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PORTABLE HYDRAULIC BANDSAW FOR USE BY DIVERS.(U)

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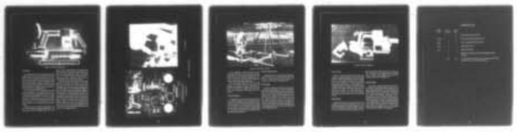

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Technical Report

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CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California 93043

PORTABLE HYDRAULIC BANDSAW FOR USE BY DIVERS

by P. K. Rockwell

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Seafloor cable repair operations generally require several cable cuts that have been time consuming and difficult for divers to perform. A hand-held hydraulic bandsaw was developed at CEL by modifying a commercially available electric model. The experimental bandsaw was tested underwater and found to perform well, cutting 3-1/2-inch-diameter double-armored coaxial cable in 1.5 minutes. The saw was redesigned to be more →

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comfortable to operate and more compatible with seawater use. The prototype saw has been shown to be extremely effective, both underwater and on land; it has cut materials such as SD list 5 and SD list 1 coaxial cable, SG cable, pipe, reinforcing bar, stainless steel rod, tool steel, synthetic line, grapnel line, and structural aluminum.

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1. Underwater cutting 2. Cable repair I. YF52.556.999.01.303

Seafloor cable repair operations generally require several cable cuts that have been time consuming and difficult for divers to perform. A hand-held hydraulic bandsaw was developed at CEL by modifying a commerically available electric model. The experimental bandsaw was tested underwater and found to perform well, cutting 3-1/2-inch-diameter double-armored coaxial cable in 1.5 minutes. The saw was redesigned to be more comfortable to operate and more compatible with seawater use. The prototype saw has been shown to be extremely effective, both underwater and on land; it has cut materials such as SD list 5 and SD list 1 coaxial cable, SG cable, pipe, reinforcing bar, stainless steel rod, tool steel, synthetic line, grapnel line, and structural aluminum.

CONTENTS

INTRODUCTION

The Naval Facilities Engineering Command (NAVFAC) is responsible for the construction, maintenance, and repair of Naval shore facilities and ocean bottom installations. As NAVFAC's research and development laboratory, the Civil Engineering Laboratory (CEL) is tasked with developing tools, equipment, and techniques for constructing, maintaining, and repairing underwater facilities. Recent efforts have been directed toward improving the methods by which seafloor cables are installed, protected, and repaired. One particularly difficult task required during a cable repair operation is the cutting of the cable to remove the damaged section. The 3-inch-diameter double-armored SD list 5 coaxial cable (Figure 1) is normally cut by Underwater Construction Team (UCT) divers using a hand hacksaw; this procedure can take 4 to 8 man-hours for a single cut. This report summarizes the development of an underwater portable hydraulic bandsaw that not only solves the cable cutting problem but also has proven to be a versatile tool both underwater and in general shop use.

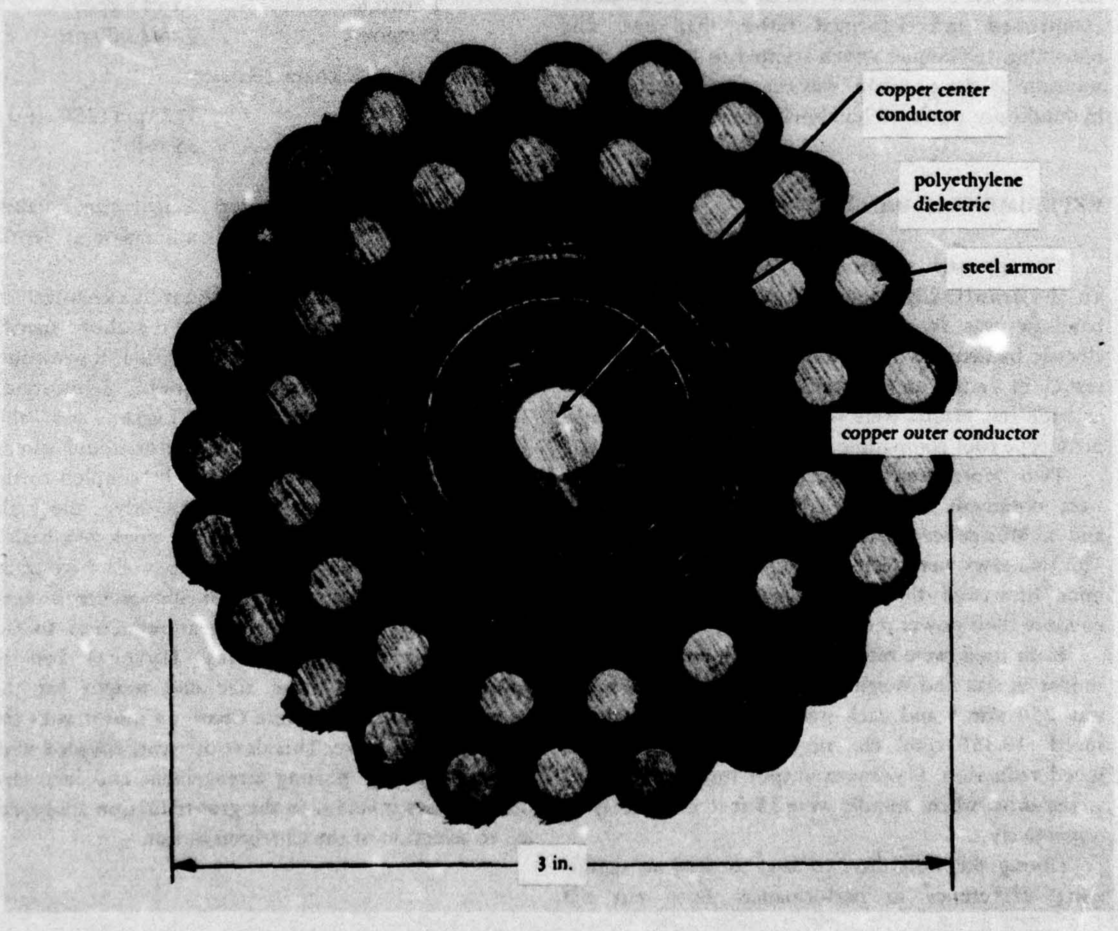

Figure 1. Double-armored SD list 5 coaxial cable.

Before developing the hydraulic bandsaw, other methods were considered for cutting SD cable. Rotary abrasive saws and grinding wheels were eliminated because of windage losses and the difficulty divers experience in controlling these tools. Reciprocating saws, previously evaluated by CEL, were found to reciprocate the diver's hands rather than cutting, because the diver is unable to apply adequate horizontal force to keep the stop against the work. Burning techniques, such as pyronol torches and welding equipment, were eliminated for safety reasons and because this type of equipment is not normally available to UCT divers. Piston-operated guillotine-type cable cutters were considered briefly. A cable cutter manufacturer felt this type of cutter would give poor results on SD armored cable as the center of the cable provides no solid resistance to motion of the armor wires; that is, the cable would be compressed and deformed rather than cut. The remaining technique, which seemed to be a practical solution to the problem, was the development of an hydraulically powered hand-held (portable) bandsaw.

EXPERIMENTAL BANDSAW

The approach selected to validate the concept of an hydraulically powered portable underwater bandsaw was to modify a commercially available electric bandsaw. This experimental model was to be tested in actual underwater construction situations, and the test results were to be utilized in designing a prototype tool compatible with seawater.

Two representative electric portable bandsaws were obtained: a Rockwell Portaband Model 9726, and a Milwaukee two-speed bandsaw Model 6225. The two saws were tested in the laboratory to determine how well they could cut SD cable and to measure their power requirements.

Both tools were rated at 1 hp (full load) and were similar in size and weight. The maximum blade speed was 250 sfm,[*] and each was powered with a high-speed (18,350 rpm) electric motor with 20:1 total speed reduction. Maximum output torque and speed at the drive wheel spindle were 35 ft-lb and 153 rpm, respectively.

During the tests the two saws showed no significant difference in performance. Both cut SD double-armored cable in approximately two minutes, using only the weight of the saw (19 pounds) as the feed pressure. Because of the similarity of the two tools, the only criterion used for selection of one to be modified was the ease with which an hydraulic motor could be adapted to the saw. The Rockwell Portaband was selected because the pulley housings were flat and, therefore, a motor could be bolted to the housing easily.

Selection of Components

The following design specifications are the ones that governed the selection of an appropriate hydraulic motor.

Power source characteristics	
Flowrate	0 to 12 gpm
Pressure	0 to 2,000 psi
Saw final drive characteristics	
Speed	153 rpm (250 sfm)
Torque	35 ft-lb

In addition to these parameters, weight, size, reliability, and suitability for seawater immersion at depths to 120 feet were considered.

CEL has used two hydraulic motors extensively in the diver tool program that meet the above specifications: the Ackley Hyrevz (high-speed, low-torque) and the Charlynn Series H (low-speed, high-torque). Their characteristics are shown in Figure 2 and Table 1. The low-speed, high-torque motor could direct-drive the drive pulley, or it could be coupled to the existing 4:1 reduction final chain drive; the high-speed, low-torque motor could be employed with a gear reduction similar to the electric tool's drive train.

Preliminary design of both approaches showed that coupling the necessary gear reduction to the high-speed motor (Ackley Hyrevz) led to approximately the same size and weight for the converted tool as using the Charlynn motor with the existing chain drive. This development, coupled with a more difficult porting arrangement and increased power losses inherent in the gear-reduction approach, led to selection of the Charlynn motor.

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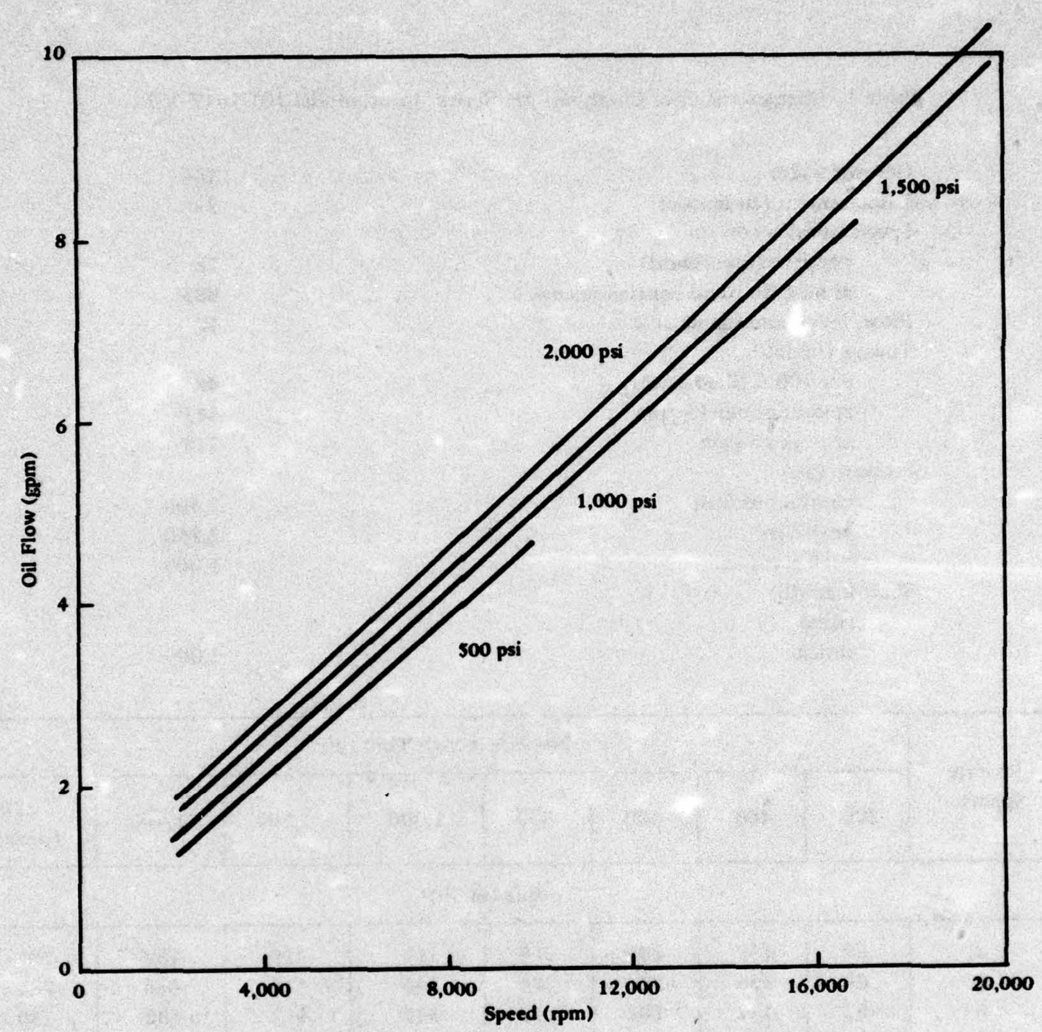
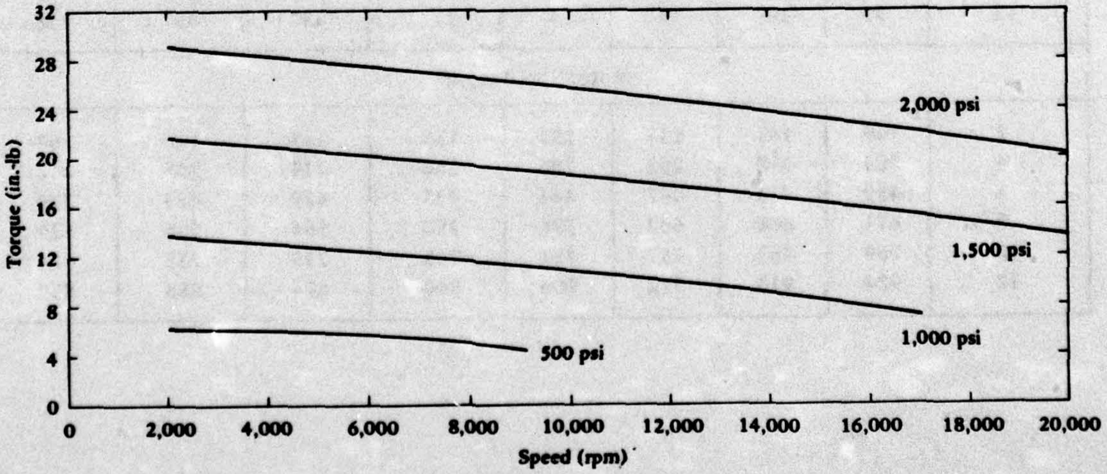
[*] *sfm = surface feet per minute.*



(a) Speed versus oil flow.



(b) Speed versus torque.

Figure 2. Characteristics of Ackley Hyrevz motor, model CW/CCW 34343-31-140.

Table 1. Characteristics of Charlynn "H" Series Motor, Model 101-1017-007

Gerotor width	1/4
Displacement (cu in./rev)	3.0
Speed (rpm)	
per gpm (theoretical)	78
at max flow and continuous psi	885
Flow, maximum (gpm)	12
Torque (in.-lb)	
per 100 Δ (theoretical)	47
at continuous 15 gpm	473
at peak 15 gpm	735
Pressure (psi)	
continuous Δpsi	1,500
peak Δpsi	2,250
back pressure	1,000
Shaft load (lb)	
radial	
thrust	1,000

Flowrate (gpm)	Pressure Across Tool (psi)							
	200	400	600	800	1,000	1,200	1,400	2,250 (peak)
Torque (in.-lb)								
2	69	139	209	279	349	419	489	787
4	66	136	206	276	346	416	486	784
6	62	132	202	272	342	412	482	780
8	55	125	195	265	335	405	475	775
10	47	117	187	257	327	397	467	768
12	37	107	177	247	317	387	457	758
Motor Speed (rpm)								
2	149	143	137	131	125	119	113	63
4	304	298	292	286	280	274	268	218
6	459	453	447	441	435	429	423	373
8	614	608	602	596	590	584	578	529
10	769	763	757	751	745	739	733	684
12	924	918	912	906	900	894	888	839

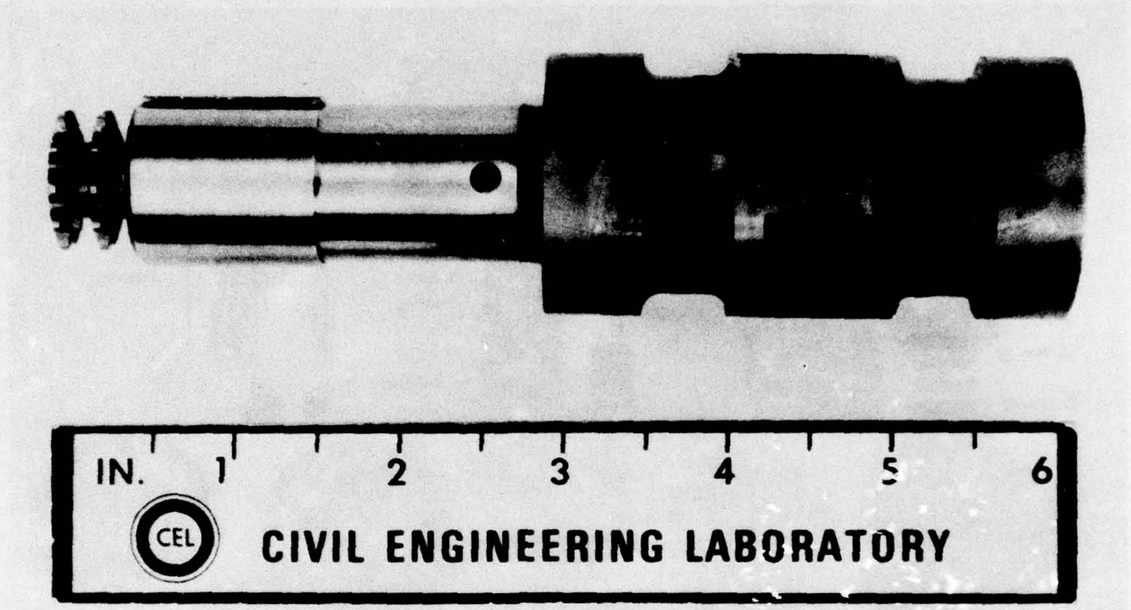


Figure 3. Charlynn motor shaft (modified).

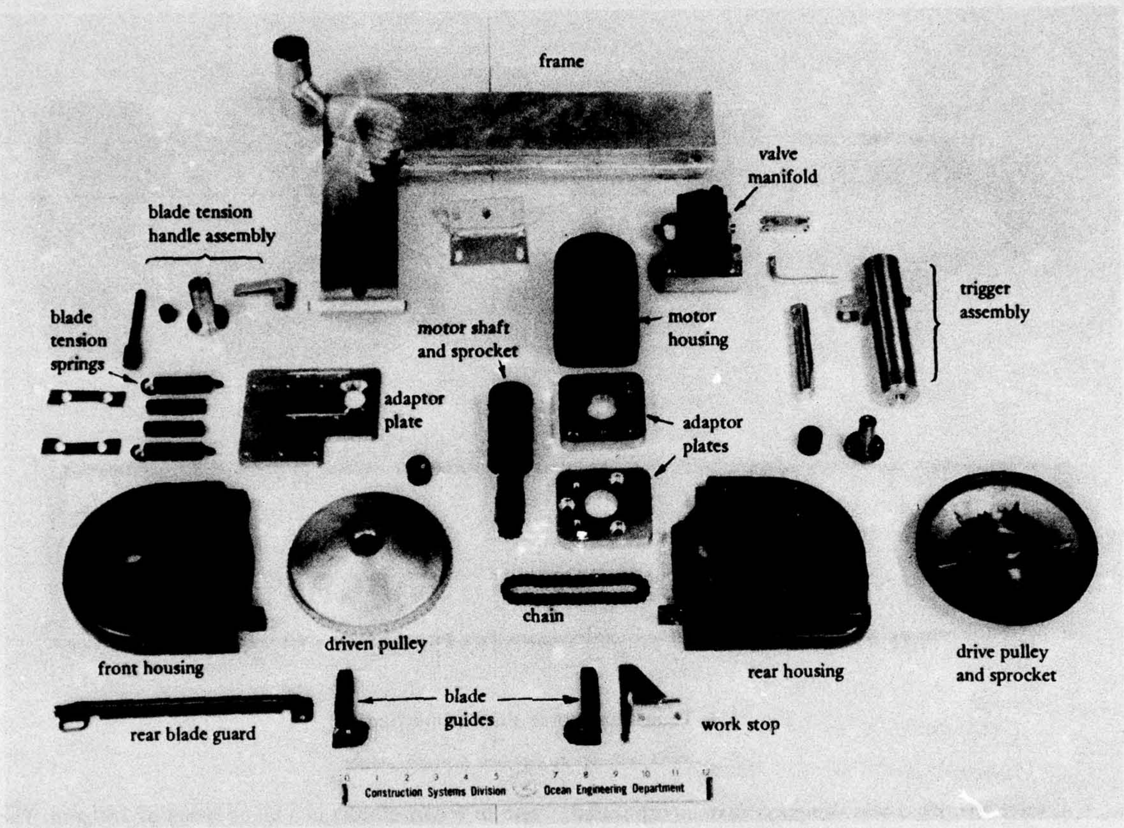
A valve manifold was designed that incorporated open-center valve components from an Ackley 6HS hydraulic impact wrench. The "dead man" trigger-operated valve manifold was attached directly to the Charlynn motor, which was purchased with O-ring ports. The output shaft of the motor was modified to accommodate the existing jackshaft and sprocket of the Rockwell drive train (Figure 3). Finally, a framework and adapter plates were designed to connect the hydraulic motor to the pulley housings, final drive mechanism, and tension adjustment mechanisms of the Rockwell electric saw. The completed experimental saw and its components are shown in Figure 4.

Test Program

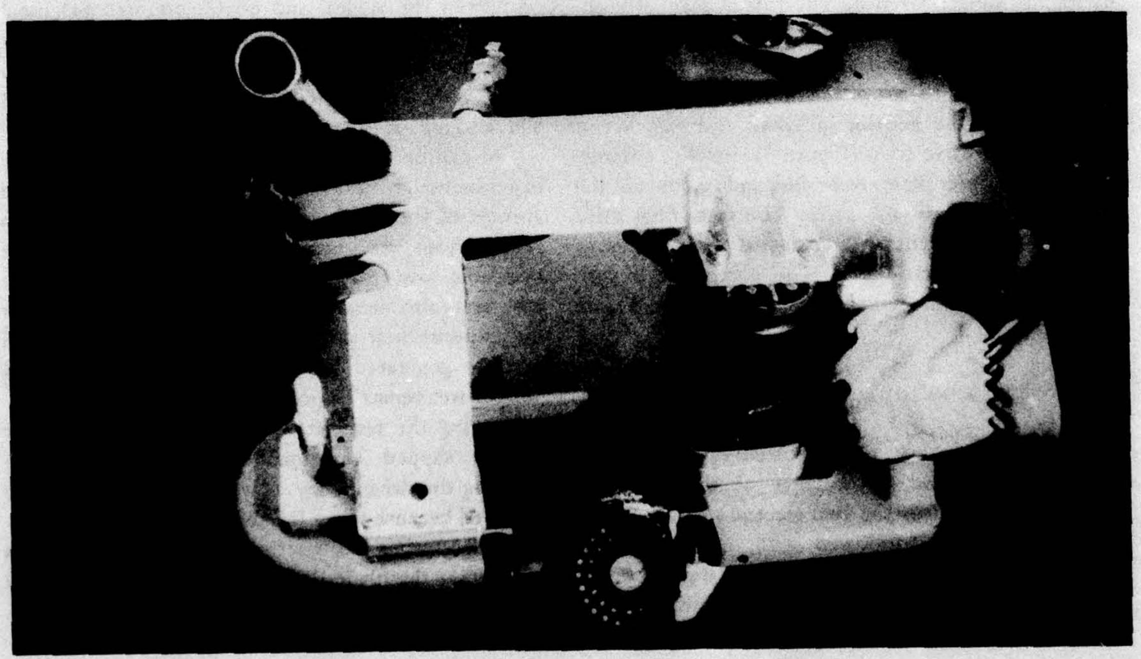
At the laboratory, a series of cuts were made to compare the in-air performance of the hydraulic bandsaw with that of the two electric models. These baseline tests were followed with tank and at-sea tests. The experimental saw was run at 8 gpm, which produces 250 to 300 psi across the tool or 1.2 to 1.4 hydraulic horsepower. As shown in Figure 5, a flow rate of 8 gpm results in a blade speed of 250 sfm. The materials cut were 3-inch steel pipe, 3-inch steel angle (cut from the angle), and double-armored SD list 5 coaxial cable. Each material was cut with four different blades: alloy steel (AS), 18 teeth per inch (TPI); alloy steel, 10 TPI; high-speed steel (HSS), 18 TPI; and high-speed steel, 10 TPI.

As can be seen in Table 2, the performance of the experimental bandsaw compared favroably with the average of the electric saws. The faster cutting times result from the increased in-air weight of the hydraulic saw (30 pounds versus 19 pounds). The tank tests also showed slightly faster cutting times for the experimental saw, again due to the higher feed pressure generated by the weight of the saw (23.5 pounds wet versus 19 pounds).

During the tests, it was discovered that the saw blades slipped occasionally on the rubber tire covering the drive pulley. It was felt that this slippage occurred because water lubricated the blade-tire interface, decreasing the coefficient of friction. It was found that the blade slippage could be eliminated by bonding an abrasive (emery cloth) to the rubber tire.



(a) Disassembled.



(b) Assembled.

Figure 4. Experimental bandsaw.

Table 2. Summary of Test Program

(Blade speed = 250 sfm)

Blade	Material Cut	Average Cutting Time (sec) for –				
		Electric Saw (in air)	Experimental Saw		Prototype Saw	
			In Air	Underwater	In Air	Underwater
AS 18 TPI	3-in. steel pipe	123	116	120	131	129
	3-in. steel angle	90	—*	73	71	127
	SD list 5 cable	150	—	105	63	140
AS 10 TPI	3-in. steel pipe	80	—	66	47	104
	3-in. steel angle	55	—	47	40	103
	SD list 5 cable	85	47	102	42	95
HSS 18 TPI	3-in. steel pipe	123	72	95	85	81
	3-in. steel angle	74	51	50	50	41
	SD list 5 cable	110	69	84	57	50
HSS 10 TPI	3-in. steel pipe	—	—	51	69	64
	3-in. steel angle	—	—	44	59	49
	SD list 5 cable	—	—	67	58	75

*Dash indicates not tested.

Comments from the divers who used the saw revealed: (1) the trigger handle to be uncomfortable due to its being vertical, and (2) the saw tended to roll to the right due to the location of the hoses, thereby requiring increased diver effort and attention to keep the saw vertical.

PROTOTYPE BANDSAW

Modifications

The performance of the experimental bandsaw was excellent. The only design modifications required were to make the saw more comfortable to operate and to select materials suitable for seawater service. To improve comfort, the valve manifold was redesigned with the hose connections at the rear, close to the centerline of the tool. This location allows the hoses to stream behind the diver-operator and eliminates the rolling moment applied by side-connected hoses. This change also allows the tool to be triggered either left-handed or right-handed. The trigger and handle were inclined 25 degrees to accommodate a natural wrist orientation, and the trigger was fabricated from tubing which allows it to nestle against the handle.

Some weight reduction was accomplished by designing a tubular framework connection from the motor to the front of the saw. The blade tension mechanism results in 120 ft-lb being applied to the tubular framework; any deflection of the frame will reduce the blade tension and cause blade slippage. A deflection analysis of this frame revealed the deflection would be limited to 0.01 inch by using 2-inch-diameter, 1/8-inch-wall 6061-T6 aluminum tubing.

Table 3. Characteristics of Portable Hydraulic Bandsaw

Envelope dimensions	21 inches long 10 inches high 7.25 inches wide
Weight	26 pounds (dry) 21-1/2 pounds (wet)
Cutting limitations	3-1/2 inches deep 4-1/8 inches wide
Operating characteristics	8 gpm 300 psid 1.4 hp
Operating range	0 to 12 gpm 0 to 2,250 psid 1,000-psi maximum back pressure

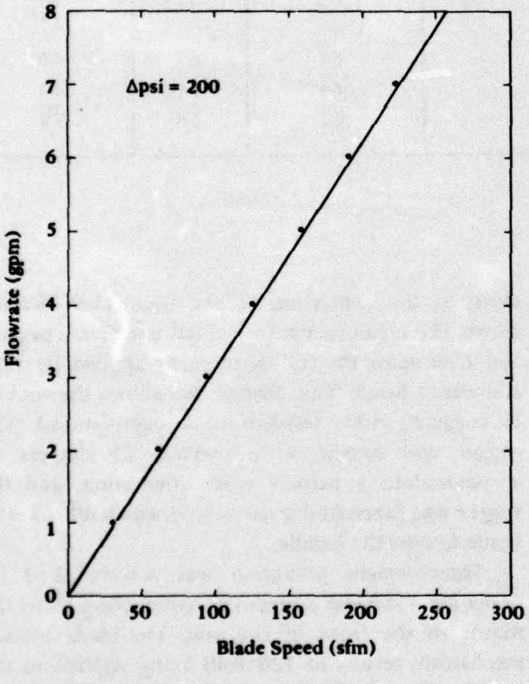


Figure 5. Flowrate versus blade speed for the experimental bandsaw.

Other design changes included an improved connection to the hydraulic motor, auxiliary handles at the front of the saw, and detents in the blade tensioning handle to eliminate inadvertent loosening of the saw blade. All components were fabricated from 6061-T6 aluminum (anodized) or 316 stainless steel for corrosion protection. For increased operator safety, the work stop was built into a movable guard that is spring-loaded to cover the blade when the saw is not cutting (Figure 6). When the diver intends to make a cut, he places the stop against the work and pushes the saw forward to expose the blade. After the cut is made, an elastic cord returns the guard to the safe position. Finally, the bearings in the two blade guides were designed with a 316 stainless steel roller over TFE bushings, as the original needle bearings became fouled with silt.

The only items remaining from the electric saw were the pulleys, the blade guides, and the chain drive components. These items had provided trouble-free service for nearly a year on the experimental model; thus, it did not appear cost effective to fabricate them from corrosion-resistant materials. The prototype saw and components are shown in Figure 7; the saw characteristics are given in Table 3.

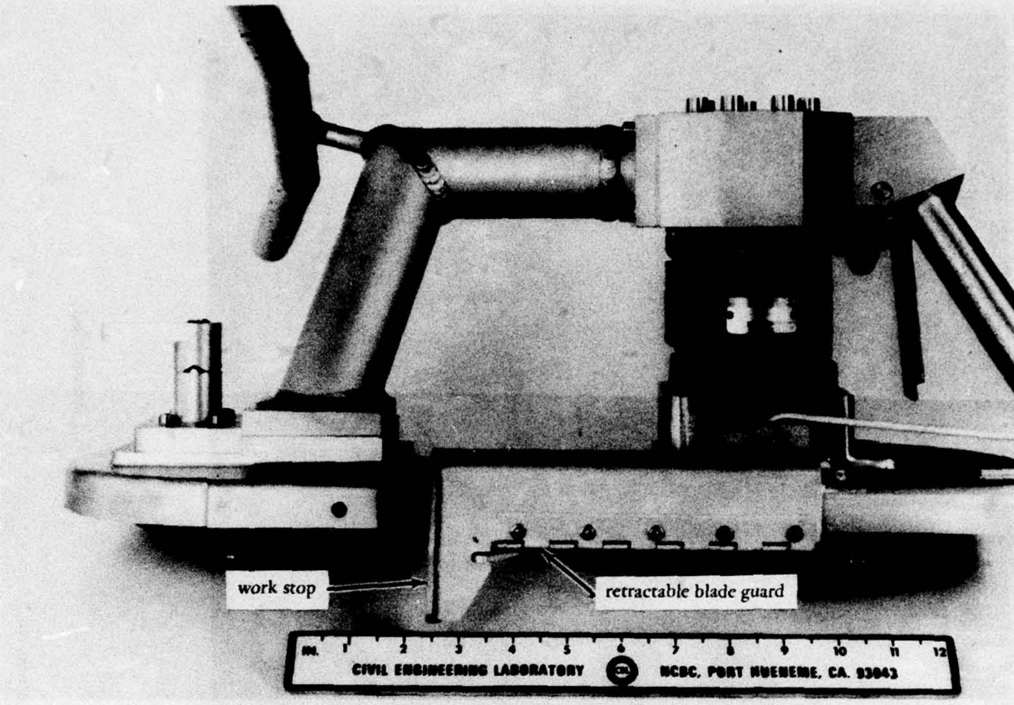


Figure 6. Retractable blade guard.

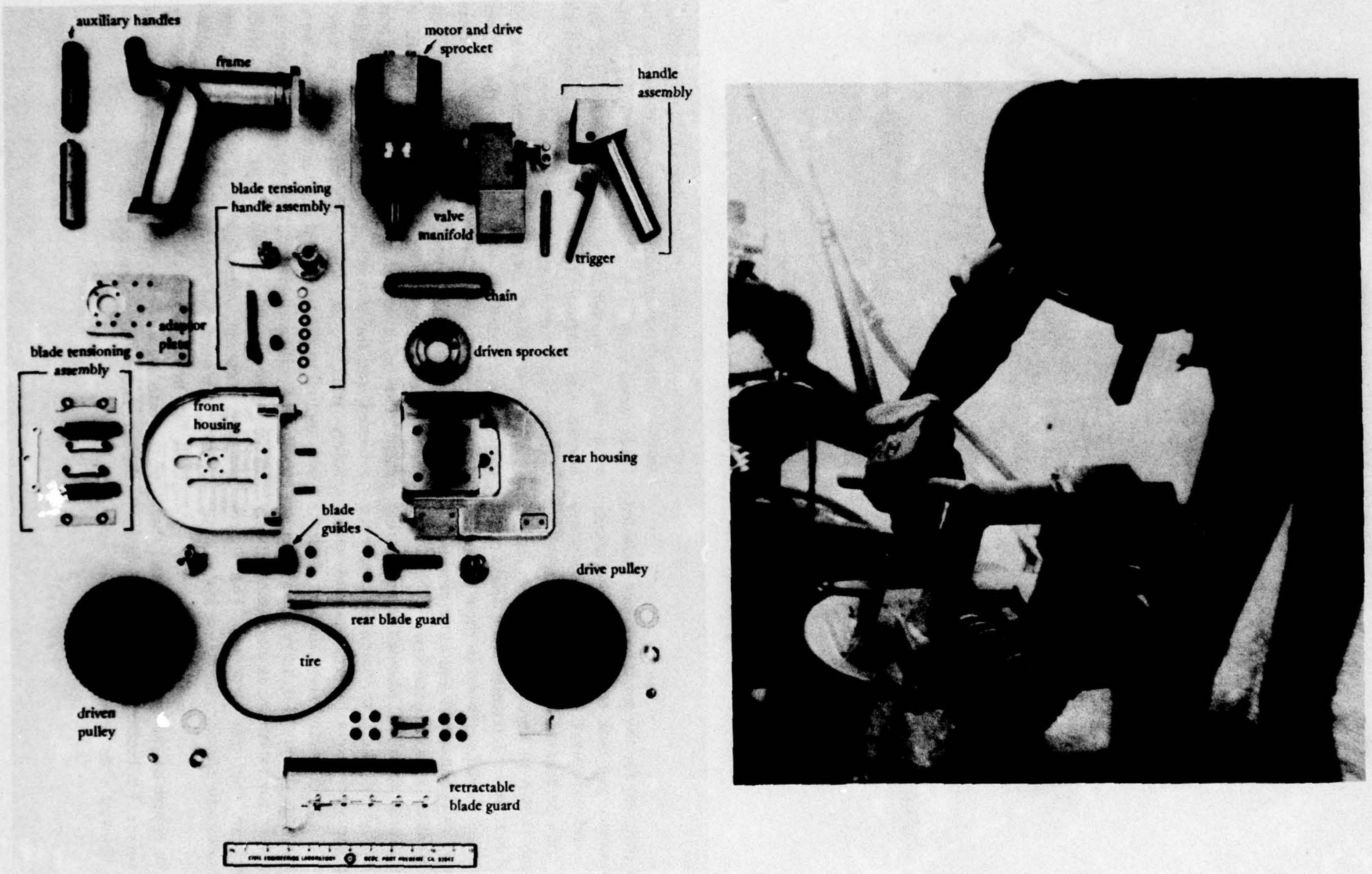
Test Program

The test program for the prototype saw included baseline laboratory and tank tests (as for the experimental saw) and expanded at-sea tests. The at-sea tests, which were performed in 50 feet of water using the test frame shown in Figure 8, included vertical and overhead cutting to determine if the divers could apply the necessary feed pressures in these attitudes. The prototype saw consumed the same amount of power (1.4 hp) as the experimental saw.

The test results (Table 2) showed in-air cutting times comparable to the experimental saw, even though the prototype weighed less (27 pounds versus 30 pounds). The underwater tests showed a slight increase in cutting times. This increase was most likely due to operator variations as many more divers were involved in the test program. The divers reported the saw to be comfortable to use and easy to handle.

During the course of the tests, it was found that the 316 SS roller/TFE bushing combinations in the blade guide showed considerable wear. They were replaced with carbide roller/oilite bushing combinations, which have eliminated the wear problem. The blade tensioning handle also showed considerable wear due to aluminum sliding on aluminum as the handle was rotated. These parts were changed to chrome-plated steel to eliminate the problem.

The emery cloth abrasive that was tested with the experimental bandsaw was bonded to the rubber drive tire with rubber cement. Since this was time consuming, some tires were sent to an abrasive belt recoating company to have an abrasive grit applied to them. The result was that only partial bonding was achieved, and the abrasive grit flaked off. Finally, 3M Safety Walk^{TM}, an adhesive-backed abrasive tape, was applied to the tires for the at-sea tests. Tests were conducted with and without the tape to determine its effect. Without the abrasive tape, extreme blade slippage occurred. After the tape was applied, one operator twisted the saw to try to make the blade bind, but he could not cause blade slippage. The rest of the tests were conducted with the abrasive tape on the tire, and no slippage occurred.



(a) Disassembled.

(b) Assembled.

Figure 7. Prototype bandsaw.

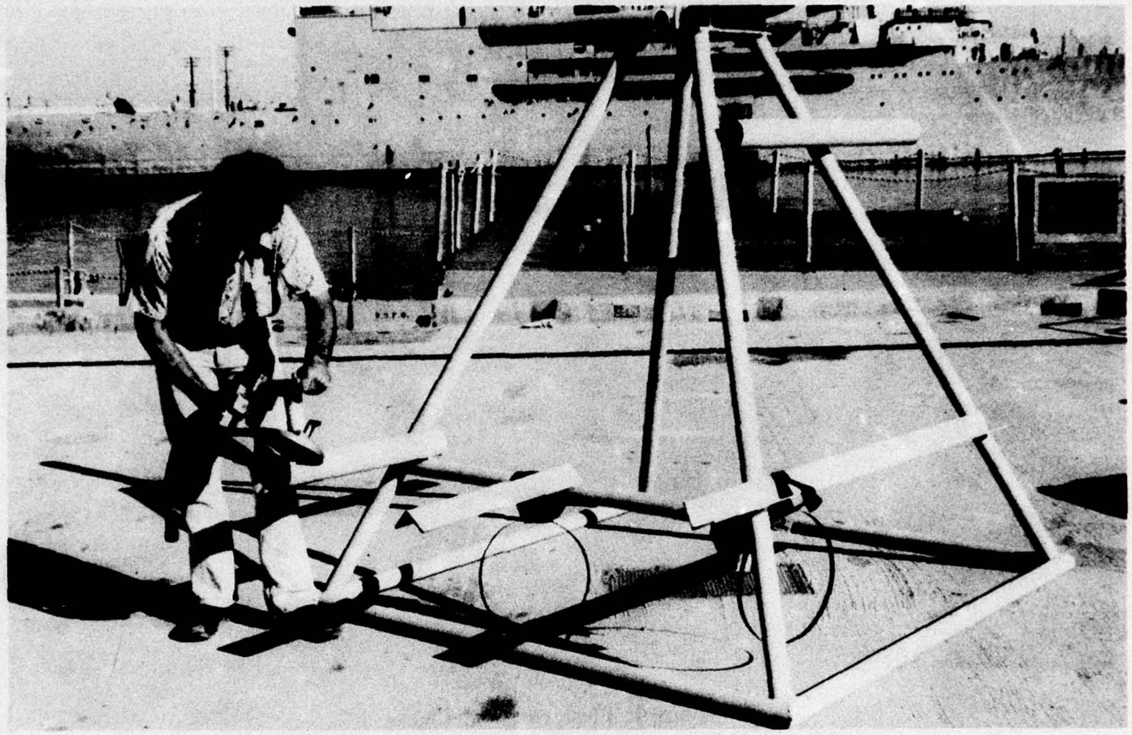


Figure 8. Underwater test frame.

It was possible to make vertical cuts, but, according to the divers, a reaction point is necessary so that adequate feed pressure can be applied. Overhead cuts were more easily accomplished, but they were also more tiring as the diver had to apply feed pressure in addition to supporting the saw.

One test was performed with a piece of cable lying on the seafloor. While the saw suffered no problems from having the wheels rotate in the sediment, it was found that a complete cut could not be made without lifting the cable slightly off of the bottom.

Future Modifications

Modifications that will be made for future saws are to make the springs out of 316 stainless steel, and to provide an access hole in the rear pulley housing so that the chain drive can be greased without removing the drive pulley and the sprocket. These changes should improve the maintenance characteristics of the saw and provide reliable operation in the field with no disassembly requirements.

OTHER APPLICATIONS

During the course of the bandsaw development, several requirements for cutting materials other than SD list 5 coaxial cable arose; the bandsaw was effectively used for these various applications.

Flush Cutting

Underwater Construction Team 1 was required to cut exposed reinforcing bar, 1-1/8 inch in diameter, flush with a horizontal concrete surface. As the work was to be done with zero visibility, a blade guide was designed that "trapped" the reinforcing bar in the saw and allowed cutting flush to within 1/8 inch of the concrete (Figure 9). Tests in the CEL tank showed that with the saw flowrate set at 12 gpm (375 sfm), the reinforcing bar could be cut in as little as 10 seconds with the diver's eyes closed. Subsequent use in the field proved the saw to be an efficient method of accomplishing this job.

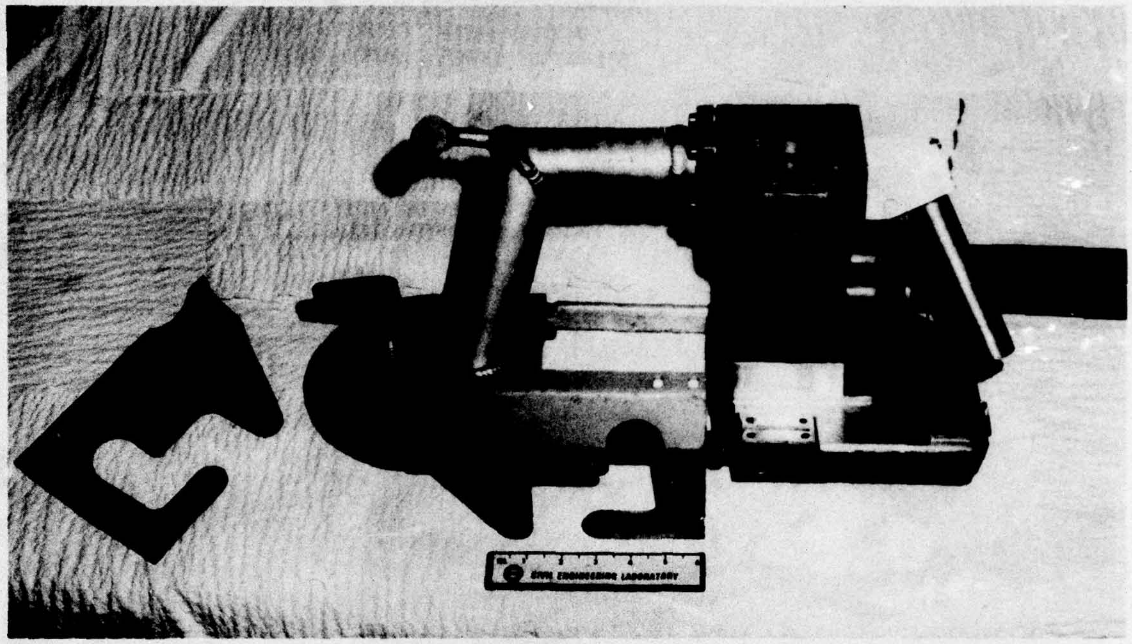


Figure 9. Flush cutting guide.

SD List 1 Cable

SD list 1 coaxial cable has no armor wires, but develops its breaking strength with a center strength member of 300 ksi improved plow steel. The requirement to cut this cable arose when CEL was testing the electrical properties of a simple butt splice that required relatively straight cuts. It was found that by reducing the flowrate to 4 gpm (120 sfm) and using an HSS 18 TPI blade, this material could be cut in less than 20 seconds. At 8 gpm (250 sfm) no combination of blade type and tooth distribution could be found that would cut the center strength member.

Other Materials

During the course of day-to-day operations at the laboratory, many different materials were cut with the hydraulic bandsaw. Running at 8 gpm with an AS 18 or 10 TPI blade, the saw cut tool steel, 1-1/8-inch 316 SS round stock, aluminum, and mild steel. At 4 gpm with an HSS 18 TPI blade, the saw was successful in cutting SG cable (single-armor coaxial cable with a 300-ksi center strength member and jute wrapping), nylon line, and grapnel line.

CONCLUSIONS

The portable hydraulic bandsaw has proved to be an effective and versatile powered hand tool for divers and for general shop use. It can effectively cut double-armored SD list 5 coaxial cable in about one minute, while consuming only 1.2 hp. It is simple to use, requires little periodic maintenance, and is comfortable for divers to handle. The saw can cut a variety of materials in sizes up to 3-1/2 inches high by 4-1/8 inches across in a variety of attitudes. The saw can be modified easily to perform flush-cutting operations. Finally, for horizontal use, the diver merely must position and trigger the saw, as the weight of the saw provides the necessary feed pressure.

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