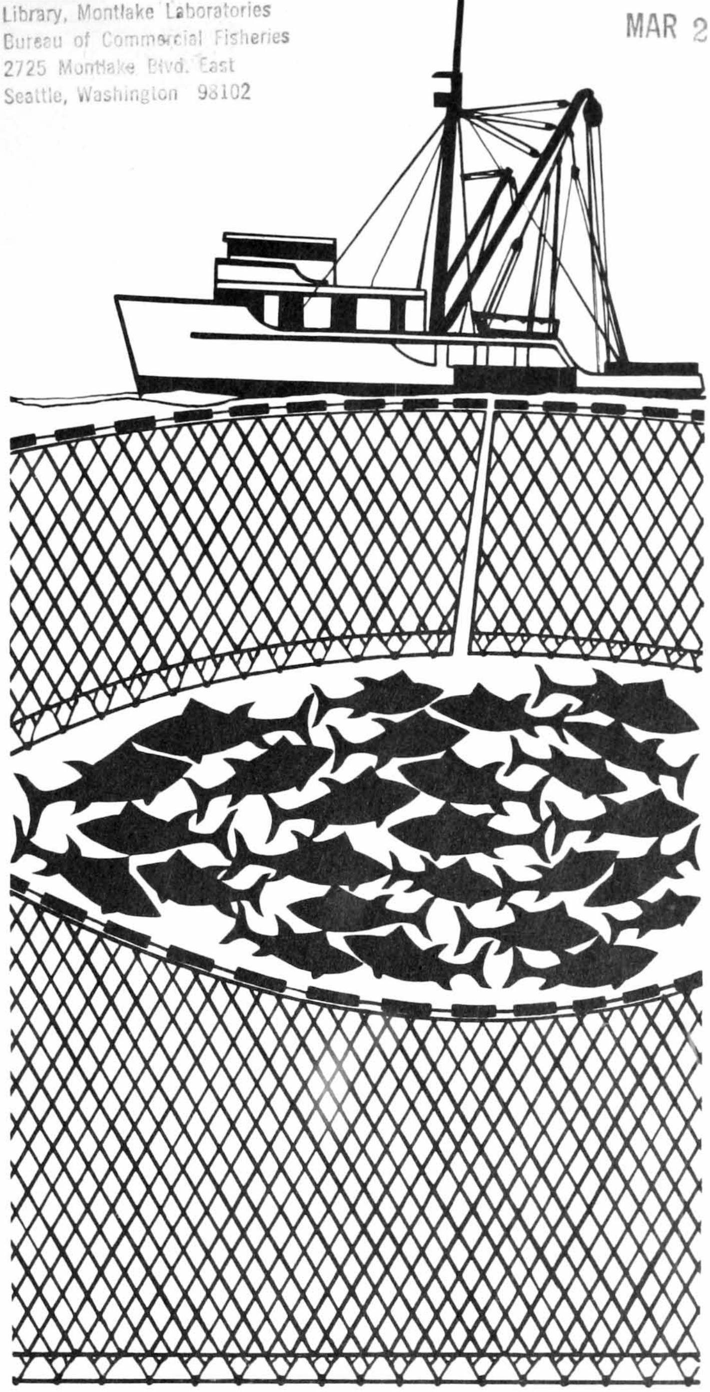

FISHERY INDUSTRIAL RESEARCH

VOLUME 4 NO. 6

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FISHERY INDUSTRIAL RESEARCH

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RAPID METHOD FOR THE ESTIMATION OF EDTA (ETHYLENEDIAMINETETRAACETIC ACID) IN FISH FLESH AND CRAB MEAT

by

Herman S. Groninger and Kenneth R. Brandt

ABSTRACT

EDTA, a quality stabilizing additive, is usually applied to seafoods by spraying or dipping, and the amount of EDTA retained by the treated product must be determined by an analytical method. A titration method based on the chelation of EDTA with thorium ion was modified for use in the determination of EDTA in fish flesh and crab meat. The modified method is both simple and rapid and gave about 90-percent recovery of added EDTA from samples of fish flesh and crab meat.

INTRODUCTION

EDTA has been reported to be useful or potentially useful as an additive to seafoods to stabilize color and retard the formation of struvite (National Academy of Sciences, 1965), inhibit enzyme-catalyzed changes in flavor (Groninger and Spinelli, 1968), and inhibit the growth of bacteria (Levin, 1967).

Often, EDTA is applied to seafoods by spraying or dipping the product. The amount of EDTA actually added must then be determined by a suitable quantitative method.

A number of methods have been developed for the determination of EDTA in various materials (Belot, 1964; Brady and Gwilt, 1962; Cherney, Crafts, Hagermoser, Boule, Harbin, and Zak, 1954; Darbey, 1952; Haas and Lewis, 1967; Kratochvil and White, 1967; Lavender, Pullman, and Goldman, 1964; Malat, 1962; Vogel and Deshusses, 1962). In all of these methods, the principle of measurement is based on the chelating capacity of EDTA. In general, each method was developed for use on a specific type of product.

Efforts were made to adapt several of these methods (Brady and Gwilt, 1962; Haas and Lewis, 1967; Vogel and Deshusses, 1962) for the analysis of EDTA in fish muscle and cooked crab meat. None were satisfactory. During the testing of the EDTA methods, we found, however, that the method of Pribil and Vesely (1967), which was developed for the determination of EDTA during the commercial synthesis of EDTA, could be modified satisfactorily for use in the determination of EDTA in fish flesh and crab meat.

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The purpose of this paper therefore is to report on the modified method. The paper gives the details of the method, the recoveries of added EDTA from fish flesh and crab meat, the precision of the method, and the precautions to be observed when EDTA is used in the presence of interfering substances.

I. DETAILS OF THE METHOD

1. Prepare extracts of fish flesh or crab meat by disintegrating 20 grams of material with 40 milliliters of 5-percent trichloroacetic acid for 1 minute in a blender.
2. Filter the mixture through Whatman No. 2v filter paper.[1]
3. Collect 2 milliliters of filtrate and adjust the pH to 11.0 with 10-percent sodium hydroxide.
4. To the filtrate, add 5 milliliters of 2-percent calcium acetate and readjust the pH to 11.0.
5. Remove the precipitated calcium phosphate by centrifugation and follow by filtration through Whatman No. 1 filter paper.
6. Wash the precipitate with a dilute solution of alkaline calcium acetate and combine the washings with the phosphate-free filtrate.
7. Adjust this filtrate to pH 3.5 with 0.5 *N* hydrochloric acid.
8. Add 5 milliliters of 0.2 *M* acetate buffer, pH 3.5, and from 1 to 2 drops of a 0.16-percent aqueous solution of xylenol orange to an aliquot.
9. Titrate the aliquot with 0.001 *M* thorium nitrate to a red-violet endpoint.
10. Calculate the content of EDTA from a standard curve prepared by the titration of solutions containing 0 to 5 μM EDTA (Figure 1).

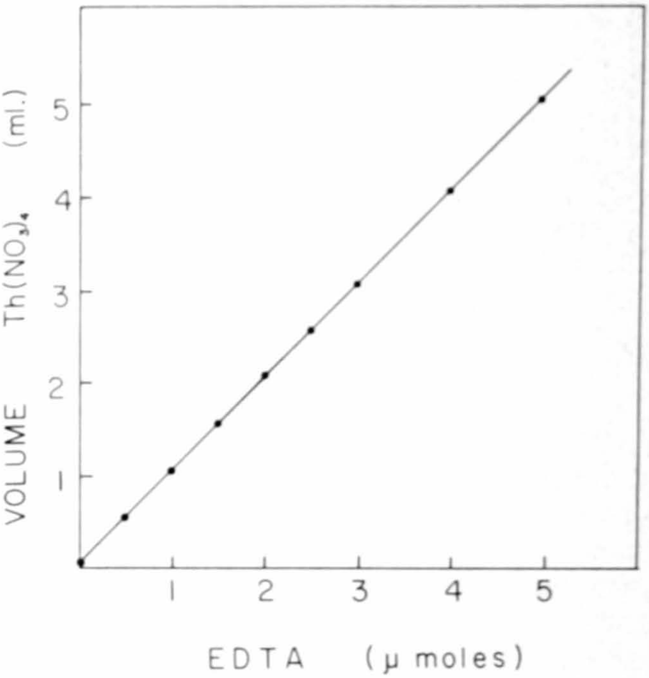

Figure 1.—Standard curve for the analysis of EDTA. Samples containing known amounts of EDTA were titrated with 0.001 M $Th(NO_3)_4$.

II. RECOVERIES OF ADDED EDTA

Table 1 shows the efficiency of recovery of EDTA added to fish flesh and crab meat. At all the concentrations of added EDTA tested, the recovery appeared to be adequate for the purposes of this determination.

Table 1.—Recovery of EDTA added to fish flesh and crab meat

EDTA added	EDTA recovered from:	
	Fish flesh	Crab meat
γ/g.	*Percent*	*Percent*
37.5	95	--
75	96	95
150	93	90
300	90	91
600	92	92

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[1] Use of trade names is merely to facilitate description; no endorsement is implied.

III. PRECISION OF THE METHOD

Table 2 gives a statistical evaluation of the recovery from samples containing 300 gammas of EDTA per gram of fish flesh and crab meat. These recovery results show that the method is suitable for determining the amount of EDTA additive in a fishery product. Also these results compare favorably with those obtained with similar methods.

Table 2.—Precision of recovery of EDTA from fish flesh

Trials	EDTA added	EDTA recovered			Standard deviation
		Range	Mean		
	γ./g.	γ/g.	γ./g.	*Percent*	γ/g.
13	300	246 -- 276	266	89	11

IV. PRECAUTIONS TO BE OBSERVED

Phosphates interfere with this method. The presence of phosphates gives high results in terms of EDTA, because these compounds combine with the thorium ion. This interference is completely eliminated by removal of the phosphates with calcium.

Citrate also interferes with the method. Usually, however, not enough citrate is present in fish and crab meat to cause a problem. In samples of crab meat in which citrate has been added, this interference can be eliminated by the removal of the citrate from EDTA by chromatography on cation resin. This separation is accomplished as follows:

1. Adjust the filtrate from the phosphate-removal step to pH 8.8 with 0.5 milliliter of 0.2 *M* tris buffer.
2. Pass the filtrate over a 5- to 6-centimeter AG 50 W-X8 (+H) column (200-400 mesh).
3. Wash the column with from 10 to 20 milliliters of water containing 0.5 milliliter of 0.2 *M* tris buffer, pH 9.0.
4. Elute the EDTA with from 10 to 20 milliliters of *N* hydrochloric acid in 0.5 *M* potassium chloride.
5. Adjust the eluate to pH 3.5 with 0.5 *N* hydrochloric acid.
6. Add 5 milliliters 0.5 *M* acetate buffer (pH 3.5).
7. Titrate the eluate just as you would a regular sample.

The overall recovery obtained when citrate is present is about 80 percent. This loss of 20 percent can be attributed to a portion of the EDTA passing through the Dowex 50 column along with the citrate.

Apparently, metal ions such as Cu^{2+}, Mg^{2+}, and Ca^{2+} do not interfere.

SUMMARY

The Pribil and Vesely (1967) titration method based on the chelation of EDTA with thorium ion was modified for use in the determination of EDTA in fish flesh and crab meat. The modified method, which is simple and rapid, gave about 90-percent recovery of added EDTA from samples of fish flesh and crab meat.

Phosphate and citrate interfere. Techniques are given for their removal from samples containing EDTA.

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DESIGN, CONSTRUCTION, AND FIELD TESTING OF THE BCF ELECTRIC SHRIMP-TRAWL SYSTEM

by

Wilber R. Seidel

ABSTRACT

The system was designed and constructed so that the feasibility of using electricity to help capture brown and pink shrimps during daylight could be determined. Components of the system were designed to produce, on a full-size commercial trawl, the stimulation needed to cause shrimp to emerge from the substratum where they burrow during the daytime.

In fishing trials off the coasts of Mississippi and Texas, the prototype electric trawl caught during daylight 95 and 109 percent of the quantity of shrimp caught at night by a conventional, nonelectric trawl. In the Dry Tortugas area off Southern Florida, where the substratum is calcareous sand-shell rather than mud as in the substratum of the Northern Gulf of Mexico, the catch taken with the electric trawl during daylight was only 50 percent of that taken with the nonelectric trawl after dark.

CONTENTS

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Preprint No. 68, issued January 1969.

INTRODUCTION

In 1961, we — that is, the staff at Gear Research Unit of the Exploratory Fishing and Gear Research Base, Pascagoula, Mississippi — evaluated electric systems that could be used on shrimp trawls to increase the harvest of brown and pink shrimps. Because these shrimp burrow in the ocean floor during daylight (Fuss, 1964), commercial fishing has been restricted to night trawling — that is, to the period when they are not in their burrows. The aim of these preliminary evaluations was to develop a system that would force the shrimp out of their burrows during daylight. If successful, it would allow around-the-clock fishing and more efficient use of harvesting gear.

Initial trials with electric shrimp-trawl systems, though encouraging, were not satisfactory because of the rates of catch during daytime were much smaller than were those at night. However, they did show that, before a successful electric trawl could be developed, the exact electrical requirements that would cause optimum shrimp response had to be determined. In 1965, Klima (1968) studied the response of shrimp to an electric field. His data provided the background information for the needed design of an adequate electric shrimp-trawl system.

The goal of the work reported here was to design a full-scale prototype shrimp trawl that would permit a test of the commercial feasibility of electric trawling during daylight (Pease and Seidel, 1967). The aim was not to build a fully engineered production-model trawl, but simply to develop one that would show whether daylight electric trawling is practical. Accordingly, the work was divided into two main parts. The first was concerned with designing and developing a full-scale electric shrimp trawl[1]; the second with testing it under actual fishing conditions.

I. DEVELOPING THE ELECTRIC SYSTEM

By using a capacitor-discharge direct current, Klima (1968) found that burrowed shrimp could be forced to leave their burrows. He also learned that the time they took to react to the electric stimulus and the distance they moved upward from the bottom depended on both the strength and the repetition rate of the pulsed current. The electric conditions that he found to cause the optimum response were:

1. A minimum field strength of 3 volts measured across 4 inches in sea water.
2. A pulse repeated at the rate of 4 or 5 times per second (both rates produced similar results).

The pulse generators that had been used during the shrimp-behavior studies could produce the necessary electric characteristics on only a small electrode array. Therefore, we had to design a large-scale pulse generator and to adapt a commercial shrimp trawl to carry the generator and electrodes that would produce the electric field needed to force shrimp from their burrows.

A. DEVELOPMENT OF A LARGE-SCALE PULSE GENERATOR

In developing a pulse generator for the system, we first had to select an operable circuit; then we had to test it. Described in this section are (1) the circuit chosen for the large-scale pulse generator and (2) the laboratory tests made before installing the generator on a prototype shrimp trawl.

1. The Circuit

Before designing the circuit for the pulse generator, we made a study of capacitor-discharge pulse generators and, on the basis of the information found, constructed several circuits for testing. Although most capacitor-discharge pulse generators are basically alike,

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[1] Public Service Patent applied for.

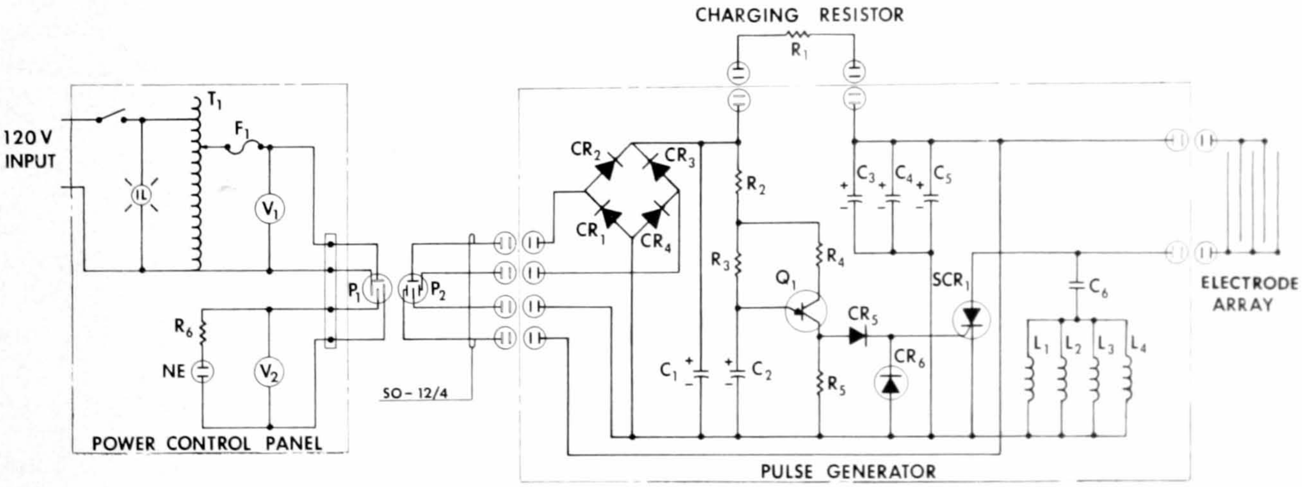
the design of a generator for the electric trawl was complicated by the high conductivity of the salt water. The total resistance of the system's electrode array in sea water, though varying slightly with changes in the salinity and temperature of the water, is normally about 0.1 ohm. Because of this low resistance, circuit capacitors in a pulse generator tend to overheat internally, and a field strength of 3 volts across 4 inches is difficult to maintain over a large array of electrodes.

The circuit that we finally chose for the generator is shown as part of the schematic in Figure 1. A comparison of the circuit and the parts list reveals that several of the components are slightly larger than necessary. However, reducing the size of the components and their cost was not considered practical at this time, since the prototype system was merely a test model.

Some of the desired components were not readily available from regular suppliers, so we used substitutes. For example, in the "turn-off" part of the circuit, we had to use a capacitor of less than optimum size in the L-C combination (L-inductor, C-capacitor); we used four inductors in parallel to give us the required low resistance at the desired inductance. In a production model of the pulse generator, these substitutions need not be made, because components of the correct size could be obtained in quantity from a manufacturer.

A p-n-p-n semiconductor — SCR (silicon controlled rectifier) — was chosen as a switch to control the power-discharge pulses of the pulse generator. This semiconductor switch has two advantages over mechanical or electromechanical switches: (1) it is simple to use and does not require much additional circuitry or mechanical devices, and (2) it does not arc when turned on, as electromechanical switches do.

When used as a power switch in a pulse circuit, the SCR is activated and then inactivated for each cycle of operation. It is activated through a standard unijunction transistor trigger circuit (Figure 2A) and is inactivated or commutated as the turnoff process is called, by forcing more reverse than forward



PARTS LIST

CR_1, CR_2, CR_3, CR_4 – 1N4136
CR_5 – 1N3254
CR_6 – 1N1770
Q_1 – 2N2647
SCR_1 – C46B
L_1, L_2, L_3, L_4 – 10 MHY – 400 MA
C_1 – 425 µf – 350 W.V.D.C.
C_2 – 3.9 µf – 50 WVDC – TANTALUM
C_3, C_4, C_5 – 1100 µf – 350 WVDC
C_6 – 100 µf – 450 WVDC – NONPOLARIZED
V_1 – VOLTMETER – 0-300 VAC
V_2 – VOLTMETER – 0-300 VDC
R_1 – 250 OHM – 200 W.
R_2 – 50K OHM – 10 W.
R_3 – 43K OHM – 2 W.
R_4 – 1.8K OHM – 2 W.
R_5 – 27 OHM – 2 W.
R_6 – 22K OHM – 2 W.
NE – NEON LIGHT – NE-51
F_1 – FUSE – 3AG – 20A.
T_1 – VARIABLE TRANSFORMER – SUPERIOR TYPE 246
INPUT 120-240 V, OUTPUT 0-280 V, 15 A
P_1 – PLUG – TWIST LOCK – FEMALE – 4 PIN – 20 A
P_2 – PLUG – TWIST LOCK – MALE – 4 PIN – 20A
CONNECTORS – 8 EACH – MECCA: MALE BULKHEAD #1849, FEMALE #1846

Figure 1.—Schematic of shrimp trawl's electric system.

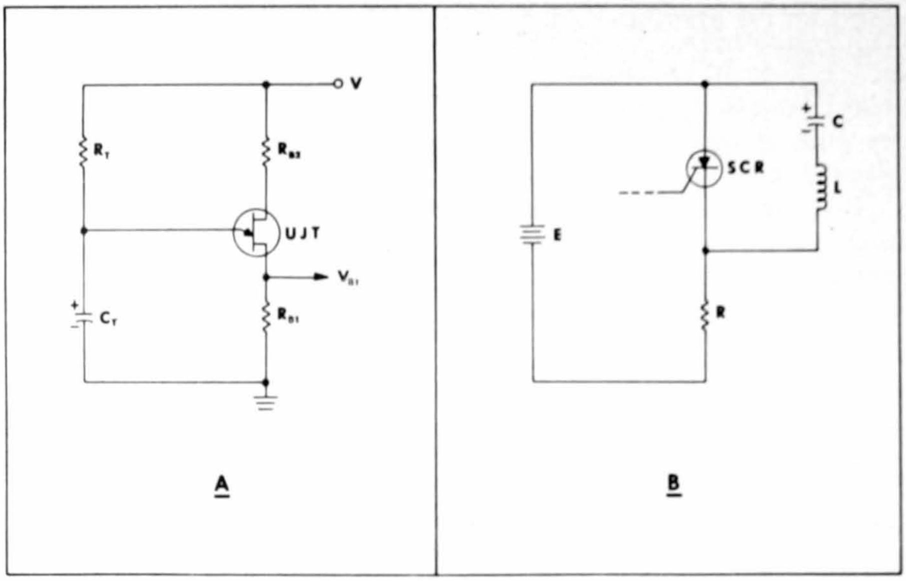


Figure 2.—A — Unijunction transistor trigger circuit.
B — Inductor-capacitor oscillator commutation circuit.

current through the SCR. In our application, an additional source of energy was necessary to produce current in the reverse direction through the SCR. To accomplish the turnoff, we chose an L-C oscillator for self commutation. Such an oscillator operates effectively with a low resistance in the output load (the electrode array in sea water); moreover, it operates on less than 10 percent of the power from the main capacitors. Hence, use of this oscillator for switching did not reduce the output pulse significantly.

The oscillator circuit (Figure 2B) operates as follows: A pulse of current flows through the resonant L-C circuit and charges the capacitor, C, in the reverse polarity. The current in the resonant circuit then reverses and attempts to flow through the SCR in opposition to the load current. When the reverse current in the resonant circuit is greater than the load current, the SCR turns off (General Electric SCR Manual, third edition, page 76, paragraph 5.5.2).[2]

The oscillator must be so designed that the resonant frequency ($f_R = \frac{1}{2\pi \sqrt{LC}}$) is not increased to the point where the first cycle of the oscillator counteracts the current discharged by the main capacitors. Commutation should be possible after the discharge current has dropped to less than 2 percent of its maximum value. To ensure this condition exists requires that the period, t, of the oscillator be at least 10 times the time constant, T, of the main pulse. Improper matching of the inductor and capacitor usually results in overheating of components in the circuit.

2. The Laboratory Tests

A prototype pulse generator was constructed and tested at a field laboratory set up at St. Andrews Bay, Florida. The primary objective of the tests was to determine if the generator was capable of producing 3 volts across 4 inches measured at the centerline between any two adjacent electrodes. For the test, an electrode array was constructed that provided a field of the same width and length that would be used on a 40-foot trawl. Five electrodes, each with a conducting surface 25 feet long, were spaced across a rectangular frame of 1.5-inch polyvinyl chloride pipe (Figure 3). Five readings were taken between each pair of electrodes, beginning at one end of the pair and repeated at each 6.25-foot in-

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[2] Use of trade names is merely to facilitate descriptions; no endorsement is implied.

terval along the 25-foot electrode. First the electrode array was placed in shallow water to permit the field voltages to be measured easily. Later, it was tested in deeper water, where SCUBA divers measured the voltage.

To ensure that the measurements of voltage would be consistent with those taken during the studies on shrimp behavior, we used the same type of pickup probes. These probes were two bronze rods 0.118 inch in diameter, spaced 4 inches apart, and insulated so that only the bottom 0.39 inch of each rod was exposed. The probes were connected to an oscilloscope, which displayed the pulse voltages. A laboratory pulse generator with measuring instruments is shown in Figure 4 at the location where the field test was made.

From these tests, we concluded that the pulse generator was capable of producing 3 volts across 4 inches measured at the centerline between any two adjacent electrodes, as required from Klima's observation (Klima, 1968) of shrimp in an electric field.

B. ADAPTATION OF THE SYSTEM TO A COMMERCIAL FISH TRAWL

We now had a large-scale pulse generator with the characteristics needed for stimulating shrimp to rise sufficiently high (3 inches) from their burrows to be captured in a moving trawl. We next faced the problem of constructing an electric system that could be attached to the trawl in such a way it would create the desired electric field without interfering with the trawl's operations. Moreover, we had to keep the design as simple and economical as possible if the system were to be useful to the fishing industry.

Figure 3.—Laboratory electrode array being set up at the test site in St. Andrews Bay, Florida.

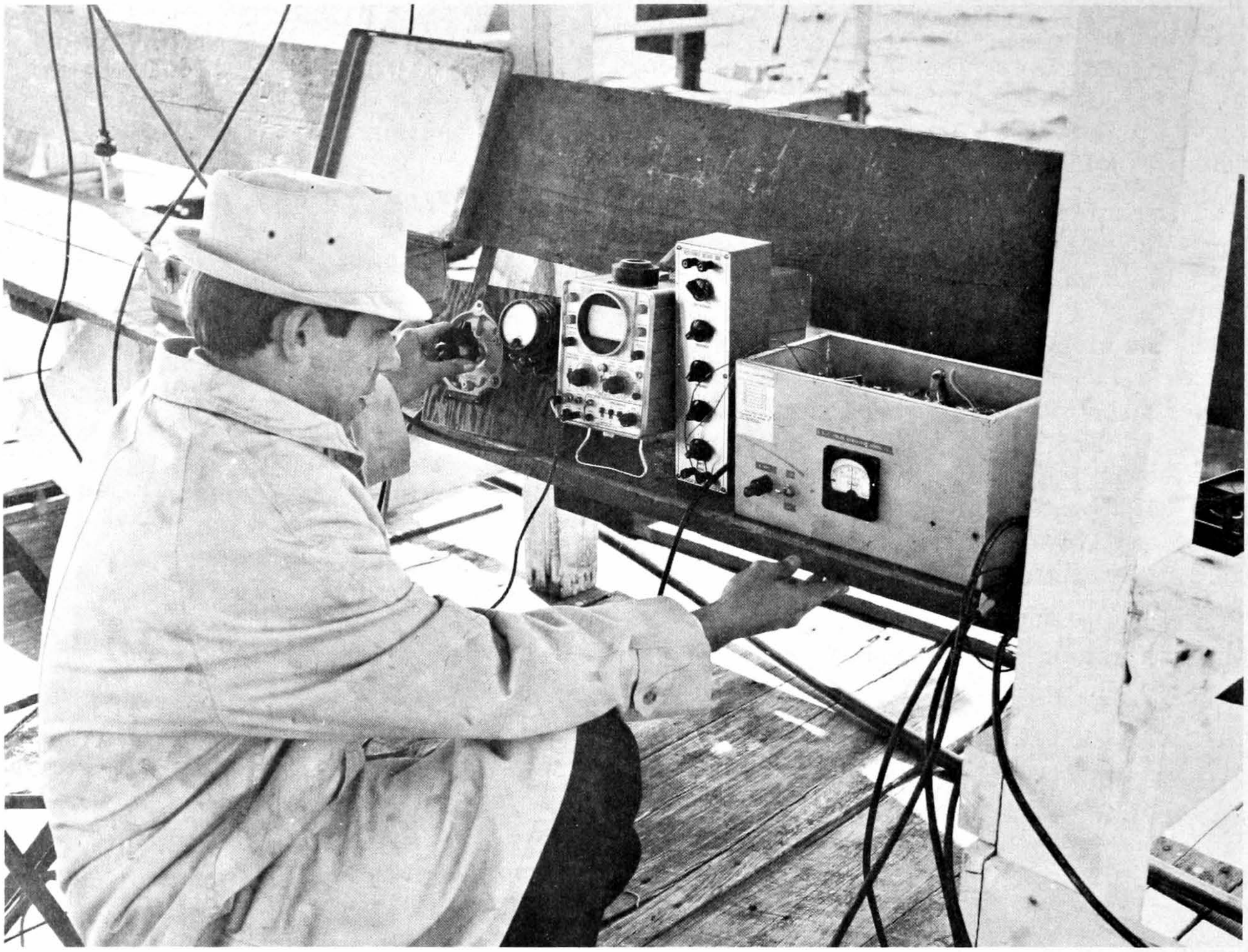


Figure 4.—Laboratory pulse generator and test equipment.

Described in this section are the components of the system that we designed and the simulated field tests that we made.

1. Components of the System

Keeping the direct-current line loss between the pulse generator and the electrode array to a minimum required that the pulser be mounted on one of the trawl doors near the array. With this configuration, four basic components were needed to make the system operational — namely, (a) a power-control panel, (b) a power-supply cable, (c) an underwater housing for the pulse generator, and (d) an electrode array.

a. Power-control panel. — The power-control panel (Figure 5) was the means for regulating the alternating current fed to the underwater unit on the electric shrimp-trawl system and for monitoring the units' performance. During field tests, the control panel was attached to an electronics panel rack aboard the *George M. Bowers.*

The variable transformer on the panel controlled the alternating current fed to the pulse generator. In a commercial model, the large transformer we used could be replaced by a cheaper one of lower voltage — or it could even be eliminated.

In addition to regulating the alternating current, the power-control panel incorporated features for monitoring the system. Two of the four conductors in the power-supply cable connect the output capacitor bank in the pulse generator with the direct-current voltmeter (in the upper right quadrant of the panel).

By keeping a constant check on the voltmeter, the operator could continuously monitor the output voltage of the pulse generator when the system was in operation. A small neon light in the direct-current circuit assisted the operator in checking the pulse rate visually. The wiring diagram for the power-control panel is shown in the schematic of the electric shrimp trawl (Figure 1).

b. Power-supply cable. — Electric power from the control panel to the underwater pulse generator was supplied by an S. O. cord, 600-volt, cable coated with neoprene. This cable contained four AWG (American Wire Gage) Number 12 conductors, only two of which supplied power — the other two led from the pulse generator to the direct-current voltmeter, as previously noted. Number 12 conductors are, of course, larger than necessary for voltage readings, but large wire was needed for the 20-ampere power requirement, and cable containing conductors of uniform size was easiest to obtain from commercial suppliers.

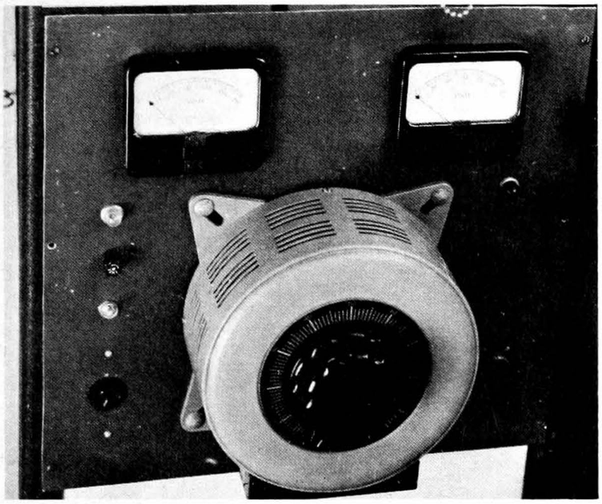


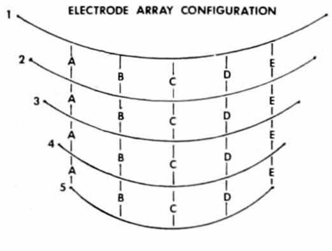
Figure 5.—Power-control panel.

The additional cable had to be handled by hand when the electric shrimp-trawl system was in use. This requirement complicated the operation of the system. However, the electric trawl cables were not fully developed when testing was started, so we felt that this method, cumbersome though it might be, would provide a more trouble-free operation for the system during the field tests.

Voltage readings taken in the electrode array during testing at two input levels of alternating current to the pulse generator are shown in Table 1. Group 1 measurements were provided by an early model pulse generator and were made on electrodes that had been constructed for test purposes. Since they were made by hand, slipping 25 feet of metal braid over a center cord of rope, thick and

Table 1.—Potential-measurement data on the electrode array of the electric shrimp trawl

Electrode material	Data group	Electrode-array position	Potential measurements in the electrode array when the alternating-current input was:							
			115 volts and the electrode pair was:				60 volts and the electrode pair was:			
			1-2	2-3	3-4	4-5	1-2	2-3	3-4	4-5
			Volts	*Volts*	*Volts*	*Volts*	*Volts*	*Volts*	*Volts*	*Volts*
Handmade	Group I (Early model)	A	1.8	2.5	1.8	3.0	0.8	1.3	0.6	1.5
		B	2.0	3.0	1.8	4.0	0.8	1.5	0.6	2.0
		C	1.8	2.0	1.5	2.5	0.6	1.0	0.7	1.3
		D	2.0	2.0	3.0	2.0	1.2	0.8	1.5	1.0
		E	2.8	1.9	5.0	2.0	1.3	0.8	1.8	1.0
Purchased	Group II (Model used in fishing trials)	A	4.5	4.5	4.5	4.5	1.5	1.5	1.5	1.5
		B	4.5	4.5	4.5	4.5	1.5	1.5	1.5	1.5
		C	4.5	4.5	4.5	4.5	1.5	1.5	1.5	1.5
		D	4.5	4.5	4.5	4.5	1.5	1.5	1.5	1.5
		E	4.5	4.5	4.5	4.5	1.5	1.5	1.5	1.5



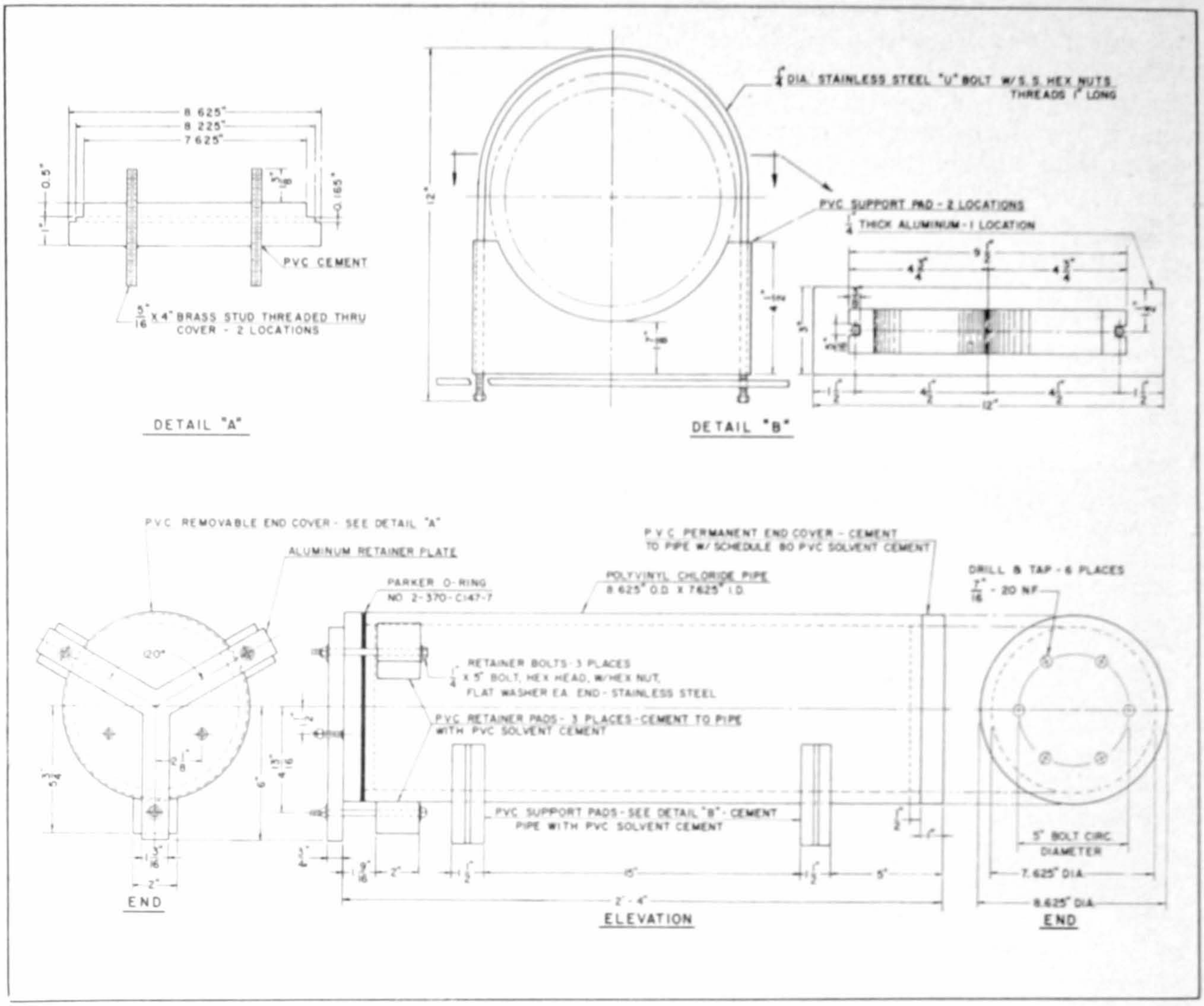


Figure 6.—Underwater housing for the electronic pulse generator.

thin spots of surface-conducting material resulted. These irregularities produced erratic voltage readings in the field. During the Group 2 voltage measurements, the pulse generator that was to be used during fishing trials was tested. These measurements were made on commercially purchased conducting cable that, being uniform, produced uniform voltage readings. During the measurements, the electrode array was placed in a parabolic shape similar to the one it would assume when attached to a trawl. The purchased electrode material was the same as that used later during field tests.

When voltage on the commercial cable was measured at an alternating-current potential of 115 volts, the pulse generator provided field strengths over the entire array in excess of the 3.0-volt minimum.

c. Underwater generator housing. — The underwater housing for the electronic pulse generator (Figure 6) was constructed of high impact, Schedule 80, polyvinyl chloride pipe. Polyinyl chloride was chosen because it is a good electric insulator and is resistant to corrosion by salt water. Moreover, as designed, it will withstand the pressure exerted at a depth of greater than 1,500 feet before collapsing. This strength provides an ample margin of safety — shrimp seldom are fished at depths of greater than 210 feet.

To keep the housing watertight, we used underwater bulkhead connectors in the permanently sealed end; on the end having a removable cover, we used an O-ring seal. Although, during our tests, the output from the pulse generator was transmitted to the electrode array by means of two threaded brass rods, underwater bulkhead connectors may be used instead.

The underwater housing was attached to the inboard door of either the starboard or the port trawl (Figure 7) by two U-bolts (Detail B of Figure 6) inserted through the back side of the trawl door. To minimize water drag, we placed the centerline of the housing 12 inches above the shoe of the door and centered it on the door's vertical centerline.

Because the buoyancy of the housing exceeded the combined weight of the pulse generator and the housing itself, extra weight had to be added to neutralize the upward force. By carefully adjusting the weight of the immersed housing to equal the weight of the water it displaced and by properly positioning the housing on the door, we ensured that the unit would have very little effect on the action of the trawl door — even though its size was fairly large.

d. Electrode array. — The width of the electrode array was important in the operation of the electric shrimp-trawl system. Two factors that influenced the width were the speed of the trawl and the time a shrimp takes to leave its burrow when stimulated electri-

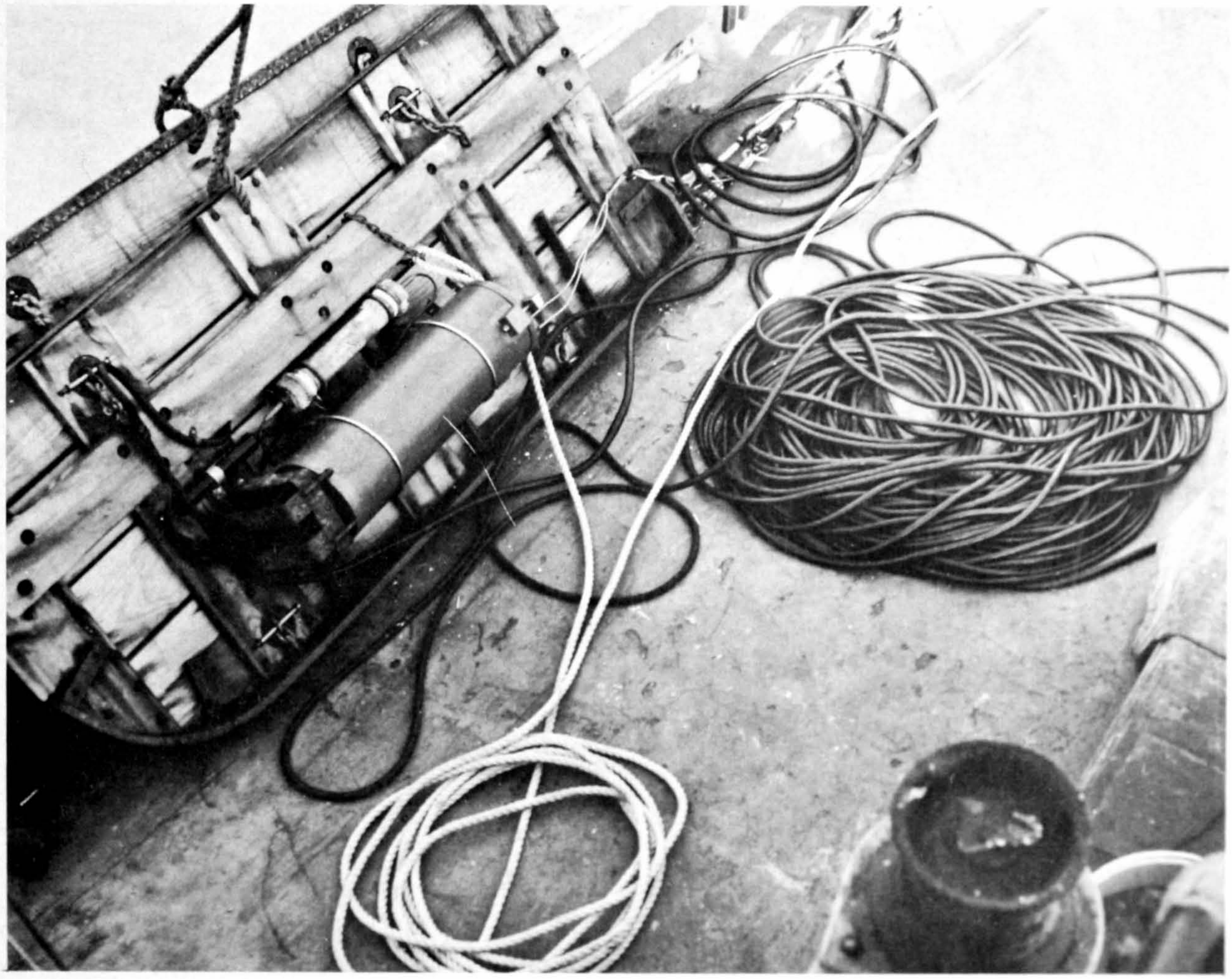


Figure 7.—Underwater housing attached to a trawl door. Also shown in the picture is a coil of the power-supply cable and a metal protector bracket to prevent damage to the underwater connectors on the housing.

cally. During behavior studies, Klima (1968) found that at 3.0 volts and 4 pulses per second, almost 100 percent of the shrimp rose 3 inches above the bottom within 1.9 seconds. A distance of 3 inches from bottom was adequate for our needs, since this is the approximate distance above bottom at which the footrope of a shrimp trawl operates. At an assumed trawl speed of 2.5 knots (or 4 feet per second) the electrode array had to be 8 feet wide to provide a stimulation time of 2 seconds.

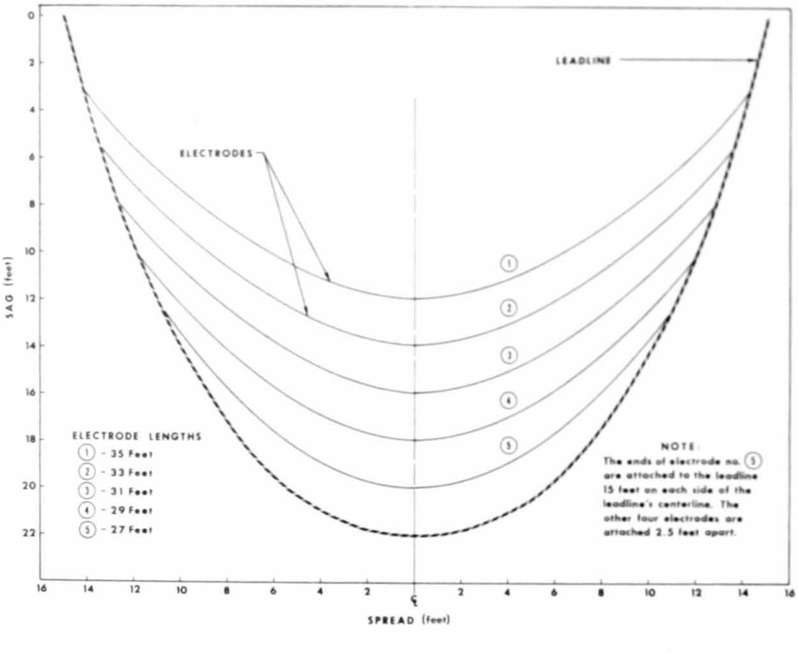
The electrode array for a 40-foot Gulf-of-Mexico flat trawl is shown in Figure 8. Five electrodes 24 inches apart at the center of the array were used to produce an electric field 8 feet wide. The lengths of the electrodes were determined from measurements made on a scale model; they will vary with the size of the trawl and its spread.

Any uninsulated, flexible, conducting cable can be used for the electrode material if it can withstand the constant chafing on the bottom of the ocean. During our simulated field tests, we used a six-stranded cable, $\frac{3}{8}$ inch in diameter. Three strands of the cable were uninsulated copper wire that carried the current, and three strands were insulated steel wire that gave the cable strength. Electrodes Numbers 1, 3, and 5 were negative, and Numbers 2 and 4 were positive. The ends of each were tied to the footrope of the trawl, and a lead wire was aligned along the trawl's footrope from each electrode to the inboard trawl door, where it was attached to the output terminal of the pulse generator.

2. Field Tests and System Modification

Now that our components were chosen and individually tested, the time had come to give the composite electric shrimp trawl a series of preliminary operating tests. The first tests in the series involved visual observations of performance; the later ones involved a large number of simulated fishing trials.

a. Observations of mechanical performance. — Before we field tested the electric shrimp trawl, we needed to check the newly designed electrode array and the underwater generator unit, including the power cable, as elements of a functioning whole to determine whether they would interfere with the operation of a trawl. We inspected the electrode array to make sure that the individual electrodes maintained their proper spacing and did not become entangled, and we checked on how the pulse generator unit affected the operation of the trawl door on which it was mounted.



NOTE: The ends of electrode no. ⑤ are attached to the leadline 15 feet on each side of the leadline's centerline. The other four electrodes are attached 2.5 feet apart.

Figure 8.—Diagram of the electrode array used on a 40-foot Gulf-of Mexico trawl.

We assumed that the best way to determine the degree of interference was to observe the trawl in operation. So we took it to Panama City, Florida, where the waters of the Gulf are clear. Two men on a diving sled made the tests. One diver controlled and maneuvered the sled around the trawl while the second diver observed and photographed it.

Figure 9 shows the position of the electrode array relative to the footrope and headrope of the net. Photographs of the trawl door with the pulse generator unit attached were valueless because silt stirred up by the door obscured the pictures. Owing to this problem, SCUBA divers checked the operation of the door visually. They found that the attitude of the trawl doors differed little from normal; we therefore concluded that the pulse-generator unit and the door were balanced properly.

b. Problems encountered in simulated fishing trials.—After we had evaluated the mechanical performance of the electric shrimp trawl visually, we installed the components of the system aboard the *George M. Bowers* and began simulated fishing trials. During these trials, we made 45 1-hour drags to check the reliability of the system. The aim was to uncover any electrical or mechanical faults in the system that might encumber subsequent fishing trials.

During these simulated trials, three faults were discovered — namely, overheating of

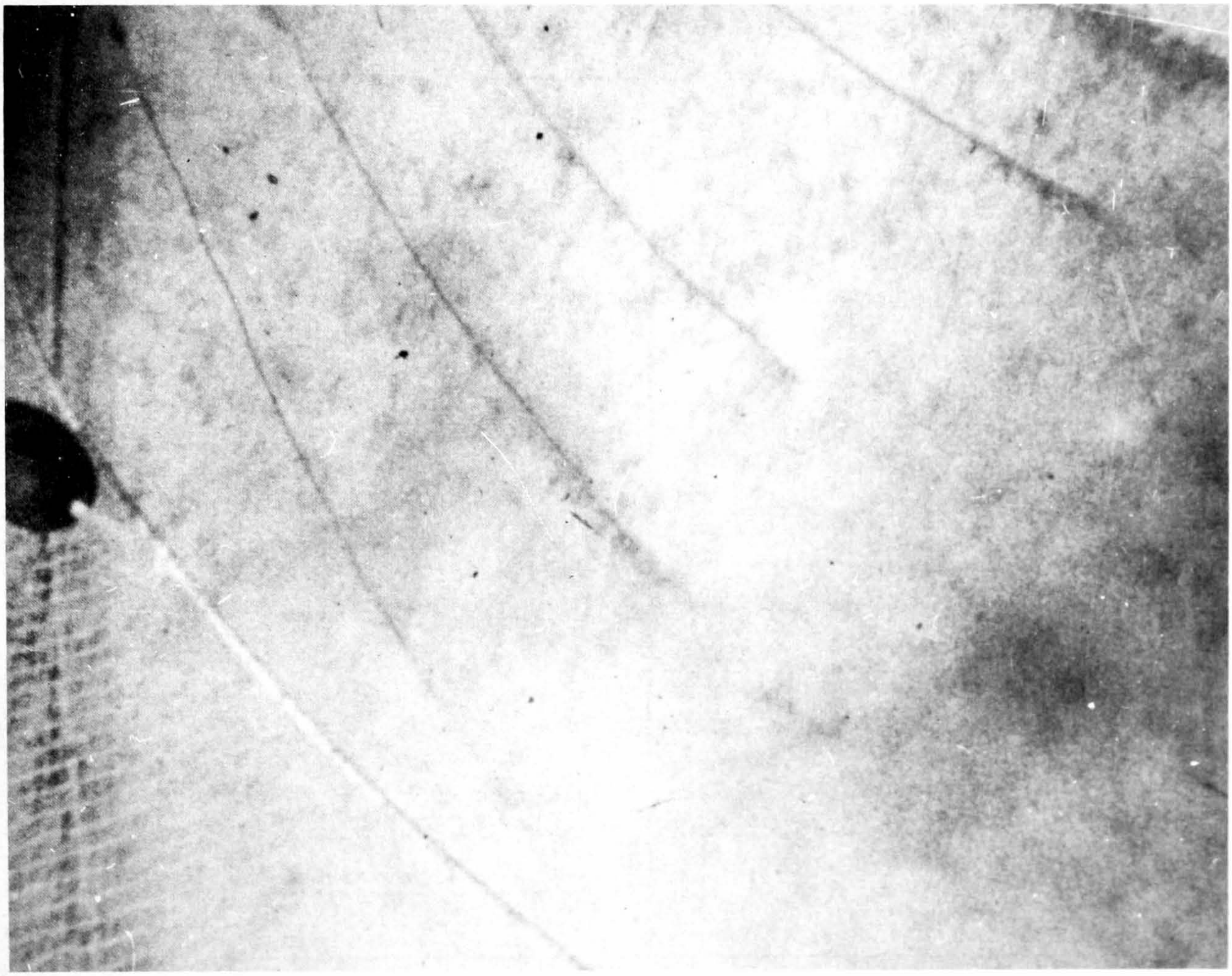


Figure 9.—Underwater view of the electrode array on a trawl. This shot was enlarged from a 16-mm. film frame taken by SCUBA divers from a diving sled while the trawl was being towed.

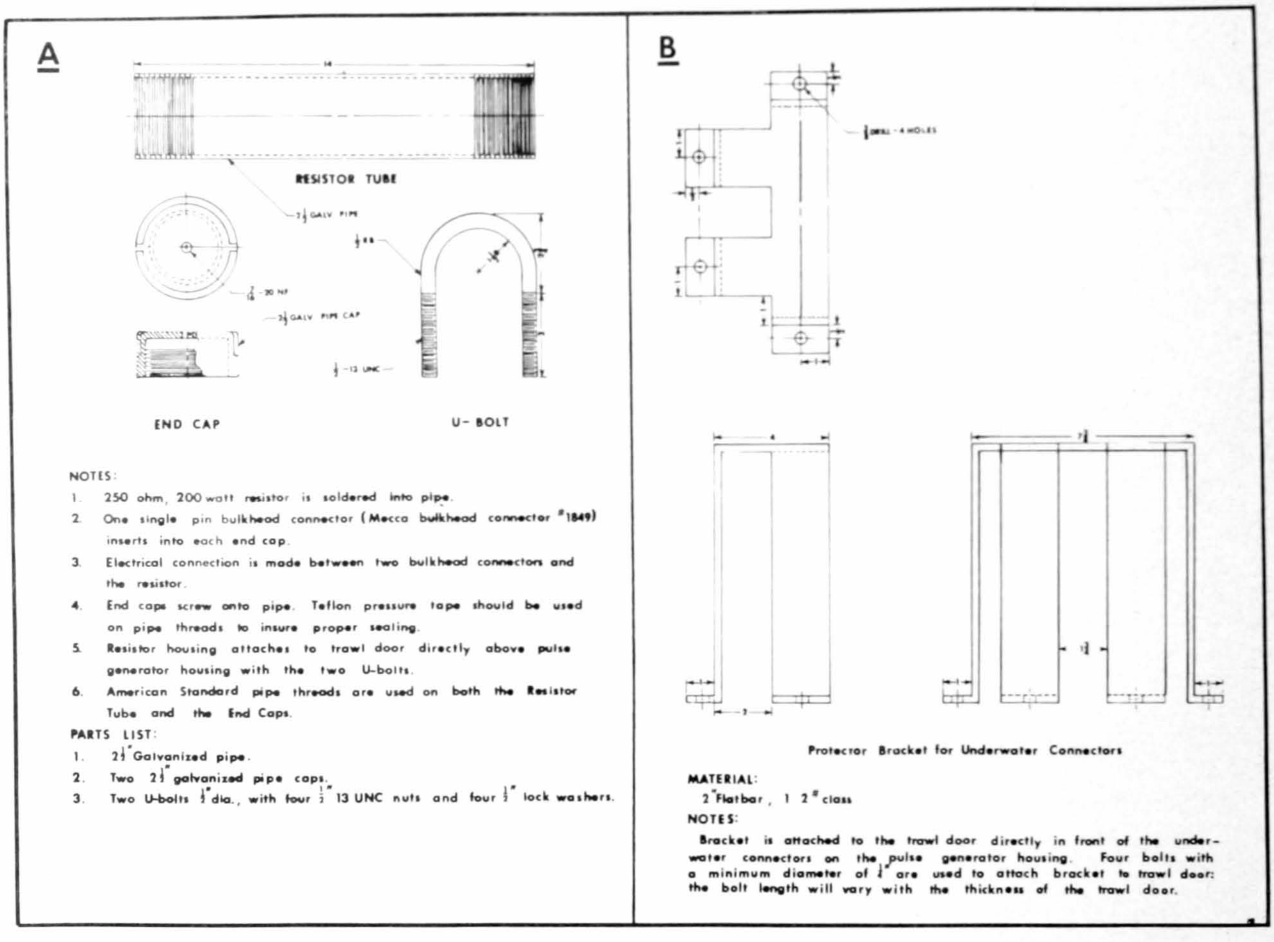
components in the pulse generator and in the oscillator, and breaking off of the underwater connector.

(1) Overheating of components. — Components in the pulse generator and oscillator overheated, causing the pulse generator to malfunction and the oscillator to breakdown.

(a) *In the pulse generator.* — The most serious problem encountered was overheating of the pulse generator components inside the underwater housing. Because of the low thermal conductivity of the polyvinyl chloride covering (1.05 BTU per hour per square foot per degree F. per inch), heat developed by the pulse generator could not dissipate adequately), so the generator overheated and then malfunctioned.

We took two steps to solve the overheating problem: (1) we removed the 250-ohm, 200-watt resistor from the housing and placed it in a separate metal housing (Figure 10A), and (2) we filled the generator housing with oil so the heat would dissipate uniformly. Because the large resistor was the principal source of heat, the second step probably was not necessary, but we took it to ensure as much as possible that the overheating would not occur during the actual fishing trials. After we made these changes, we readjusted weights to make the pulse generator unit again neutrally buoyant.

(b) *In the oscillator.* — A second problem that became apparent during the simulated fishing tests was caused by the turnoff



NOTES:

1. 250 ohm, 200 watt resistor is soldered into pipe.
2. One single pin bulkhead connector (Mecca bulkhead connector #1849) inserts into each end cap.
3. Electrical connection is made between two bulkhead connectors and the resistor.
4. End caps screw onto pipe. Teflon pressure tape should be used on pipe threads to insure proper sealing.
5. Resistor housing attaches to trawl door directly above pulse generator housing with the two U-bolts.
6. American Standard pipe threads are used on both the Resistor Tube and the End Caps.

PARTS LIST:

1. 2½" Galvanized pipe.
2. Two 2½" galvanized pipe caps.
3. Two U-bolts ½" dia., with four ½" 13 UNC nuts and four ½" lock washers.

MATERIAL:

2" Flatbar, 1 2# class

NOTES:

Bracket is attached to the trawl door directly in front of the underwater connectors on the pulse generator housing. Four bolts with a minimum diameter of ¼" are used to attach bracket to trawl door: the bolt length will vary with the thickness of the trawl door.

Figure 10.—A — Housing for the charging resistor of the pulse generator.
B — Metal bracket to protect the underwater connectors on the front of the pulse generator housing.

circut of the pulse generator — after several hours of use, the capacitor in the oscillator circuit would break down. This failure, which was caused by internal overheating of the capacitor, resulted from the use of a resonant frequency slightly higher than required. Because of the time needed to obtain special-order components, a capacitor whose value was slightly smaller than the exact value had been substituted. The result was a time period shorter than optimal.

We also substituted inductors of sizes that would be readily available from commercial sources. We had to use four inductors in parallel to obtain a resistance low enough for the oscillator circuit to operate properly. Each inductor was 10 millihenries and had an internal resistance of 0.325 ohm. When four of them were used in parallel, the resistance became about 0.08 ohm at an inductance of 2.5 millihenries.

The optimal value of the capacitance is determined as follows: The time constant (T) of the main capacitor discharge is found by substituting the resistance of the electrode array in sea water (R = 0.1 ohm) and the value for the discharge capacitors (C = 3,300 microfarads) into the equation $T = RC$. Solving the equation gives a time constant T = 330 microseconds. As previously discussed, the time period (t) for the oscillator circuit must be at least 10 times that of the main pulse constant; then it will be 3,300 microseconds (t = 10 x 330). Since frequency can be expressed by $f = \frac{1}{t}$ and the resonant frequency of an oscillator circuit with negligible resistance by the equation $f_R = \frac{1}{2\pi\sqrt{LC}}$, the correct capacitance of the circuit can be obtained by using a suitable value for the inductance L and solving for the capacitance C.

Solving the resonant equation for C with t = 3,300 microseconds and L = 2.5 millihenries shows that a capacitance of 112 microfarads is necessary to provide the desired time period for the circuit. Nonpolarized capacitors that could be obtained readily were rated at either 100 or 200 microfarads. To avoid a long delay in getting a capacitor on special order, we used the 100-microfarad capacitor. This substitution resulted in some internal overheating, which eventually shortened the life of the capacitor. A nonpolarized capacitor with a value of 125 microfarads would probably eliminate the problem.

(2) Breaking off of the underwater connector. — A third problem discovered during the operation of the system was that the underwater connectors on the housing of the pulse generator were easily damaged. When the trawl was being set, the power-supply cable formed a loop that wrapped around the connectors and either bent them or broke them off. We solved the problem by adding a metal protector bracket in front of the housing (Figure 10B).

II. TESTING THE TRAWL IN ACTUAL FISHING TRIALS

The second main phase of the project was to determine the practicality of the electric shrimp-trawl system. In this phase, the system was tested under actual fishing conditions.

A. PROCEDURE

Two trawls (one electric and one nonelectric) were dragged simultaneously, day and night. The average catch of the nonelectric trawl at night was established as a measure of the quantity of shrimp available to be caught. When the average daytime catch of the electric trawl was compared with the nighttime catch of the nonelectric trawl, the efficiency of the electric trawl could be estimated. This proportion then indicated how much shrimp that could be caught at night with a standard trawl was being caught in the electric trawl during the day.

In this work, the *George M. Bowers* was rigged with two standard 40-foot Gulf-of-Mexico shrimp trawls (Bullis, 1951). The electric trawl was used as the starboard trawl, and the standard nonelectric trawl was used as the port trawl. We tried to make the nonelectric trawl identical with the trawls used by commercial fishermen. The trawls were fished on a straight-line course except when circumstances required the vessel to change course.

Loops of chain were hung across the footrope to keep the electric net within the 3-inch distance from the bottom that had been established, during the earlier behavior and design studies, as the maximum height it should be above the bottom. Each loop was 15 inches long; its ends were attached every 12 inches across the footrope from wing to wing of the net. An equal amount of chain was used on the nonelectric net to keep the operating characteristics of the two trawls similar. Thus, except for the electric system on the starboard trawl, the trawls were rigged identically.

The nets were tested on major shrimp grounds in the Gulf of Mexico. Off Mississippi and Texas, they fished for brown shrimp, and off Southwest Florida, for pink shrimp. To take representative samplings from each shrimp ground during the limited time available for testing required that a series of test drags be made in several small areas within each shrimp ground. In each small area, several 1-hour drags (or stations) were made during daylight; then, beginning immediately after sunset, additional 1-hour drags were made in the same area. This comparison of day catches and night catches was repeated several times on each shrimp ground. Based on a summary of the 24-hour test cycles, ratios of effectiveness were obtained — they indicated how much of the shrimp that would be available to a standard trawl at night was being caught by the electric trawl during the day.

Table 2.—Log of Research Vessel *George M. Bowers* Cruise 66 off coast of Mississippi

Date in 1966	Data on day tests					Data on night tests				
	Station number	Starting time (1-hour drags)	Depth	Catches by: Nonelectric trawl	Catches by: Electric trawl	Station number	Starting time (1-hour drags)	Depth	Catches by: Nonelectric trawl	Catches by: Electric trawl
			Fathoms	*Pounds*	*Pounds*			*Fathoms*	*Pounds*	*Pounds*
August 9	42	0745	3	6.0	17.5	46	1935	3	18.0	13.5
	43	Pulser malfunctioned				47	2045	3	21.5	15.5
	44	1415	3	8.0	16.0	48	2210	3	15.0	7.0
	45	1530	3	6.0	15.0					
August 10	49	1025	3	7.0	15.0					
	50	1140	3	24.0	30.0					
	51	1305	3	31.0	31.0					
	52	Electricity was not turned on								
August 11	53	0940	3	5.0	15.0					
	54	Pulser malfunctioned								
August 30						55	1820	3	14.0	16.0
						56	1930	3	17.0	13.5
						57	2045	3	15.0	15.0
						58	2200	3	21.0	11.0
August 31	59	0930	3	1.5	10.5	63	1900	3	16.0	16.0
	60	1045	3	5.5	19.0					
	61	1630	3	6.0	16.0					
	62	1745	3	10.0	22.0					
September 1	64	1055	3	1.5	12.0	70	1850	3	17.0	13.5
	65	1205	3	3.0	12.0	71	2015	3	8.0	9.0
	66	1330	3	2.0	14.0	72	Fouled lazy line on nonelectric trawl			
	67	1445	3	4.5	19.0					
	68	1615	3	1.0	17.0					
	69	1730	3	8.0	19.0					
September 2	73	0725	3	8.5	18.5					
	74	0840	3	1.0	18.0					
	75	Bag untied								
Total				139.5	336.5				162.5	130.0
Average ...				7.3	17.7				16.3	13.0

B. FINDINGS

1. Data

The results appeared to be related closely to the type of bottom, for the results differed markedly, depending upon whether the fishing was done on the predominantly mud bottom off Mississippi and Texas or on the predominantly calcareous-sand bottom off Southwest Florida.

a. Catch from mud substratum off Mississippi and Texas.

(1) Catch off Mississippi. — Table 2 lists catches made at stations off the coast of Mississippi during tests of the electric shrimp trawl. (All weights of shrimp given in this paper are those of shrimp with heads on.) With the nighttime catch of the nonelectric trawl (16.3 pounds per hour) representing 100 percent of trawl efficiency, the daytime catch of the electric trawl (17.7 pounds per hour) produced an effectiveness ratio of 109 percent.

The pulse generator failed twice during the tests. These failures were caused by a breakdown of the capacitor in the oscillator, a type of failure that was discussed previously. We had expected this failure to occur periodically but had decided that replacing the capacitor was cheaper and more expedient in the prototype trawl than requiring a specially made capacitor to be used during experimental developments.

(2) Catch off Texas. — Off the coast of Texas, the daytime catch of the electric shrimp trawl was 15.4 pounds per hour, and the nighttime catch of the nonelectric trawl was 16.2 pounds per hour (Table 3). The efficiency of the electric trawl thus was 95 percent in the Texas Area.

Table 3.—Log of Research Vessel *George M. Bowers* Cruise 67 off coast of Texas

Date in 1966	Data on day tests					Data on night tests				
	Station number	Starting time (1-hour drags)	Depth	Catches by:		Station number	Starting time (1-hour drags)	Depth	Catches by:	
				Nonelectric trawl	Electric trawl				Nonelectric trawl	Electric trawl
			Fathoms	*Pounds*	*Pounds*			*Fathoms*	*Pounds*	*Pounds*
September 22	1	1110	14	0.5	18.5	5	1905	14	19.0	16.5
	2	1225	14	1.0	17.0	6	2020	14	13.0	9.0
	3	1340	14	2.0	18.5	7	2135	14	5.0	9.0
	4	1450	14	1.0	20.0					
September 23	8	0855	14	0.0	10.5	13	1935	16	20.0	7.5
	9	1020	13	0.0	10.5	14	2055	17	23.0	12.0
	10	1150	14	0.0	8.5	15	2210	17	20.0	9.0
	11	1305	15	0.0	17.0					
	12	1420	15	0.0	18.0					
September 24	16	Pulser malfunctioned				20	1840	17	30.0	17.5
	17	1115	17	1.0	22.5	21	2015	18	17.0	10.0
	18	1235	17	0.0	16.0	22	2130	18	22.0	15.0
	19	1350	17	0.5	17.5					
September 25	23	1415	18	1.0	16.0	26	1755	18	12.0	12.0
	24	1525	18	0.0	13.5	27	1910	19	13.0	5.5
	25	1640	18	1.0	16.0	28	2030	20	12.5	6.5
						29	2150	20	22.0	10.0
						30	2300	19	23.0	10.0
September 26	Went into port					31	1845	14	16.0	7.0
						32	2010	15	15.0	10.0
						33	2125	16	13.0	9.0
September 27	34	0945	16	0.5	16.0					
	35	1100	17	1.0	16.5					
	36	Shorted deck plug								
	37	No electricity applied								
September 28	41	0615	13	0.0	4.5	38	0230	14	11.5	7.0
						39	0345	14	10.0	8.5
						40	0500	14	7.0	7.0
Total				9.5	277.0				324.0	198.0
Average ...				0.5	15.4				16.2	9.9

The pulse generator failed once; again the failure was caused by the capacitor's breaking down. One other failure in the system occurred when water entered the electrical connector on the winch while the deck of the vessel was being washed and caused the circuit to short.

b. Catch from calcareous sand - shell substratum off Southwest Florida.—Table 4 lists the results of fishing trials around the Dry Tortugas Area in Southwest Florida. Here the daytime electric trawl caught 18.9 pounds per hour, whereas the nighttime nonelectric trawl caught 37.7 pounds per hour. The efficiency of the electric trawl thus was 50 percent in the Southwest Florida Area.

During this series of tests, data taking was hampered by two different types of failure. One type was caused by the breakdown of another capacitor, resulting in two stations not being fished at all. This failure was presaged when the pulse generator began to operate erratically at Station 16; it finally failed at Station 17. The other type was caused by an

Table 4.—Log of Research Vessel *George M. Bowers* Cruise 69 off South Florida (Tortugas)

Date in 1966	Data on day tests					Data on night tests				
	Station number	Starting time (1-hour drags)	Depth	Catches by: Nonelectric trawl	Catches by: Electric trawl	Station number	Starting time (1-hour drags)	Depth	Catches by: Nonelectric trawl	Catches by: Electric trawl
			Fathoms	*Pounds*	*Pounds*			*Fathoms*	*Pounds*	*Pounds*
October 23	1	1230	18	0.0	9.5	5	1745	18	44.0	25.0
	2	1345	18	0.0	46.0	6	1900	18	100.0	47.0
	3	1500	18	0.0	31.0	7	2015	18	41.0	45.0
	4	1625	18	2.5	20.0					
October 24	8	1005	18	0.0	10.0	12	1740	20	37.0	17.0
	9	1120	18	0.0	25.0	13	Bag untied on nonelectric trawl			
	10	1235	19	0.5	30.0	14	2010	20	14.0	16.5
	11	1345	20	0.5	41.0	15	2125	21	42.0	35.0
October 25	16	Pulser malfunctioned				20	1740	20	28.0	23.0
	17	Pulser malfunctioned				21	1855	20	21.0	14.0
	18	1310	20	0.0	13.0	22	2010	20	17.0	12.5
	19	1425	20	1.0	17.0	23	2125	20	22.0	23.0
October 26	24	1000	20	0.0	9.0	30	1815	17	15.5	12.0
	25	1135	21	0.5	12.0	31	1930	17	39.0	37.0
	26	1250	21	0.5	11.0					
	27	1425	18	0.0	16.0					
	28	1540	17	0.0	7.0					
	29	1700	17	7.0	15.0					
	Discontinued work for 5 days because of bad weather									
November 1	32	0945	14	0.0	3.0	38	1750	16	41.0	33.0
	33	1100	15	0.0	10.0	39	1905	16	44.0	24.0
	34	Broken electrodes				40	2020	16	26.0	27.0
	35	1405	15	0.0	10.0	41	2135	16	27.0	23.0
	36	1520	15	0.0	12.0					
	37	1635	16	10.5	23.5					
	Discontinued work for 7 days because of bad weather									
November 8	42	Electrodes broken, huge catch of sponge - nets torn				44	1645	18	39.0	41.0
	43	1530	18	1.0	26.5	45	1800	19	44.0	24.0
						46	1915	19	69.0	28.0
						47	2030	18	47.0	38.0
November 9	48	Catch lost because of jellyfish				56	1720	18	57.0	*32.0
	49	0810	18	0.0	*10.0	57	1835	18	28.0	*18.5
	50	0925	18	0.0	*17.0	58	1950	18	24.0	*14.0
	51	1045	18	0.0	38.0					
	52	1200	18	0.0	28.0					
	53	1315	18	0.0	21.5					
	54	1430	18	0.0	15.0					
	55	1550	18	0.5	21.5					
Total				24.5	548.5				866.5	609.5
Average ...				0.8	18.9				37.7	26.5

* Jellyfish very numerous.

agency extraneous to the system. For the first time during fishing trials with the electric shrimp-trawl system, electrodes broke — four at Station 34 and five at Station 42. In both instances, the damage was caused by loggerhead sponges. During the 1-hour drag at Station 42, several thousand pounds of sponges fouled both trawls and extensively damaged both the nets and the electrodes.

2. Discussion

The low daytime catches of the nonelectric trawl relative to the catches by the electric trawl show that the shrimp had been burrowed. The higher daytime catch by the nonelectric trawl in the Mississippi Area than in the areas off Texas and Florida may be attributed to large catches at Stations 50 and 51 after wind and rain had produced turbid water.

The nighttime catch of the electric trawl was consistently less than that of the nonelectric trawl at night. The explanation may be as follows: During the daytime, when the shrimp are burrowed, most of the 2-second stimulation time passes while the shrimp are being forced from the substratum. The remainder of the 2 seconds passes while the shrimp are rising the desired 3 inches minimum height. At night, on the other hand, when the shrimp are already moving about above the bottom, some of them may use the 2-second interval to avoid the trawl. On the assumption that they react in a random manner to the electric stimulation, some of those near the wings of the net or the footrope could move in a direction that would allow them to escape capture.

Off the coast of Mississippi, the daytime catch by the electric trawl slightly exceeded the nighttime catch by the nonelectric trawl; whereas off the coast of Texas, the nighttime catch of the nonelectric trawl slightly exceeded the daytime catch by the electric trawl. On the Dry Tortugas shrimp ground, the daytime catch of the electric trawl was only 50 percent of the nighttime catch of the nonelectric trawl.

The low catches from the Dry Tortugas shrimp grounds may have been due to the substratum. Klima (1968) demonstrated that electrically stimulated shrimp emerge faster and rise higher from a mud substratum than from any other type of bottom. The mud substratum is common to shrimp grounds of the Northern Gulf, where the highest rates of catch were obtained with the electric trawl. In contrast, the substratum of the Dry Tortugas shrimp grounds is primarily calcareous sand-shell. Although the bottom was not studied thoroughly, the adhesion-compactness characteristics of the Dry Tortugas bottom may have slowed the shrimp's reaction time and thereby reduced the rate of catch.

Field personnel noted that the best daytime catches of shrimp on the Dry Tortugas shrimp ground were made when the electric trawl was towed against the current of water. On these particular drags, the trawl moved more slowly over the bottom than usual and stimulated the shrimp for a longer time. This observation strengthens our theory that the substrate of the Dry Tortugas shrimp ground slows the reaction time of the shrimp.

The low rate of catch on the Dry Tortugas shrimp ground would make the practicality of daytime fishing questionable. The electric trawl can probably be used profitably only when shrimp are abundant. If further study proves that the Dry Tortugas substrate actually does slow the shrimp's reaction time, the addition of one or two more electrodes to extend the electric field in front of the trawl would increase the rate of catch. In any event, a minimum potential drop of 3 volts must be maintained across 4 inches throughout the enlarged field.

The catch rate of the electric trawl in the Northern Gulf established that the system is effective in harvesting shrimp during daylight. If one net can take 17.7 pounds per hour and 15.4 pounds per hour, then two nets fishing 12 daylight hours should take 425 and 370 pounds of shrimp, respectively. Important is the fact that the electric trawl caught about the same amount of the shrimp during daylight that a standard trawl could catch at night. In the Northern Gulf, day shrimping thus is potentially as profitable as night shrimping.

SUMMARY

Because brown and pink shrimps burrow in the substratum during the day, they are fished commercially at night, when they emerge. Since this condition limited shrimp production, we, in the Bureau, studied the feasibility of forcing the shrimp out of their burrows with an electric stimulus to extend commercial shrimp fishing to a 24-hour day. On the basis of the study, we developed and tested a prototype electric trawl that could be used to catch shrimp during the day. The purpose of this article is to report on that prototype.

Klima (1968) had found that to force shrimp out of their burrows requires four or five pulses per second of electricity having a 3-volt gradient across 4 inches of sea water. When we were designing the trawl, our two major problems were to develop a pulse generator that would produce an electric field with the characteristics dictated by the findings of Klima, and to adapt the electric stimulating system to a commercial shrimp trawl. The electric field was produced by five 25-foot long electrodes in an 8-foot wide array so designed that it would not interfere with the operation of a 40-foot flat trawl moving at 2.5 knots.

A p-n-p-n semiconductor switch was chosen to control the power-discharge pulses of the pulse generator. The switch is turned on by means of a standard unijunction transistor trigger circuit; it is turned off by means of an oscillation circuit.

In initial engineering tests, we encountered a number of minor problems caused primarily by overheating of components in the polyvinyl chloride-housed pulse generator. Removing a 200-watt resistor and placing it in a metal housing separate from the generator largely solved the difficulty. Other adjustments required were minor.

The three principal shrimp-producing areas in the Gulf of Mexico were sampled during fishing trials with the prototype electric shrimp trawl. In the northern part of the Gulf, off the coasts of Mississippi and Texas, the daytime catches of the electric shrimp trawl were 109 and 95 percent of the nighttime catches by the nonelectric trawl. In the area around the Dry Tortugas off Southwest Florida, they were only 50 percent.

Although the rate of catch on the Dry Tortugas shrimp ground would not always be profitable with the system we tested, the increased rate of catch on the large shrimp-producing area of the Northern Gulf of Mexico would be acceptable commercially.

ACKNOWLEDGMENTS

Edward F. Klima conducted an electrical shrimp behavior study that established the proper field strength and pulse rate required to produce optimum shrimp response. William DeGrove designed the first pulse generator for the electric shrimp-trawl system. Frank Hightower, Jr., aided in the construction, testing, and subsequent fishing trials with the system.

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MS #1810

CARE OF FISH HOLDS

by

Wayne I. Tretsven

ABSTRACT

The stowage of iced fish in the hold of a fishing vessel causes the hold to become wet and dirty, which in turn may cause deterioration of the vessel as well as spoilage of the fish handled thereafter.

This problem was studied, and procedures for solving it were developed and used effectively on commercial vessels. The procedures involve: (1) use of better methods of cleaning and sanitizing the hold, (2) use of a solubilized, copper-8-quinolinolate to preserve the wood in wooden holds, and (3) application of plastic sheeting, 6-mils (.006-inch) thick, to line the hold in order to prevent it from becoming wet and dirty and to prevent the fish from contacting it.

CONTENTS

INTRODUCTION

Holds in fishing vessels have long been a problem to those who build the vessels, to those who own them, and to those who work in them. Holds are usually the cause of unnecessary spoilage of fish. They are difficult or impossible to clean, and they require much care and maintenance. The purpose of this report is to suggest techniques for taking care of holds. Three main topics are discussed: (I) cleaning and maintaining fish holds, (II) using wood preservatives in wooden holds, and (III) lining the holds or pens with plastic sheeting.

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I. CLEANING AND MAINTAINING FISH HOLDS

Fish slime, blood, and excreta can make holds excellent places for the growth of spoilage bacteria. Unless these materials are removed, the bacteria contaminate the incoming ice and fish — hence the fisherman's often-repeated statement: "Bilgy holds produce bilgy fish."

Fish in direct contact with wooden surfaces in the hold usually spoil quickly, undergoing an anaerobic type of spoilage — that is, spoilage without free oxygen, and take on a bilgy or sour flavor and odor.

Numerous procedures have been used to solve the problem of cleaning a hold and maintaining it. Some of these procedures involve cleaning and sanitizing the hold after it has become contaminated; others involve the prevention of contamination by use of protective coverings and preservatives (Linda and Slavin, 1960). Examples of the former are scrubbing, steam cleaning, and rinsing after the hold has been unloaded, including the use of detergents and bactericides. Examples of the latter are (1) the application of coatings such as paint, (2) the application of coverings and screens of metal or plastic, and (3) the application of so-called preservatives, such as diesel oil. Some of the methods commonly used are effective; others may do more harm than good.

Ordinarily, the hold is washed to remove dirt and decaying matter. It then may be sanitized through an operation in which the remaining bacteria are destroyed. This procedure is good, provided that all of the dirt is removed. Unfortunately, all of it seldom is removed, because holds ordinarily are not constructed in such a way as to facilitate adequate cleaning. Adequate cleaning of holds constructed of wood is almost impossible, because moist debris becomes lodged in corners and gouged areas, where it cannot be removed. In many wooden holds, debris passes between wooden parts of the ship's structure, where it hastens the decomposition of the wood as it decays. Steel holds, because of improper construction, usually cannot be cleaned adequately. For easy cleaning, the holds should have smooth surfaces and rounded corners.

Paint has been used to coat wood in the hold. Although painting has been advocated for many years, its value has been questioned. As one halibut skipper stated: "It does not pay, because the wood gets soft and sour under the paint."

Undoubtedly, the ineffectiveness of paint is the reason that so many holds are no longer painted in the North Pacific fleet. Damage to the coating occurs, owing to piercing, cuts, blows, and abrasion. This damage permits moisture and filth to enter, often resulting in blisters and foul-smelling (anaerobic) accumulations under the coating. This condition may be worse than that in uncoated wood. Canadian studies (Fisheries Research Board of Canada, 1958-1959) on the use of paints and various coatings on wood in fish holds revealed that: "None of the surface coatings prevented the underlying wood from gaining moisture while in service."

In this section of the report, we consider (A) general cleaning practices, (B) additional treatments, and (C) improved facilities.

A. GENERAL CLEANING PRACTICES

Immediately after the fish are removed from the hold and before the surfaces of the hold become dry, cold water (either fresh water or clean sea water, but not contaminated harbor water) is applied at high velocity to loosen and flush down as much soil as possible. The application of water is stopped when the water in the bilge is clean and free from murky materials.

After the hold has been flushed with cold water and before any surfaces dry, a concentrated detergent solution (as much as 10 times as concentrated as will provide good cleaning at a low concentration) is applied either by means of a pressure sprayer or directly from a bucket by means of a brush. The detergent used may be any one of the numerous general-purpose detergents available, provided that it is especially suited for removing material of a proteinaceous nature. The most common ones consist of a mixture of various alkaline phosphates and a wetting agent. Synthetic, household, laundry-type detergents obtainable from a grocery store are often effective. Organic acid-type cleaners are also proving to be effective. The detergents are most effective when used with warm water, but they can be used with cold water.

All of the exposed surfaces are scrubbed with a stiff brush. After the surfaces have been cleaned, cold water is applied as before until the water in the bilge again becomes clear.

Steam cleaning — that is, directing live steam at the surface to be cleaned — is a poor method of cleaning a wooden hold. If heat for cleaning is desired, better results are obtained by the use of hot water. Use of high temperatures in cleaning may cause the wood to take up more water, may cause fatty materials present to spread readily and penetrate deeply into the wood, and may cause proteins to be precipitated within the wood, making the job of cleaning even more difficult.

B. ADDITIONAL TREATMENTS

Sanitizing treatments may be used advantageously after the hold has been cleaned. The following three treatments are helpful:

1. A hypochlorite solution (about 500 to 1,000 parts per million available chlorine) is effective when sprayed on all of the surfaces of the hold after it is cleaned and again, just before ice is taken, if a day or two elapses between the cleaning of the hold and the loading of the ice. This sanitizing treatment also improves the odor of the hold.
2. Spraying the surfaces of the hold with a quaternary ammonium compound is also effective. It remains in and on the surface of the wood and controls the growth of bacteria and fungi. It should not be applied before or with a chlorine sanitizer, because the chlorine will destroy it.
3. Granulated salt may be sprinkled on all wet surfaces. It minimizes the development of fungus while the hold is not in use.

C. IMPROVED FACILITIES

Improvements are being made in equipment, detergents, and procedures for cleaning the hold. Both stationary and portable equipment have been developed for heating and applying the detergents at high velocities to the surfaces. Chlorinated and iodinated-type detergents are available that react chemically with proteins, causing an effervescence of carbon dioxide that actually lifts the soil from the surface.

II. USING WOOD PRESERVATIVES IN WOODEN FISH HOLDS

The hold is a vital structural part of the vessel, and its maintenance and preservation are essential to both the integrity of the vessel and the quality of the catch.

The wooden hold is especially susceptible to decomposition, because of the wet conditions. Various coatings — such as paint, epoxy and phenolic resins, and varnishes — have been applied to the surface of the wood to protect it and keep it dry. None of the coatings, however, prevent moisture from being absorbed. Use of wood preservatives in treating the wood is effective, because the preservatives contain fungicides that control the cause of rot. However, their use in fish holds has limitations. They must not cause the fish to become toxic or cause the flavor of the fish to change, and they should be effective for a long time.

A fungicide, copper-8-quinolinolate was suggested to the Bureau of Commercial Fisheries by Scheffer (1962)[1] for use in preserving wooden fish holds.

Copper-8-quinolinolate is a potent fungicide, and its mammalian toxicity is low. Suit-

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[1] Personal communications — letter, dated September 25, 1962, from T. C. Scheffer, *Pathologist*, U. S. Forest Products Laboratory, Madison, Wisconsin 53706.

ably used, it has been approved by the Food and Drug Administration for treating materials such as cloth, paint, and wood that may come in contact with foods. Because it is chemically stable and relatively insoluble in water, acids, and alkali, it was applied to wood in the hold in a formulation incorporating water repellents.[2] These features make it an effective preservative for long periods of time, even after continued leaching by melting ice and repeated washing of the hold. Fishermen report that it makes the wood easier to clean.

In a study of the use of this product, we found that it was easily and efficiently applied to the wood in the hold and to the wood between the planking and skin in dry vessels. A nozzle at the end of a long hose was introduced through holes made at the top of the skin and was inserted down between each rib. The solution of wood preservative was applied to all of the surfaces. Any of the preservative draining into the bilge was recirculated until it disappeared (owing to penetration and evaporation). During application, precautions were taken against fire, because the solvent in which the preservative is dissolved is inflammable.

Diesel oil has been applied to fish holds as a wood preservative. Its use in material in contact with fish is questionable as is also its effectiveness as a wood preservative. Scheffer stated, "We believe that diesel oil has relatively slight or negligible bacteriocidal or fungicidal properties. We would expect diesel oil to be wholly ineffective as a preservative for protecting wood in most service situations involving decay hazard."

III. LINING HOLDS OR PENS WITH PLASTIC SHEETING

Disposable plastic sheeting was used successfully to prevent fish holds from becoming wet and dirty and to protect the fish from becoming contaminated.

In this section of the report, we consider (A) our experimental use of plastic, (B) the plastic sheeting used in holds of commercial vessels, and (C) our recommendations for use of plastic sheeting.

A. EXPERIMENTAL USE OF PLASTIC

In an earlier study of ways to protect halibut from possible contamination by foreign material, we used plastic sheeting as a barrier between the hold and the fish. In an experiment to test several variables, a single layer of 4-mil polyethylene sheeting was used to line pens, the surfaces of which had been: (1) cleaned and sanitized and (2) treated with diesel oil. After 10 days of storage, iced fish that had been separated from the surfaces by the sheeting were found to be good, whereas those in direct contact with the wooden surfaces had become bilgy and tasted of diesel oil when cooked. The plastic sheeting kept the surfaces of the wood dry and free from slime.

B. SHEETING USED IN HOLDS OF COMMERCIAL VESSELS

Use of the plastic sheeting to accomplish similar results in fishing vessels was discussed with skippers of commercial vessels. Many expressed interest, primarily because plastic sheeting could reduce the problem of cleaning and of maintaining a clean and dry hold.

Skippers who used the plastic sheeting to line the hold reported that it did keep the hold clean and dry. Some stated that, at first, they washed the dirty plastic for reuse but that they discontinued this practice, because the cost of replacing it with new plastic was not high. Lining the hold in a salmon troller, for example, cost less than $1.00, and lining the hold in a halibut schooner holding 80,000 pounds of iced halibut cost about $10.00.

Fishermen found that the sheeting was easy to apply and to remove (Figure 1), that fish close to refrigeration coils were easier to remove when frozen, and that the messy part

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[2] A solubilized concentration of copper-8-quinolinolate and water repellents (U. S. Patents No. 2,561,379 and 2,561,380) known as "Cumilate" was used in 2 volumes of industrial white spirits having a flash point of 103° F. (Use of this trade name is merely to facilitate descriptions; no endorsement is implied.)

Figure 1.—Removal of disposable plastic sheeting. The surfaces behind the sheeting are clean and dry.

of cleaning the hold was largely eliminated. Some said that the fish kept better, and one fisherman stated that it protected his salmon from lubricating oil and fuel.

Difficulties were usually encountered, however, the first time that plastic sheeting was used in a hold. These difficulties were due to using sheets of improper size, to encountering problems in fastening the sheeting, and to unnecessary piercing and tearing of the plastic on sharp objects. The sharp objects consequently had to be removed.

C. RECOMMENDATIONS FOR USE OF PLASTIC SHEETING

1. Determine the size of plastic sheeting required for each pen. Use a single whole sheet to cover the entire area.
2. Use polyethylene sheeting of 6-mil thickness or thicker. (Several brands of polyethylene sheeting are available in widths up to 32 feet and in lengths of any size.)
3. Fasten the sheeting to the dry hold before taking on ice (Figure 2).
4. In fastening the sheeting at the top of the sides and back of the pen, use tacked or stapled lath or clips attached along the top of the pens (Figure 3). Drape the hanging sheet so that it covers both sides and back of the pen, including any refrigeration coils, and extends down along the back and into the alley. Fold the sheeting to fit contours.
5. While cleaning the alley and any dirty parts of the hold, leave the sheeting in place to prevent the surface behind the sheeting from becoming wet and dirty.

6. Use sanitary-type metal pen boards that are designed to permit drainage of melt-water through or between them at the front of each pen. (A number of ½-inch holes in each pen board allows for drainage, and the holes are convenient when hooks must be used to remove the pen boards.)

Figure 2.—Lining a dry pen in the hold of a halibut vessel before ice is taken on.

SUMMARY

Cleaning and maintaining fish holds present problems. Accordingly, this article suggests methods of cleaning and sanitizing the hold. For the treatment of the wood in the hold, it recommends an approved fungicide having a low toxicity to man. It also describes an effective method for applying a preservative to wooden holds . Finally, it reports that polyethylene sheeting used between the fish and the hold is effective in preventing undesirable changes that occur in fish when they are stored in contact with wood — in short, that the use of the polyethylene sheeting to line the hold, or the pens in the hold, is a practical method for keeping the fish and ice from contact with the hold and for keeping the hold clean and dry.

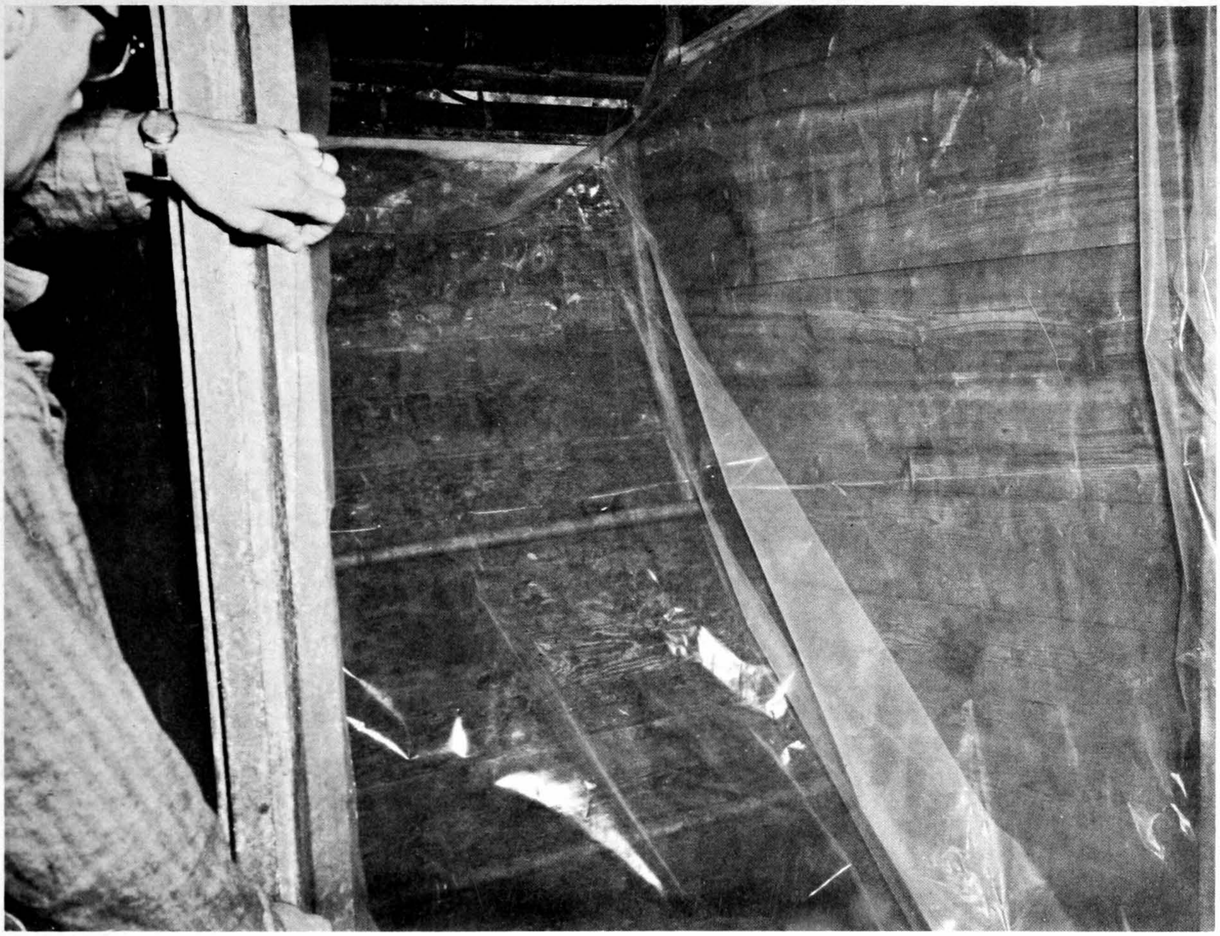

Figure 3.—Single sheet of disposable polyethylene film attached at the top by tacked lath and draped to prevent the iced fish from contacting the pen surfaces.

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MS #1848

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SUGGESTIONS TO AUTHORS WRITING FOR FISHERY INDUSTRIAL RESEARCH

by F. Bruce Sanford, Lena Baldwin, and Mary S. Fukuyama

A. APPROACH

Write your paper for a reader who has had advanced scientific training. Organize and write it in such a way that he can read it rapidly, yet understand it the first time through.

B. COMPONENTS OF THE PAPER

1. Title

Select a title that reveals the overall purpose of your research. When appropriate, include scientific names of species.

2. Abstract

Make the abstract semidescriptive: tell what the report is about, and end with a statement of your overall conclusion. (This conclusion will answer the question stated, or implied, by your overall purpose.) Keep the abstract short, but do not use the title of the paper as the assumed antecedent of otherwise irreferable pronouns.

3. Contents

Include a table of contents.

4. Introduction

In the introduction, (1) orient the reader to your overall purpose, (2) state the purpose explicitly, (3) orient the reader to the subpurposes, and (4) end with a listing of the subpurposes.

Include in each orienting discussion all the important words that will occur in the subsequent statement of purpose. Avoid unnecessary reviews and economic data.

When stating the overall purpose, include a word such as "purpose" so that the reader can quickly identify the statement for what it is.

5. Main Divisions

Do not use such generalized divisions as "Experimental." Instead, be specific by making the main divisions of the paper correspond to the main divisions of your research—Experiment I, Experiment II, and so on. Give each experiment a specific title so that the reader will gain immediate insight into the scope of the experiment.

For main divisions, do not use "Materials," "Procedures," and "Results" (except when, as is rare, your paper reports only a single unit of research, such as Experiment I); instead, use these headings for minor divisions. When you use them, consider the following suggestions:

a. Materials and methods.—Describe in detail the materials and the methods used in your first experiment. If the materials and methods used in succeeding experiments are similar to those in the first, merely describe the differences when you report the succeeding experiments.

If a method includes several closely consecutive steps, number them and write out the steps; use the active voice—for example, "In the separation of acids from the aqueous phase, the analyst:

1. Neutralized a 1-milliliter portion of the aqueous layer to a pH of 10 with 0.1 N NaOH.
2. Transferred the neutralized solution to Flask A.
3. Placed Flask A in a bath . . . ."

b. Results.—Report all numerical data in tables and graphs—avoid cluttering the text with numbers. In the discussion of results, do not repeat the data that are contained in the tables and graphs. Instead, analyze the data by pointing out significances and implications. Use summary tables; do not overwhelm the reader with unnecessary tables of raw data.

6. Conclusions

Draw conclusions from your results. Make sure that the overall conclusion and the subconclusions correspond with your overall purpose and subpurposes. Present the conclusions in logical sequence.

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End the report with a summary. Make the summary quantitative, not merely descriptive. If the report is short, end it with "Summary and Conclusions." If it is long, separate the two.

8. Acknowledgment

Avoid titles of individuals—such as mister, doctor, or professor. Simply acknowledge the assistance received.

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Make your citations complete and accurate so the reader can find the original with ease. Follow the format used in *Fishery Industrial Research.*

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1. Abbreviations

Avoid abbreviations unless you have compelling reason to use them—for example, if you lack space in your tables. If you use abbreviations, use the ones standard in your discipline. End the abbreviation with a period. See the latest issue of *Fishery Industrial Research.*

2. English Usage, Punctuation, and Capitalization

Meticulously follow established practice in grammar, punctuation, and capitalization. For precise, forceful statements, use personal pronouns where appropriate and thereby avoid illogical constructions or ambiguities.

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Use the system of headings shown in the latest edition of *Fishery Industrial Research.*

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Use Arabic numbers unless you have a compelling reason to use Roman numbers or to write the numbers out. See the latest issue of *Fishery Industrial Research.*

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