviate this condition, the 3/16-inch-diameter hydraulic hoses which had been used were replaced with 5/16-inch-diameter hoses. Due to delivery problems, this was accomplished after the experimental equipment was delivered to you for field testing; thus, the pressure changes resulting from this substitution have not been measured.

In the evaluation of the experimental equipment in the laboratory without the 250-foot-long transmission wire and at an operating pressure of 1,640 psi, the unit operated satisfactorily, but the current drawn by the electric motor was 18 amperes, i.e., the motor was overloaded. With the transmission wire connected into the system, the unit would not operate at 1,640 psi because the increased current caused a greater voltage drop and this, in turn, decreased the motor efficiency and power output. It was necessary to limit temporarily the operating pressure to approximately 1,000 psi until the larger diameter hose could be installed; it was expected that this change would provide more power for the actual operation of the experimental equipment. The substitution of a 0.9-gallon-per-minute pump for the 1.5-gallon-per-minute pump used in the power-pack assembly would be an alternate way to increase the operating pressure, with some sacrifice in the speed of operation.

Following the preliminary laboratory evaluation of the experimental equipment, the unit was demonstrated under field conditions at one of your tunneling sites. The operation of the unit was satisfactory and a good feel for the operating characteristics and potential of the experimental tool was obtained. A maximum operating pressure of 1,000 psi was sufficient to do the work needed, and the scraper blade was generally selected as the most effective of the three types. As a result of the field testing, some modifications were suggested for the hydraulic-cylinder assembly. However, since these modifications did not appreciably change the basic operation of the experimental unit and could not be established definitively without additional experience with the unit, the experimental tool was left with you for further evaluation. Following this evaluation, the hydraulic-cylinder assembly was returned for final modification under this research program. By this time, the experimental tunneling tool had been established as a very satisfactory workable unit.

Modification of Hydraulic-Cylinder Assembly

During field evaluation of the tunneling tool, you and your associates made the following modifications on the hydraulic-cylinder assembly: (1) a quick-change adapter was provided for the blade and the base plate, (2) the hydraulic-cylinder end caps were replaced to incorporate a quick-change adapter part for the base plate on the bottom end and a piston-rod wiper on the front end, (3) a guard was provided at the front of the cylinder to aid in protecting the operator's hands and to deflect the soil from the unit, and (4) the control valve was relocated closer to the base plate and the disc-type handle was replaced with a rod-type handle. Based on additional field tests and evaluation by you, the following additional modifications of the hydraulic-cylinder assembly were mutually agreed upon, and were subsequently incorporated, to complete the activity under this research program: (1) an aluminum-alloy handle was added to the blade adapter, (2) the weight of the cylinder end caps was reduced, (3) the control valve was relocated about 7-1/2 inches from the front of the cylinder, (4) an aluminum-alloy 7-inch-square base plate was provided, with two 1/2-inch-deep feet extending along the bottom of the base plate on two opposite sides, (5) the guard was retained, but the wiper housing was removed

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from the cylinder end cap and incorporated in the guard, (6) to minimize possible breakage or loosening of the fixed piping, an epoxy resin was used to support the stainless steel tubing on the hydraulic cylinder, and (7) an alternate aluminum-alloy base plate, 4-1/2 x 6 inches, was provided. The weight of the hydraulic-cylinder assembly was thus reduced from 18 pounds to 16 pounds, including the larger base plate. The modified experimental hydraulic-cylinder assembly, shown in Figures 2 and 3, was shipped to you on April 12, 1960.

Future Work

The experimental tunneling tool which was developed under this program is primarily a build-up of standard manufactured components. The hydraulic-power-pack assembly was designed as a compact portable unit, and the electrical components were about as compact as can be expected. It might be worth while to group these components more effectively with a carrier vehicle. Further, the design of the hydraulic-cylinder assembly could be improved; this assembly could be prepared as an integral unit which included the cylinder, valve, and cylinder piping. The end caps could be designed to incorporate the base-plate quick-change adapter and the guard and rod wiper. The use of aluminum-alloy castings would be considered in an improved design of this kind.

It has been a pleasure to work on this project with you and to know that the experimental tool has made the tunneling operation much easier. In accord with our conversation on May 19, 1960, we shall prepare a proposal for the construction of a modified unit and shall submit this in the near future.

Sincerely,

A. B. Westerman

A. B. Westerman

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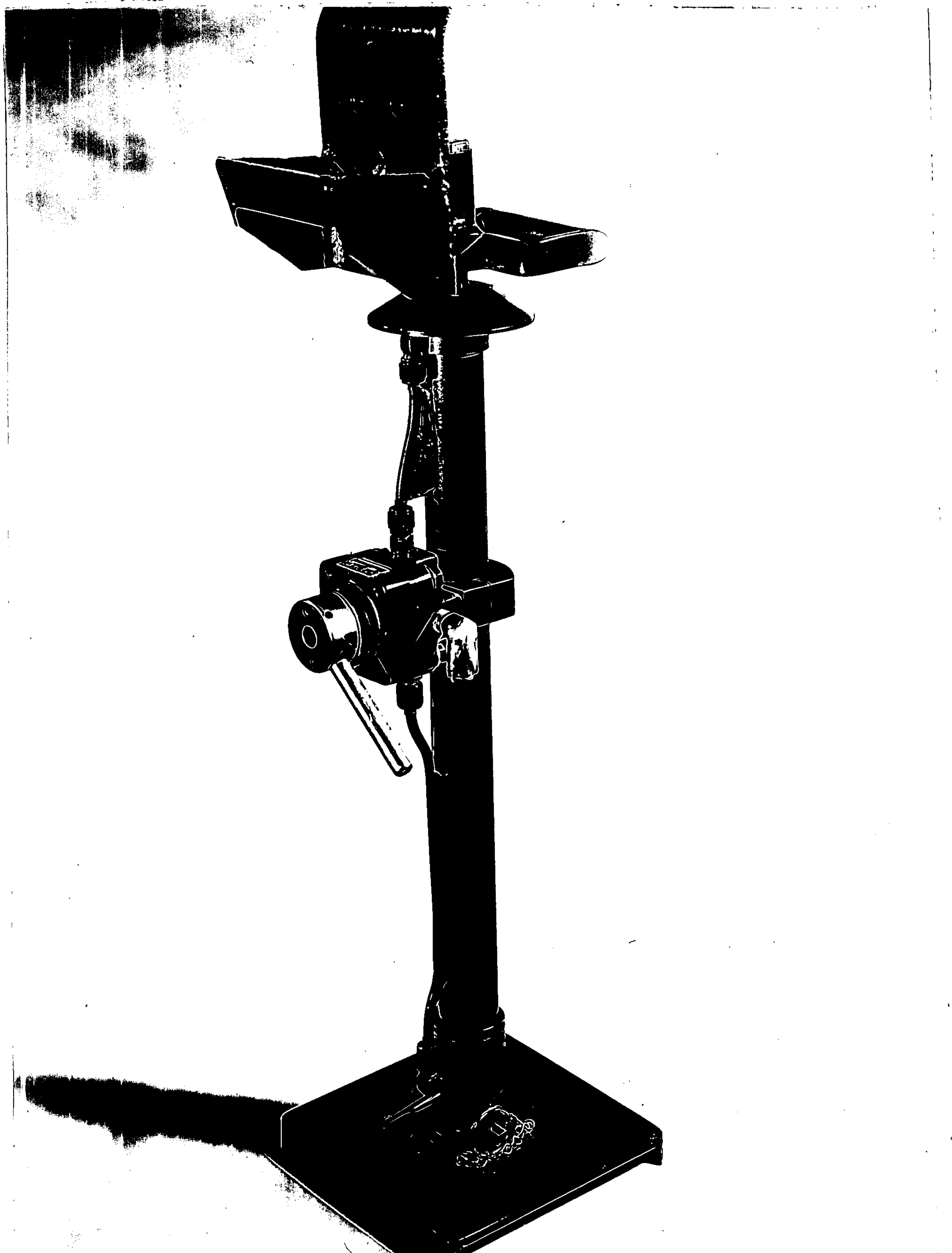

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Figure 2. Modified Hydraulic-Cylinder Assembly

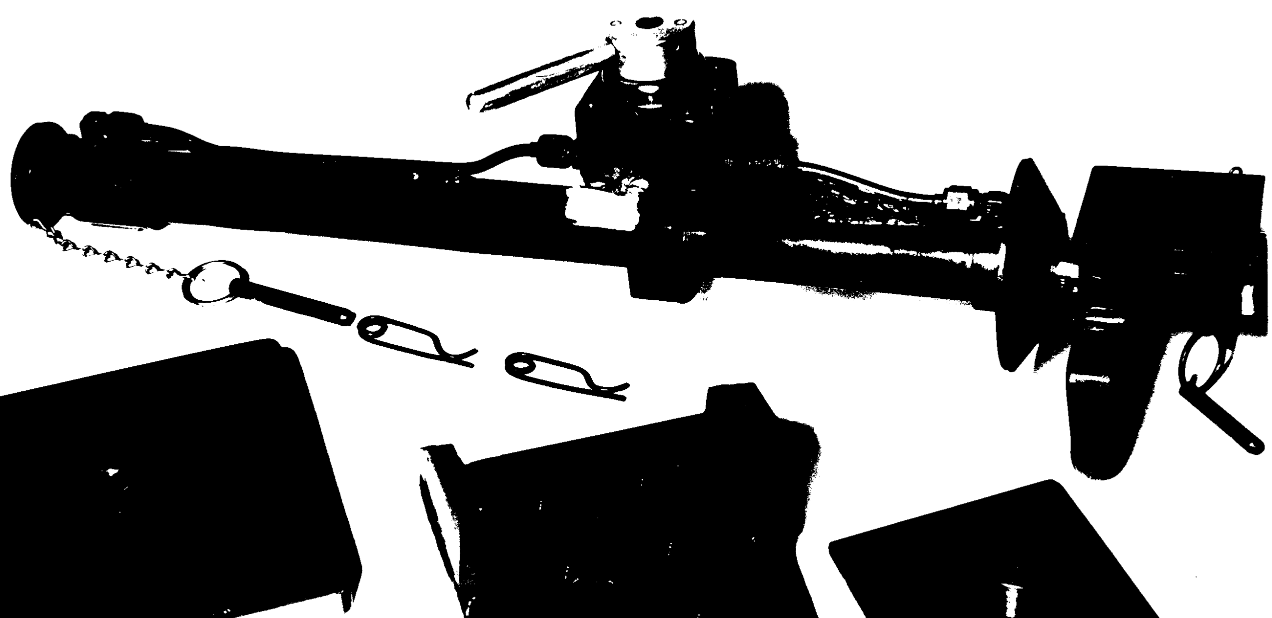

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Figure 3. Modified Hydraulic-Cylinder Assembly With Scraper Blade and Base Plate Disconnected (Alternate Base Plate Shown)

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