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GERMAN COMMERCIAL ELECTRICAL FISHING DEVICE1/

By Robert B. Houston, Jr., American Vice Consul

At the Hamburger Werft near Hamburg, Germany, the former German Navy minesweeper, R 96, is being fitted with an electrical device to be used in sea fishing. The device was invented by Dr. Konrad Kreutzer, a graduate of the University of Freiburg and a physicist who is responsible for several basic patents on the selenium rectifier. He was led to his latest invention by his work on electro-shock apparatus for the firm Siemens-Reiniger during the war. In reviewing the literature dealing with the effects of electricity on animal life, he saw the possibility of using electricity to catch fish. Several experimenters had recorded that fish of the usual commercial varieties reach the state of electrotaxis when subjected to voltages between head and tail of say, 0.5 - 1.5 volts; the state of electronarcosis between, say, 1.5 - 5.0 volts; and that they will be killed if subjected to greater voltages for a period of time long enough for electrolysis of certain body elements to take place. Furthermore, earlier experimenters had noted that fish were responsive to polarity of electric fields, and when free to move, tended to orient themselves so that the head pointed in the direction of increasing potential.

In short, Dr. Kreutzer reasoned that fish could be caught by placing two electrodes into the water and putting a varying positive voltage on one electrode. The positive voltage on this one electrode (the anode) would cause the fish to point towards it. The varying electric field along the spine of the fish would cause the tail muscles to contract and relax, moving the tail and propelling the fish into a net near the anode.

On June 18, 1949, the writer visited Dr. Kreutzer on board the minesweeper R 96. Because patents have not yet been obtained on his device, Dr. Kreutzer was not willing to reveal all details of it. However, he did indicate that in the experimental model he hopes to test at sea late this summer, the anode will be incorporated in the fishing net and the cathode rounded to minimize the effects of

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1/ American Consulate Report No. 11, Bremerhaven, Germany, June 24, 1949.

electrolysis and kept near the boat. The wave-form of the anode voltage will be impulsive and approximately triangular, with a sharp rise from null and a much slower decay. The pulse length will be about 2 milliseconds and the pulse rate variable from 2 - 20 per second depending upon the natural wiggling frequency of the particular type of fish sought. Because of the low electrical resistance of sea-water, the pulse voltage will not be great but the peak pulse current will be about 10,000 amperes.

The features of the device which Dr. Kreutzer hopes to patent are pulse shape, pulse rate and electrode arrangement. The pulse form is of great importance, according to him; the failure of previous electrical fish-catching devices he attributes to their use of an inappropriate wave form. The optimum pulse rate is dependent on the size and type of fish to be caught; more impulses per second are required to keep in motion a small fish capable of moving its tail rapidly in response to an applied voltage. About the electrode arrangement, the inventor was vague. Herbert PEGLOW, an engineer collaborating with Dr. Kreutzer, indicated that a single conductor down the center of a conventional net could be used for the anode, and a large iron sphere near the boat for the cathode. On the other hand, it would seem that the anode should be constructed so that no energy is wasted to the rear of the net and so that the voltage gradient is kept at the optimum value in a more or less conical region extending as far forward from the net as possible.

From his experiments in fresh water on Lake Constance, and from his small scale experiments in salt water, Kreutzer has calculated that with a pulse generator consisting of a 6,000 rpm, 20 kva alternator, and two switching tubes operating in a full-wave arrangement, an electric net of 100 sqm. area can be made as effective as a conventional net of 1,000 sqm. area. The electric net is also superior in that it does not have to be drawn so rapidly as a conventional net and because, floating several meters off the bottom, it does not have the ground resistance of the conventional trawl.

Kreutzer has not made public any quantitative results of his previous experiments. He seems to be convinced of the usefulness of his device, and together with Peglow, has financed the venture to date. At one time an American food packer was ready to contribute capital, but the Military Government's prohibition on foreign investment in Germany prevented the plan from being consummated. To complete the equipping of their experimental boat, the two now are trying to raise DM 30,000 (approximately $9,000), either from the trawler owners' association or from public funds. On July 8th, they will explain their project to a group of university professors and marine scientists in the presence of representatives of the fishing industry. They hope thereby to convince the fishing industry that their device is sound enough to warrant the investment of DM 30,000 (approximately $9,000).

Even if Dr. Kreutzer and Peglow get the money, they will still have to obtain the permission of the British Military Government to install on shipboard the 200 kva alternator they want for the experimental model of their device. They evidently do not expect difficulty in obtaining this permission, as the Military Government Fisheries Control Officer has shown an interest in the project.

Kreutzer is convinced that electro-fishing will prove itself not only because of its economy but also because it is the most conservative way of fishing yet developed. It is estimated that 90% of the fish brought up in nets of German trawlers at the present time are too small to be brought to port. Many of these undersized fish are dead when put back into the water. Electro-fishing, on the other hand, would enable the fisher to control the size and to some extent the type of fish caught by regulating the pulse rate, potential gradient and net speed, which can be made low so that only those fish large enough to be affected by the electric field before they hear the net approaching will be prevented from escaping. The large fish which have been able to live for years by taking refuge under rocks when the net approached will no longer be able to escape as the electric field will reach down into the rocks and cause them to swim upward into the net, which will be held a fixed distance off the bottom by an inclined plane and counterbalance arrangement.

From the standpoint of conservation alone, Dr. Kreutzer believes the electric technic to be especially suited to whale fishing. He has had no opportunity to measure the reaction of whales to electric fields but envisages that a whale-boat could be equipped with an electrode - instead of an harpoon - catapult. Upon shooting the electrode into the water near the whale, the pulse generator could be turned on. This would cause the whale to swim towards the electrode, and when sufficiently close to it, to lie stupified on the surface. The whale-boat could approach, measure the whale and then either kill it or free it depending upon its size. The whale presumably will not be harmed by being in a state of electronarcosis for this period of time.

Kreutzer's invention, if successful, will revolutionize commercial fishing. The big question at the moment is whether the German fishing industry at the July 8th meeting can be convinced sufficiently of the invention's possibilities to put up the risk capital needed to complete the experiments.

On July 18, 1949, in American Consulate Report No. 28, Mr. Houston states that the verdict of the fisheries experts who questioned the inventors on their device at the July 8th meeting in Hamburg was favorable and that all assistance should be given to the pair to enable them to complete their tests. Among the examining experts were Dr. Mond, Director of the Physiological Institute of the University of Hamburg, Dr. Luckner, also of the Physiological Institute, Dr. Kollath, the Deputy Director of the State Physics Institute of the University of Hamburg, and Dr. Denzer, Director of the Fisheries Institute of Land Nordrhein-Westfalen. The address of the inventors is: Arbeitsgemeinschaft Peglow - Kreutzer, Postfach 1281, Hamburg 8, Germany.

In a later communication from Mr. Houston, dated August 21, 1949, the Fish and Wildlife Service was informed that the inventors expected funds soon from the German fishing industry and that sea tests would begin in February 1950. In American Consulate Report No. 26, October 17, 1949, Mr. Houston reported the inventors have been given the sum of DM 80,000 (approximately $19,048) from the so-called Ausgleichsstock to complete their tests. It was also mentioned that the invention was patented in the United States. (A search of patent records has not revealed a patent of this type under the name of the inventors. It is possible a patent may have been applied for, however, in which case information would not be available until it was granted.)

SUPPLEMENT

ELECTRICAL FISHING AT SEA

The Fish and Wildlife Service presents herein translations of articles concerning the electrical fishing methods which were published in the German periodical, "Fischereiwelt," Zeitschrift fur die gesamte Seefischwirtschaft, Erster Jahrgang, Heft 3, September 1949, pp. 33-37. The translations were made by the Division of Language Services, Department of State.

ELECTRIC FISHING AT SEA?

Fishing with the aid of an electric current is a tested fishing method which is quite possible and practical in inland waters. To be sure, the method cannot simply be used by everybody, since some danger might be connected with its application if precautionary measures are not taken when it is practised. Furthermore, it is also necessary to limit its application in order to prevent misuse which would result in depletion of fish life. Registration is therefore obligatory, and electric fishing may only take place under supervision.

Can and should one use this method in ocean fishing also? This question has become acute because the engineer Herbert Peglow and the physiologist Dr. Conradin Kreutzer have publicly presented such a plan which has already attracted much attention. As we reported recently, the problem was the subject of a discussion meeting one evening. Here it will now be presented again for a larger audience, and we invite a discussion. In addition to the article by Mr. Peglow we are printing several observations on methods and experiences in the electrocution of whales, since the new method is also recommended as being applicable to whaling. It seems absolutely necessary that the question of electric ocean fishing be taken up by the fishing industry, and we should be very happy to print opinions on the question here.

USE OF ELECTRO-PHYSIOLOGICAL EFFECTS IN OCEAN FISHING

By Herbert Peglow

A completely new type of fishing quite different from the mechanical filtration of bodies of water which has been used in the past is offered by the use of electric current. In fresh water, which is a poor conductor and where the electric effect is therefore small, this fishing method can be used to remove a controlled quantity of fish [Zwangsweise Abfischung], or, if so desired, to remove all fish life from the waters. In this manner electric fishing in inaccessible inland waters has been carried out successfully for some years, to be sure under official supervision. In fish breeding institutes the method is also used in order to remove predatory fish, to extract spawning fish and to regulate the supply of fish. There are now new possibilities of using electric fishing in ocean fishing, since a method has now been found to circumvent the need for an extremely large amount of power caused by the high conducting ability of the salty ocean water. This was accomplished by use of an electric current with a high physiological effect, where the undesirable accompanying effects of the usual technical currents, such as the magnetic, electrolytical and heat effects, are at a minimum.

In order that people engaged in practical fishing can get an idea of the manner in which electric fishing works, I shall first discuss the phenomena of electric fishing in fresh water and shall then proceed to discuss the possibilities of using electric fishing at sea and give a technical description thereof.

Anybody who has an opportunity to watch electric fishing in inland waters is completely surprised at seeing that from within a certain area all fish which otherwise hide in the water or under the banks immediately appear and are forced to swim toward the collecting anode until at a certain distance from it they are paralysed and can then be lifted out of the water without any effort. People are also very much impressed by the fact that above all it is the large fish that are caught and the young ones are not affected.

This shows that the fish in water that conducts electric current are exposed to the effect of the current in an especially effective manner. That is also the cause of their special reaction to electric current (electrotaxis) which can be utilized as a means of catching fish. For with direct current, after the fish have lined up with their bodies parallel to the lines of force, i.e., the head in the direction of the positive pole, they are stimulated to move in the same direction until they reach the area of higher current density in the vicinity of the anode, and are paralysed there. The valuable peculiarity that large fish react more strongly to electric current than small ones is explained by the fact that all fish of one type, independently of size and age, have approximately the same sensitivity to current, which is shown by the constant of their body potential. Thus by varying the voltage used, it is possible to select the fish to be caught according to size. Since as a result of their larger bodies the large fish will tap a higher voltage than the small fish in the field of tension between the electrodes, the large fish will reach the threshold of stimulus sooner so that they are stimulated to move toward the anode before any reaction is produced among the small fish.* Electric fishing thus affords special protection of the small fish, and injury to the large fish is eliminated since as a result of the paralysis the latter cannot of themselves get into the field of still higher current density. Any possibility that the fish may be injured by being exposed for a short while to the effect of the current is eliminated by their ability to recover unbelievably fast after a paralysis or electric narcosis which usually hardly lasts even for a few seconds.

It is impossible today to get a complete picture of the use of these electric effects in ocean fishing and its manifold possibilities. It is to be expected that this will bring about new developments in fishing gears. It is possible to catch large fish such as shark, tuna and whales by use of electricity without special fishing equipment. By means of electrodes towed by the fishing vessel and with the ship as the counterpole these animals, as soon as they have entered a favorable area between the ship and the anodes, may be made unconscious by electric shock and caught. Moreover, in a way similar to that customary in whaling, one could also shoot an electrode from a greater distance to the vicinity of the school of fish so that the animals are immobilized in the electric field in front of the electrode. Animals which are not yet grown could be separated from the catch while still alive.

Trawl fishing provides another revolutionizing opportunity to use the electric effect. The collecting anode in the form of a long rope is placed at some distance before the opening of the trawl net by attaching it to the top trawl boards or the main cable, etc.

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*Conradin Kreutzer and Herbert Peglow write on the scientific basis of electric ocean fishing in the October issue of the Archiv für Fischereiwissenschaft.

The side and top trawl boards are used as counterpole or cathode. Thus the total water area swept by the trawl is filled with electric current and becomes a fishing field which can be ten times larger than that covered by the actual opening of the trawl net. From a certain size on up the fish within the area of these trawl boards are caught by the field which runs ahead of the trawl net and are forced to swim toward the opening of the net in the direction of the lines of force until they are paralysed and then caught by the net. Thus the mere fact of the geometrical increase in the size of the field should increase the catch of the trawl net many times. Furthermore, the catch of large fish will become greater than before, since for practical and biological reasons the area will not be swept entirely clear of fish. The voltage of the electric current used for fishing will be selected so that only the larger fish which can be marketed are covered by the current in order not to have an unnecessary load of small fish in the net.

A considerable increase in the catch of the trawl nets may also be caused by the fact that the fish are effectively prevented from flying from the approaching trawl, since the field in front of the trawl will counteract the flight reaction (electrotactic effect). Another factor that will increase the intake is the fact that the electric current penetrates the bottom of the sea. Thus the bottom is no obstacle to the current, and within its field of action the current will reach even the fish which are best concealed; they are forced to rise toward the opening of the net. The nets can therefore be towed at some distance above the bottom.

The additional equipment needed by a vessel for electric fishing consists in the main in a motor of low performance and a special generator which produces current of a special curved form and special frequency and is capable of a very high load. For if normal commercial current were used, the high conductivity of salt water would necessitate such a large output in order to maintain the necessary tension that a floating power plant would be required. The equipment further consists of either single or double sea cables leading to the electrodes, according to the method used.

As regards the economy of electric fishing at sea, it seems that it has a great many more advantages than disadvantages. The electric fishing method makes it possible to utilize every opportuity that presents itself on the fishing expedition without taking along many kinds of specialized fishing gear. This factor, as well as the effect of the electric current as such, provides a greater certainty of a successful catch. The larger fishing field gives a shorter fishing period, thus a shorter voyage and consequently a faster circulation of capital. Furthermore, it will be possible to include new fishing areas with stony or unclean bottoms, since the net does not have to trail on the bottom. As a disadvantage there is only the cost of the electric equipment and its installation, which amounts to approximately 3% to 5% of the value of a medium-sized ship. Any increase in fuel consumption may be disregarded, since the fishing expeditions may be expected to be of shorter duration. Additional members of the crew will not be needed since the electric installations are very simple to operate. The space needed for such installations depends on the type of motor used. The high-powered steam turbines need less space than in the case of diesel power. On an average, one may estimate from 6 to 8 square meters of rectangular floor space in the engine room, in addition to which, to be sure, the sea cable must be stored either below or above deck. Certain emergency solutions with regard to space will no doubt be possible in already existing ships. The danger of accidents is not higher in electric fishing than by using the usual methods. The electrical installation is protected within the area of the ship, and farther out the power of the electric field is so small, even when the fishing vessel serves as an electrode, that no electric effect is felt in the vicinity of the ship. Furthermore, by means of emergency switches on deck the electrical equipment can be turned off immediately.

As is always the case, practical experimenting with electric fishing at sea will have to cope with initial difficulties before the goal is reached. Conversion of the technical data from the fresh-water experiments in consideration of the higher conductivity of salt water and the larger scale of ocean fishing is done according to definite electronic laws; the consumption of power is higher, but the physiological effects are more favorable. The most suitable arrangements and the most practical methods for the new fishing technique, however, must be established in large-scale experiments. The carrying out of such experiments is more an economic problem than a technical one, owing to the high cost, which in addition to the initial cost of the installations includes the ocean-going ship and its crew. In proportion to the results to be expected, however, these factors seem insignificant.

EXPERIENCES WITH ELECTRIC FISHING IN INLAND WATERS

By Dr. W. Denzer

Schönfelder (1925), Wilkening (1926), and Schiemenz (1927) were the first to undertake experiments in the twenties involving large-scale electric fishing, and to present their experiences to the professional world in publications. Shortly before (1924), Scheminsky had explained the physiological basis of electric fishing in his experiments on electrotaxis and electronarcosis. During the following 15 years the fishing industry made use of the above knowledge with varying success. Smolian (1944) as the secretary of the Technical Committee for Electric Fishing was therefore able to report on the efforts on the part of science and industry which had been made during the last 15 years and which had been expanded considerably in the scientific field by Holzer's experiments (1931). In 1941 Scheminsky gave an over-all description of the physiological bases for electric fishing in his "Tabulae Biologicae."

After the war the attention of the industry was again directed to the use of electric fishing, mainly for economic reasons. In Bavaria, in Württemberg, and in Hesse commercial electric fishing was promoted by many technical improvements. The State Institute of Fisheries in Nordrhein-Westfalen likewise took up the results of earlier experiments in order to develop electric fishing further by cooperation between science and industry. The newly founded Technical Committee for Electric Fishing in the Central Association of Inland, Coast, and Ocean Fishers will this year for the first time bring up for discussion the results of the various efforts after the war.

All work in the field of electric fishing, with the exception of a few scientific experiments, involves electric fishing in inland waters. The results attained by electric fishing so far justify us in calling it an important new development in fishing technique which is here to stay, and in which we may place great hopes.

The development of electro-fishing had until now been hampered by the lack of cooperation between practice, science, and technique. It is therefore understandable that many things which had been established by scientific research for the development of more efficient gear were not utilized, or that in cases where science and practice worked together many projects failed when confronted with technical difficulties. In the interest of the promotion of fishing, such cooperation in the field of electric fishing is at present the most urgent requirement.

The efforts to make electric fishing practicable for ocean fishing, too, give us reason to consider in large outline the experiences gathered in electric fishing in inland waters: Where is electric fishing used, what purpose does it serve, what gear is used, and what future development must now be demanded?

In spite of all combinations of the means available at present, electric fishing is now possible only in waters not larger than a small river with a water level of a maximum of two meters. Here one must distinguish between improved fishing and complete removal of the desired fish; the latter is limited to smaller waters.

Electric fishing is used to catch spawning fish, clear waters containing the choicer varieties of fish, remove fish which are too large, test a group for fish diseases, determine the amount of damage caused by waste water, determine the quality of a body of water, and for purposes of scientific research.

The electric fishing gear consists of gasoline dynamos producing alternating or direct current of a capacity of from 500 to 5,000 watts and so-called battery devices, a combination of 12 volt automobile batteries and converters. In principle direct current is preferred. The electric current which has commonly been used until now is between 200 and 360 volts, and approximately 0.8 to 15 amperes.

Abroad (in Switzerland, Sweden, and the United States) a considerable higher voltage is used at times (up to 2,000 volts). The newest types of gear also employ interpolated relays or thyratrons in order to utilize physiological knowledge to improve the efficiency of fishing (by pulsating release of current within the framework of the physiological conditions for reception of electric current by the fish nerves). Metal screens for the two poles are generally used as collecting electrodes, and in smaller bodies of water also the Käfer electrode attachment. Aside from the size of the waters, electric fishing in inland waters is to a great extent dependent on the chemical composition of the water, the undissolved substances in the water, and the temperature of the water. Gear which functions excellently in mountainous regions on primary rock often fails on alluvial soil in lower areas. Large fish are easier to catch everywhere than small ones; this phenomenon is caused by their greater tap on voltage.

Electric fishing in inland waters can and must be promoted by better use of physiological and electronic facts (high frequency techniques), by electro-physiological research, and by combined use of electric fishing gear and the usual fishing gear (nets and fish traps of various forms). In this manner it will be possible to assure better fishing so that it will also be feasible to fish in larger inland waters and to facilitate fishing in mountainous regions.

Fresh water and sea water differ basically in respect to electric fishing in the relation between their conductivity and that of the fish bodies. Physiological experiments have shown that in order to have a successful effect on a fish in sea water, a much larger amount of electric energy is needed. This fact does not exclude the possibility that the use of electricity can be of importance in ocean fishing, too. Considerably larger amounts of energy are necessary, however, as well as the combination of electric fishing gear and nets. Such application of large amounts of electrical energy creates special electronic requirements, and in no field of electric fishing is the cooperation of physiologists, high-frequency technicians and electric technicians so necessary as here. It would be desirable if the authorities in both administration and industry would get together to promote these efforts.

ELECTROCUTION OF WHALES

By Dr. Kurt Schubert
of the Institute for Ocean Fishing, Hamburg

In 1881 the Norwegian Alfred Nielsen undertook the first experiment. In 1904 Birkeland's experiments were resumed. A solution of the problem could not be found at the time because of the stage of technological development of that date and the insufficient knowledge of the physiological effect of electric current on living beings.

In 1929 the German engineer Albert Weber started the experiments again in Norway in behalf of the A/S Elektrisk Hvalskytning. After years of deduction and experimentation, Weber found the technical solution in 1935.

Electrocution of the whale is effected by means of a 200 volt alternating current of 50 cycles per second and a one-pole current supply lead (Figure 1). The current returns via a harpoon

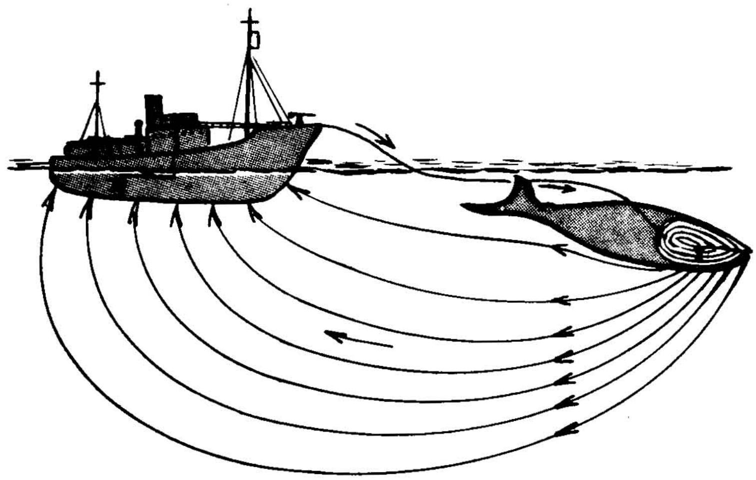

Figure 1.--Course of current in electrocution of whale.

from the mucous membranes of the mouth, emerging from the barbels (Figure 2). All intermediate stages from sudden death to partial contraction of the muscles may be observed.

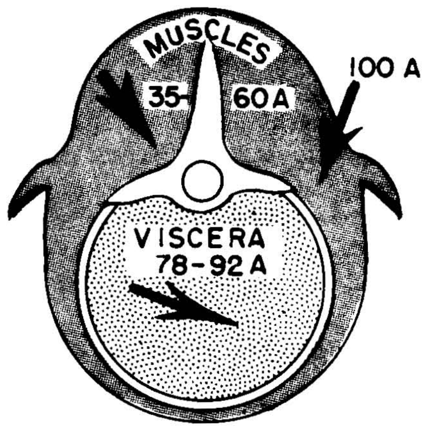

Figure 2.--Cross section of a whale showing various hits and current intensity.

A shot in the muscles of the back has always been the most common and the most effective type. All whales immediately turn on the side, whereby the current intensity fluctuates between 35 and 60 amp. (Figure 1). The whale is paralysed immediately and floats in the water, the breast and tail fins sticking out of the water. Death can be determined with certainty 10 seconds to 2 minutes thereafter by observing the rapidly sinking breast fin and the opened mouth. In the case of hits below the spinal column (visceral hits) a higher current intensity is necessary, namely between 78 and 92 amp. Shots in the lungs and the heart kill instantly.

The hit may thus be either in the muscles, using a small current intensity (Figure 3), or in the viscera, using greater

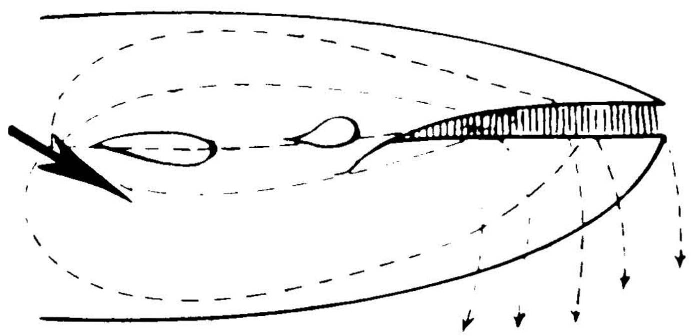

Figure 3. --Exit of current in the right whale. (From Weber).

current intensity. As an exception one can occasionally observe shots which cause a shunt, for example, if the hook on the harpoon sticks out of the body. An electric charge of more than 100 amp. will then occur. The whale is nevertheless held securely. In case of a miss a short circuit will occur. The electrocuted whale floats on the surface of the water, for the shot takes place when the whale has inhaled and its specific gravity is smaller than that of the water. The sudden cramp-like tension of the muscles prevents the movements of the tail necessary for diving. On the other hand, a whale which has already dived does not float on the surface.

The effect of the current on the different types of whales likewise seems to vary. According to observations the fin whale is more sensitive than the blue whale. The whale's age and physical condition are also of importance. One can distinguish between two kinds of killing methods. The first produces death within a few seconds, the other after unconsciousness occurs, depending on the length of exposure and the current intensity. By switching off the current it is possible to bring the whale back to life. The physiological reactions are exactly the same as those in humans, except that the fatal current intensity is greater.

Weber's electrocution of whales has one shortcoming, to be sure, which is shared by the shell harpoon. It does not eliminate misses. Weber chose the electric harpoon because by penetrating into the body it eliminated the uncertain resistance of the skin against passage of current. The ideal method would, of course, be to eliminate the misses completely. The ship would still function as one of the electrodes and the other electrode would be shot away from the ship in order to make it possible to kill the whale by means of the current between the two electrodes. However, it has not been possible to carry out that experiment as yet owing to technical difficulties and our insufficient knowledge of the effect of current on the skin and thereby on the whale.

The current affects the body, so far as we know today, via the free nerve ends in the skin. However, the skin of the whale, due to its adaptation to life in the water, has a structure which is completely different from that of the skin of other mammals. The skin of the whale is comparatively thin. The surface is smooth and the epidermis has a thin but tough horny coat, the thickness of which varies for the different kinds of whales (the blue whale, 2 to 3 mm.; the finback, 4 mm.; the humpback whale, 6 to 9 mm.; the sei whale, 1.5 mm. on the average). The tissue of the hypodermis has been developed into an enormous layer of fat, the blubber (in the rorquals and humpbacks (balaenopteridae), 10 cm. to 15 cm.). The surface of this tissue rises in enormous, protruding papillae which supposedly contain almost nothing but vascular loops. There are no sweat glands. The skin nerves are also said to be only incompletely developed. It seems necessary to check the latter point again, however, since skin nerves have been found on the blue whale but not on the other whales, with the exception of the tactile hair on their head. After all, it is not easy to see why the whale should not have skin nerves like the other mammals.

Therefore it does not seem unreasonable to assume that whales also can receive current through every part of the body. If so, it would be possible to eliminate the factor of uncertainty (misses) in electrocution of whales. A prerequisite, to be sure, is success in producing an adequate voltage at sea over an area about 70 to 100 meters long which will kill the whale. But at the same time there would be an opportunity to hunt the small whales which so far have usually been caught only occasionally.

Voltage and Current in Electrocution of Whales
(from Weber)

Location of Wound	Joules Amperes	Cycles Voltage	Fatal tension Voltage
1. Muscle	50 ' 60	220 ' 210	35.5--42.6
2. Muscle in the vicinity of the back fin	36 ' 39	170 ' 160	34.5--37.5
3. Muscle in the neck	46 ' 49	160 ' 152	15.5--16.5
4. Partial muscle wound (One hook has penetrated the layer of blubber)	40 ' 110	220 ' 170	12.6--28.8
5. Lungs	78 ' 80	198	42.5--43.6
6. Heart	80 ' 90	200 ' 184	48.8--55
7. Belly	80 ' 92	200 ' 186	81.5--93

ON ELECTROCUTION OF WHALES

By Capt. W. Reichert, Hamburg

Electrocution exeriments were undertaken for the first time in 1881. Outwardly the method is in every way adapted to the use of gun harpoons. The same guns are used and the harpoons are of the same size and the same weight. The only difference is that the forerunner carries an electric cable in each rope strand. One hundred percent safety for the crew operating the gun is attained by not closing the fatal circuit until the harpoon is 10 meters from the gun. With the electric method the whale is killed instantly or stunned to such an extent that death soon follows. The lapse in time from the moment the animal is hit until the voyage can be continued, i.e., including bringing up and pumping up the whale and making it fast alongside the steamer, amounts on the average to approximately only 10 minutes, while one must figure on an average of approximately 45 minutes when a gun harpoon is used. If the whale is hit so unfortunately that the harpoon is anchored only in the back blubber, a second shot will be needed because of the loss of current into the water. Almost always, however, the whale is so paralysed that one can immediately move up alongside it and reach it with an electric spear fastened to a long stick. It then takes only a few seconds to kill the whale by driving the spear into the back flesh. In belly wounds part of the current is also lost through the mucous membranes of the throat and the mouth. But in this case, too, the animal is dead within two to three minutes.

The best results of electrocution occur at 200 volt alternating current and from 50 to 60 amperes. If the ammeter shows more than 60 or even as much as 120 amperes one knows that it is a belly hit or that in being pulled back a fluke of the harpoon has emerged from the whale, or that a short circuit has occurred in the electric wire. The advantages over the gun method are the following:

a) Killing time from hit until whale is towed away:
   Electrocution: 10 minutes   Gun: 45 minutes

b) Number of forerunners used in one season:
   Electrocution: 8   Gun: 25

c) Whaling lines used:
   Electrocution: from none to one   Gun: at least 6

d) Use of shells:
   Electrocution: none   Gun: 400

e) Loss in whales:
   Electrocution: none   Gun: 2-6

When shells are not used the electrocuted whale is, of course, free from shell splinters. That is an immense advantage since it protects the machines in the processing of the meat aboard the factory ship. It is a disadvantage, to be sure, that an electrocuted whale is not drained of blood and that the whale meal is therefore somewhat darker and does not sell at as high a price as that of light meal. The quality is, of course, equally good.

Unfortunately no method has been found which eliminates misses entirely. The extent to which the new method of using electric current on the whale is applicable must first be proved by experiments. Since the whale is a 100 ton giant which swims at an average speed of 10 knots, such experiments will meet with great technical difficulties. From the whaling steamer which is the fixed electrode it would surely have to be possible to shoot a second electrode to a point several hundred meters removed, in order to create a power field in front of the steamer. The question is whether a field of lines of force can be created which will have an effect great enough for such a giant. Furthermore, there is still too little information available regarding the physiological effect of the current on the skin of whales. Above all, it is not yet established whether the whale, a warm-blooded mammal, is subject to anodal effects. From my personal experience I know of a case in which a glancing shot of an electric harpoon wounded only the blubber; it had penetrated the skin but no effect was produced. On the other hand, I have observed a glancing shot which tore open the layer of blubber and killed the fin whale by the resulting brief electric shock, so that it was only necessary to pump up the whale and fasten it.

The new fishing method should by no means be rejected offhand as a possibility in whaling. After all, there is the possibility that a greater physiological effect on the whale might be obtained by using interrupted direct current, which is technically possible today, instead of the alternating current which has been used up to now. It is my experience that whales which were wounded by gun harpoons and could be towed up to the bow in order to be electrocuted by an electric spear could be killed faster with interrupted shocks of alternating current than with a continuous flow.

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