THE SUBMARINE SIGNAL Co PORTABLE DEPTH RECORDER.

by

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Recording ocean depths on a strip of paper to give a continuous profile of the bottom is not new. It was done by the French as early as, or before, 1922 and the Marti recorder has been described in great detail in French publications and in the International Hydrographic Bureau Special Publication N° 14, of August 1926. Commander K.T. ADAMS, U.S. Coast and Geodetic Survey, made a special trip on the "S.S. Oregon" in November 1931 to observe operations of such a recorder, and a copy of his report was published in Field Engineers Bulletin N° 4, December, 1931.

Consideration was given to the purchase of a French depth recorder in 1932 but certain patent complications made this unfeasible.

During the development of the Fathometer, I devised a plan for a recorder for use with the 312 type Fathometer in which repeaters for both the indicator and the recorder could be used at different parts of the ship. However, neither the manufacturers nor the public were interested in recorders at that time, so all efforts were concentrated on the improvement of the visual indicator.

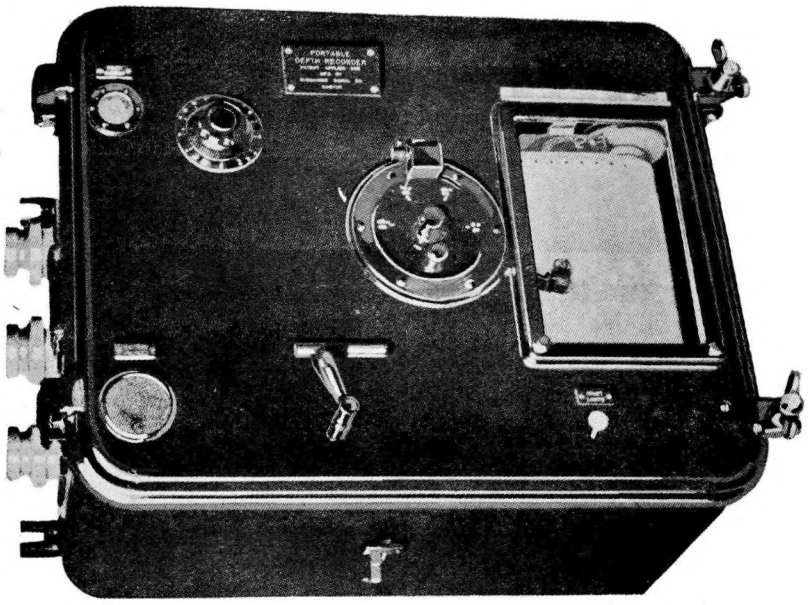
In the past few years, more and more favorable reports were received concerning the successful operation of a British depth recorder. Demonstrations witnessed by Captain G.T. RUDE and Lieutenant Paul A. SMITH led to the conclusion that this type of echo sounding machine had now reached the stage of development where it had practical use in hydrographic surveying.

Since echo sounding machines for launches are one of the most pressing needs of the Bureau, it was decided to include in the equipment for the new "*Explorer*" a depth recorder of a portable type which could be used in launches. Accordingly, specifications were drawn and bids invited. The following excerpts from the specifications show what was contemplated :

"It is the intent of these specifications to describe a complete, portable automatic-recording depth sounder, for use in hydrographic surveying, which is capable of producing clear, accurate, legible and permanent records of depth when the instrument is operated in a motor launch or other small boat from 24 feet to 32 feet long at any speed up to at least ten knots in all water depths between three feet and 90 feet in clear or muddy water which may be fresh, brackish, or salty.

"This recorder is to be used on small boats having no electrical power supply of their own and, consequently, must be capable of operating from storage batteries of not more than 12 volts which will furnish all power for operation. The total power consumed should not be over 250 watts. Each part shall be ruggedly constructed and seaworthy but also easily portable.

"The recorder mechanism shall be enclosed in a case which includes the recording paper, stylus for making the record, motors to drive all moving parts, take-up on paper roll, signal-sending contacts, motor governor to prevent variations of motor speed of more than a fraction of one per cent even with voltage variations of 20 to 30 per cent; a battery-operated motor generator to supply the high voltage for charging the condenser



Submarine Signal Co. — Portable Depth Recorder.

to send the signal and for anode supply in the amplifier. Also, any other parts necessary for smooth functioning to produce a reliable record in any depths from three feet to 90 feet under the sending and receiving oscillators.

"The recording mechanism shall be such that the record itself may be plainly seen at the time the depth is recorded and the accuracy of the recorder shall be such that the errors of recording shall be less than one foot in depths of 100 feet. Means shall be provided for making notes on the recording paper at the time the record is made or shortly thereafter; also for making a mark on the record by pressing a button to register the occurrence of any event, such as when a fix or surveying position is made".

The Submarine Signal Company of Boston, Massachusetts, was the successful bidder for the portable depth recorder, and a demonstration of a completed model aboard their experimental launch, the "*Rodman Swift*", on October 26, 1939, was witnessed by Captain G.T. RUDE, Lieutenant H.C. WARWICK, and me.

There are three parts for a complete recording system, an amplifier and recorder, an underwater unit, and a 12-volt storage battery.

The underwater unit consists of two identical rectangular bundles of nickel laminations, each interlaced with a few turns of rubber-covered wire. These are held in a brass casting inserted into a mahogany casing about eight inches square and 30 inches long with corners and ends rounded to make it streamlined. Each of these groups of nickel punchings acts as a magnetostriction device having a natural frequency of about 20,000 cycles per second, well above the audible range of most persons. One acts as a sender of compressional waves and the other as a receiver. They are only nine inches apart so that the error introduced by their separation will be very small even in the shoalest water. The brass compartment in which they are clamped is closed at the bottom by thin rectangular diaphragms; not watertight, however, since it is desirable to keep the laminations and wire windings wet. The wires are brought out through two pipe fittings at the top of the brass compartment. When in use, these wires are passed up through two iron pipes screwed into the pipe fittings, the pipes being secured to athwart-ship members so as to support the "fish", as the unit is called, in the water. In the demonstration the "fish", was placed about three feet under the surface of the water, a little aft of the amidship section and perhaps two feet outboard from the hull. The estimated weight is about 80 pounds out of water and about 30 pounds when submerged.

The recorder is housed in a cabinet 10 inches deep and 17 inches high by 21 inches wide, the longer dimension being in the direction of motion of the recording paper. This cabinet contains the entire recording element, paper, and amplifier. It is made of aluminium castings, with a glossy black finish and the cabinet, mechanism, and amplifier weigh about 125 pounds. It may be mounted on a vertical bulkhead or panel, or placed face up on deck or on a table. The latter method was used for the demonstration. The main door of the cabinet is hinged on the left, as one faces it, and accordingly opens from right to left. It is secured by two large and convenient wing nuts at the right side. A glass door near the right covers the recording paper, exposing the record as it is made and about 2-1/2 inches of the completed record which is automatically wound on a take-up reel at the right. Looking at the record in this position, with paper moving to the right, the profile of the bottom is disclosed in its natural position, that is, with the zero line or sea surface at the top of the record, which enables one to read depths readily without any mental gymnastics.

This cabinet is practically watertight and could probably endure rather severe weather, either rain or waves, without harm to paper or mechanism. Rubber gaskets are inserted in grooves around the edges of the main door and the glass door. The latter is secured by a thumb screw and when raised permits access to the record as noted above, on which may be made any desired notes either by pencil, black or colored, or by fountain pen. By leaning over the cabinet, when this glass door is opened to make brief notes, one's body would probably furnish sufficient protection to prevent the record from getting wet, even in a rather heavy rain.

All controls are mounted on the front of the cabinet door; they include the start-stop switch, a voltmeter to show battery voltage, a gear shift for changing from feet to fathoms, a phasing lever, the sensitivity control, a position marker, and the zero adjustment hand screw.

All of the moving mechanism is mounted on the inner surface of the door; the driving motor, governor, gear box rotating arm, contractor, and a motor generator supplying 300 volts used for B-battery current for the amplifier, and which also actuates the magnetostriction sender. The driving motor operates a train of gears to rotate the arm and contactor approximately 11 times per second at fast speed and 1/6 that at slow speed. The rotating arm of 4.5-inch radius carries at its end a stylus of fine steel piano wire which sweeps across the recording paper in an arc. A condenser is charged continuously through a resistor by the 300 volts from the motor generator. Once each revolution, contactors are closed by the rotating arm, normally at the instant the steel wire passes the zero of the paper scale. These contactors discharge the condenser into the magnetostriction sender, producing a short pulse of vibrations at the rate of 20,000 per second and thus the signal is sent. The position of the contactors, with reference to the zero of the scale may be changed in two ways. Slight adjustment may be made by means of a knurled thumb screw while the machine is running, so that the record on the paper may be easily and quickly adjusted to the exact zero, or if desired, to a position fixing depths from the water surface, thus compensating for the draft of the "fish".

At the high speed (11 soundings per second) the scale reads from zero to 55 feet or at slow speed it would be zero to 55 fathoms. Suppose, however, that the contactors were advanced in the cycle of rotation, so that the signal was sent the equivalent of 35 feet (or fathoms) before the stylus reached the zero of the paper scale; the scale then would read depths between 35 and 90 feet (or fathoms). This advancing of the contactors is called "phasing" and it is accomplished on the face of the indicator simply by lifting a little knob and turning an arm to the respective phase desired, there being four phases in all, 0 to 55, 35 to 90, 70 to 125, and 105 to 160 feet or fathoms. This knob has a plunger which drops into a hole when the pointer is moved to the selected setting so that there is no danger of not having the exact position. Each phase overlaps the preceding by 20 feet (or fathoms) so that no soundings need be lost when changing from one phase to another. The phase may be shifted quickly from any position to another either forward or backward. No mark at the zero of the paper is made except for the zero to 55 scale. Even then the zero mark may be suppressed by a switch, so that the zero marking will not interfere with extremely shoal depths, for example, depths less than three feet under the "fish".

The recording paper is a standard type used in some of the facsimile systems. It has a black body coated with a light gray surface. It is seven inches wide with 6-1/4 inches of the width ruled into 55 sub-divisions, each representing one foot or one fathom depending on which speed is used. Since the scale must lie along the arc of a circle due to the rotating arm, the graduations are closer together near the edges, but the distance between lines, measured along the arc is 1/8 inch. The ruled lines and four numerical scales of depth, 0 to 55, 35 to 90, 70 to 125, and 105 to 160 are printed on the gray surface with black ink. The numerals of the individual scales are about 1-1/4 inches apart and are repeated in the sequence stated above. Regardless of which scale is being used the printed numerals will always be within 2-1/2 inches of any point of the record, facilitating easy reading. This does not apply to the visible portion of the record while being made, since the linear length of only about 2-1/2 inches is then exposed to view. However, every fifth line is printed heavier than the others, and as the observer should know which phase is being used and as proximate figures of separate scales differ by 15, it is easy to read the actual depth. It is, of course, necessary to mark on the record at the time, which phase is being used. Depths recorded in fathoms are readily distinguished from those in feet, the former being blacker and the trace of the stylus, along its natural arc, shorter.

The record is actually produced in a rather unique manner. The magnetostriction receiver is connected to an amplifier which is located inside the cabinet of the recorder. This greatly simplifies the wiring, there being only two wires running into the cabinet from the battery, sender, and receiver. The amplifier is a three-stage tuned push-pull type, completely shielded, with a total of six tubes having their six-volt heaters grouped in three pairs in series on the 12-volt storage battery. No other batteries are required as all other voltages are supplied from the motor generator. This is extremely convenient as there are no dry batteries to deteriorate gradually and be forgotten until trouble appears, such as frequently happens with "C" batteries. The total load on the battery is ten amperes (120 watts). With maximum gain the amplifier is sensitive to 0.2 microvolt. A graduated gain control knob is located on the front of the cabinet door. The echo is amplified until the third pair of tubes develops a voltage of about 180 volts across an output transformer. This voltage is applied between the stylus and the metal plate under the paper so that a series

of sparks of diminishing intensity pass through the paper at the time the signal is sent, and upon reception of the echo. These sparks either burn off the gray surface of the paper or disintegrate it so as to leave the black paper visible, as though a series of closely spaced dots had been made in black on the gray surface. The dots are scarcely discernible unless magnified and consequently the record appears as a rather broad band with more or less smooth contour at top depending on the roughness of the bottom passed over, as shown in the reproduction of some of the trial records. No trigger tube action is used such as that in the Fathometer to produce the red light, and the intensity of the record appears to be proportional to the strength of the echo. Second echo records were fainter than those of first echoes and decreasing the gain decreases the intensity. Rubbing the face of the paper with a pencil eraser will remove the gray surface, exposing the black beneath. The sparks from the stylus are visible in dim illumination. A small lamp may be switched on to view the record. Position fixes may be recorded by pressing a button at the left side of the cabinet face and when this is done one or two revolutions of the rotating arm produce a black arc clear across the record.

The paper moves about two inches per minute under the stylus. Thus a 50-foot roll of paper will last for five hours when soundings in feet are being recorded or 30 hours for soundings in fathoms.

The paper is used dry, with no treatment before or after recording. The new roll is placed in a convenient holder beneath the rotating arm whence it passes across the recording plate to an automatic take-up reel at the right. These rolls are readily accessible by opening the cabinet door, to which the holders are secured inside. Tests were made in the Chart Division of the Survey to determine how much the dimensions of the paper changed with variations in humidity. From "bone" dry to normal humidity the change in width was 0.6 mm.; from dry to saturation by steam it was 1.5 mm. In terms of the scale this would mean 0.6 foot in 55 feet or 0.6 fathom in 55 fathoms or a trifle more than one per cent change, under extremes probably never encountered in practice.

Excessive heat does not seem to affect the color, Even burning a hole with a cigarette only darkens the paper about a sixteenth inch around the hole. The black back has a slight tendency to rub off on white objects or one's hands. Some facsimile paper has the back coated with thin aluminum and it is probable that some way of overcoming the smudging quality may be found.

The speed of the motor is controlled by a governor built by Leeds & Northrup of Philadelphia. This is a highly reliable type of centrifugal governor which has been tested and proved its reliability on delicate instruments used by the federal government. The governor is enclosed and its adjustment cannot be changed unless the motor is stopped. No device is used to show that the motor is running at its correct speed. However, by changing the gear to slow speed the revolutions may be easily counted while timing by a stop watch. An accuracy of timing of at least one per cent should be attained over a three-minute period. If this is not a sufficiently accurate method of checking the speed, or if it proves desirable to have a continuous check, it will be a simple matter to install somewhere on the cabinet a vibratory tachometer, mechanically operated, such as have been used on the 312 Fathometers. These are accurate to about three parts in 1,000 and have given excellent service. With the yearly check-up which is now standard practice, they probably give the most constant and accurate indication of correct speed attainable without going to a complicated system involving a tuning fork.

The *Rodman Swift* moved around the harbor at five to six knots crossing and recrossing a dredged channel in a depth range of about 15 to 55 feet and passed through the wakes of several steamers. Gears were shifted, phase changed, sensitivity varied, positions "marked"; nothing went wrong. I listened particularly for changes in motor speed when shifting from low to high gear but could detect none whatever.

"Bar-checks" were made by lowering a thin aluminum plate covered by a rubber pad to different fixed distances from three feet to 16 feet below the "fish". The various depths gave corresponding values on the record. The aluminum plate was very convenient. The sheet of rubber was necessary to reflect the sound, as it would otherwise go right through the aluminum without sufficient reflection.

The entire construction appears to be first class. It is ruggedly built and finely finished. There is no crowding of the various parts and all seem readily accessible. I predict for it a brilliant future in coastal surveys.