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MODIFICATION OF A PNEUMATIC TRACK DRILL FOR UNDERWATER USE BY DIVERS

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The Navy relies on explosive excavation techniques for channel deepening and the emplacement of underwater pipelines in rocky bottoms. Effective use of these explosives requires that they be placed in holes drilled into the rock. Although Navy-issued self-propelled track drills offer an advantageous method of drilling these holes, they have quickly failed when used under water.

Under sponsorship of the Naval Facilities Engineering Command, NCEL (continued)

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has successfully modified a Navy-issue Worthington Model 1290D Track Drill for underwater use to depths of 120 feet. The main modifications include sealing and pressure equalizing the hydraulic system, sealing to the extent possible the pneumatic system, repositioning the controls for better diver operator visibility, and improved lubrication of the pneumatic components. This report describes these modifications, the test program, and suggests further improvements.

INTRODUCTION

For channel deepening and the emplacement of underwater pipelines and cables on rocky bottoms the Navy often relies on explosive excavation techniques. Effective emplacement of the explosive charges requires holes about 2-3/4 inches in diameter and as much as 20 feet deep drilled into the rock.

Among the alternative methods for drilling holes in competent rock on the seafloor are diver-held rock drills, jack-up platforms, and self-propelled track drills. A self-propelled track drill offers some advantages over the other two methods: it can drill holes deeper and faster than a diver can with a rock drill, and the cost per foot of holes drilled is less than for a jack-up platform.

The Navy has used Navy-issue terrestrial track drills for underwater drilling, but the equipment experienced early and frequent failures. The Naval Civil Engineering Laboratory (NCEL)* with sponsorship by NAVFAC investigated these failures and as a result successfully modified a standard Navy-issue Worthington Model 1290D track drill for underwater use to depths of 120 feet. This report describes these modifications and the field tests at San Nicolas Island and suggests further improvements.

BACKGROUND

NCEL has been developing tool systems and underwater vehicles to support the underwater missions of the Naval Construction Forces under the sponsorship of the Naval Facilities Engineering Command (NAVFAC). The objective of this program is to increase the working diver's effectiveness by providing him with safe, reliable underwater tools and support vehicles.

In mid-1971, as a part of this work, NCEL received a pneumatically powered Worthington track drill that had been used in the Azores for underwater rock drilling (Figure 1). During the 12-day operation of this equipment, it was removed from the water 10 times to repair the drifter (the drifter is the pneumatic motor which provides rotation and linear impact to the drill steel). Some of the other deficiencies observed were:

1. The track drill was difficult to maneuver because of low ground clearance and poor traction on rough terrain.

* On 1 January 1974 redesignated the Civil Engineering Laboratory (CEL) of the Naval Construction Battalion Center, Port Hueneme, California.

2. The drifter and the hydraulic actuators were subject to seizure from corrosion of the interior walls, pistons, and check valves.

3. Actuator controls and pneumatic exhaust ports were located very poorly with respect to diver safety and visibility of the area immediately ahead of the drill.

4. The thickness, length, and stiffness of the pneumatic hose from the compressor made it difficult for the diver to maneuver the drill.

NCEL's investigation showed that water intrusion into the hydraulic and pneumatic systems was the chief cause of component failure. Two approaches were proposed for modifications to the track drill to prevent these malfunctions. The first consisted of sealing the existing hydraulic and pneumatic systems, moving the actuator controls, and venting the exhaust away from the diver. The second approach involved replacing the pneumatic components with hydraulic counterparts. A suitable hydraulically powered drifter, however, was not available; thus, successful conversion to a fully hydraulic system required development of a new drifter. On the basis of cost, the first approach for improving the track drill was selected.

DESCRIPTION OF MODIFICATIONS

Three systems of the basic track drill were modified: (1) the hydraulic system which positions the drifter mast, (2) the pneumatic system and (3) the track drill frame (Figures 2 and 3).

Hydraulic System

Figure 4 shows a schematic of the modified hydraulic system. The oil reservoir was originally unsealed and consequently flooded with seawater when submerged. The seawater emulsified the hydraulic oil, contaminated the hydraulic pump, and corroded the double-locking check valves in the hydraulic cylinders. The solution was to fill the reservoir and seal it. Two oil-filled flexible diaphragms were attached to the reservoir (Figure 5) to accommodate the change in volume of the hydraulic oil in the reservoir as the cylinder rods were extended or retracted. The flexible diaphragms protected by a metal shield also serve as pressure compensators, preventing a pressure differential and thus avoiding possible structural collapse of the reservoir.

The hydraulic control levers were moved onto a movable boom so the operator could position the drifter mast while close to the drifter: a necessity with the normally poor visibility under water.

Pneumatic System

All four pneumatic motors and the drifter (Figures 6 and 7) failed because seawater entered the casings and subsequently corroded the vanes or pistons. Three candidate corrective procedures were investigated: (1) complete sealing of the casings, (2) installation of check valves in the exhaust ports to prevent seawater intrusion when the air supply was turned off, and (3) use of lubrication and preventive maintenance to minimize corrosive action.

From a mechanical-design viewpoint, the first procedure would have been the most desirable but was impractical with the motors at hand because the seals and exhaust ports were either inaccessable or were extremely difficult to seal. The second method was used successfully with all four of the pneumatic motors, and the last method was effectively used with the drifter. Each of the modifications is discussed below.

Tramming Motors. Check valves were installed on the tramming-motor exhaust ports as shown in Figures 8 and 9. To accomplish this, the exhaust deflectors were unscrewed and 90-degree elbows brazed onto each. The deflectors were then replaced and a brass check valve placed in line. This was followed by 180-degree pipe bends. Sections of hose were fastened to the pipe bends and strapped along the main air-supply hose. Thus, the exhaust flowed away from the diver, and simultaneously the exhaust hose served as a muffler.

Hydraulic Pump Pneumatic Motor. The pneumatic motor which powers the hydraulic pump was sealed by placing a check valve on the exhaust port (Figure 8). The exhaust was then piped away from the diver in the same manner that was used with the tramming motors.

Pneumatic Chain Feed Motor. The air motor has 5 small ports which are impossible to seal individually with check valves. The ports were brazed shut (Figure 10), a new hole drilled along the axis, and a check valve inserted. This modification is not recommended for future refits as the casing itself leaked and the brazing can warp the cylindrical portion of the vane rotor housing. The alternative is to replace the existing motor with a more suitable pneumatic motor or exchange it for a hydraulic one.

Drifter. As indicated earlier, the drifter was the single largest problem encountered in the Azores operation. For the modification, total sealing was desirable, but it was not possible because the wall thickness and the component mating surfaces were too thin or too rough for O-rings or other seals. The inaccessibility and the shape of the exhaust ports made it impossible to install check valves. The only alternative was to assure that the air supplied to the drifter contained a large amount of lubricating oil.

The original lubrication system was unsatisfactory as it stored only enough oil to supply the drifter for 4 hours of operation. A system was designed to allow divers to add oil while the drill was submerged. The design used is shown schematically in Figure 11. A SCUBA bottle, added during the modifications to the track drill, was modified (Figures 11 and 12) to store lubrication oil under pressure supplied by the main supply hose. Thus, oil was then forced into the supply manifold. The delivery rate was monitored in the clear tubing between the SCUBA bottle and the supply manifold. The tank was exchanged by merely disconnecting the quick disconnects supplied on the hose. Without replenishment, a full SCUBA tank could operate for up to 4 hours. In this manner oil is supplied to the drifter whenever air is flowing through the drifter. Of course, the drifter floods when the air supply is stopped.

Track Drill Frame

The track drill frame and track assemblies were protected from corrosion by placing sacrificial zinc anodes on the aft towing hitch (Figure 5) along the drifter mast, and on each hydraulic cylinder check valve.

To increase their visibility to the diver, the boom and mast were painted with yellow fluorescent paint. First the base metal was painted with a common white paint, followed by the yellow fluorescent spray paint, and then covered by a clear boat varnish for protection.

FIELD TESTS

The modified track drill was tested at San Nicolas Island, California, between 7 May and 16 May, 1973. During this time, approximately 30 holes 2-3/4 inches in diameter and up to 10 feet in depth were drilled. The rock was fractured sandstone with a uniaxial compressive strength from 550 to 15,500 psi. The water depths ranged from 3 to 6 feet with wave heights up to 6 feet.

No mechanical difficulties were encountered. The drifter was disassembled twice to inspect for corrosion, but none was found. No seawater contamination was found in the hydraulic system; all components functioned perfectly.

During the field tests, the preventive-maintenance program outlined below was used and undoubtedly prevented many problems, thus shortening the drill's downtime. It is recommended that this preventive maintenance program be applied for any future operations.

1. Wash down with fresh water each time the track drill emerges from the ocean.

2. Grease all fittings, using Sta-lube boat-trailer axle grease or equivalent.

3. Drain gear box, tramming motors, and final drive.

4. Fill tramming motors with diesel fuel, cleaning solvent, or WD-40 (preferably WD-40) and run for 3-5 minutes, then drain (overnight, if possible). (A further recommendation: if the track drill is to be left exposed for any period of time, the gear box, tramming motors, and final drive should be filled to capacity with lubricating oil. Then, before using the drill again, the excess oil should be drained to the recommended level.)

5. Spray entire vehicle (especially the exposed cylinder rods) with WD-40 or equivalent.

6. Remove, dismantle, and clean the drifter each time the vehicle comes out of the water.

Even though these modifications were quite successful, the terrestrial track drill continues to present problems when it is used under water: an operational condition for which it was not designed. The maneuverability of the drill around obstacles is limited by the low ground clearance. When crossing the surf the diver must steer by using his feet on the tramming motor controls as he holds his head above the waves. He cannot see the terrain ahead and must remain alert at all times to judge quickly whether or not the drill might overturn. In addition, drifter operation is hazardous to the diver because of the resulting percussion and noise from the exhaust air. This particular problem is severe enough to cause nausea, vomiting, and vertigo to the diver-operator.

RECOMMENDATIONS FOR FUTURE MODIFICATIONS

The following items are suggested for future track drill modifications. The suggestions relate to Worthington Model 1290D that NCEL modified but can also be used, when appropriate, for other drills.

1. Modify the drifter to accommodate the placement of hoses on the exhaust ports.

2. Install a tool rack containing

   (1) pipe and crescent wrenches

   (2) sledge hammer

   (3) drill bit rack

3. Install a screen over air-motor hydraulic-pump assembly to prevent eel grass, etc., from fouling the drive shaft.

4. Install hand holds at locations on the track-drill frame and install a J-shaped pipe section below the drifter mast for the diver to hold onto at chest or armpit level while steering the track drill.

5. Move drifter feed controls closer together; replace the rotation valve assembly with one made from a material compatible with salt water.

6. Install a feed motor which would (a) feed at a constant load as opposed to a constant rate and (b) stop automatically when the drifter bottomed out against the bottom of the mast.

7. Install check valves on tramming motor vents to inhibit flooding.

8. Add numbers on side of mast to help operator determine hole depth.

9. Place open mesh wire grips (Kelham grips) onto the outside of the pneumatic hose. Attach them to the manifold to prevent whipping should the hose connector fail.

10. Add pneumatic greaser to preventive-maintenance inventory for surface, or even submerged, lubrication of track, swivels, etc.

11. Install guards over hydraulic controls.

SUMMARY AND CONCLUSIONS

The pneumatic track drill can be successfully modified for use underwater for short periods of time with a corresponding improvement in reliability over an unmodified drill. Modifications as described require approximately 100 hours of technician time, 80 hours of shop fabrication time, and $1,000 in material and parts.

The modified track drill can provide the required holes faster and deeper than existing diver-held rock drills and requires substantially less capital investment and logistical support than a jack-up platform.

However, it should be kept in mind that the track drill has several distinct disadvantages when used underwater. Each pneumatic component will in time flood and corrode because of nonexistent assembly seals, nonreplaceable vent caps, etc. The track drill, while adequate for rock quarries, cannot maneuver safely over large obstacles found in underwater terrain. The unmodified pneumatic drifter is a safety hazard for the diver.

Figure 1. Unmodified track drill being used under water in the Azores.

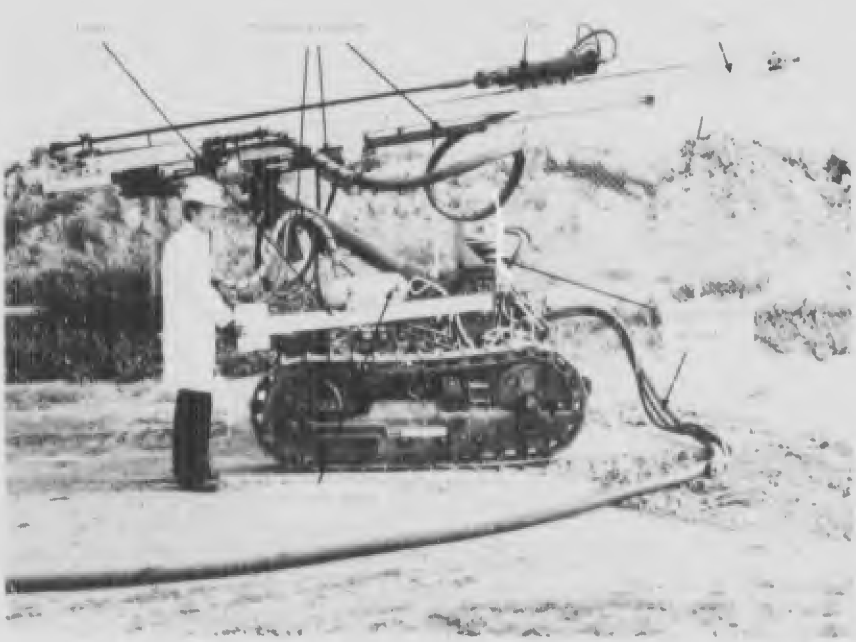

Figure 2. Modified track drill.

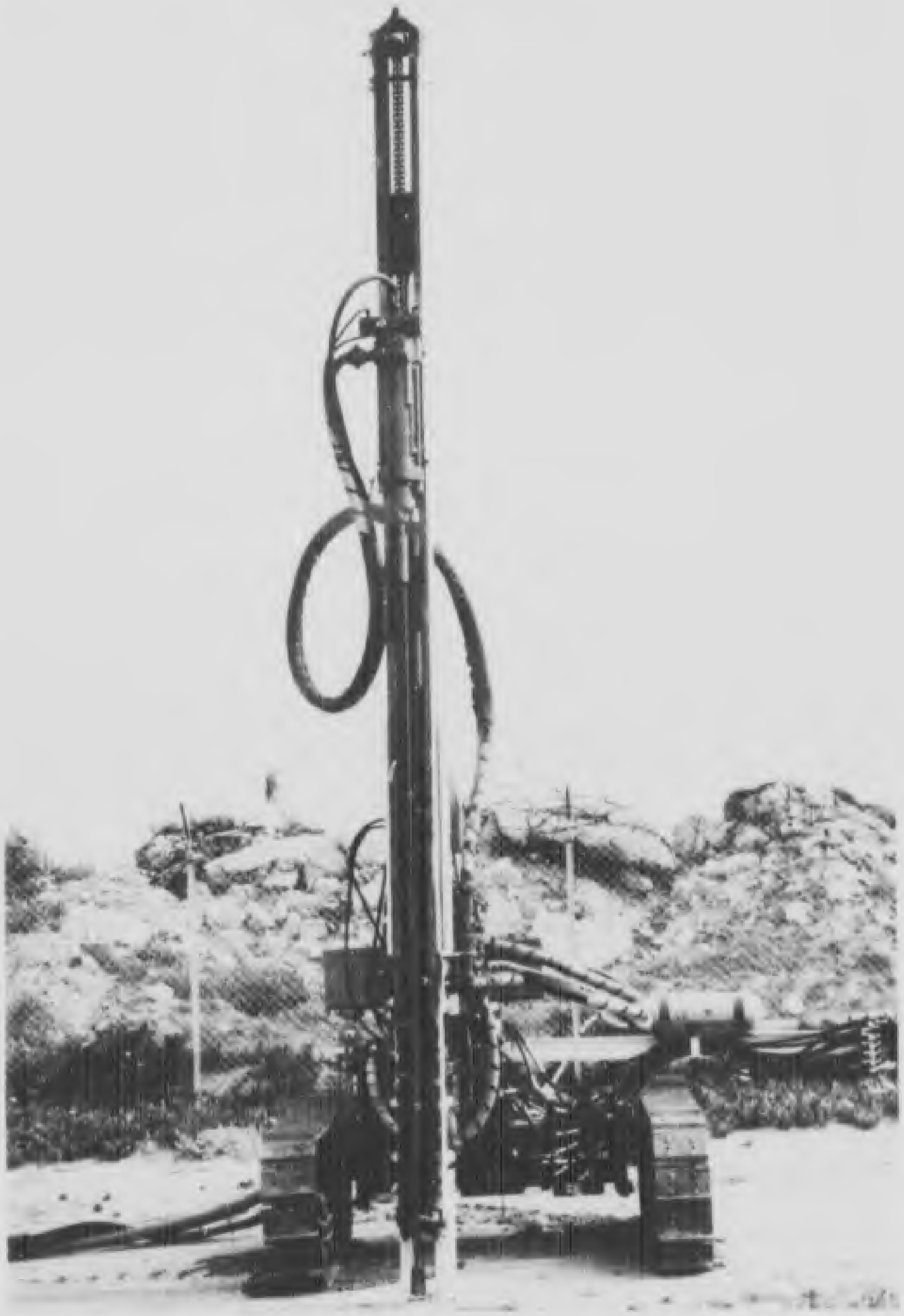

Figure 3. Front view of modified track drill.

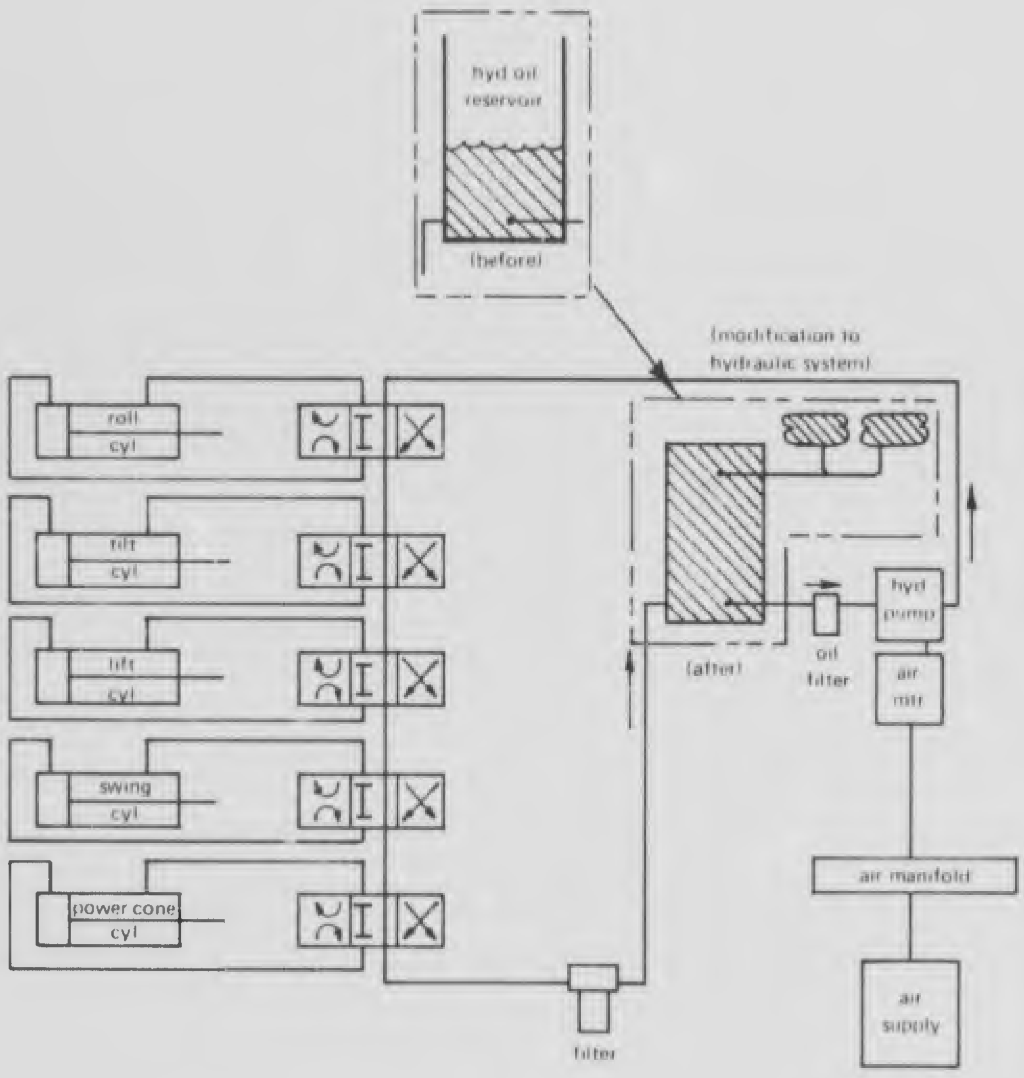

Figure 4. Hydraulic system.

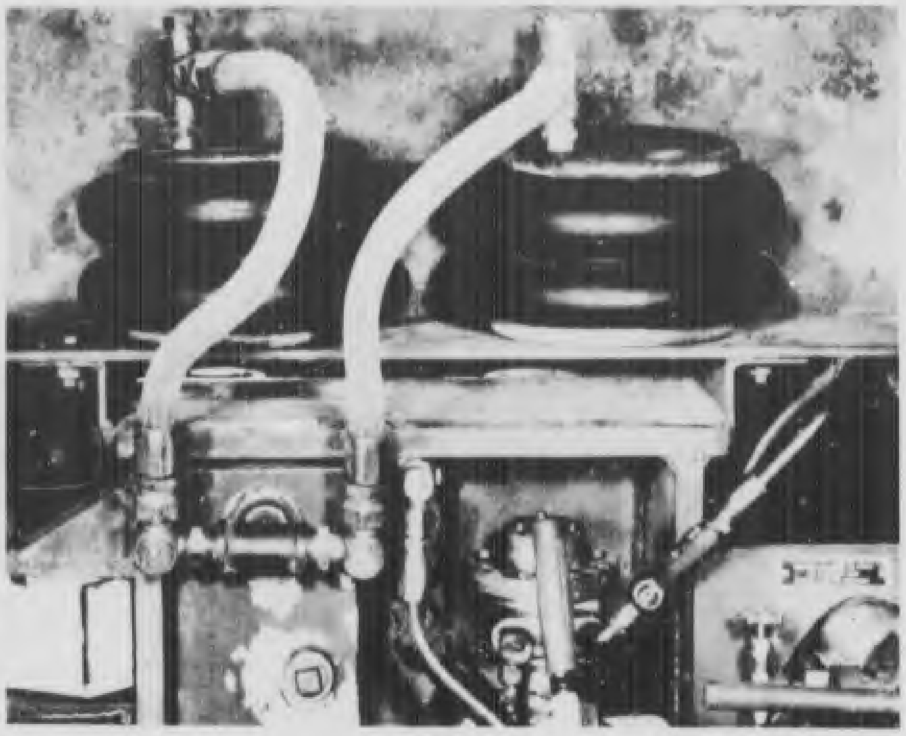

Figure 5. Detail of hydraulic compensation system.

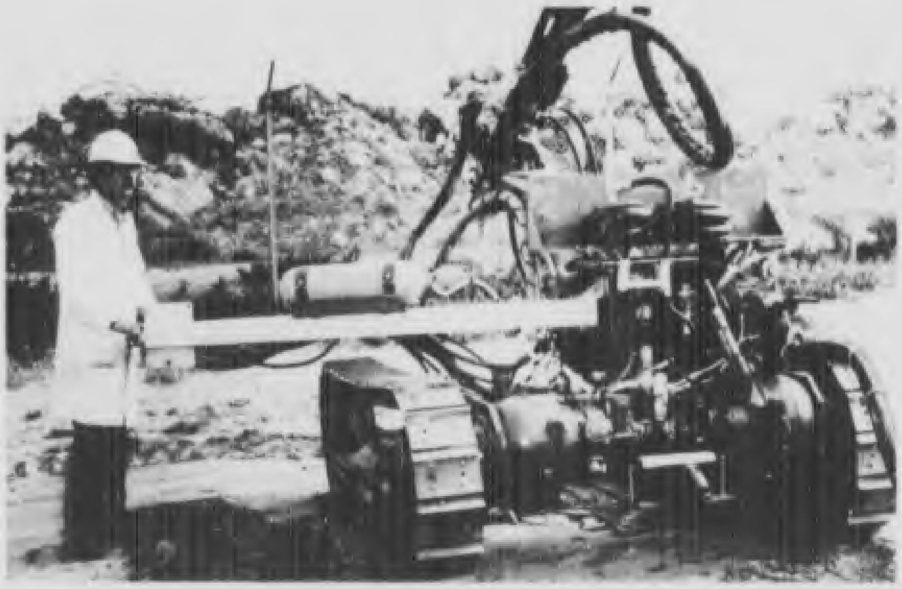

Figure 6. Track drill showing boom and lubrication system.

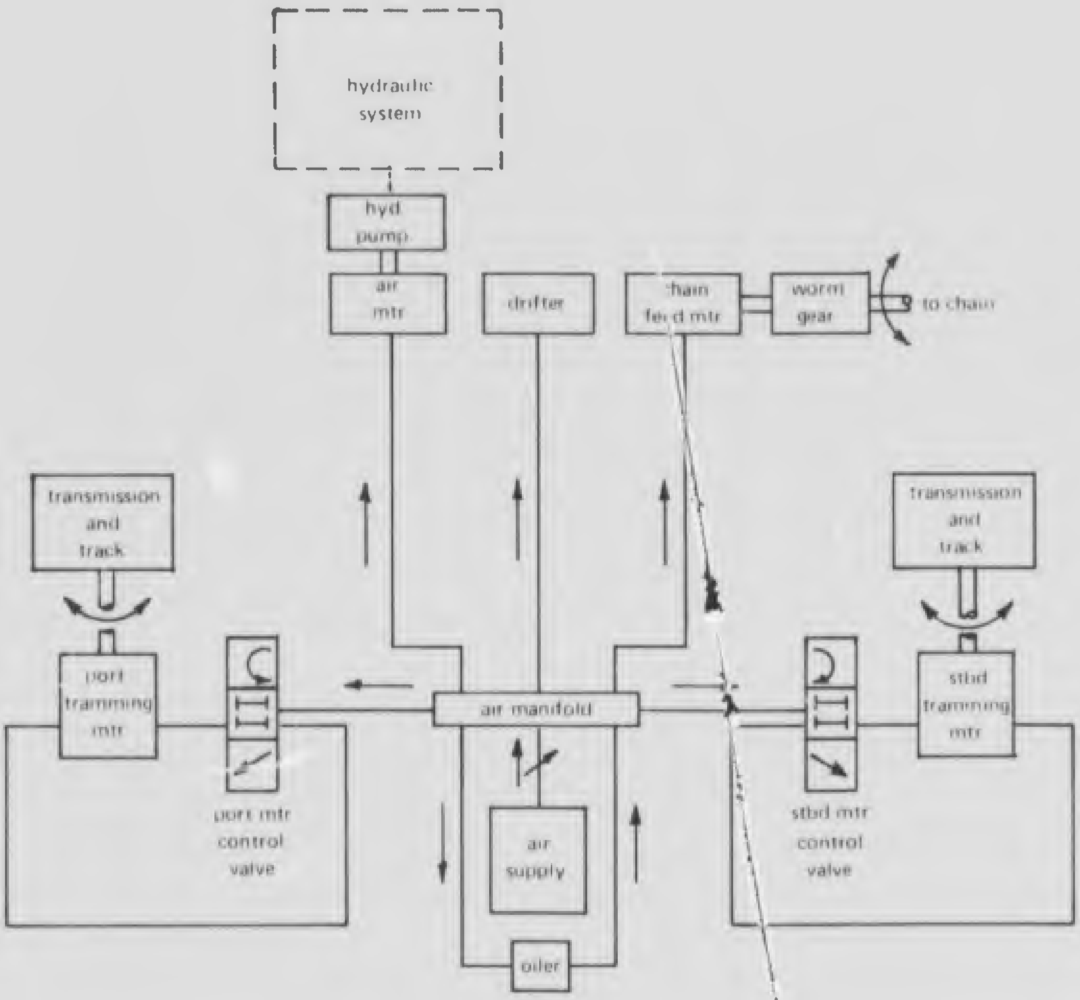

Figure 7. Pneumatic system.

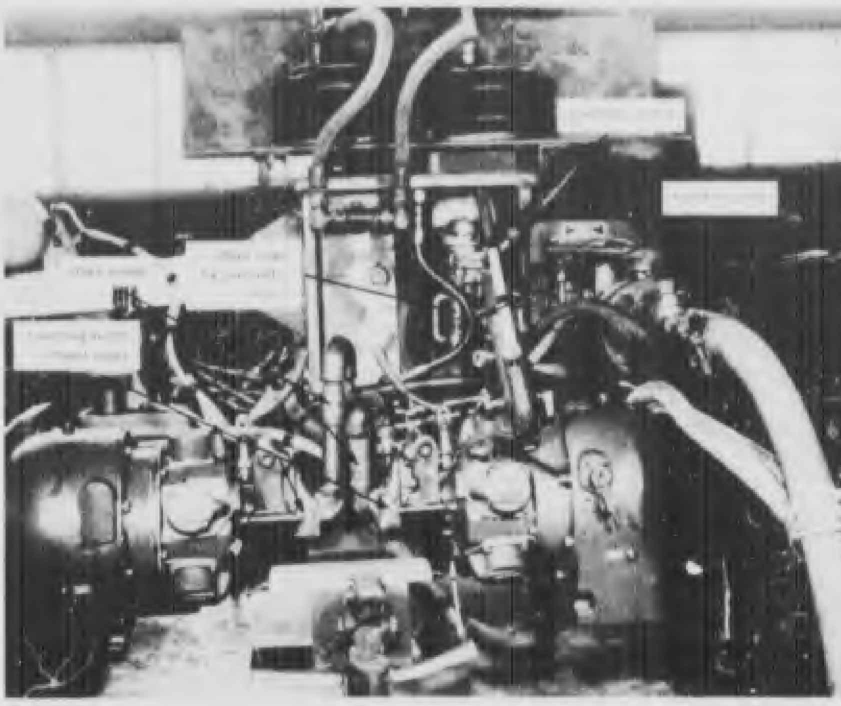

Figure 8. Aft view of modified track drill.

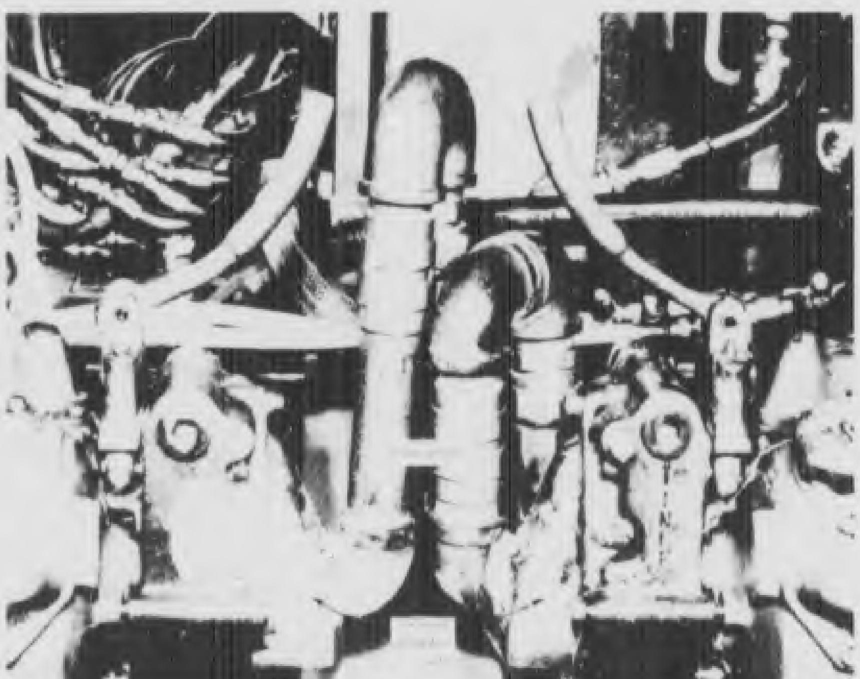

Figure 9. Detail of tramming motor exhaust.

Figure 10. Close-up of main drive air motor exhaust.

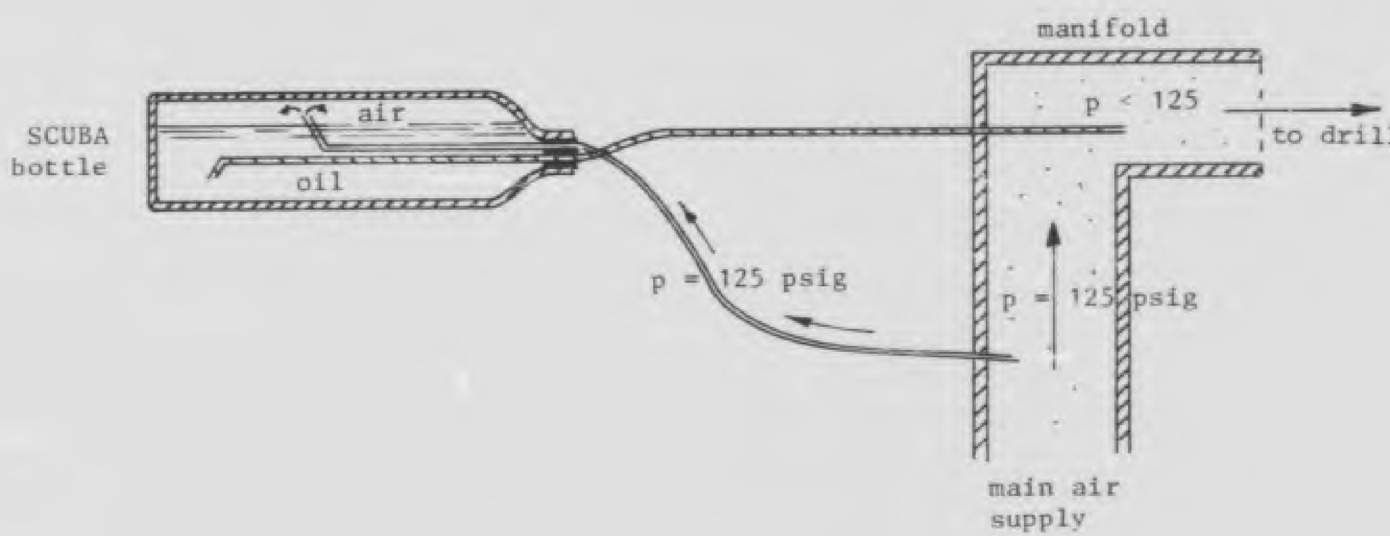

Figure 11. Schematic of air lubrication system.

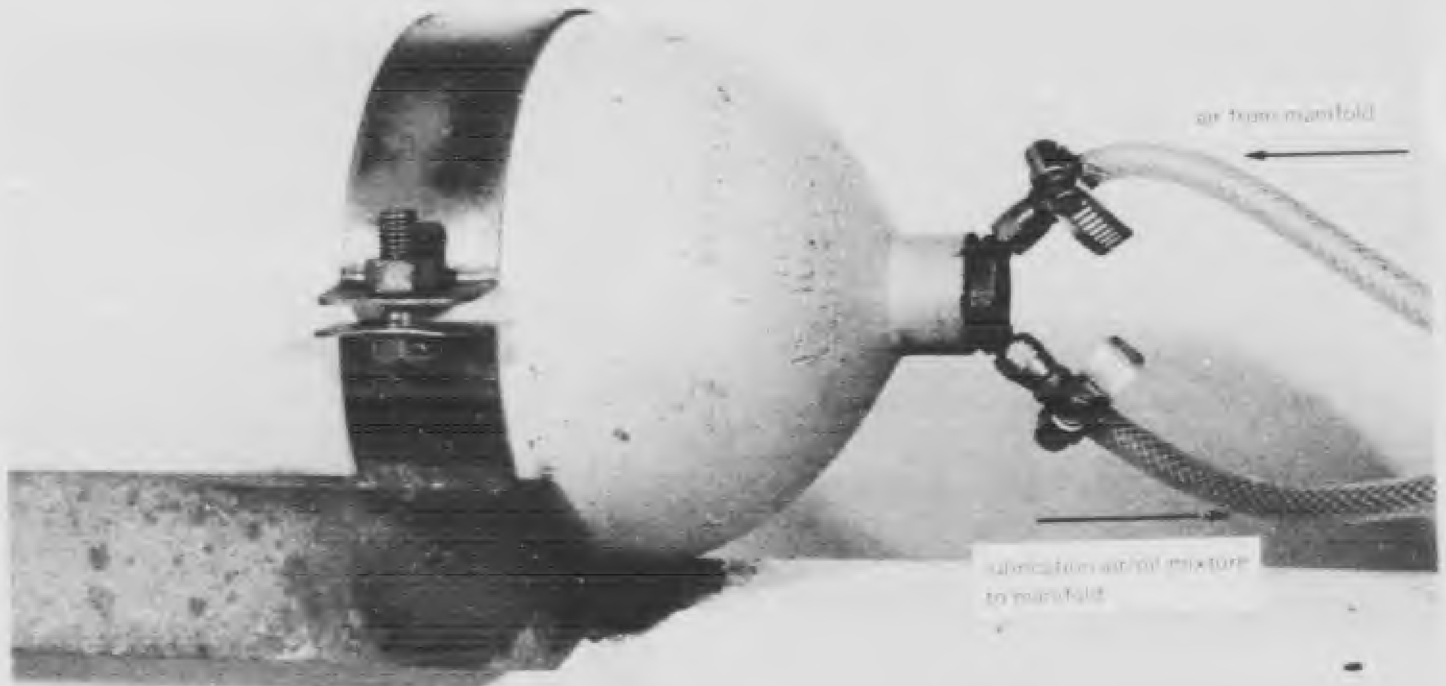

Figure 12. Close-up of SCUBA bottle modification.