DEVELOPMENTS IN NAVY DIVER UNDERWATER CONSTRUCTION

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ABSTRACT

Two Underwater Construction Teams (UCTs), the Navy's diving Seabees, were established in 1970 to provide a basic underwater construction capability. Over the years the UCT missions have broadened and their capabilities have improved by development of new tools and techniques. Underwater powered tool systems have changed from pneumatic to oil hydraulic, and now include highly portable, lightweight power sources. This paper gives a brief introduction to recent tool developments including seawater hydraulics, electrical safety, grout dispenser, rock drills, navigation and survey, cable tracker, cleaning systems, and inspection and work techniques. These tools and techniques provide for more effective and safe underwater construction and repair.

BACKGROUND

Diving by the Navy's Seabees in support of underwater construction began during World War II. At that time diving projects consisted of the removal of obstructions and diver support of surface construction in harbor areas. In 1970 Seabee divers were formed into two Underwater Construction Teams (UCTs) to support an increasing Navy requirement for ocean construction. One of the teams is located at Little Creek, Virginia and the other at Port Hueneme, California.

Since they were formed, the UCT size has steadily grown to handle the expanded missions and workload which today includes the following: (a) installation and repair of communication and power cables; (b) installation and repair of instrumentation systems (such as underwater ranges); (c) installation, inspection, and repair of fleet moorings; (d) inspection and repair of offshore towers; (e) underwater inspection and repair of harbor facilities; and (f) occasionally, the removal of an unusable facility or obstruction.

The UCTs are the only Navy units with a mission for underwater construction and repair of facilities. They are somewhat unique in that while they have a military contingency mission for which they train regularly, they also have a peacetime mission to accomplish a heavy workload of underwater construction. During peacetime the UCTs deploy in small detachments to construction sites throughout the world. Typical projects may require deployment of detachments of 5 to 20 men for periods of one to eight weeks. Because these detachments move from one job site to the next, their equipment must be lightweight and highly mobile. They often work at remote sites and typically operate from small boats varying from as large as an LCM-6 boat (60 feet) down to a more typical 16-to-20 foot inflatable.

At the core of the UCTs are the Navy enlisted divers with construction knowledge and training to use those skills underwater. Training is formally received through Navy diving schools as well as basic and advanced Underwater Construction Technician courses taught at the Naval Construction Training Center in Port Hueneme, California.

TOOLS AND TECHNIQUES

The tools and techniques initially available to the UCTs were basically water-proofed versions of those used on dry land. Pneumatic tools were the first power tools used underwater. While these were an improvement over hand tools, they required daily teardown and cleaning, had short life expectations, were extremely noisy in many cases, and their performance was depth sensitive. Soon thereafter, oil hydraulic tools from terrestrial construction were adapted for underwater use. These offered improved reliability and performance, but did not provide the needed range of underwater work capabilities. Over the ensuing years, a variety of specialized instruments, tools, and techniques have been developed to support the full spectrum of underwater construction, inspection, and repair requirements. These are summarized below. For detailed information the reader is directed to the cited references in each section.

Site Survey

The UCTs are often called upon to conduct site surveys in order to select facility locations, cable or pipeline routes, or to assess characteristics of the seafloor for
design of a foundation or stabilization system. Many site surveys are conducted visually and are documented using portable underwater color television systems.

The Diver Geotechnical Survey System (Figure 1) consists of five individual tools for assessing the engineering properties of the seafloor and three devices for obtaining bottom cores. These include an InSitu Vane Shear device for measuring the shear strength of cohesive soils, a miniature jet probe for indexing the strength and density of granular soils, a water jet probe for determining the soil depth to hard layers or rock, two soil corers for obtaining samples for subsequent testing and analysis, and a modified Schmidt Hammer for indexing surface rock strength. The two corers include a 3-foot impact piston sampler for obtaining relatively undisturbed cohesive soil samples and an 8-foot vacuum-assisted sediment corer for deeper sampling but with sample disturbance (reference 1).

Tracking and recording the position of the divers during surveys can be accomplished by a number of techniques. The most common methods in use today are: (1) to use compass and boat position to track the near future, these data will be plotted relative to shore-based bench marks using the survey portion of this system (reference 2).

Another survey need unique for UCT divers is to track or locate existing signal and power cables which may be buried in the seafloor. The Cable Tracking System uses a diver-carried probe to monitor a tone injected on the cable. The tone may be applied by either directly connecting a signal injector to the shore end of the cable or underwater using a battery powered magnetic induction system. The diver carried probe (Figure 2) gives the diver a visual and acoustic display of the signal strength. Cable location is accomplished using a signal strength nulling technique. Cables buried as deep as 10 feet can be tracked. The probe may also be used from the surface to track cables in water depths to 70 feet (reference 3).

Safety Devices

In the conduct of any diving operation safety is of primary importance. One new safety device available to UCT divers is a stray Electrical Field Detector (EFD). The EFD (shown in Figure 3) is a lightweight diver-carried probe which can be used to survey the construction site to detect the presence of damaged power cables, overactive impressed current corrosion prevention systems, or to identify faulty electrical equipment. The EFD sounds an audible and visual warning for low field strength (.1 v/ft). A high field strength alarm, activated at .2 v/ft, warns the diver that he is in danger of injury (reference 4).

Divers use a variety of electrical devices (lights, television cameras, and tools) which may be powered from the surface. To protect the diver from accidental shock, the 2.5 kVA Ground Fault Detector and Circuit Interrupter was developed. When installed in a power line, this device (shown in Figure 4) will shut down the power in less than 10 milliseconds if insulation resistance drops to a point were the fault current reaches 2.5 mA (reference 5).

Navy Diver Recall has traditionally been accomplished using a pyrotechnic device called the M-80 explosive detonation simulator. While small and compact, the M-80 presents safety problems. Additionally, use of optical surveying instruments from shore to track a surface float balloon towed by the diver. A Diver Navigation and Survey System capable of +/- 5 foot accuracy in a 3,000 foot square area is currently being developed. This diver-carried, acoustic-based navigation system visually informs the diver of his location and automatically records his position for later use. The system has a feature to allow the diver to manually record special locations. In the near future, these data will be plotted relative to shore-based bench marks using the survey portion of this system (reference 2).

Underwater Inspection

Inspection of underwater facilities has in the past been limited to visual observations. Visual inspections cannot be accurately conducted until the surface is cleaned of marine growth. To facilitate cleaning for inspection, a high-pressure cleaning system was developed. The system consists of a diesel driven power source and a hand-held water jet pistol with interchangeable cavitating fan and straight jet nozzles (reference 7). The power source delivers 12,000 psi seawater at flow rates to 5 gpm and also provides separate power for oil hydraulic tools. Used in combination with the cavitating nozzle the system produces primary cleaning rates to 8.5 ft/min on concrete structures.
Other devices available to supplement inspections include underwater voltmeters to measure the effectiveness of cathodic protection systems and Go/No-Go gauges for single and double link measurements of wear or corrosion on mooring chain. The gauges are calibrated at 90% and 80% of the original wire diameter.

While visual inspections provide useful information, hidden deterioration cannot be visually identified until it progresses to the point where it is revealed by an abnormal surface condition or by structural failure. A number of ultrasonic devices are available for measuring the thickness of metal underwater. Unfortunately, much of the steel used in underwater facilities is corroded on both sides, making it difficult to obtain accurate thickness measurements when severe pitting is present. A computer controlled ultrasonic inspection measurement system, now in development, offers a future solution to this problem (reference 8).

A set of tools for underwater inspection of concrete is now under development. The set will include: (1) an electromagnetic device for locating steel reinforcing bar and measuring the amount of concrete cover over the rebar; (2) a concrete surface hardness tool; and (3) an ultrasonic concrete inspection device that can be used to estimate compressive strength, detect cracks, and provide a general condition rating of the concrete (reference 9).

Construction Support Tools and Techniques

The UCTs have available a suite of oil-hydraulic tools to support general construction work. The tool suite includes a diesel driven power source, several rock drills, impact wrench, rotary disc grinder, a portable band saw, and a pile cutter. The band saw, rock drills, and pile cutter are tools unique to UCT work requirements. The band saw (Figure 6) provides the diver with the capability to quickly cut double armored communication cable up to 3.5 inches diameter. Other items such as pipe, wire rope, rebar, and metal plate angle can be accommodated with the 3.5 inch wide opening and 4 inch depth of cut.

The hydraulically powered underwater pile cutter (Figure 7) was developed to allow divers to cut timber piles up to 13 inches in diameter at the mud line. This work is often necessary when preparing a site for new construction or for removing debris from an abandoned facility. The past technique, using an oil hydraulic chain saw, was hazardous for the diver. With the pile cutter, a typical wooden pile can be removed in less than one minute (reference 10).

Holes must often be drilled in seafloor rock and coral to facilitate the installation of anchor bolts to stabilize cables and pipe stabilization and to place explosives for excavation. To meet these needs, light and heavy duty rock drills were developed. Improved commercial rock drills are now available. The light-duty drill can produce holes to 1.5 inches diameter and the heavy-duty tool drills holes up to 3.5 inches in diameter (reference 11).

The Lightweight Oil Hydraulic Power Source (Figure 8) provides power for hydraulic tools when diving operations must be accomplished from small boats or inflatables. The power source is driven from the shaft of a standard 35 hp outboard motor which can be mounted on the boat transom. The lightweight power source is capable of providing 8 gpm hydraulic oil at pressures to 2000 psi (reference 12).

Since 1976, the Navy has been developing the technology for hydraulic systems that use seawater instead of oil as the power transmission fluid. Seawater hydraulic systems offer unique advantages in that they are compatible with the environment and require only one hose for pressurized fluid delivery. The used water is exhausted at the tool. In 1986, UCT field acceptance testing of the seawater hydraulic tool system was successfully completed. The first Multifunction Tool Systems are now being fabricated and will be delivered to the UCTs in the near future. Each system will consist of a diesel-driven seawater power source (the prototype is shown in Figure 9), two hose reels (Figure 10), and four tools: impact wrench, rotary disc grinder (Figure 11), portable band saw, and rock drill. These tools are expected to replace the oil hydraulic tools currently in UCT use (reference 12).

An Epoxy Grout Dispenser (Figure 11) provides the diver with a capability to automatically mix and dispense two-part epoxies on the seafloor. This tool was developed to provide improved holding strength of fasteners installed in soft, porous coral. The tool can be reloaded underwater. Pull out tests of 1-inch diameter grouted rebar fasteners installed 12 inches deep in coral demonstrated an average holding capacity of 15,500 pounds (references 13 and 14).

UCT divers need more than the best tools to effectively perform their assigned jobs. The detachment leader must develop a work plan and select the best work techniques for the specific site and task. To help with the preparation and implementation of underwater work, the UCT Conventional Inspection and Repair Techniques manual was prepared (reference 15). This manual provides information relating to: preparation for deployment; planning and estimating guides; shipping and handling procedures; underwater work techniques; underwater inspection procedures; site survey procedures; and underwater installation procedures.
Since their formation in 1970, the capabilities and responsibilities of the Underwater Construction Teams have continued to grow. The trend is not expected to change in the near future. The tools and equipment described above have been well received and are regularly being used by team detachments. To maintain their effectiveness, new support equipment and work techniques will be needed. Other tools and work techniques presently in development or planned for future development include: diver lift systems for moving and placing heavy objects on the seafloor; a metal detector for locating buried pipe, mooring chain and anchors; a lightweight and a submersible power source for operating seawater hydraulic tools from small boats; a seafloor excavation tool for removing seafloor sediments to uncover buried equipment; a modular work platform for construction support at remote sites; work aids for performing construction in the surf zone; and work techniques manuals for special tasks and contingency or expedient repair operations during times of national emergency.

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FIGURE 1. Components of the Diver Geotechnical Survey System for obtaining information on seafloor sediments.

FIGURE 2. The battery operated Cable Tracking Probe displays the strength of a 25 or 1000 hz tone impressed on cables to be tracked. A nulling technique points the probe at the cable location.

FIGURE 3. The battery operated Electric Field detector warns the diver when the field strength reaches .1 and .2 V/ft.

FIGURE 4. The 2.5 kV Ground Fault Detector is installed between the underwater equipment and the power source and will shut down in 10 ms if the fault current reaches 2.5 mA.

FIGURE 5. The self-contained Diver Recall System sounds either a siren or yelp and can easily be heard at distances to 300 yards underwater.

FIGURE 6. The seawater hydraulic band saw can be used to cut 3.5 inch diameter cables and other shapes. Note only one hose for seawater supply.
FIGURE 7. This oil hydraulic powered tool can cut through 13 inch diameter wooden piles in less than one minute.

FIGURE 8. A hydraulic system is driven from the outboard motor shaft to provide a lightweight system for powering diver tools. This power source is mounted on the transom of an inflatable boat.

FIGURE 9. The prototype seawater hydraulic power source is capable of providing 14 gpm seawater at 2000 psi and will power two tools simultaneously. Also shown is the seawater impact wrench.

FIGURE 10. Two seawater hydraulic hose reels with flow control valves are provided with each Multifunction Tool System.

FIGURE 11. The seawater hydraulic rotary disc grinder is powered by a 3 hp vane motor and drives a 7 inch diameter disc. The lightweight tool features plastic gears and plastic body.

FIGURE 12. The epoxy grout dispenser can be reloaded underwater and simultaneously mixes and dispenses two part epoxy grouts.