STANDARD FORM NO. 64

Office Memorandum • UNITED STATES GOVERNMENT

DATE: June 18, 1951

TO : The Director, Fish and Wildlife Service
Washington, D. C. A ttn: Mr. E. Dahlgren

FROM : Acting Chief, North Atlantic Fishery Investigations
Woods Hole, Mass.

SUBJECT: Ms. "Echo-sounding experiments conducted aboard the Albatross III"

Enclosed are three copies of the manuscript noted above, with illustrations.

Subject to your approval, this manuscript is submitted for publication as a SPECIAL SCIENTIFIC REPORT.

Clyde C Taylor (ED)
Clyde C. Taylor

Encl: (3)

1 copy detached for miss griffith
ms

51-1

1 Edwards
2 Jones

STANDARD FORM NO. 64

Office Memorandum • UNITED STATES GOVERNMENT

File 800

TO : Laboratory Director, BCF, Woods Hole, Massachusetts DATE: April 25, 1961

FROM : Acting Chief, Branch of Marine Fisheries

SUBJECT: Manuscript by Miles

In order to clear our files, we are forwarding the accompanying manuscript which may still be of some interest to you.

JEK
Joseph E. King

Attachment

United States Department of the Interior

Oscar L. Chapman, Secretary

Fish and Wildlife Service

Albert M. Day, Director

Special Scientific Report -- Fisheries

No. ______

ECHO-SOUNDING EXPERIMENTS CONDUCTED ABOARD THE ALBATROSS III

By

Ernest Lee Miles, Fishery Aid

Branch of Fishery Biology

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ILLUSTRATIONS

INTRODUCTION

The possibility of locating schools of fish through echo-sounding machines and of determining the species of fish located by the type of trace made on the echogram has been the subject of research by a number of investigators since 1933. It is the purpose of this report to discuss the history and development of echo-sounding and to present data concerning echo-sounding observations obtained aboard the _Albatross III_, a fisheries research vessel of the United States Fish and Wildlife Service (fig. 1).

Figure 1.--_Albatross III_, a fisheries research vessel of United States Fish and Wildlife Service

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HISTORY OF ECHO-SOUNDERS

The lack of instruments needed to combat the dangers of the sea which imperiled early navigators have been overcome one by one. Among the devices developed to eliminate these dangers were (1) the chart to tell the navigator the best course to follow from one point to another, (2) the compass to enable him to maintain his course, and (3) the chronometer and sextant to determine his position. An accurate instrument, however, to determine depths was greatly needed. As a result, the echo-sounder was designed and developed to overcome this problem.

Before the development of the echo-sounder, the most dependable instruments used for determining depths were the hand leadline, suitable down to 25 fathoms, and the deep-sea leadline (which is identical to the former except that it has a heavier lead weight). To make reliable soundings with the hand leadline, it was necessary for a ship to reduce its speed as the depth increased. In depths beyond 100 fathoms, therefore, soundings with the deep-sea leadline became very difficult, laborious, and time consuming.

With the need of an instrument to determine the depth of water under a ship that would be superior to the leadline, a number of devices were designed. Three of these devices were the detachable-weight type of deep-sea leadline 1/, the Sigsbee Sounding Machine 2/, and the Lord Kelvin device 3/ for measuring the hydrostatic pressure at the bottom of the sea (Submarine Signal Company, 1945). These devices, however, did not prove

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1/ A heavy lead weight attached to a strong line in such a manner that upon striking the bottom the weight became detached.

2/ The Sigsbee Deep Sea Sounding Machine consisted of a reel of about 1,500 fathoms of piano wire, a pulley, a hoisting engine, a sounding rod detachable weight, a device to regulate the tension of the wire to show the instant the weight hit the bottom, and a register which showed the amount of wire run out.

3/ The Lord Kelvin device to measure the hydrostatic pressure was a tube, closed at one end, which had an inner coating of silver chromate. The degree of discoloration of the silver chromate (from salmon to milky white) was a measure of the depth by means of the hydrostatic pressure (Submarine Signal Company, 1945).

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to be any great improvement over the older devices employed. With the first two devices, the ocean currents would cause the lines to sway from the perpendicular plane, thus causing exaggerated depth recordings. The Lord Kelvin device was time-consuming and had to make mechanical contact with the bottom in order to record the hydrostatic pressure. Investigators continued the search, therefore, for newer devices for recording depths that would be more accurate and time saving.

Although investigators had noticed that sound could be heard under water, it was not until 1807 that a French physicist, Dominique Francois Jean Arago, presented the theory that it might be possible to determine depths of water by utilizing the successive production of sound (Adams, 1942). Unfortunately, there was very little progress made with Arago's proposal, and it was not until 100 years later (1907) that A. F. Eells (Adams, 1942) of the United States was issued a patent for a sounding device based upon the principles of echo-sounding. These principles, basically, consist of measuring the depth of water by bouncing sound waves off the sea-bottom and timing the passage of the sound and the returning echoes.

The sinking of the Titanic in April, 1912, caused such investigators as Dr. A. Behm of Germany, Professor R. A. Fesseden of the United States, and others (Adams, 1942), to become interested in designing and developing equipment to detect icebergs. The experiments conducted by Professor Fessenden resulted in the development of a powerful oscillator which could produce sound of great intensity in the water, and an instrument to change sound travel time into distance.

During World War I and the years that followed -- the years between 1917 and 1925 -- many important experiments led to the practical application of echo-sounding for navigational purposes. In 1917, Professor Langevin (Adams, 1942) invented the piezoelectric ultra-sonic projector [4/] which made

4/ A projector based on piezoelectricity -- electricity or electric polarity due to pressure, especially in a crystallized substance, such as quartz.

it possible to use supersonic sound waves, and in 1919, soundings were made in depths as great as 4,000 meters by the cable ship Charente. It is thought that the first practical application of echo-sounding was made by the French Hydrographic Department, using the <u>Marti</u> sonic apparatus, when they recorded the bottom's contour between Marseilles and Philippeville (Adams, 1942).

A very important contribution to echo-sounding was made in 1923 by Dr. Herbert G. Dorsey of the United States (Adams, 1942), who developed a visual-indication device which measured extremely short time intervals, by which shoal and deep depths could be automatically registered. His application of the red neon discharge tube as a visual indicator of the depth was a great advancement in echo-sounding.

The period since 1925 has been significant for the refinement of apparatus and for furthering the development of the theory of acoustics.

INVESTIGATORS EMPLOYING ECHO-SOUNDERS FOR LOCATING FISH SCHOOLS

Since the summer of 1933, when fish were first detected by the use of echo-sounding, such investigators as Ronald Balls, Oscar Sund, William C. Hodgson, Ian D. Richardson, Albert L. Tester, J. Renou, P. Tchernia, Gerhard Krefft, Friedrich Schuler, Kurt Schubert, and others, have been experimenting with locating schools of fish with echo-sounders and trying to determine the species by the type of trace recorded on the echogram.[5/] Their results have been very encouraging but have shown also

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5/ Echogram (Echolog) — the trace recorded on the paper of the fathometer.

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the need for further refinement of equipment and for more intensive study.

In the summer of 1933, Ronald Balls (1948) had his drifter Violet and Rose fitted with the echometer YH 757 and, employing sonic methods, he began searching for herring under commercial drifter conditions. His conclusions were that this first attempt in commercial sonic fish soundings was somewhat of a failure. He hoped, however, that it might prove helpful in supplying an adequate working knowledge for future experiments in using echo-sounding methods to locate fish on a commercial scale.

In 1935, Oscar Sund (1935), aboard the Norwegian research vessel Johann Hjort, made the first identified record of cod (Gadus morhua). It was the first authentic evidence put forth to show that fish schools could be located by the recording type of sounders.

In 1943, Albert L. Tester (1943) came to the conclusion that it was possible to locate herring with echo-sounders with greater efficiency and speed than with the feeling wire.[6/] Also, he found that the echo-sounder would show the extent or depth range of the school at a depth in which the impulses from the wire were muted and indiscernable because of the vibrations from the wash of the ship.

6/ The feeling wire, a thin flexible wire with a weight attached to its end, is used to determine depths and density of fish schools by the vibrations of the wire.

In 1946, J. Renou and P. Tchernia (1947) conducted a series of four echo-sounding experiments aboard the French escort vessel Le Grenadier, a former American sub-chaser (PC 625). The echo-sounding equipment for the experiments consisted of a Sonar (Asdic) sounder and an American recording-type sounder N.J.3. The results received from locating schools of sardine, sprat, tuna, and herring proved the validity of their three hypotheses for the experiments, which were:

"(1) It should be possible to have ultra-sound echoes from fish shoals;

(2) These echoes should easily help to distinguish echoes from the bottom, wrecks or any other inert obstacle even though moving;

(3) These echoes should be able to give the special characteristics, to define, permitting to recognize, in connection with the ecological factor, the species composing the shoal."

Dr. William C. Hodgson (1950) has proposed a classification of echoes based on the differences in the characteristics of traces made on the echogram from echoes caused by herring, pilchard, sprat, mackerel, coalfish, and pollock.

Ewing Lawrence, Jr. (1950) reported that sponge and live coral, unless very dense, will not be recorded on the echogram. Wrecks, wood or steel, are recorded on the echogram, with steel giving a much heavier trace.

Thus, through experimentation, and making available the facts derived from such experimentation, the echo-sounder is well along the way to becoming a necessity in the commercial fisheries. It will reduce expenses per trip and allow a vessel to reap from the sea a maximum catch in fewer days.

ECHO SOUNDING EXPERIMENTS CONDUCTED ABOARD ALBATROSS III

Depth Recorders Used

In January 1950, investigators aboard the Albatross III, a fisheries research vessel of the United States Fish and Wildlife Service, began experiments to determine the possibility of locating schools of fish with echo-sounders and to investigate the traces characteristic of each species recorded on the echogram. Two supersonic depth recorders, the Bendix Echo Sounder DR-6 (fig. 2) and the Submarine Signal Fathometer No. 1215, (fig. 3) were used in the experiments.

Figure 2.--Bendix Echo Sounder DR-6

Figure 3.--Submarine Signal Fathometer No. 1215

The fundamental features of both recorders are practically the same. Each has an electrical impulse produced by a keyed electronic oscillator. The transducer converts these electrical impulses into supersonic waves which are beamed towards the bottom of the sea. At this point the stylus (pen) is at the zero line and makes a mark on the paper. The supersonic waves travel downward until they strike anything with a density different from that of water, such as the bottom, submerged objects, or marine life. A portion of the beam is reflected back to the transducer as an echo. The transducer is automatically connected to the electronic receiver, which amplifies the weak electric impulses generated in the transducer by the echo and passes it on to the stylus. Due to the lapse of time, the stylus is then in a different position and records a depth mark or indications of submerged objects and marine life on the chart. This process if repeated over and over will give a continuous line on the chart to indicate the profile of the bottom and of other objects located in the area between the hull of the ship and the bottom of the sea (intermediate area).

The major difference between the two machines is the time rate of the recordings on the chart. The time rate of the Bendix DR-6 is 30 inches every hour on the foot scale and 5 inches every hour on the fathom scale. The Submarine Signal Fathometer No. 1215 has three chart recording rates which are 6 inches, 18 inches, and 30 inches per hour. The time rate of the chart is important, because if this factor and the speed of the ship is known, it is possible to estimate the size of a school of fish or the size of an object on the sea-bed.

The controls of both machines are essentially the same, with the Submarine Signal Fathometer No. 1215 having one extra feature, i.e., the red illumination depth indicator, which gives flasher recordings of the depth. The control panels consist of four controls labelled: Feet-Off-Fathoms, Sensitivity, Illumination Switch, and Index Button.

Of the four controls, the sensitivity control is the most important for locating schools of fish and submerged objects, and for studying the contour of the sea-bed. Without proper adjustment of the sensitivity none of the above can be studied, because a minimum sensitivity adjustment will produce little or no trace from objects in the intermediate area and only a faint trace of the sea-bed. A maximum adjustment of the sensitivity control will produce "strays" (false indications caused by electrical noises in the ship or echo-sounding equipment). Therefore, the optimum adjustment for the sensitivity had to be determined for the two machines.

On January 4, 1950, experiments were started to try to establish an optimum sensitivity adjustment in order to operate the machines effectively. After a few days, it was observed that the best results were obtained if the machines were operated to give a moderate multiple echo. There were less strays, less burning of holes in the paper by the styli, and good recordings of marine life and submerged inert objects. In order to obtain this optimum sensitivity, it was found that the sensitivity control of the machines had to be increased to approximately two-thirds or three-fourths of their maximum sensitivity.

Sampling Methods

To determine the identity of the species responsible for the traces, it was decided to use (1) the 1-1/2 Iceland otter trawl, (2) the radio-telephone, and (3) the handline. In the first place, the 1-1/2 Iceland otter trawl (an excellent gear for catching ground fish) would furnish adequate samples of the fish schools recorded along the sea-bed. Secondly, when recording traces of fish schools in an area near commercial fishing vessels or party boats, radio-telephone contact with such vessels would supply information of what fish were being caught and at what depths. With this information the species being recorded by the echo-sounders could be determined. Finally, the handline would provide a check on the species being recorded in the intermediate area and would be useful when recording traces in an area where there were no party boats or commercial fishing vessels.

Observations of Fish Schools Made Aboard *Albatross III*

After determining the optimum sensitivity and the causes of faulty traces, selecting the sampling methods and the paper time rate to be used, and considering the location, the season, and the ecological conditions, the search for fish schools was begun.

Over a ten-month period, the following species were recorded on the echogram: scup (*Stenotomus chrysops*), menhaden (*Brevoortia tyrannus*), croakers (*Micropogon undulatus*), mackerel (*Scomber scombrus*), ocean perch (rosefish) (*Sebastes marinus*), sea herring (*Clupea harengus*), whiting or silver hake (*Merluccius bilinearis*), haddock (*Melanogrammus aeglefinus*), cod (*Gadus morhua*), and pollack (*Pollachius virens*).

Operating the Albatross III off the coast of North Carolina between Cape Hatteras and Cape Fear during January and February 1950, recordings and samples of schools of scup, menhaden, and croakers were obtained. The traces appearing to be characteristic of the above species are described below.

Scup or northern porgy

While trawling approximately twenty miles southwest of the Frying Pan Lightship (latitude 33° 16.5' N., longitude 73° 32.5' W.) schools of scup or northern porgy were recorded along the bottom contour. These schools were sampled with the 1-1/2 Iceland otter trawl gear with rollers, no tickler chain, and with a liner in the cod end. In a one-hour tow, out of a school covering a distance of three-fourths of a mile and with a mean height of ten feet from the bottom, 6,750 scup weighing 1,578 pounds were caught. In another one-hour tow, over a school with approximately the same dimensions, 4,125 scup weighing 930 pounds were caught.

The characteristic trace made on the echogram by the scup is very dense throughout. When the scup are feeding on crustaceans, mollusks, and some vegetable matter along the sea-bed, the traces recorded show the same denseness as that of the bottom and are often mistaken as being part of the bottom contour (fig. 4). When feeding on squid or fish, and

Figure 4.—Scup or northern porgy schools recorded 20 miles southwest of Frying Pan Lightship

schooling above the sea-bed, the very dense pattern characteristic of scup is seen vividly.

1-1/2 Iceland otter trawl gear to identify the species responsible for the traces on the echograms.

In the first tow, 1,899 croakers weighing 450 pounds and 6 black sea bass (*Centropristes striatus*) were caught. The second tow yielded 1,477 croakers weighing 350 pounds and 1 giant butterfly ray (*Pteroplatea altavela*). The fact that the total croaker catch was 3,376 as compared to the catch of fish of 7 miscellaneous species makes it relatively certain that the trace received on the echogram is characteristic of croakers.

Croakers give a very different type of trace than that of scup or menhaden. Their traces are characterized by diffuse striations and appear on the echogram as a picket-fence would appear to a person who was riding by it in a speeding automobile. The diffuse schooling habits of this species are thought to be so because croakers are a carnivorous species and must school diffusely in order to receive an adequate food supply.

Mackerel

While trying to locate fish with echo-sounders, very good traces were obtained from mackerel off the coast of New Jersey, ocean perch (rosefish) in the Gulf of Maine, and whiting, sea herring, and gadoid fishes (haddock, cod, and pollack) on Georges Bank.

Off the coast of New Jersey, approximately 4 miles southeast of Scotland Lightship (latitude 33° 27' N., longitude 77° 44' W.), the echo-sounders recorded traces that had a dense, striated pattern (fig. 7)

Figure 7.—Mackerel school recorded 4 miles southeast of Scotland Lightship

which has been described by Hodgson (1950) as the trace characteristic of mackerel. Radio-telephone contact was made with a large number of party boats fishing in this area and the skippers reported catching mackerel. The reported depths at which mackerel were being caught agreed with the depths of the school recorded on the echograms.

Ocean perch (rosefish)

On May 3, 1950, while fishing in the Gulf of Maine with the ocean perch (rosefish) fleet approximately 57 miles southeast of Mount Desert Rock and 53 miles southwest of Lurcher Shoals (latitude 43° 11.5' N., longitude 67° 23' W.) a very dense trace, thought to be characteristic of ocean perch, was recorded on the echogram (fig. 8).

Figure 8.--Ocean perch (rosefish) school recorded in Gulf of Maine

This trace appeared on the echogram as if it had been superimposed on the bottom's contour with india ink. Upon sampling the school with the 1-1/2 Iceland otter trawl for a half hour (5:20 - 5:50 P.M.), 734 ocean perch were caught as compared to 94 fish of miscellaneous species.

Sea herring

The sea herring traces recorded by the echo-sounders on Georges Bank (latitude 41° 22.5' N., longitude 66° 53' W.) are essentially the same as those described by Hodgson (1950) and other workers (fig. 9).

Figure 9.--Sea herring school recorded on Georges Bank

These traces appear on the echogram as a very diffuse trace irrespective of the density of the school. These fish were identified by the general "signs", i.e., by noting the presence of gannets (Moris bassana) and by watching the fish break the surface of the water.

The experiment was conducted by using a Sperry Spotlight containing a 500-watt light bulb directed towards the surface of the water from the bridge of the ship, the beam shining approximately 10 feet off the starboard side. The school was concentrated between depths of 40 to 80 feet. When the light was turned on, the school seemed to have an immediate shock reaction which caused it to disperse, but the fish slowly schooled again between 60 and 80 feet and began to rise towards the surface. When the lights were turned off for 5 minutes the school seemed to level off again at about 40 feet. Upon turning the light on again the school rose still higher than it did in the initial test (fig. 11).

Figure 11.--Effect of light on a fish school

Dr. Krefft and Herr Schubert (1950) made light experiments on herring and mackerel using 100- and 200-watt light bulbs submerged in the water at different depths. They observed, using the 100-watt light bulb submerged just below the ship's hull, that the fish would congregate around the hull. Upon using the 200-watt light bulb, at the same depth, the fish congregated 200 meters below the hull of the ship.

Schuler and Krefft (1951) studied the effect of light on herring and mackerel schools with the light suspended just above the surface of the water and found that the schools would rise close to the light. With the light bulb submerged below the surface, the schools sometimes would rise above the light.

The Dutch (Krefft and Schuler, 1951) in 1949 and 1950 experimented with the effect of light on herring schools using ultra-violet and 200-watt white lamps submerged from 5 to 8 meters below the surface of the water. The ultra-violet lamp caused the herring to swarm or congregate in about 20 minutes, while the 200-watt lamp caused the school to disperse and seek deeper water.

The Russians (Krefft and Schuler, 1951) used 100- and 1,000-watt light bulbs on the deck of their research vessel to study the effect of light on herring schools. Using the 100-watt light bulb, their observations showed the fish had a tendency to congregate, but when using the 1,000-watt light bulb the fish dispersed and descended to deeper levels.

Miscellaneous Traces

Sometimes, strange traces are recorded on the echogram that are often mistaken for fish schools. These traces arise from numerous causes (Adams, 1942). Some observations made aboard the Albatross III showed that a bathythermograph, some Nansen bottles, a wreck, the shooting of the trawl, and an acid-wake were recorded on the echogram.

In January 1950, while collecting hydrographic data at sea, the echo-sounders recorded traces of the bathythermograph being lowered. At this same station Nansen bottles were recorded on the echogram while they were being used to collect water samples (fig. 12).

Figure 12.—Echo-sounding traces of bathythermograph and Nansen bottles

Henry Wood and B. B. Parrish (1950) reported that the echo-sounder employed in their research had recorded the bathythermograph.

While trawling at latitude 40° 26.5' N., and longitude 69° 46.5' W., 12 miles southwest of Nantucket Lightship, the echo-sounder recorded what at first appeared to be a school of fish, but which was found subsequently to be a wreck. At that time this wreck had not been charted, and its presence did considerable damage to the trawl. The wreck, 48 feet long, was located in 33 to 40 fathoms of water (fig. 13).

Figure 13.--Wreck recorded 12 miles southwest of Nantucket Lightship

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While collecting data on the effect of the acid-iron waste disposal at sea and recording directly astern the disposal barge of the National Lead Company, approximately 10-1/2 miles south of Ambrose Lightship, the echo-sounders recorded the acid-wake which was caused by the disposal of ferrous sulphate and sulphuric acid into the sea (fig. 14).

Figure 14.--Acid-wake recorded 10-1/2 miles south of Ambrose Lightship

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Another operation common to the catching of fish was frequently recorded also, i.e., both the setting and the hauling of the trawl net (fig. 15).

Figure 15.--Shooting the 1-1/2 Iceland otter trawl

SUMMARY AND CONCLUSIONS

After many years of experimentation to develop an instrument to measure the depth of water under a ship, the recording-type echo-sounding machines were developed. In 1933, fish were detected by echo-sounding and since then many investigators have conducted experiments to find out if it were possible to locate and identify schools of fish by this method.

Observations made aboard the Albatross III, a fisheries research vessel of the United States Fish and Wildlife Service, to determine the possibility of locating and identifying fish schools during a ten-month period clearly showed that fish schools can be located and to a certain degree identified by the use of echo-sounding methods. The extent of these schools in area and depth can be determined also. However, these observations showed the need for further refinement of the apparatus.

Experience has shown that fish schools are located by chance when the recording-type sounders are used, especially in the case of ground-fish where there are no "signs" to indicate their presence. Fishing for pelagic species, however, the visual indications for the presence of fish schools are very significant when attempting to locate these schools by the recording-type machine sounding methods (Hodgson and Richardson, 1949).

Experiments to determine the effect of light on pelagic and ground fish schools have been conducted by investigators in various contries throughout the world. The pelagic species tend to congregate at shallow depths with less intense light and to disperse and descend with light of great intensity. Ground fish do not seem to be affected by the light for any great period of time. They have a tendency to rise for a short period, possibly only out of curiousity, and then to descend to their original depths irrespective of the length of time the light is shown upon the water.

Further observations made aboard the Albatross III showed that a number of miscellaneous objects can be recorded on the echogram by the supersonic sounders. Among these objects recorded on the echogram were the bathythermograph, Nansen bottles, wrecks, an acid-wake, and shooting the trawl.

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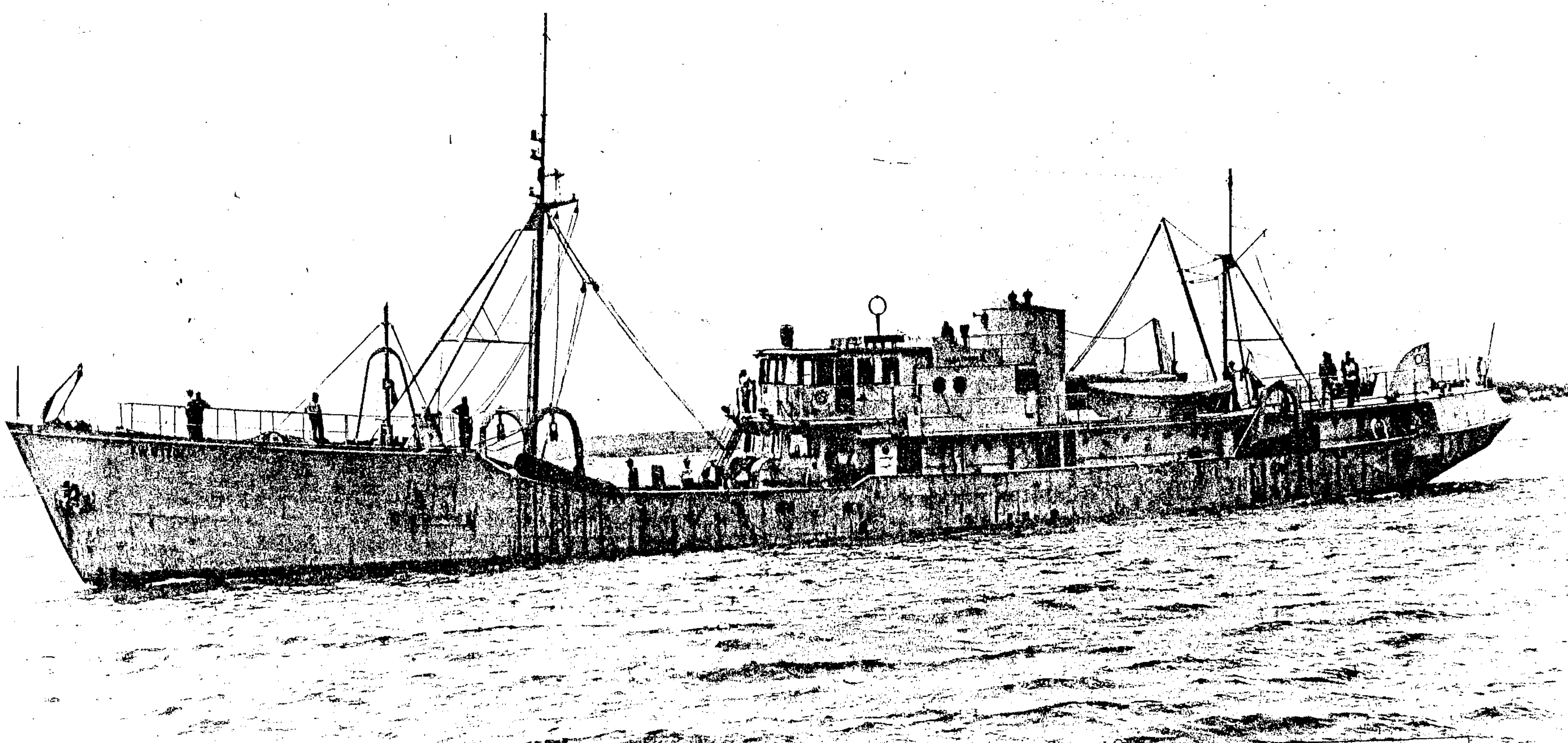


FIG. 1. *Albatross III*, a fisheries research vessel of United States Fish and Wildlife Service.

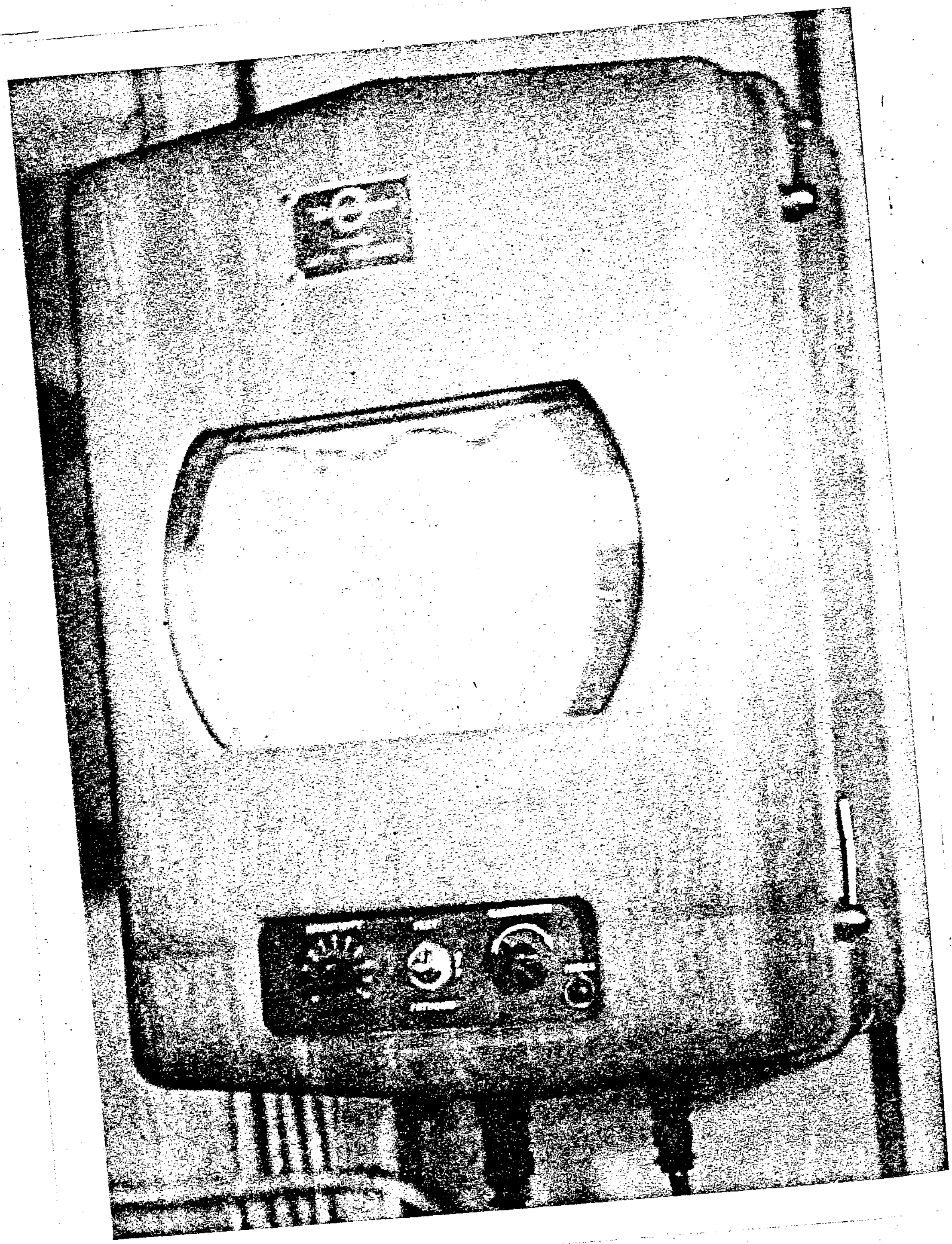


FIG. 2. Bendix echo sounder DR-6.

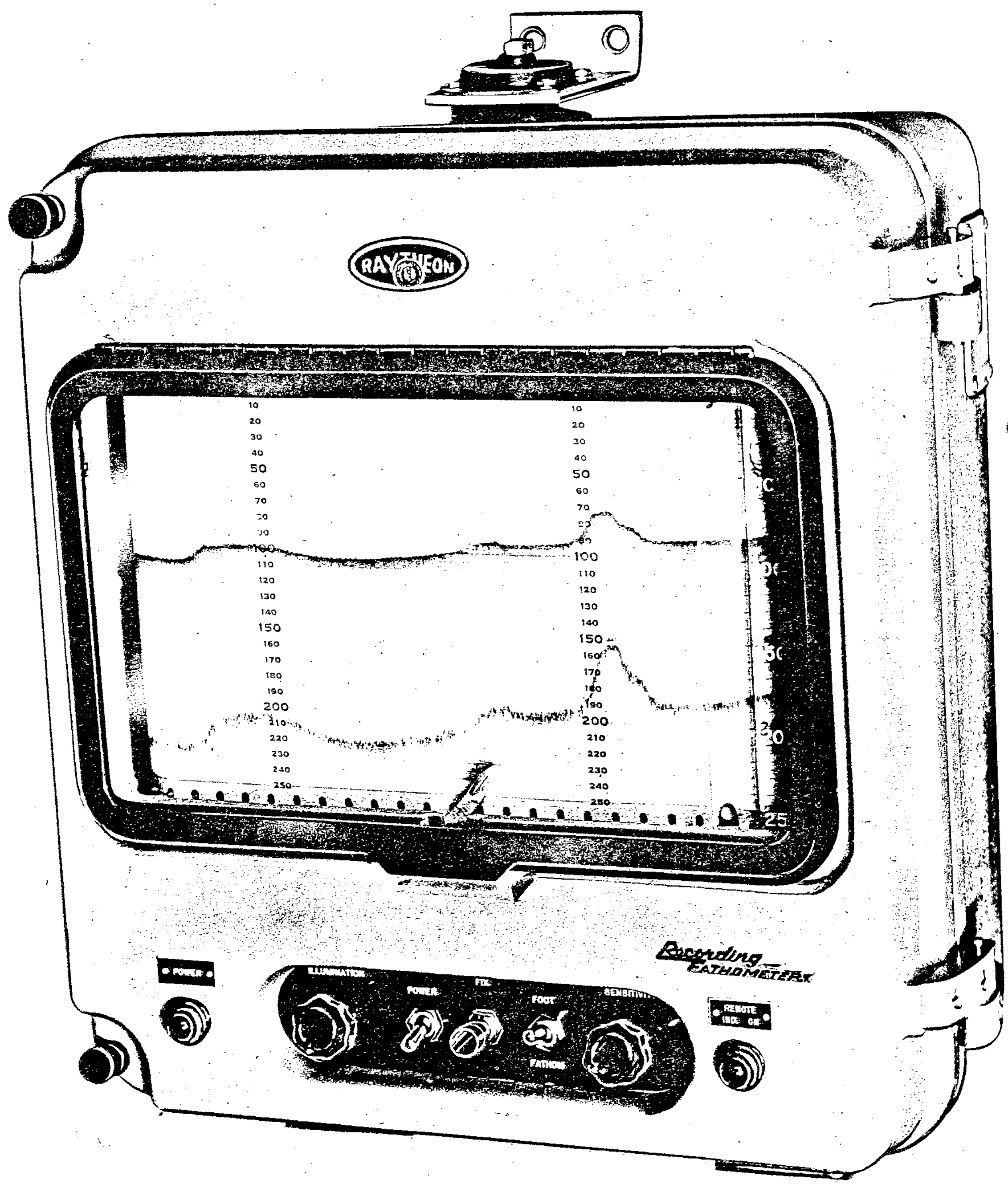
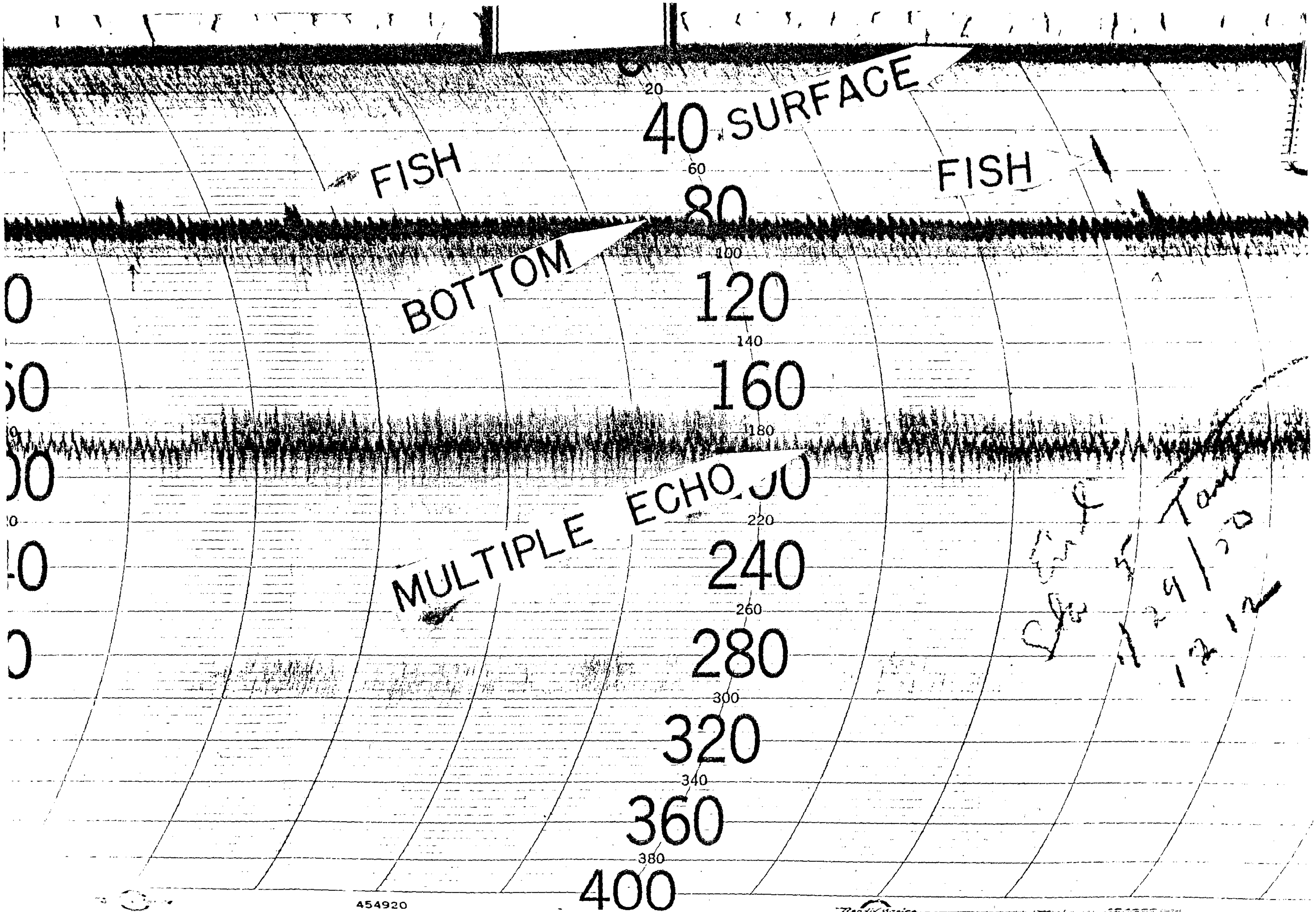


FIG. 3. Submarine Signal Fathometer No.1215.



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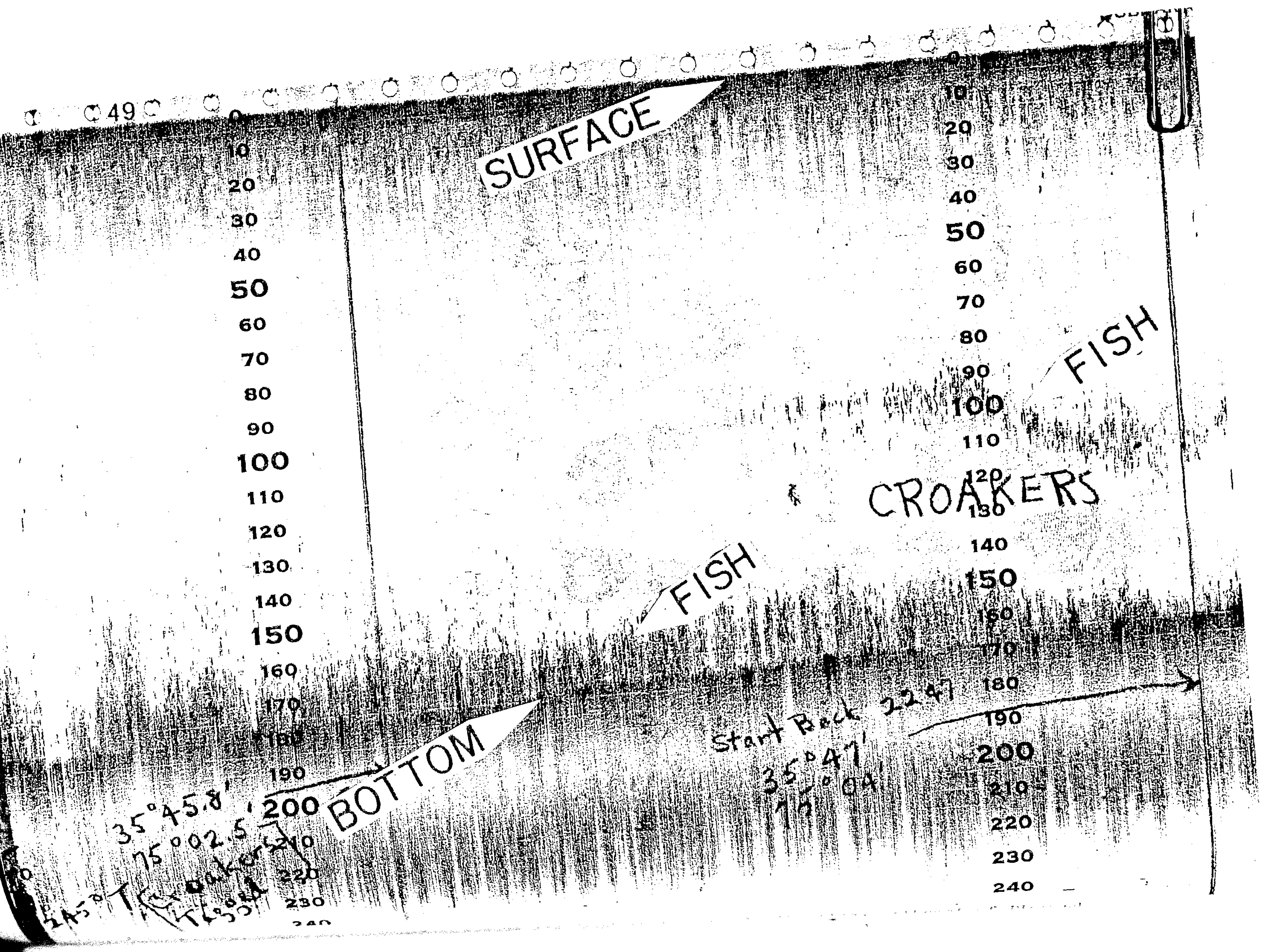
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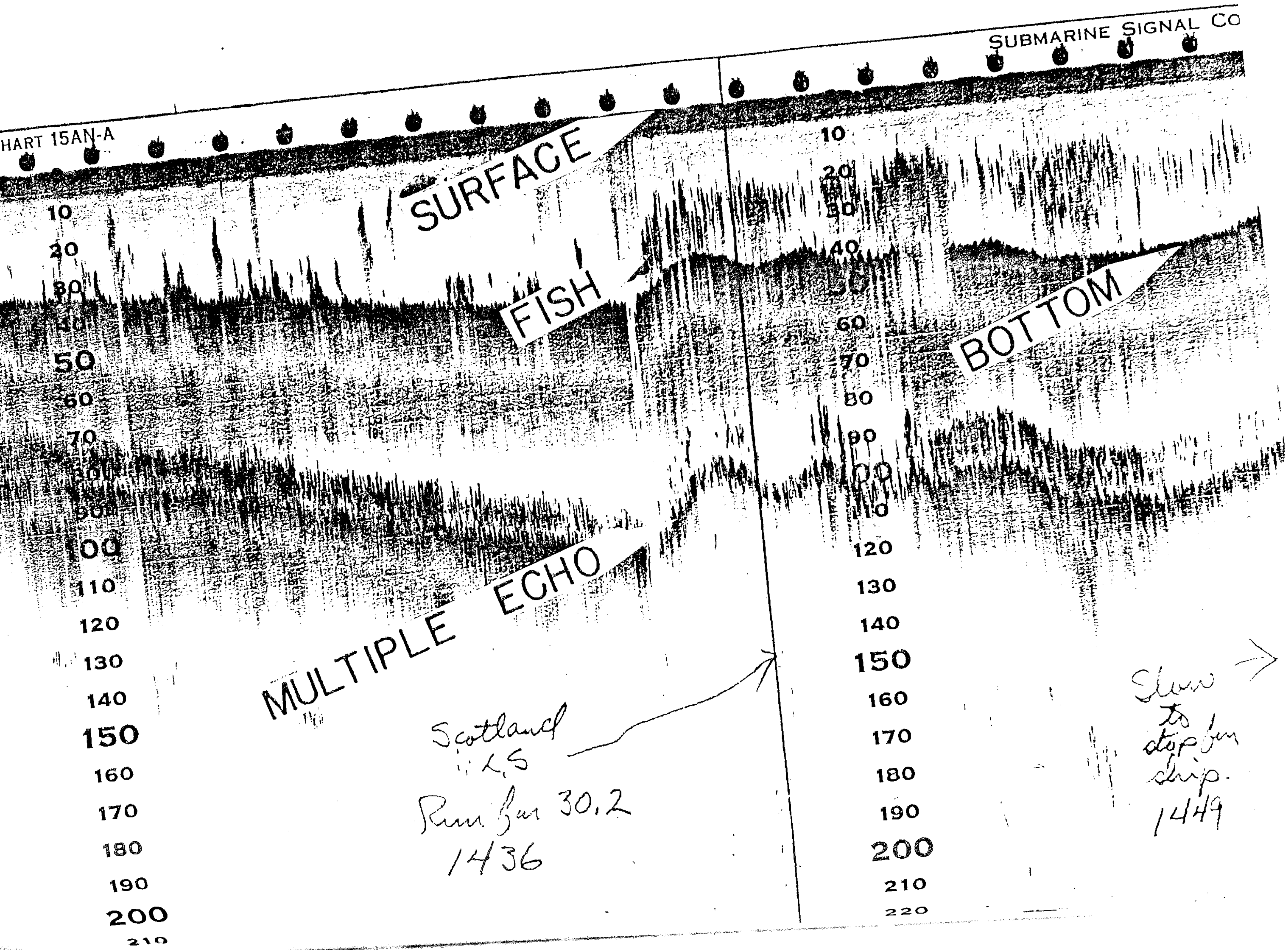
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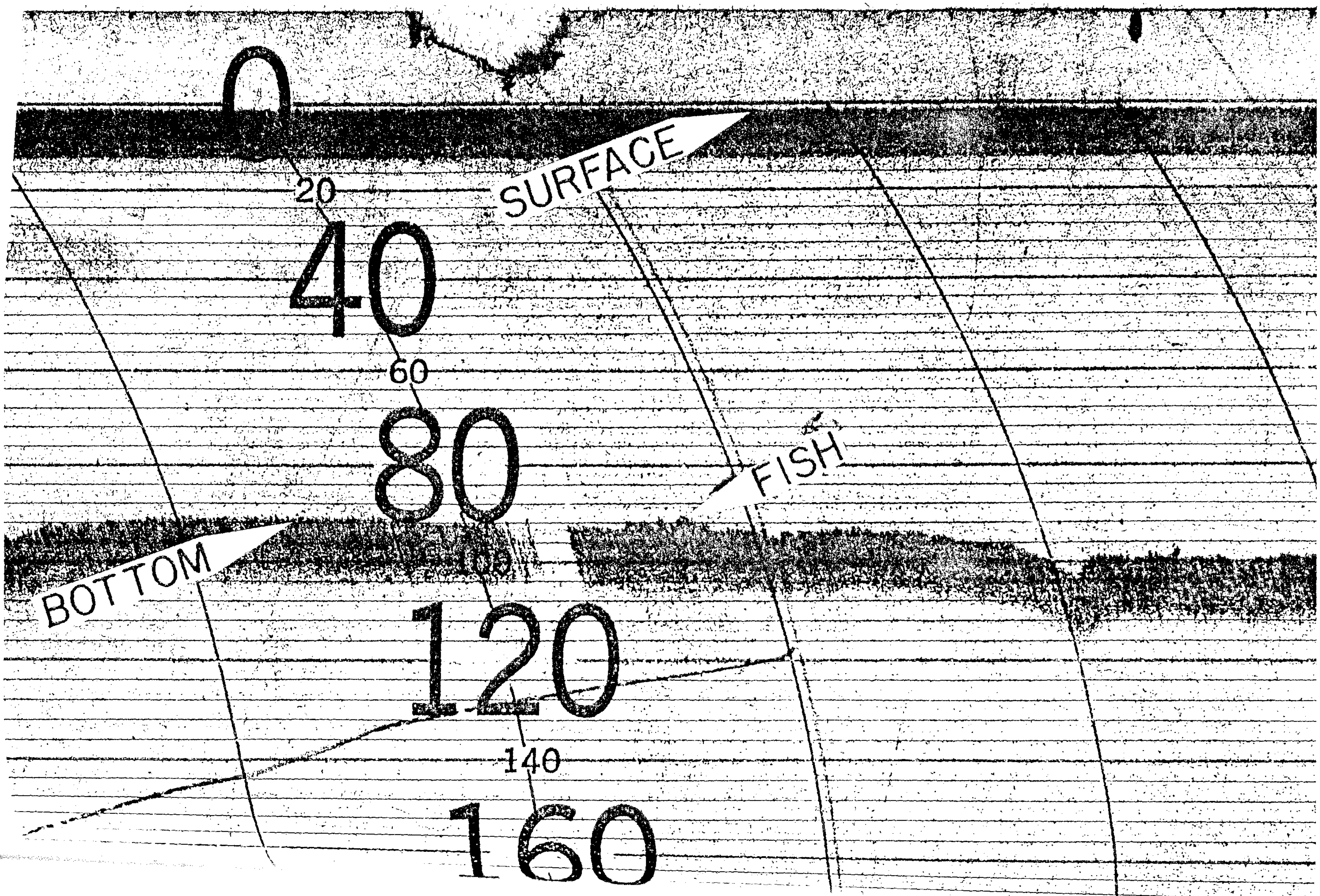
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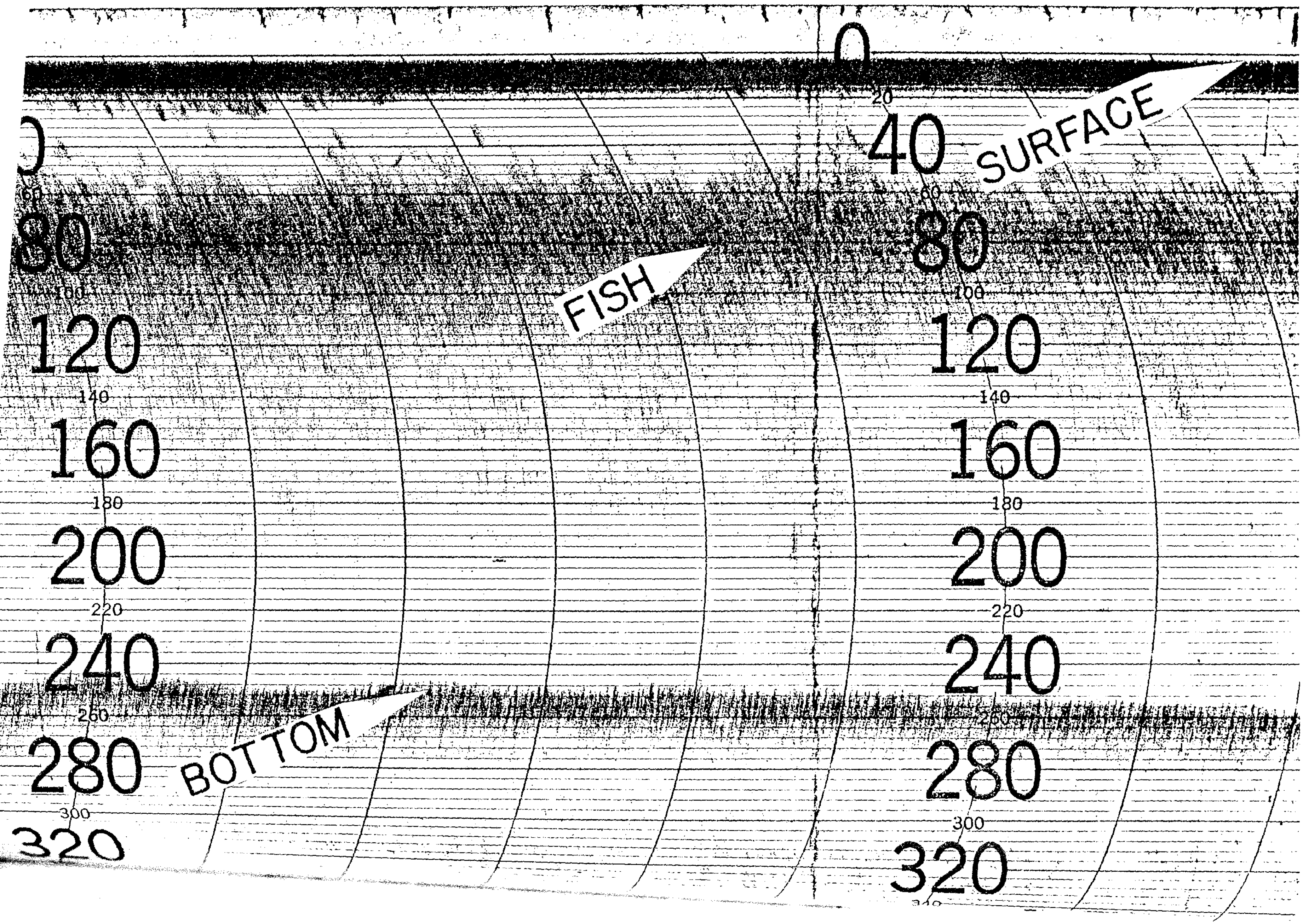
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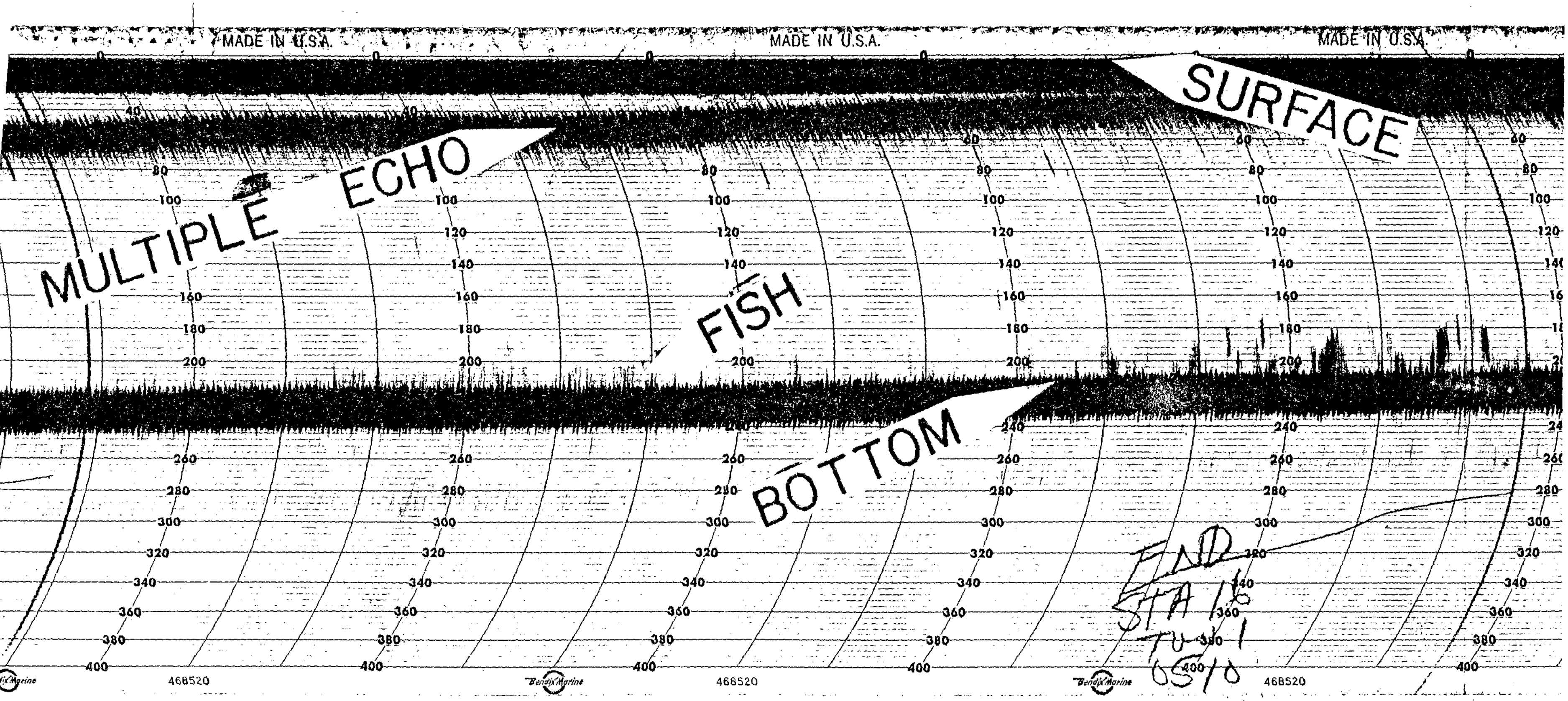
200
220
240
260
280
300
320
SURFACE
FISH
BOTTOM


MADE IN U.S.A.
SURFACE
MULTIPLE ECHO
FISH
BOTTOM
END
STA 16
468520

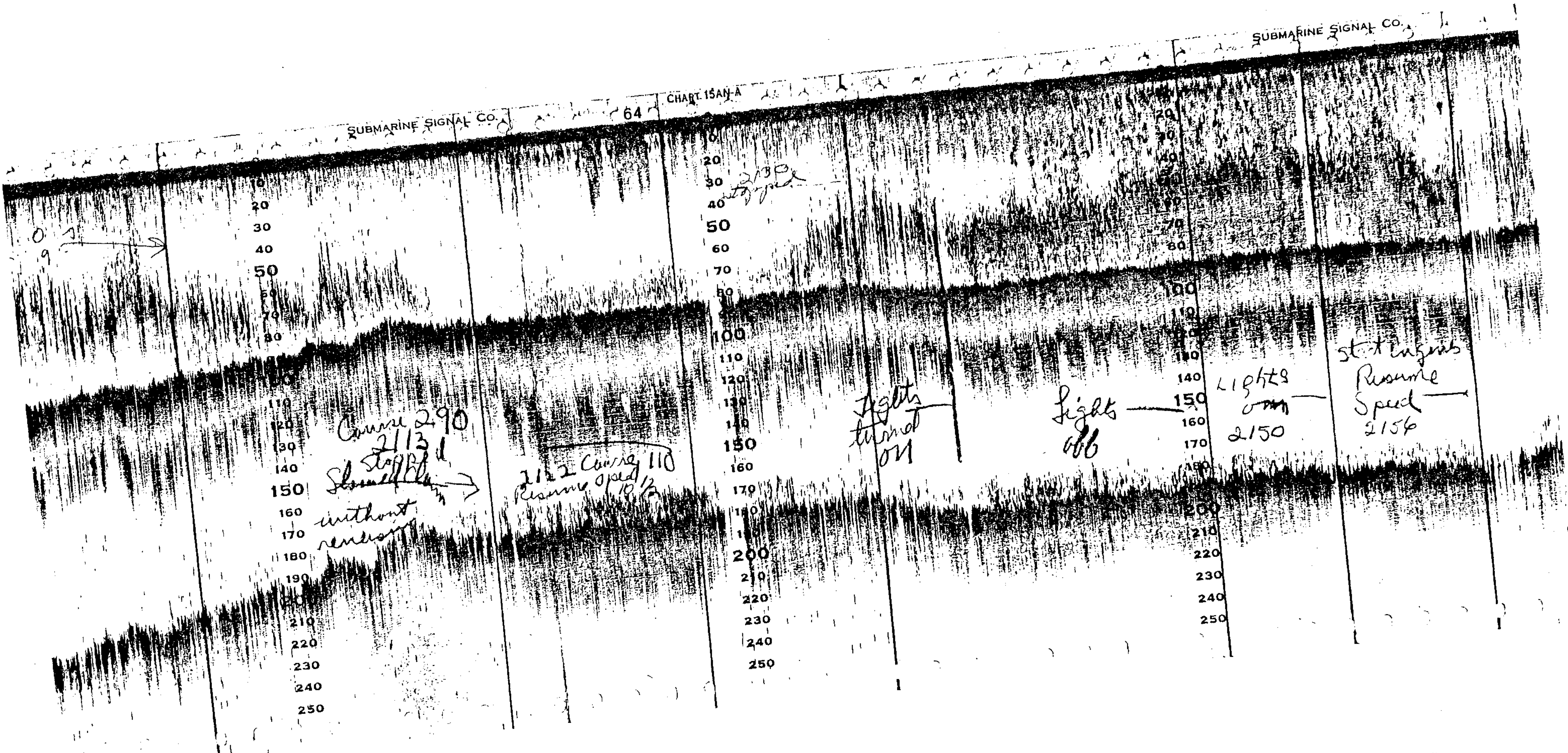
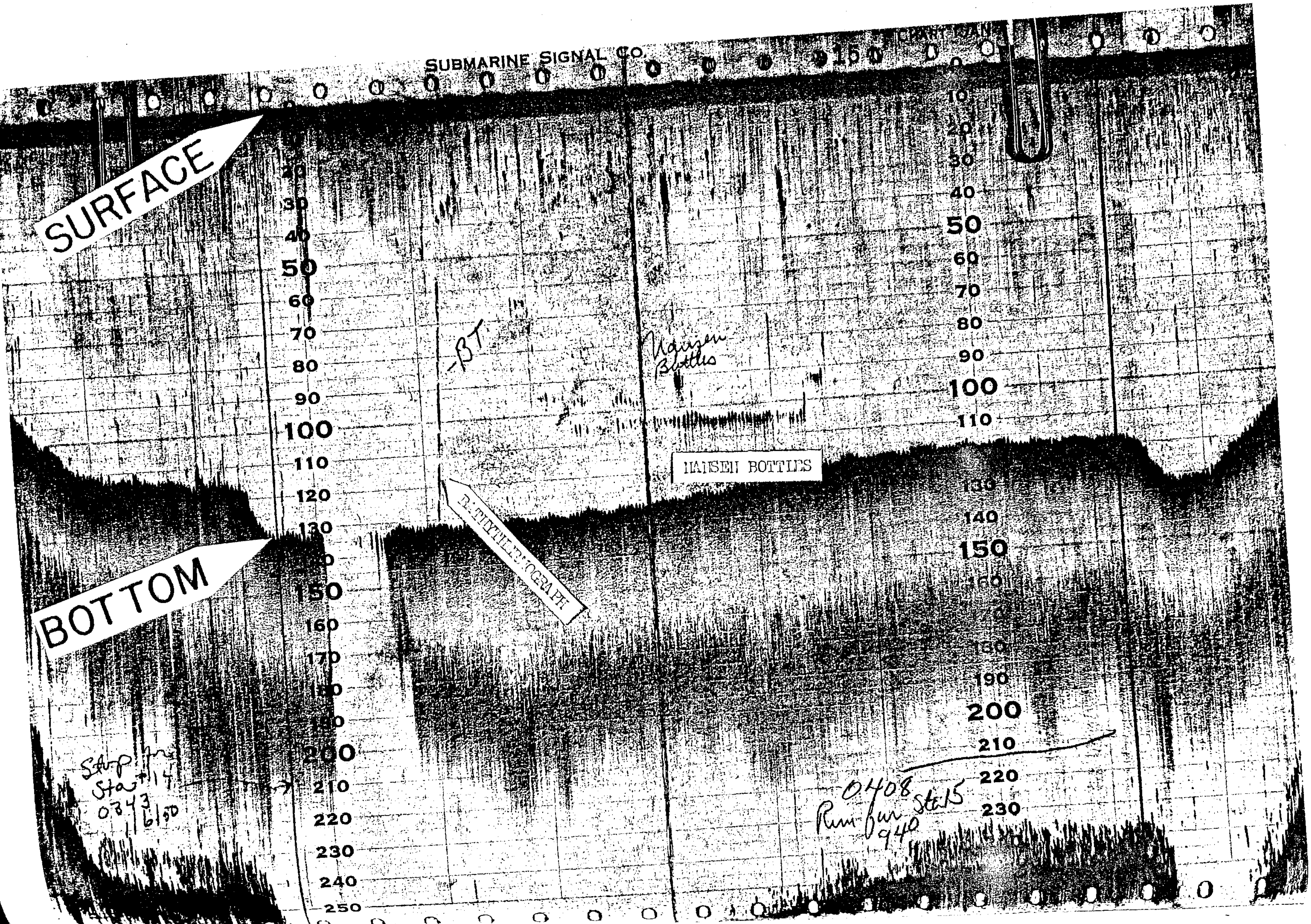
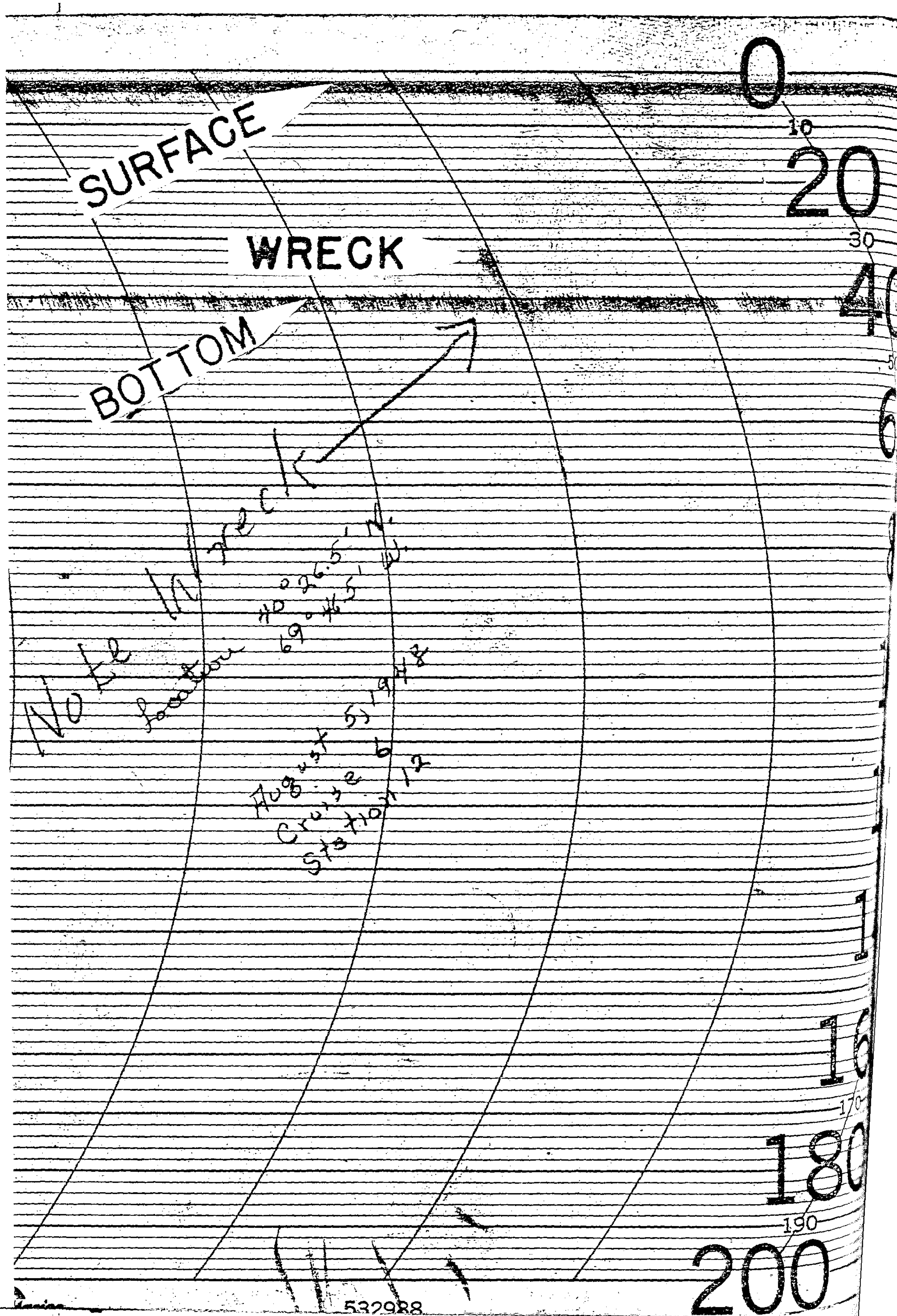
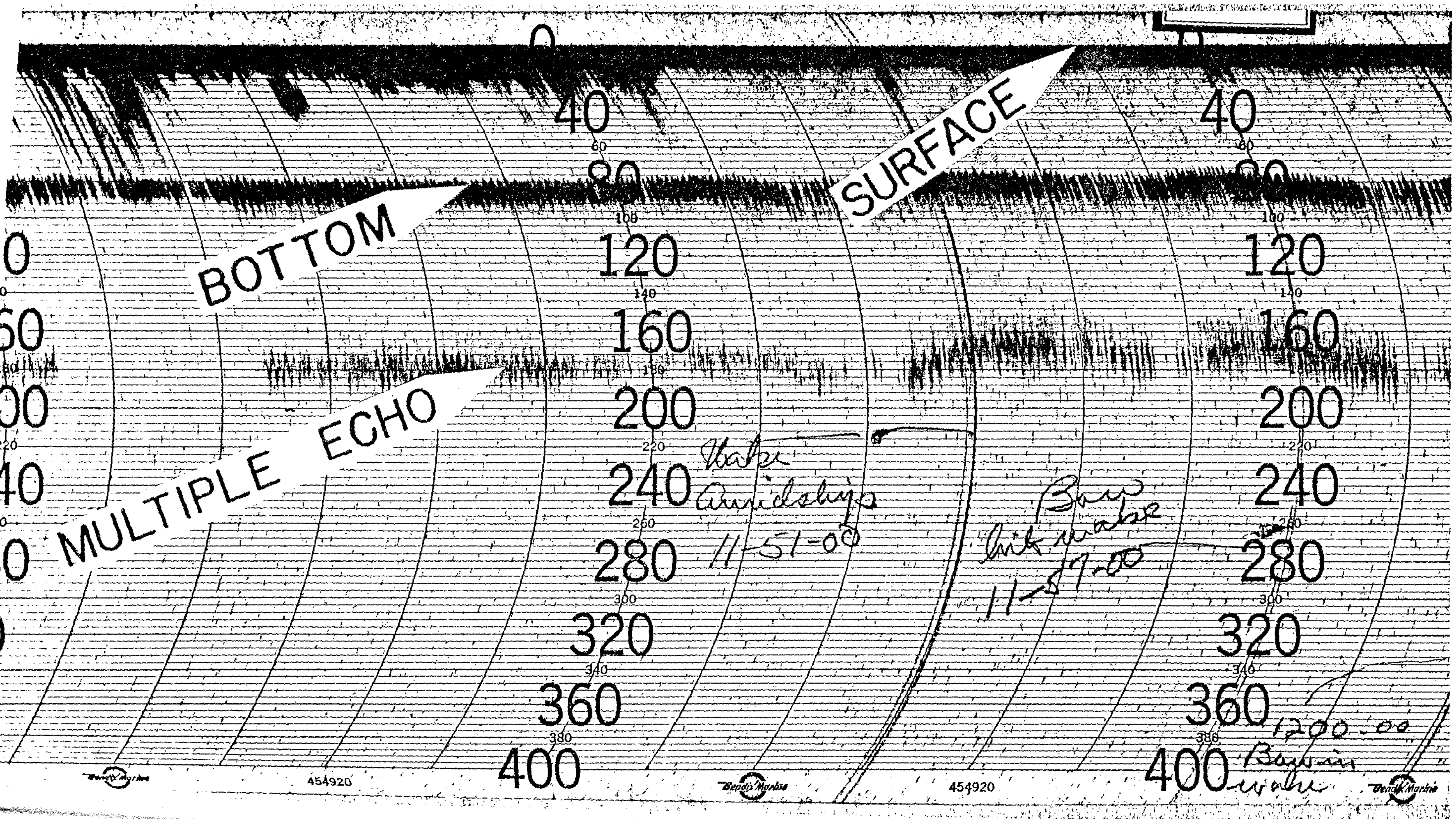
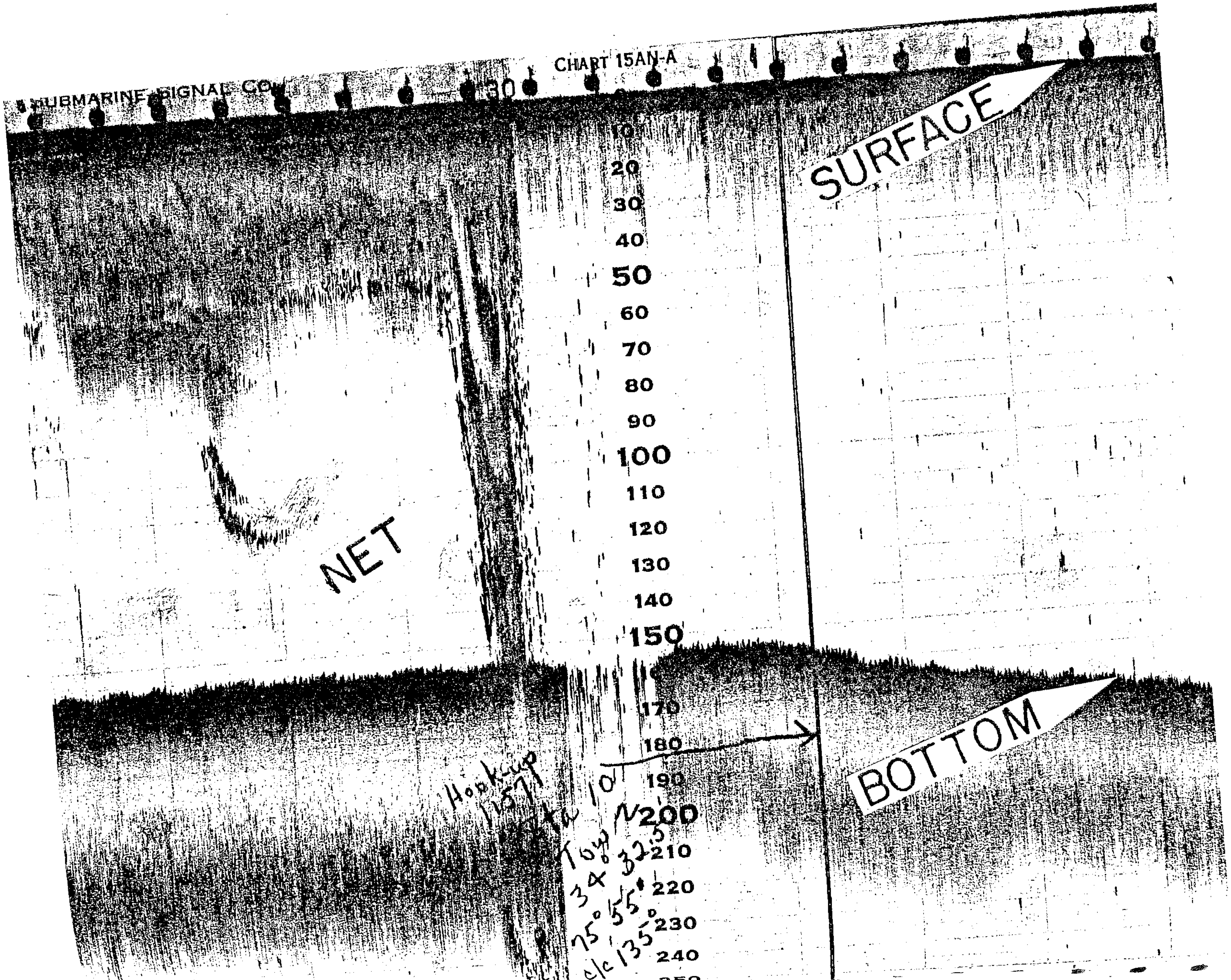


FIG. 11. Effect of light on a fish school.


SUBMARINE SIGNAL CO.
SURFACE
BOTTOM
HANSEN BOTTLES
BATHYTHERMOGRAPH
BT
Nansen Bottles
Stop for Sta #14 0343
0408 Run for Sta 15


SURFACE
WRECK
BOTTOM
0
10
20
30
170
180
190
200
Note Wreck
location 40° 26.5' N.
69° 46.5' W.
August 5, 1948
Cruise 6
Station 12
532988


SURFACE
BOTTOM
MULTIPLE ECHO
Wake
Amidships
11-51-00
Bow
into wake
11-57-00
1200-00
Bow in
wake
454920
454920


SUBMARINE SIGNAL CO
CHART 15AN-A
SURFACE
NET
BOTTOM
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
170
180
190
200
210
220
230
240
250