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UNDERWATER OPERATION EXPERIMENTS EVALUATION

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ABSTRACT

This report combines the results of three evaluation studies of operations in a zero "G" engineering mock-up facility. The requirements to modify a standard impact wrench for underwater operations are presented. A regulator valve used in the exhaust port of a high altitude suit to maintain working pressure under a hydraulic head is described. The results of an evaluation of three types of hatches used to provide ingress and egress to the S-IVB workshop are given.

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MANUFACTURING ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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UNDERWATER OPERATION EXPERIMENTS EVALUATION

SUMMARY

The results of three evaluation studies of operations in a zero "G" engineering mock-up facility are combined in this report. The following were studied: requirements to modify a standard impact wrench for underwater operation; a regulator valve used in the exhaust port of a high altitude suit to maintain working pressure under a hydraulic head; and the results of an evaluation of three types of hatches used to provide ingress and egress to the S-IVB workshop.

INTRODUCTION

With the advent of underwater simulation in the zero "G" engineering mock-up facility it became necessary to make equipment modification commensurate with the underwater working conditions. It was necessary to modify a standard electric impact wrench so that it would operate under approximately 12 ft (3.6 m) of water; it became essential to develop a pressure regulator which would keep the pressurized suit at a constant 3.5 psi (24 131 N/m^2) above the outside pressure or hydraulic head; it was necessary to know how easily the hatch entrance to the S-IVB workshop could be opened so that an airlock could be fitted to the opening. This report gives the results of the studies made in these areas.

MODIFICATION OF STANDARD IMPACT WRENCH FOR UNDERWATER USE

In order to complete the tests on the 72-bolt hatch on the S-IVB stage in the zero "G" engineering mock-up, it was necessary to modify a standard electric impact wrench so that it would operate under approximately 12 ft (3.6 m) of water. Early attempts at modifying the wrench for underwater duty by covering it entirely with glove rubber were unsuccessful. After an hour's immersion in a bucket of water, approximately a pint (0.0005 m^3) of water had leaked into the wrench. Most electric motors will rotate when they are immersed in water but will not develop any noticeable horsepower because of the great hydrodynamic drag on the armature. Therefore, it is necessary to exclude all water from the rotating elements of the motor and gearcase.

The wrench selected for the job was a Black and Decker 12 Vdc impact wrench. The low voltage is necessary to prevent electrocution of a diver using the tool underwater.

The air vents in the aluminum body of the tool were sealed by an aluminum ring which was machined to fit the inside diameter of the tool body so that it would cover the vents. The ring was slit longitudinally with a 0.25-in. (0.006-m) metal saw cut; then it was covered with rubber tape and inserted into the barrel, covering the vents. A wedge was driven into the cut out portion of the ring, expanding it and forcing the rubber tape against the interior wall of the motor housing. This sealed the vents completely.

The armature with its fan on the same shaft was chucked in a lathe. Enough metal was cut off the fan so that it would clear the ring that closed the vents.

The motor was also vented at the brush end of the armature. This opening was sealed by a metal cap, which was machined to the outside diameter of the motor housing, and a rubber sleeve, which was fitted over the motor barrel and fastened with a large hose clamp. The metal cap was inserted in the other end of the rubber sleeve and clamped as can be seen in Figure 1.

The opening in the motor housing in the base of the handle, which accommodates the wires to the motor, was closed by the use of a fast setting acrylic potting compound.

Closing the vents made it necessary to provide for cooling the motor armature. This was accomplished by a 0.125-in. (0.003-m) stainless steel tube threaded 0.5-in. (0.013-m) on one end. A nut and flat washer were placed on the threaded end of the tube. The tube was inserted into a no. 30 hole drilled in the motor housing in the base of the handle. A rubber washer, flat washer, and nut were placed on the threaded end of the tube inside the motor housing and tightened. This provided an air inlet into the motor housing that was water tight and provided a means of cooling the armature and pressurizing the housing. A small hole was drilled in the metal cap at the end of the rubber sleeve to provide for air flow. Another tiny hole was drilled into the gear housing from the motor compartment to pressurize the gear housing.

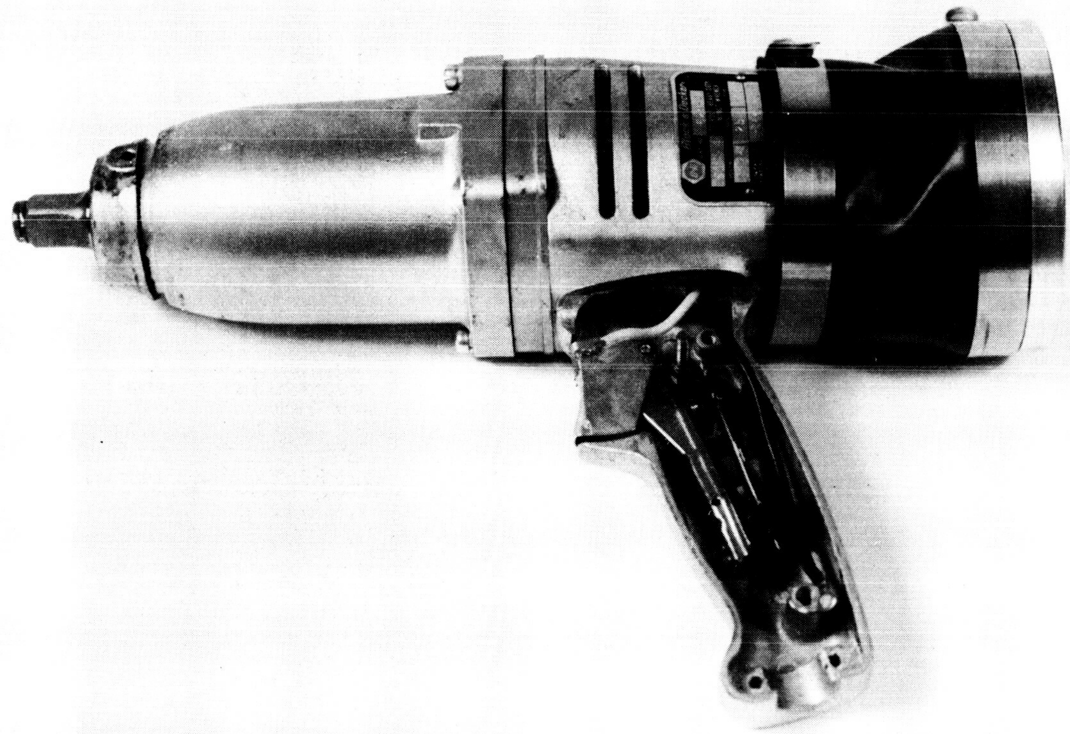

FIGURE 1. IMPACT WRENCH WITH TRIGGER EXPOSED

As the water in the zero "G" engineering mock-up is heavily chlorinated, it was necessary to modify the switch contacts in the handle. This was accomplished by removing most of the switch mechanism and replacing it by a hermetically sealed reed switch and a small permanent magnet, which is slid up and down the glass body of the reed switch by the trigger mechanism to actuate the reed. The reed switch wires and the motor wires were connected to a four-wire rubber covered cable. The reed switch was connected to close a relay at the other end of the rubber covered cable and turn on the motor. This modification is shown in Figure 2.

The relay to start and stop the motor is necessary because the reed switch contacts will not endure the motor current. It also allows the use of low voltage to the reed housing, thus preventing a current flow through the water between the reed switch terminals. The reed switch terminals were waterproofed with potting compound.

A small rubber hose was connected to the stainless steel pressurizing tube and taped to the rubber covered power cord. The hose was then connected to an air regulator.

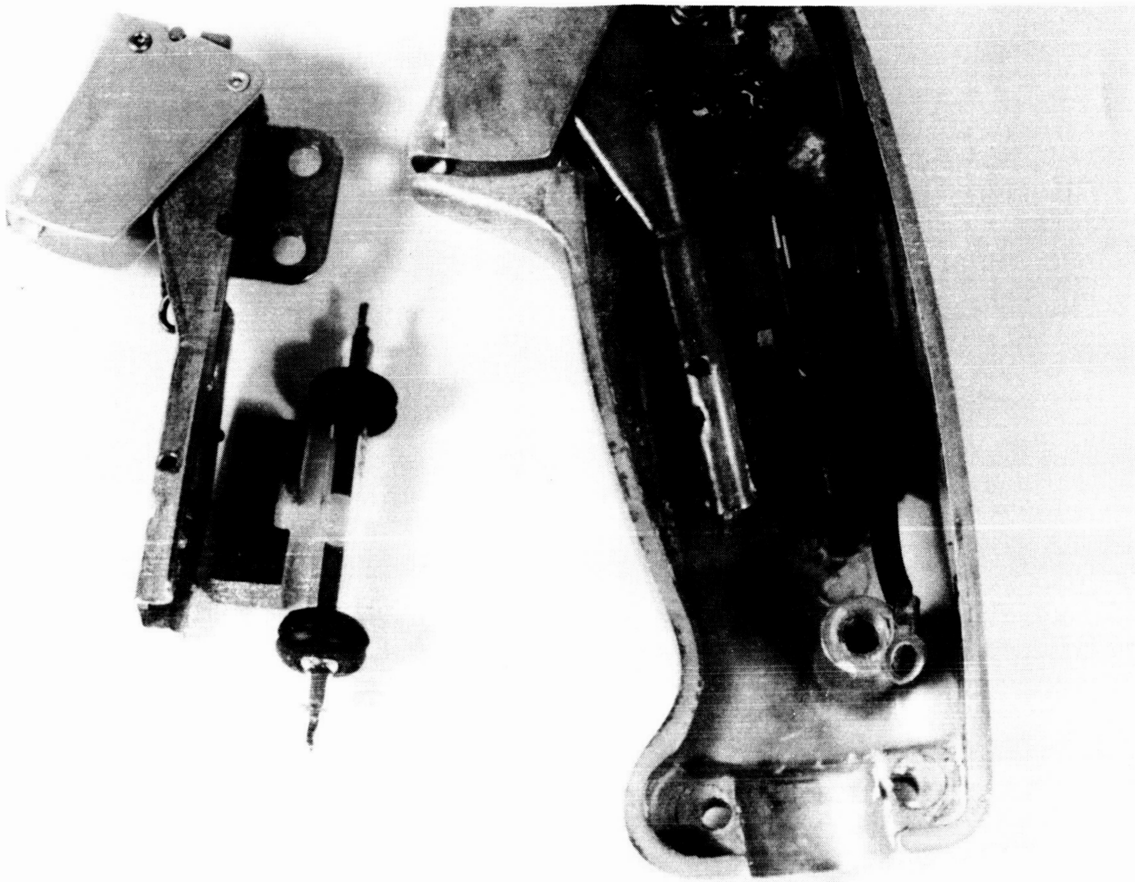

FIGURE 2. MODIFIED TRIGGER MECHANISM AND
MODIFIED TRIGGER INSTALLED

REGULATOR VALVE FOR UNDERWATER PRESSURE SUITS

Underwater simulation in the zero "G" engineering mock-up at MSFC made it necessary to develop a pressure regulator capable of keeping the pressurized suits at a constant 3.5 psi (24 131.6 N/m^2) above the outside pressure or hydraulic head at any given operating depth. A constant differential pressure at varying water depths is necessary if the space simulation is to be realistic.

In designing such a regulator valve the following criteria were used for the the pressure suit exhaust regulator.

1. The suit exhaust must be piped to the water surface so that the bubbles will not interfere with underwater photography and the vision of the test subject in the pressurized suit.

2. The regulator must maintain a constant differential pressure between the suit and the hydraulic head adjustable between nominally 0 and 5 psi (0 and 34 473. 8 N/m^2).

3. To prevent the possibility of suit blow-up and subsequent injury or death of the test subject, the regulator must have a flow rate capability to handle more than the suit intake could ever be reasonably expected to exceed.

4. The regulator must also have a large volumetric capacity to take care of rapid changes in hydraulic head caused by the vertical translation of the test subject.

Since the exhaust port in the suit was found to be of adequate size, the intake to the regulator was made the same diameter to insure adequate flow.

The regulator shown consists essentially of a cylindrical barrel and a piston as in Figure 3. The regulator exhaust ports are in the sides of the barrel; and when the piston is in the bottom of the barrel, the exhaust ports are completely covered. The air exhaust from the suit pushes against the bottom of the piston, forcing it upward and at the same time uncovering the regulator exhaust ports. The water surrounding the suit or the hydraulic head pushes down on the top of the piston, tending to shut off the exhaust ports; and, therefore, a balance is achieved between the external and internal suit pressure. With nothing else the suit would fill with air and maintain life support for its occupant.

A spring with an adjusting knob presses down on the piston top. When the spring attains the proper tension, its force adds to the force of the water on the piston top; and the suit pressurizes until its internal pressure balances the combined forces of the water and the spring and allows air to flow out the exhaust ports.

Since the regulator exhaust is to the water surface, the pressure at the surface must not affect the operation of the regulator. It is for this reason that the exhaust ports are in the sides of the cylinder barrel. The exhaust pressure affects the operation of the regulator very little as long as it is held constant.

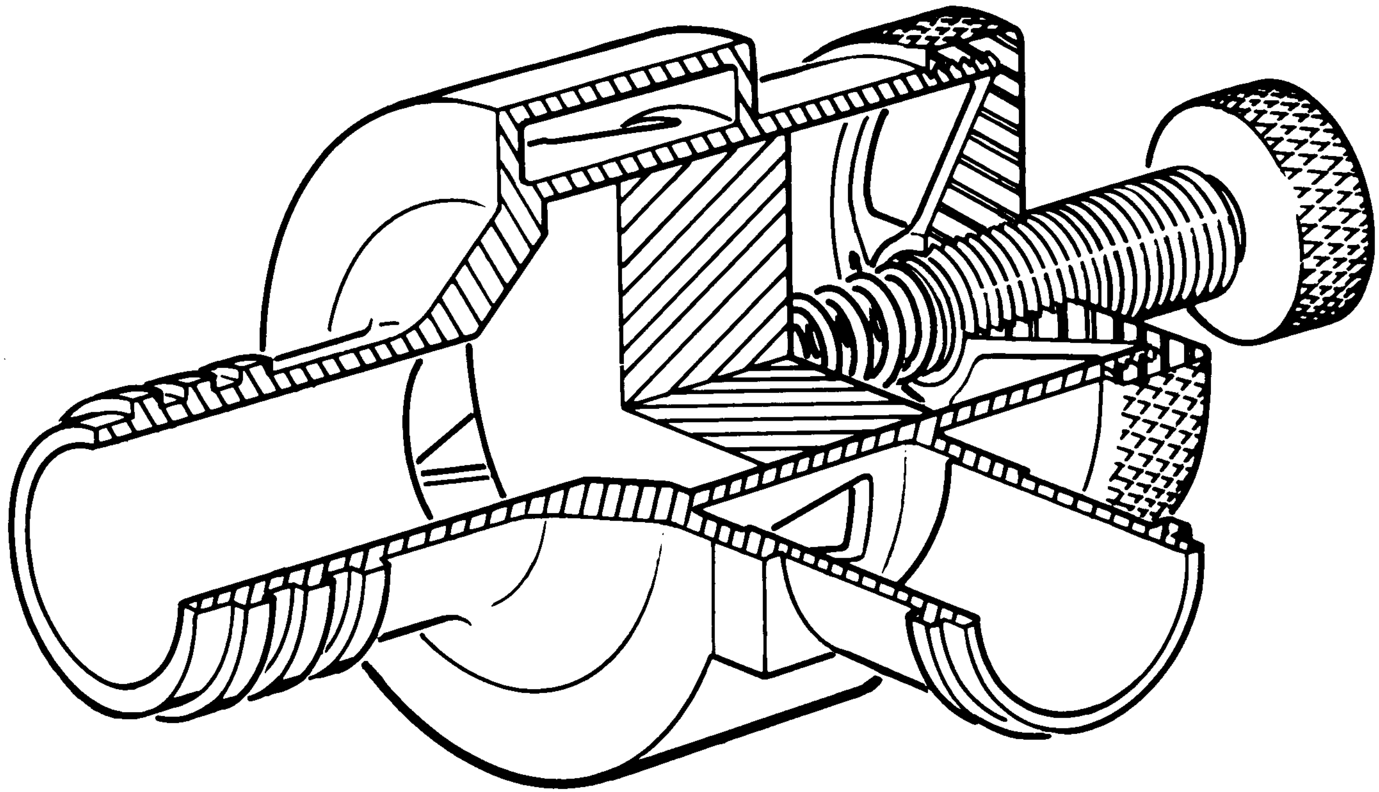

FIGURE 3. PRESSURE REGULATOR VALVE DRAWING

When the exhaust ports are fully open, their area is twice the area of the regulator intake; and the collector ring and output nipple on the exhaust side of the regulator are twice the area of the exhaust ports. Thus, free flow is insured at all times. The shape of the exhaust ports, which was derived empirically, prevents oscillation of the regulator. If the exhaust ports are slits, the piston can assume a sinusoidal motion which allows the pressure in the suit to flutter. This is extremely painful on the ears of the test subject. The same thing can happen when the exhaust ports are round.

The usual procedure for using the valve is to start with the adjusting knob all the way out. The test subject seals the suit; the air intake to the suit is turned on, and the regulator is adjusted to the desired suit pressure. The regulation of this valve is surprisingly good. Tests show a deviation of 0.1 psi (689.5 N/m^2) with a 15-ft (4.6-m) hydraulic head.

EVALUATION OF S-IVB WORKSHOP HATCHES

Since entrance into the S-IVB workshop by an astronaut is desired it becomes necessary to know how easily the hatch entrance can be opened so that an airlock can, in turn, be fitted to the opening.

Three hatches have been tested in the zero "G" engineering mock-up in the Manufacturing Engineering Laboratory at MSFC. One hatch was designed and developed by the Douglas Aircraft Corporation and will be hereafter designated as the DAC hatch (Fig. 4). The second hatch was designed and developed by the Propulsion and Vehicle Engineering Laboratory at George C. Marshall Space Flight Center and will be called the P& VE hatch (Fig. 4). The last hatch is the hatch that normally covers the entrance and will be called the 72-bolt hatch (Fig. 4) because of the number of fasteners involved.

The DAC hatch (Fig. 5) consists of an expanding ring and a cocking mechanism which can be operated either by hand or by a high pressure gas reservoir. During underwater testing of the DAC hatch, the gas-operated mechanism leaked water and did not function effectively. Since an astronaut will never have to cock the mechanism, it was cocked by hand for each test by a diver.

Several test runs were made by a test subject in an Apollo suit and a Mark IV Goodrich suit neutrally buoyant and fully pressurized to 3.5 psi (24 131.6 N/m^2). The hatch can be uncocked and removed so easily that the time and effort to do the task is negligible. This is not an endorsement of the other properties of this hatch. Only its ease of removal was tested.

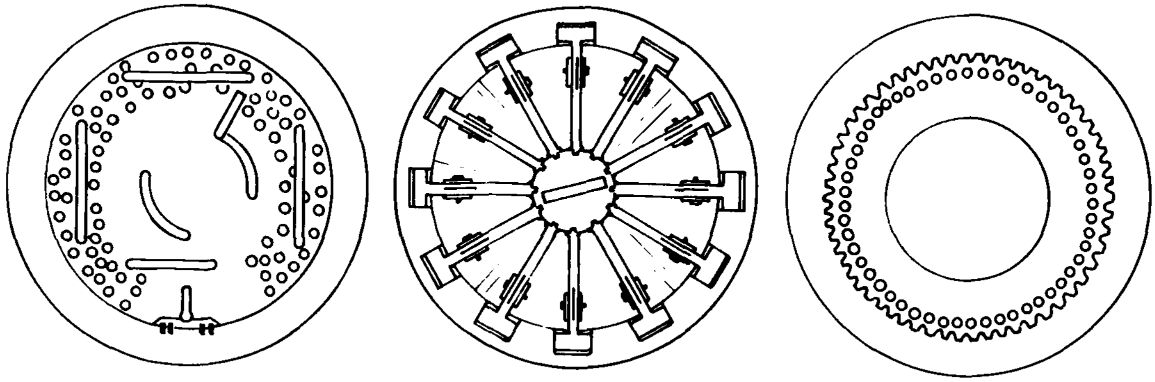

FIGURE 4. DAC HATCH, P& VE HATCH, AND 72-BOLT HATCH

The P&VE hatch (Fig. 6) locks in place with 12 dogs actuated by 12 separate levers held in the closed position by notched disks mounted in the center of the hatch as can be seen in the photograph. Several test runs were made on this hatch. The time of removal by a test subject neutrally buoyant, fully pressurized, in an Apollo suit or a Mark IV Goodrich Suit runs between 2 minutes and 5 minutes. In no case did the time exceed 5 minutes. The P& VE hatch, like the DAC hatch, is rather awkward to install but this is not the astronauts' problem.

The 72-bolt hatch (Fig. 7) has an 11-in. (0.28-m) working space between the airlock unit and the hatch. Also a wrench or tool for the removal of bolts is needed. The tool used in this experiment was a Black & Decker electric impact electric impact wrench specially adapted for use underwater (Fig. 1).

Several test runs were made on this hatch. The removal time averaged 21 minutes with practice. Without practice, removal time never exceeded one hour.

The suit was pressurized with air for these tests. Average weight for neutralization of buoyancy is 138 lb (62.6 kg) of lead distributed in a harness with the addition of ankle and wrist weights.

Evaluation of EKG and respiratory data show that none of these tasks is particularly strenuous; however, the tests show that the DAC hatch is the easiest to remove; the P& VE hatch is next; and the 72-bolt hatch is the most difficult.

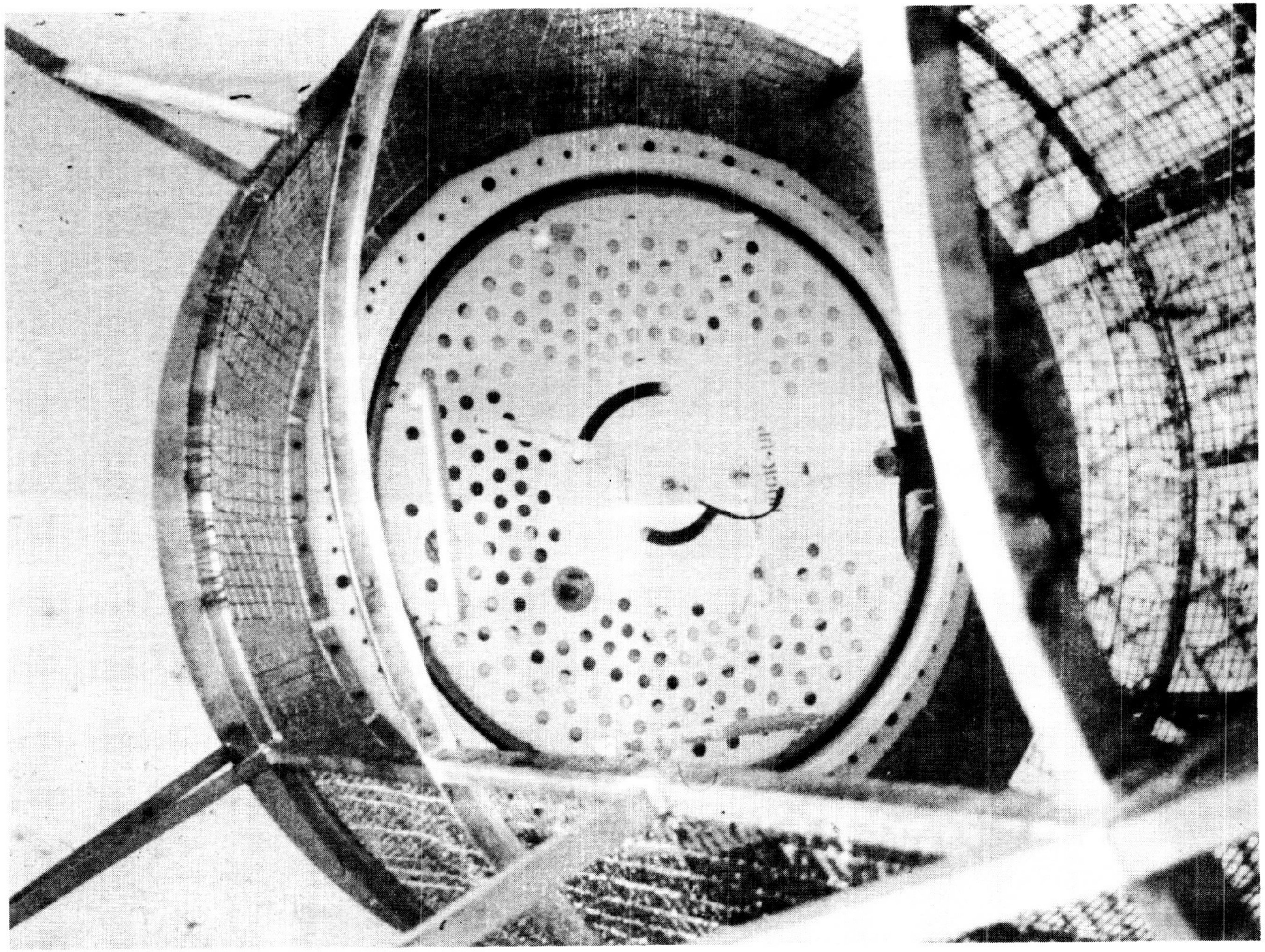

FIGURE 5. OPERATIONAL DAC HATCH IN UNDERWATER MOCKUP

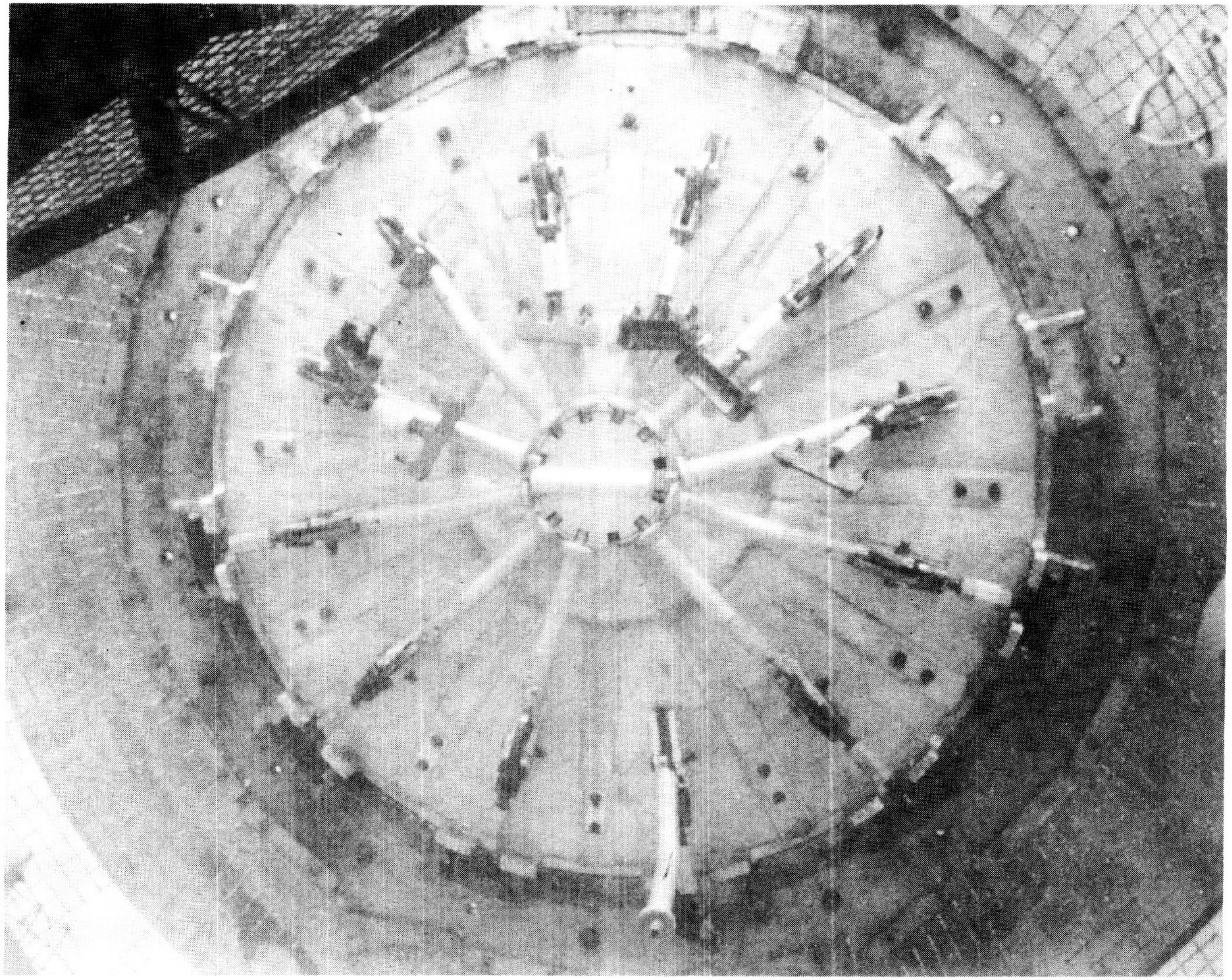

FIGURE 6. OPERATIONAL P&VE HATCH IN UNDERWATER MOCKUP

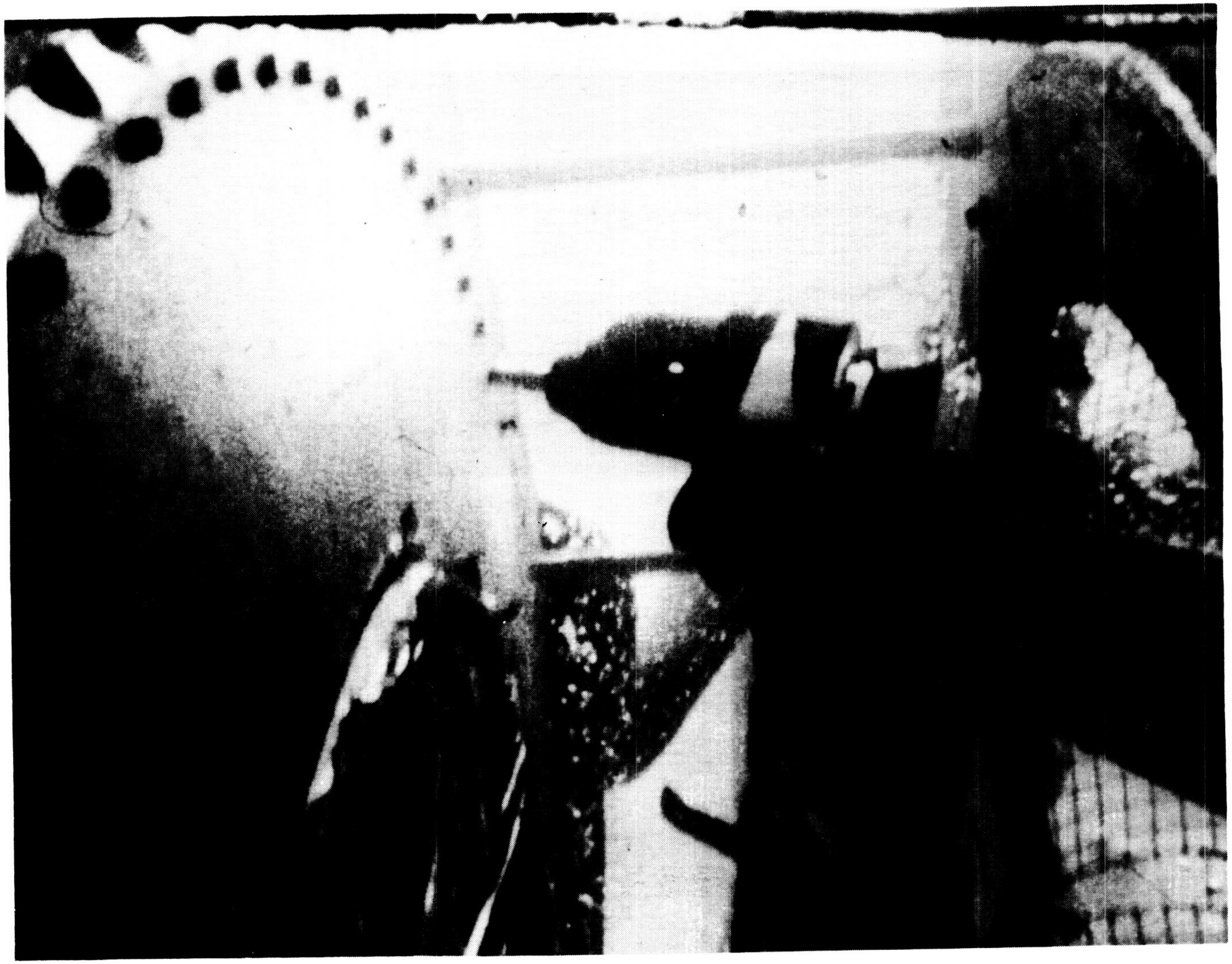

FIGURE 7. OPERATIONAL 72-BOLT HATCH IN UNDERWATER MOCKUP SHOWING BOLT REMOVAL WITH IMPACT WRENCH

CONCLUSIONS AND RECOMMENDATIONS

The Black & Decker 12 Vdc impact wrench has been used successfully under 12 ft (3.6-m) of water. No water has entered the tool. It has been found that the best air pressure to use on the pressurizing hose in approximately 40 psi (275 790.3 N/m^2). This is the minimum pressure required to maintain a good flow of bubbles out the hole in the back plate in 12 ft (3.6-m) of water. The use of a rubber sleeve over the back of the Black & Decker 12-Vdc motor housing allows the operator to reverse the wrench because reversal is accomplished by changing the brush position on the motor.

The piston in the pressure suit regulator was originally made of Teflon. This material was chosen because if its self-lubricating qualities. However, Teflon was found to be unsatisfactory because of its thermal coefficient of expansion which caused the piston to jam when the regulator was immersed in the warm water of the neutral buoyancy tank. It was found that a nylon piston works satisfactorily if coated with a light film of silicone grease. It is recommended, however, that a better material than nylon be found for the piston because the smooth operation of the piston is most essential for a smooth operating regulator valve. It is also recommended that, for proper and safe operation of this valve, the exhaust lines be at least as large as the exhaust nipple on the regulator.

An improvement could be made in the P& VE hatch by a change in the locking disk in the center of the hatch. This would make the time of removal longer but the astronaut would have more control of the situation. The improvement would be to make only one slot in the locking disk instead of twelve. While this would allow the removal of only one dog at a time, it would enable the astronaut to relock the actuating lever down again after the dog was removed. This would keep the dogs and levers from floating around out of control after the release.

The impact wrench used in the tests was too long. A special wrench should be made that is 9 in. (0.23-m) or less in overall length. This would greatly facilitate the removal of the 72-bolt hatch.

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John R. Rasquin

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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