two-thirds of the menhaden fleet has converted to a new and more efficient fishing procedure it is suggested that they not rest, but continue to experiment with such things as improved pursing techniques, including the use of wire purse line for the purpose of reducing purse line expense and simplifying the pursing operation. The fishermen should seek further rearrangement of the purse boats into a more efficient fishing vessel, modification of the hull lines of the purse boats to allow better use of net protection in the stern, and continued experimentation in a thorough and systematic manner of widely different fishing systems, including the use of small catcher boats. The development should lead to each working a net by itself, together with carry-away steamers, and larger self-sufficient seine boats similar to those used on the west coast, but designed specifically for catching menhaden.

It has been gratifying to see the results of a complete modernization of a historic method. Whether we realize the fact or not, progressive work of this type is being done in fisheries throughout the world, and in many cases the underdeveloped areas are producing fish with cheaper labor at less man hours per ton than we are in this country. We must devote every effort toward mechanization if we are to maintain and improve our present position in world fisheries.

The Use of Electricity in Commercial Fishing in the Sea

CONRADIN O. KREUTZER
Smith Research and Development Company, Inc.
Lewes, Delaware

THE USE OF ELECTRICITY for the purpose of fishing goes as far back as the beginning of the century. The oldest literature about electric fishing with direct current known to me was written in 1908. Since that time the application of this fishing method has increased steadily, especially in middle European countries.

At the same time fresh water fishing with electricity was introduced, physiologists started to examine the specific reactions of fish under the influence of electric fields. Depending on the voltage to which the fish is exposed, three different reactions can be observed. At a certain minimum voltage in the water, the fish shows a jerking of the whole body and will escape from the electric field. If the voltage necessary for the escape reaction is doubled, the fish will not swim out of the field, but in the direction of the current field lines toward the positive electrode. If the voltage is increased again by the same amount, the fish will stop all swimming movements, turn over on one side and go into a state of narcosis. If the current is disconnected soon the fish immediately recovers from the narcosis, without suffering any damage.

The threshold values of the necessary potentials for each of these reactions is found to be constant for fish of the same species, independent of the length of the particular fish. If the chosen voltage in the water is just enough to reach the reaction when fish of a certain desired length will swim toward the positive electrode, smaller fish will have a potential across their body which will only be enough for an escape reaction. This fact makes it possible to select certain sized fish.

In salt water we find the same three reactions of electricity on fish as in fresh water. Nevertheless, electric catching methods could not be introduced on a large scale in either the salt water fisheries, or in fresh water fisheries, since the reach of the electrical field is only 40-60 feet, and it must be considerably longer than this to be economically feasible. A serious further problem is created in salt water since to create electric fields of the necessary strength in a medium of such high conductivity, extremely high currents are necessary.

The first difficulty—the necessary high power requirement—can be overcome by turning on the electric field for only a very short time and then turning it off for a relatively long period. The fish behave in such an interrupted field about the same way as in a continuous field. The effect is similar to that in motion pictures. Here the eye gets the impression that the screen is continuously lighted, although there is between each individual picture a relatively long dark period. Only if the projected pictures per second are below a certain number can the eye see the dark periods. The same effect is achieved electrically with the fish. If the number of current pulses per second exceeds a certain number the fish will react a similar way to that in a continuous field. The ratio of the "on" and "off" periods determines the saving of electric power.

For the second difficulty, which is the short reach of the electrical field, a solution has not yet been put into application. But even with the short reach of the present gear there are certain applications which can be utilized. For example, in the North Sea, schools of large tuna weighing about 500 pounds and a length of approximately 10 feet are caught commercially with hook and line. When these fish take the hook, they put up a vigorous fight and many are able to escape, particularly the larger fish. To avoid this loss we developed gear using the hook as an electrode and stunned the fish as soon as they took the hook. In this case a high enough current is sent through the hook into the water so that the voltage across the fish is sufficient to stun it. This fish can then be brought aboard without any fight. The reach of the field in this application does not have to be large since the hook is already in the fish's mouth.

A second application where even the short reach of the electrical field can be utilized, is in the menhaden fishery. Menhaden are caught with purse-seines. After the net is pulled in the fish are concentrated in the bunt, which is about thirty feet deep and approximately twenty feet in diameter. The fish are then pumped from the bunt into the boat.

In this operation the fish, which are usually at the lowest part of the bunt, have to be raised to the surface. They can only be pumped if they are concentrated to such an extent that they are not able to escape the suction of the pump. The raising can be done either mechanically or manually, by the crew. The raising of large sets of 200,000 fish and more is difficult and sometimes such large sets are lost. Therefore, we developed equipment using the pumphead as the positive electrode, sending a current into the water that causes the fish to swim toward the pumphead, thus concentrating them. When the current is turned on the menhaden will rush within a fraction of a second to the pumphead and will be caught by the pump. The end of the hose does not have to be close to the surface but can be lowered as far as desirable.

It might be expected that all the 100,000 to 200,000 fish in the net would swim toward the pumphead at the same moment, but this does not happen. The first fish reaching the pumphead form a dense sphere around it. These fish have a considerably lower conductivity than the surrounding sea water, so the cage which is the anode is insolated to a certain extent towards the water and a considerably lower current will flow into the water. The reach of the field is thus lowered and no more fish will swim toward the pumphead. When the fish get pumped away, more current will go into the water and new fish will be attracted. In this manner a certain equilibrium is reached between the amount of fish attracted and the ones pumped away. This dense sphere of fish has a diameter of four-six feet. If, due to the rolling of the boat, the hose is raised and lowered the ball of fish will go up and down with the pumphead as if it were part of it. The ball of fish with the pumphead can be raised out of the water up to one quarter of its diameter without disintegrating.

This process has the advantage that it is no longer necessary to raise the bunt with its heavy weight of fish, and that pumping can be started as soon as the hose is overboard. We have not lost a set, even large ones, with 300,000 fish. If large fish like sharks are in the bunt, they will be stunned and fall to the bottom of the net and can not be sucked into the pumphose, avoiding the common circumstance of a pumphose blocked by a large fish which can cause considerable loss of time.

The question is naturally raised how members of the crew would be protected against being hurt by the electricity. We have solved the problem by constructing the control-circuits in such a way that the current can only be turned on if the electrodes are under salt water. There was still the possibility that a man could fall into the part of the water which is penetrated by the electric field. Fish react at voltages of about 1.5 volts, but a human being does not feel the voltage until it reaches at least twenty volts. At the field strength used in this operation a six foot man would have about ten volts across his body as he falls into the water, and he will not feel or have any ill effects from this experience. It would take twice the voltage for him to feel it and many times this voltage to hurt. In order to prove to the crew that it was not dangerous, one of our men dressed only in his trunks, swam close to the electrode with the unit in operation.