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HYDROGRAPHY

CONSTRUCTION AND OPERATION OF THE WIRE DRAG AND SWEEP

By

LIEUT. COMMANDER J. H. HAWLEY
U. S. Coast and Geodetic Survey

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PREFACE

The United States Coast and Geodetic Survey began the survey of our coastal waters with the wire drag in 1904 and has carried on the work continuously since that time. The first apparatus was patterned after the drag used at that time by the Corps of Engineers, United States Army, on the Great Lakes, which in turn was an improved form of the long-rope sweep introduced by French hydrographers. The Survey has gradually developed and perfected the equipment and methods used for this work until at the present time the improved wire drag is a very efficient mechanism. Two modifications of the drag, known as the light-wire drag and the wire sweep, have also been devised. Under certain conditions the use of the sweep in conjunction with the drag results in a considerable increase in speed and reduction in cost of this class of survey work.

The earlier developments of the drag to meet the requirements for coast work are described in Appendix 6, Report of the Superintendent of the Coast and Geodetic Survey for 1905, and in Appendix 7 of the report for 1907. The Description of the Long Wire Drag, published in 1910, a revised edition published in 1914, and the Construction and Operation of the Wire Drag, published in 1919, give the general details concerning equipment and methods used up to the dates mentioned. On account of the improvements effected during the past five years and the recent development of the light-wire drag and the wire sweep, a new publication is necessary.

The Survey receives frequent requests for information concerning the details of its wire-drag work from foreign countries, other organizations of our Government, and from private interests. To supply such information to all those who may desire it and to standardize in so far as possible the drag and sweep operations of this bureau, having in mind the widely differing conditions and special problems encountered in the various localities where such work is required, is the object of this publication. The equipment and methods of operation used for the standard wire drag, the light-wire drag, and the wire sweep will be described in the order named. Specifications for various items of equipment are given in the appendix.

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CONSTRUCTION AND OPERATION OF THE WIRE DRAG AND SWEEP

THE STANDARD WIRE DRAG

INTRODUCTION

The wire drag was adopted as a means of supplementing standard methods of hydrographic surveying, whereby it would be possible to discover and chart all obstructions of small extent, such as pinnacle rocks, bowlders, sharp ledges, and coral formations. Such obstructions are especially dangerous to navigation, and it had become evident that it is only by chance that they are found during the course of an ordinary hydrographic survey by which soundings are obtained only at certain points over a given area.

As the result of successive improvements the drag is now adapted to the different requirements of three classes of work—first, to determine whether or not apparently clear water areas are free from obstructions; second, to find all obstructions in a shoal area; third, to develop the maximum safe depth in a channel.

The drag has been used on the coasts of New England, Florida, Porto Rico, and the Virgin Islands; on the Pacific coast, on the coast and inside waters of Alaska, and in the approaches to the Panama Canal. That it fulfills its purpose is shown by the fact that in the 6,000 square miles of water area dragged to date about 4,000 unknown obstructions have been discovered.

CONSTRUCTION

The wire drag (lower part of fig. 1) consists of a wire, called the bottom wire, maintained at any desired distance below the water surface by weights suspended by cables from buoys that float on the surface. The wire is made up in 100-foot units with a special open socket at each end. Any desired length of bottom wire is obtained by connecting these units with swivels. A heavy weight is attached to the bottom wire at each end of the drag and smaller weights at intervals of from 300 to 600 feet, depending on the nature of the work and the total length of drag.

The cables, or uprights as they are called, connecting weights and buoys are graduated in feet and pass through a center pipe to a hoist on the top of each buoy, so that the distance of the wire below the surface can be adjusted at any time to conform to the bottom contours, as shown by leadline surveys, and to the rise and fall of the tide.

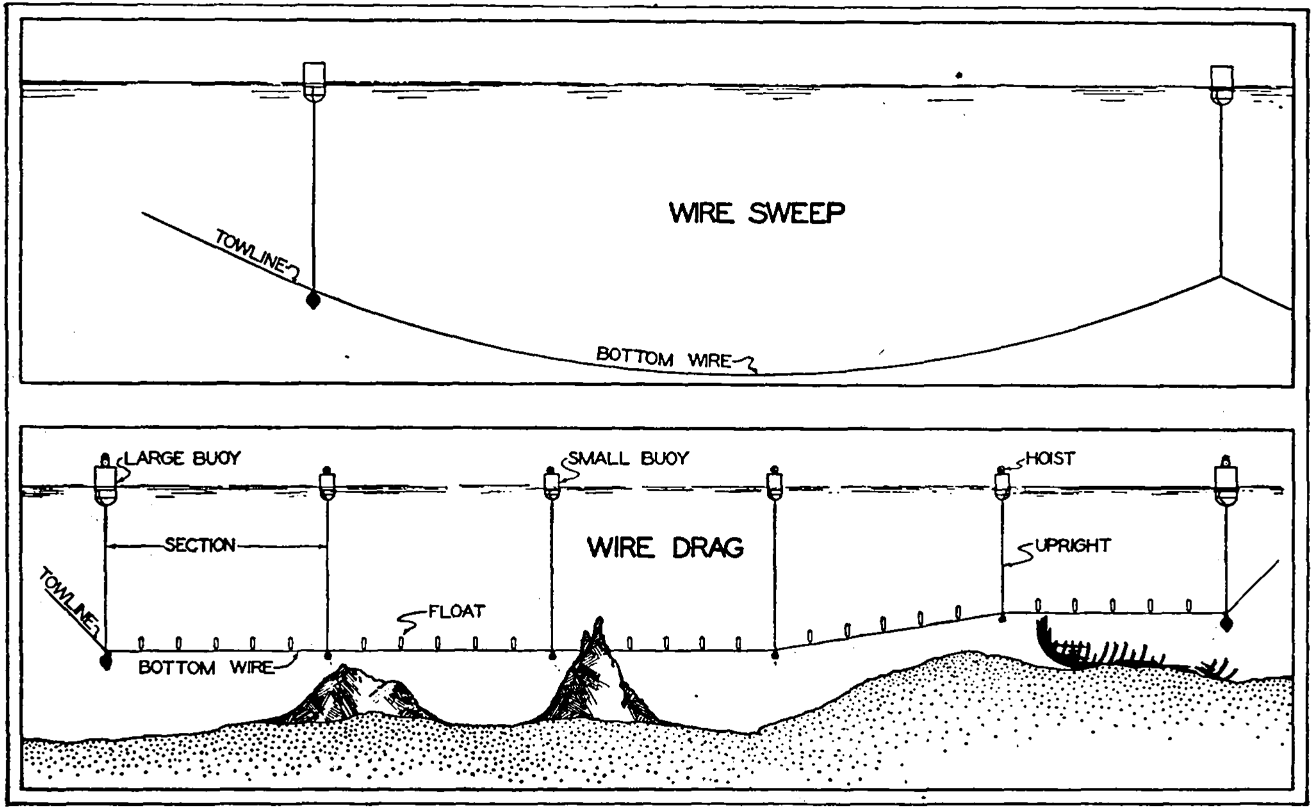


FIG. 1.—Wire drag and sweep construction diagrams

Metal floats that will just support the weight of 100 feet of wire are attached at each swivel connection between the weights. When the drag is towed and the wire is under tension their action is negligible, but when the drag is not under way they keep the wire from sagging and catching on the bottom.

For the sake of clearness the following definitions of terms used in wire-drag work are given:

Length of upright.—The distance from the water line of a buoy, when the drag is at rest, to the point of attachment of the upright to the bottom wire.

Drag depth.—The distance between the water surface and the bottom wire when the drag is under way.

Effective depth.—The distance between the plane of reference, such as mean low water, and the bottom wire when the drag is under way.

Length of drag.—The length of bottom wire between ends of drag.

Section.—That part of the drag between two adjacent uprights.

Unit.—The part of the bottom wire between sockets that break its continuity.

BOTTOM WIRE

Double-galvanized, 7-strand steel wire is used for the bottom wire. One-eighth-inch diameter wire, having a tensile strength of about 1,850 pounds, is a very convenient size to handle and can be used to advantage with towing launches not over 60 feet in length in regions where the currents are moderate. Under other conditions wire three-sixteenths of an inch in diameter, with double the tensile strength, will give more satisfactory service.

This wire, which can be obtained in any continuous length desired, is cut up into 100-foot lengths and a special drop-forged open socket (fig. 2) is attached at each end by the Roebling method. In this method the end of the wire is passed through the socket and seized with fine wire at a distance back from the end equal to the length of the butt of the socket. The wires beyond the seizing are then unstranded and bent out radially from the seizing. After removing the galvanizing from these wires by immersion in acid, they are drawn back into the socket and the butt is filled with pure commercial zinc melted in a ladle. After the zinc has cooled a light tap with a hammer on the end of the socket will drive it back on the wire so that the zinc cone on the end of the wire can be inspected. This method will not give satisfactory results unless the galvanizing is entirely removed by the acid. This can be tested by dipping the wires in the ladle containing the melted zinc. If the acid action has been sufficient the wires will come out entirely coated with zinc, which will not adhere to a galvanized surface. This test should be made not only to insure complete acid action but also to prevent oxidation of the wire during the period between the removal from the acid and the pouring of the zinc. It is important to make sure that there is no moisture in the sockets before pouring the zinc, as the sudden generation of steam will cause the spelter to fly in all directions. As an additional precaution all men should wear gloves and goggles when making up this wire.

Bottom-wire units are connected by galvanized, drop-forged steel swivels, one-fourth-inch swivels being used for the one-eighth-inch wire and five-sixteenths-inch swivels for the larger wire. To facilitate attachment of floats and weights, a link about 3 inches long of round steel having the same diameter as the swivel is welded into one of the eyes of each swivel. This link in conjunction with the hinged staple weight affords the most convenient and the quickest method of attaching the weights when setting out the drag. It is difficult, however, to provide a link as strong as the other parts of the bottom wire connection; and when the maximum strength of bottom wire is desired, as in regions where large towing vessels are used or strong currents encountered, it is best to omit this and attach the weight by means of a shackle that will slip over the waist of the swivel but not over the swivel eye on either side. Both connections are shown in Figure 10. When the bottom-wire units are connected all swivels should be oiled and tested to make sure that they turn freely.

LARGE AND SMALL WEIGHTS

The shape and dimensions of the large weight, which weighs 180 pounds, are shown in Figure 2. This weight is a cast-iron sphere with one flat surface to prevent rolling about deck in a seaway. While only one staple is required for attaching this weight at each end of the drag, two are provided for convenience in handling.

The small weight (fig. 2) weighs 35 pounds. For attachment to the wire, one side of the staple is formed by a hinged steel rod. A slotted brass sleeve slides on this rod and fits into a section of galvanized pipe cast in the sphere. When the pin in the rod engages the right-hand slot the sleeve can be lifted far enough to swing clear. When the staple is closed the sleeve is turned so that the pin engages the left-hand slot, thus locking the staple. When the shackle connection is used a solid staple can be provided at less expense.

LARGE AND SMALL BUOYS

The large buoy (fig. 3) is a standard, galvanized, 55-gallon, gasoline drum modified by the installation of a 1½-inch, double strength, black-iron central pipe, a rounded wooden bottom, and a hoist for adjusting the length of upright. The pipe can be installed at small expense by any machine shop or by the field party if provided with a few tools. A method for installing this pipe is given in the appendix. The wooden bottom serves to decrease the resistance of the buoy when being towed through the water. It can be turned to shape or hewed with an adz, the latter method being preferable as turning opens the pores of the wood. The bottom is waterproofed by boiling in oil. A short section of pipe suitably inserted through a hole in the wood serves as a continuation of the buoy pipe. This bottom is attached to the drum by three or four vertical straps of 1-inch iron, nailed to the wood and riveted to a horizontal strap of the same material that passes around the drum just above the lower corrugation, being held in place by one bolt in the same manner as a hose clamp.

Specifications and drawing of the large buoy hoist are given in the appendix. This hoist is placed on the top of the buoy, with

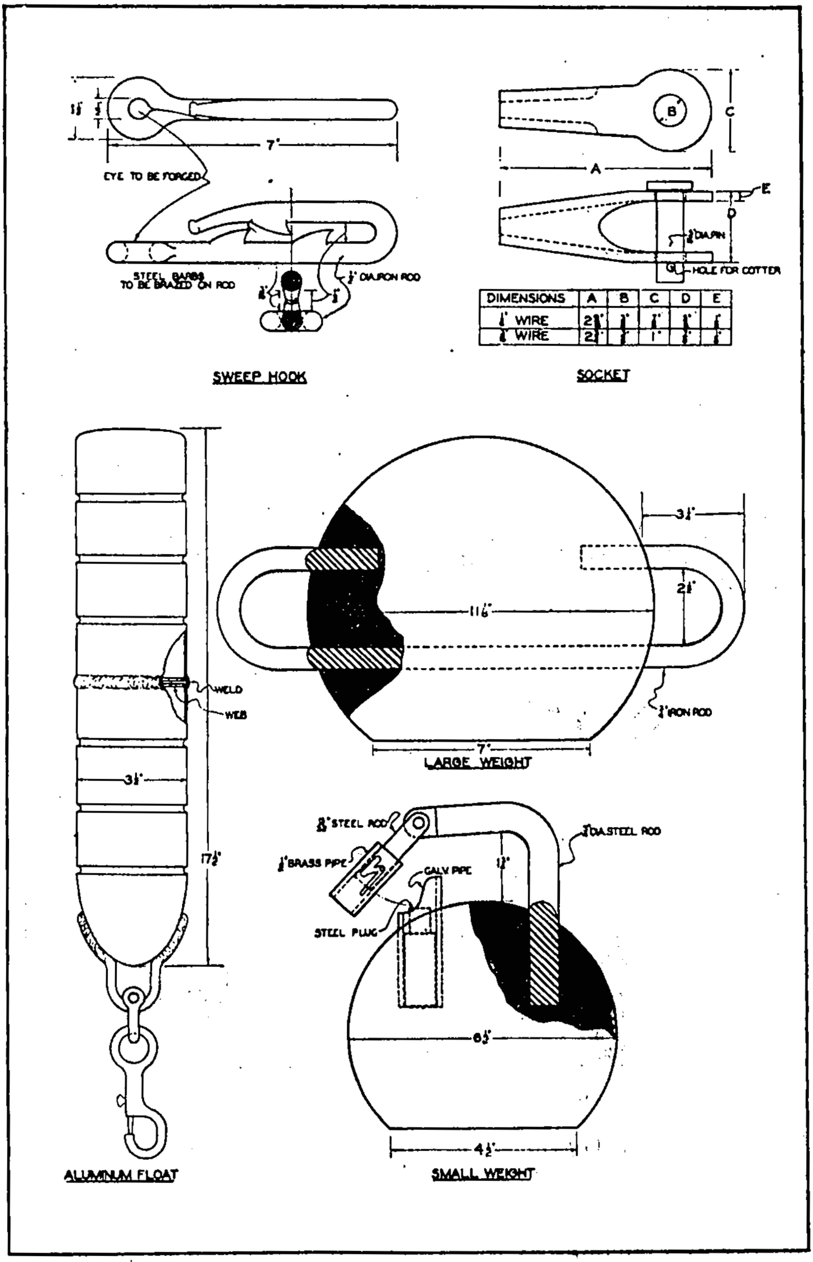


Fig. 2.—Socket, float, sweep hook, large and small weights

the center pipe projecting up through the hole in its base, and is secured by a nut on the center pipe. The hoist is operated by turning the upper shaft with a removable crank. To give a good bearing surface a wooden washer is provided between the hoist and the top of the drum. Best results will be obtained with a washer of 2 by 12 inch planking cut with rounded ends so that it will extend entirely across the top and fit closely inside the rim of the drum, with its lower side dished out slightly to conform to the top of the drum.

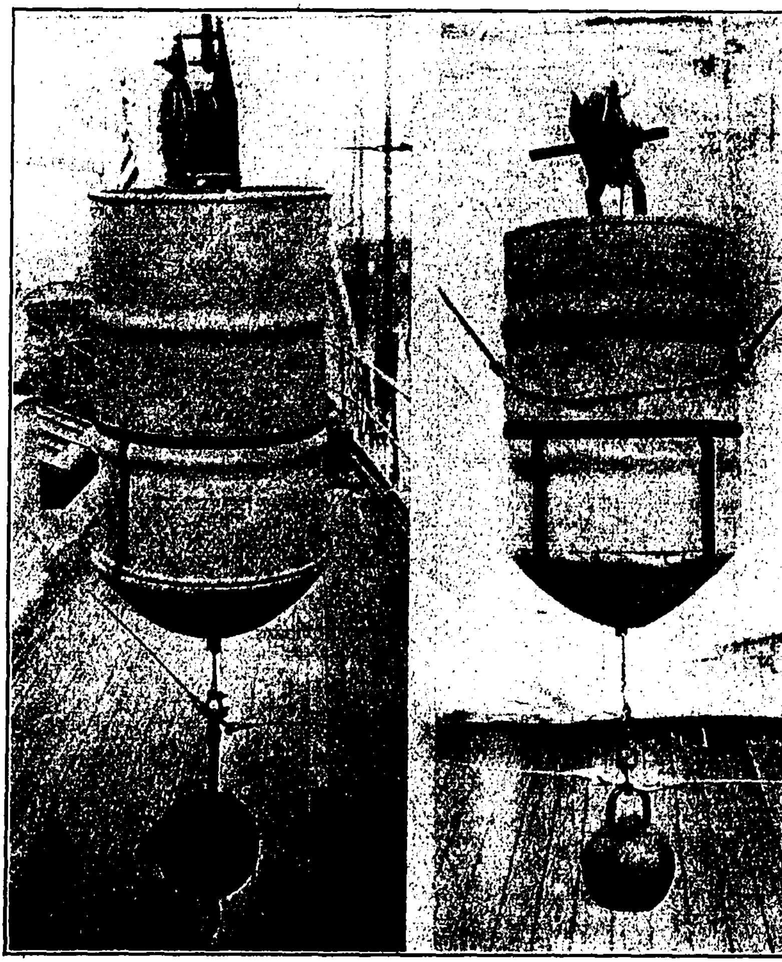


FIG. 3.—Large and small buoys, weights, and uprights

The small buoy (fig. 3) is a standard 15-gallon oil drum altered in exactly the same manner as the large buoy. These drums are not very strong and offer little resistance against crushing if the buoy is submerged. Under certain conditions, therefore, as when dragging in strong currents, it is desirable to provide an automobile-tire air valve and to compress the air in the buoy. If the center pipe is installed properly and the bung plugs of the can provided with well-leaded gaskets, these buoys will hold compressed air with little loss of pressure for at least one week. The pressure should be from

15 to 20 pounds to the square inch. A double-acting hand tire pump and a low-pressure tire gauge may be used for this purpose.

Specifications and drawing of the small buoy hoist are given in the appendix. It is attached in the same manner as the large buoy hoist and is operated by turning the main shaft with a removable crank. Rope lanyards are attached to all buoys to secure them when making depth changes.

Motorcycle type external contracting brakes have been used to replace the ratchets and dogs on the small buoy hoists. The brake drum is keyed to the main shaft of the small hoist while the brake band and lever are attached to the frame of the hoist. When the brake is applied it is locked by a steel latch that engages the brake lever. When skillfully handled the use of this device will result in some saving of time required for making changes in length of upright. It is important, however, that an adjustable latch be provided and care taken to compensate as often as may be necessary for wear of the brake lining, as otherwise the locking will not be reliable.

Experiments have also been made with the object of improving the large buoy hoist by using a worm gear to replace the upper shaft and gear, but these have not yet been completed.

FLOATS

The standard float of proper size for the one-eighth inch bottom wire is shown in Figure 2. It is constructed of aluminum plate and is strengthened by corrugations and an internal web, as it must stand submerging to 150 feet without crushing. The float is attached to the drag by a No. 1 swivel eye, tinned, harness snaphook, shackled to the small bale at the end of the float with a one-fourth inch galvanized screw anchor shackle.

If metal floats can not be obtained, wooden floats, preferably of well-dried cedar, can be used. These should be waterproofed by treating with oil before using. With maximum depths of drag the wooden floats become water-logged very quickly and at best their buoyancy is changing constantly. As a single water-logged float on the drag may cause the wire to sag and catch below the drag depth, it is desirable, before dragging close to bottom with wooden floats, to test them by coiling up a unit of bottom wire and ascertaining whether or not each float will support the coil in the water.

UPRIGHTS

The total length of each upright should be equal to the maximum effective depth of drag required, plus the maximum height of tide in the region where work is to be done, plus an allowance of about 5 feet for lift. For work in Alaska an upright 110 feet long is provided.

For the large buoy upright galvanized aircraft cord, one-fourth inch in diameter, made up of 7 strands of 7 wires each, is used. This cord has sufficient strength and flexibility and is small enough so that an upright 110 feet long can be wound on the hoist sheave.

For the small buoy upright, either three thirty-seconds-inch galvanized aircraft cord, made up of 6 strands of 7 wires each and a cotton center; or three-sixteenths, extra-flexible, steel-wire rope made up of 6 strands of 19 wires each and a hemp center, is used. The advantages of the former are that the entire upright can be wound on the hoist sheave and that the small cross section offers little resistance against towing through the water. The cord, however, is not so durable as the wire rope and is harder to handle in the operation of clearing the drag from shoals. In regions where the equipment receives hard usage, due to strong currents, ice fields, or other conditions, or where the discovery of numerous shoals may be expected, the wire rope will give more satisfactory service.

Only about 65 feet of the wire rope can be placed on the hoist sheave, and for drag depths over this length one or two supplemental fixed-length uprights, to be attached to the lower end of the regular upright, are provided. The lengths of these supplemental uprights depend on the nature of the work, but one 20 and another 30 feet long for each buoy will usually suffice.

At the lower end of each upright a five-sixteenths-inch, galvanized, drop-forged swivel is attached with a served clove hitch. All uprights are graduated in feet. As the reference point on all buoys is the top of the central pipe, the graduation should start at a distance above the swivel equal to the height of the pipe top above the surface of the water when the drag is at rest. (See definition of length of upright.)

Beginning with this point as zero the upright is graduated by placing paint marks about 3 inches long every 10 feet in accordance with the following scheme:

Color	Feet	Feet	Feet
Red	0	50	100
White	10	60	110
Blue	20	70	
Red-white	30	80	
White-blue	40	90	

The foot is in the middle of the painted mark for single colors and at the junction for the two color marks. Short red paint marks divide each 10-foot section into 2-foot lengths.

Experiments have been made with the idea of supplementing the upright graduation by installing a registering sheave on each hoist in such a manner that the length of upright will be shown by an indicator.

TOWLINES

The towline is simply a continuation of the bottom wire from each end of the drag up to the towing vessels. A towline from 300 to 500 feet long is used, depending upon conditions that will be discussed later. When single-vessel control is used an invariable towline base is secured by adding an upper bridle to the end-launch towline. This is formed by one or two 100-foot units of bottom wire, one end being attached to the large buoy and the other to the towline connection 100 or 200 feet from the large weight. For attachment to the towline a special hook, called a sweep hook (fig. 2) is shackled to the end of the bridle.

DRAG LENGTHS

Lengths of drag under 3,000 feet are rarely used except in channels of less width, clean-up work alongshore, or final examination of shoals. The following table gives information relative to drag lengths in ordinary use:

Length of drag	Length of section	Effective width	Conditions
	Feet	*Feet*	
Less than 3,000 feet	300	----------	Narrow channels.
3,000 feet	300	2,700	Very broken bottom.
4,000 feet	400	3,600	Broken bottom.
5,000 feet	500	4,500	Fairly clear bottom.
6,000 feet and over	600	----------	Deep water.

Lengths of drag over 6,000 feet are usually 9,000, 12,000, and 15,000 feet, depending on the area to be covered, current conditions, etc. A drag 24,000 feet long, towed by four launches, has been used, but the above lengths are about all that can be handled with the two towing launches generally available.

LIST OF PARTS

The following list gives the amount, cost, and life of equipment required for a 15,000-foot drag with no spare parts, using the stronger wire and wire-rope uprights. Costs vary considerably and the life of equipment depends on the nature of the work and other conditions, so that the information under these headings is given only to convey a rough idea of these subjects. There will be some decrease in cost when the smaller wire is used, as the wire, floats, and fittings with all cost less. The amount of spare equipment required depends on the nature of the work and the distance from dealers or other sources of supply. Under ordinary conditions, when the maximum length is used infrequently and replacements can be made without undue delay, one additional large buoy, two large weights, double the amount of upright material, and a 10 per cent surplus of other items will probably be ample. The paint marks on the uprights become indistinct with use and it is desirable to have two complete sets on hand so that one can be repainted while the other is in use.

Quantity	Article	Cost		Life
		Unit	Total	
16,200 feet	Bottom wire, 3/16-inch	\$0.016	\$259.20	12 months.
2	Large weights	10.00	20.00	Indefinite.
24	Small weights	6.00	144.00	Do.
2	Large buoys, complete	40.00	80.00	24 months.
24	Small buoys, complete	15.00	300.00	12 months.
6	Buoy cranks	1.50	9.00	Indefinite.
145	Floats	4.00	580.00	24 months.
3,000 feet	3/16-inch wire rope	.05	150.00	6 months.
324	Sockets	.385	124.74	24 months.
250	3/16-inch swivels	.30	75.00	Indefinite.
200	Harness snap hooks	.12	24.00	12 months.
2	Sweep hooks	1.00	2.00	Indefinite.
4	Towline hooks	1.00	4.00	Do.
145	¼-inch shackles	.20	29.00	Do.
30	Shackles [1]	.30	9.00	Do.
Total			1,809.94	

[1] These shackles are used to attach the weight and upright to the bottom wire. As the dimensions of swivels and shackles vary somewhat, it is necessary to select a shackle of suitable size to slip over the waist, but not over the eyes, of the swivel used.

TOWING VESSELS

The selection of towing vessels depends, of course, on the floating equipment available, and also to a large extent on the nature of the work and the locality where it is done. The most economical arrangement is to have a shore party carry on the work, using two launches about 60 feet long for towing the drag. This is feasible in thickly settled regions where harbors and towns are available, so that the run between port and working ground does not require much more than an average time of one hour. In localities where this arrangement is impracticable it is usually best to provide towing vessels large enough to house the party. This can be done by replacing one of the launches with a suitably designed vessel about 100 feet in length. The overhead expense mounts rapidly with the increase in size of the vessels, but in this case there is some compensation, due to the fact that the party can use anchorages near the work and utilize more of the day for effective work.

Another condition is encountered when a survey ship carries on extensive wire-drag work in conjunction with other surveying operations. In this case it will usually be found advantageous to provide two towing launches but to use the ship, if suitable for such work, at one end of the drag and the second launch for other work, except in special cases, as when dragging in close quarters or in very strong currents, when the ship and second launch can change places temporarily. The advantages of so using the ship are that the work can be supervised more closely by the chief of party, long runs to and from the work are avoided, and the machine tools and a part of the crew of the ship are always available for repair and maintenance work on the drag equipment.

The vessel from which the work is directed is called the "guide" and the other the "end launch or vessel."

A description of the launch designed by the survey for its drag work when carried on by shore parties will give an idea of the requirements. The outboard profile of this launch is shown in Figure 4. Its dimensions are: Length, 60 feet; beam, 14 feet; draft, 3 feet 7 inches; depth, 7 feet; freeboard, forward, 6 feet 9 inches; freeboard, aft, 4 feet. It has a flush deck with pilot house forward and is strongly constructed of southern pine. It has quarters forward for two men and a large hold for storage of equipment when the party changes headquarters. It is propelled by two 40-horsepower, 4-cycle, 4-cylinder gasoline engines and has a speed of about 10 knots. Ample power for towing is usually furnished by one engine, while on runs to and from the work both engines are available to increase the speed and reduce the unproductive part of the day's work. This launch, or a smaller launch of the same type, can be used for the end launch, but the length of the end launch should not be less than 40 feet and it should have the same speed as the guide launch.

When the members of a party are housed on the towing vessels or when launches are used by a survey ship to carry on wire-drag work in conjunction with other operations it is desirable to modify the launch design to provide living quarters for about two officers and six men. In these cases a large hold for carrying equipment is not essential.

In addition to sturdy construction, ample power, and speed, the important features of a satisfactory wire-drag launch are an

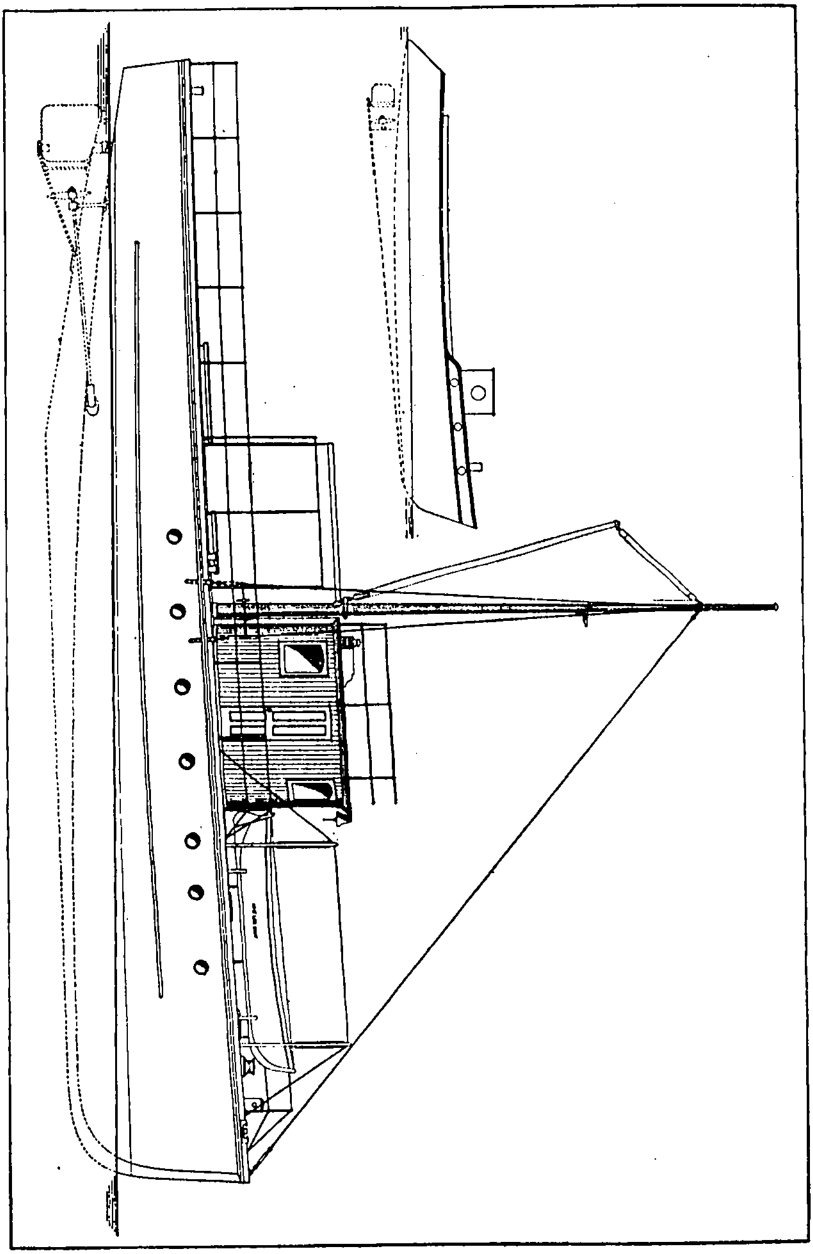


FIG. 4.—Outboard profiles of wire-drag launch and tender

arrangement for pilot-house control of the engine so that one man can handle the launch while setting out and taking in drag, location of exhaust where the exhaust vapors will not interfere with observing and plotting angles, and as much clear deck space as possible, especially near the stern.

AUXILIARY LAUNCHES

In addition to the two towing vessels, a small launch is used as a tender to patrol the drag, change its depth, sound on shoals, clear it from shoals, remove fishing gear from its path, etc. In regions where numerous shoals are found it is desirable to provide one or two small dinghies, equipped with engines, called sounding tenders, to sound on shoals, assist the tender, etc. Time on shoals can then be reduced as their approximate position can be marked with buoys soon after the drag grounds, after which the drag can be cleared and proceed while the small boats remain to complete the examination.

The tender should be an open launch of the ablest possible type, as it must stand considerable rough weather and be capable of replacing one of the towing vessels in emergencies. When a survey ship is used at one end of the drag it is very desirable to provide a tender that can be hoisted. The outboard profile of the tender adopted by the survey is shown in Figure 4. This launch has a small cruiser cabin forward, a self-bailing cockpit, and is heavily constructed. Its dimensions are: Length, 30 feet 2 inches; beam, 7 feet 8 inches; draft, 3 feet 2 inches. It is propelled by one 28-horsepower, 4-cycle, 4-cylinder gasoline engine.

The sounding tenders should be of the dinghy type, 14 to 16 feet long, propelled by a 2-horsepower gasoline engine, and equipped with oars.

OPERATING EQUIPMENT

The greater part of the operating equipment is installed on the towing vessels. This consists of power winches for setting out and taking in drag, an arrangement of platforms and rollers at the bow and stern over which the wire passes, signaling apparatus, buoy racks, drafting table, and miscellaneous items.

The arrangement of equipment on one of the special wire-drag launches is shown in Figure 5. This may be considered the standard installation, subject to any modification that may be necessary when vessels of different size or deck plan are used. Specifications and drawing of the winch are given in the appendix. It is driven by a 7-horsepower stationary gasoline engine of the double flywheel, make-and-break ignition type, installed in the hold. On vessels with limited hold space the engine can be installed on the same deck as the winch. On steam vessels a standard steam cargo winch with extra wide flanges, installed in the most suitable position, can be used.

The platforms holding the rollers should be constructed of durable wood and securely bolted to the deck. Timbers 4 inches square, spaced about 18 inches from center to center, form the fore and aft sides of the platforms. The horizontal rollers may be of hardwood or of pipe with end plugs and should have a diameter of at least 4 inches. Probably the most satisfactory roller is specially constructed of cast iron. It is spool shaped, is hollow and has a center

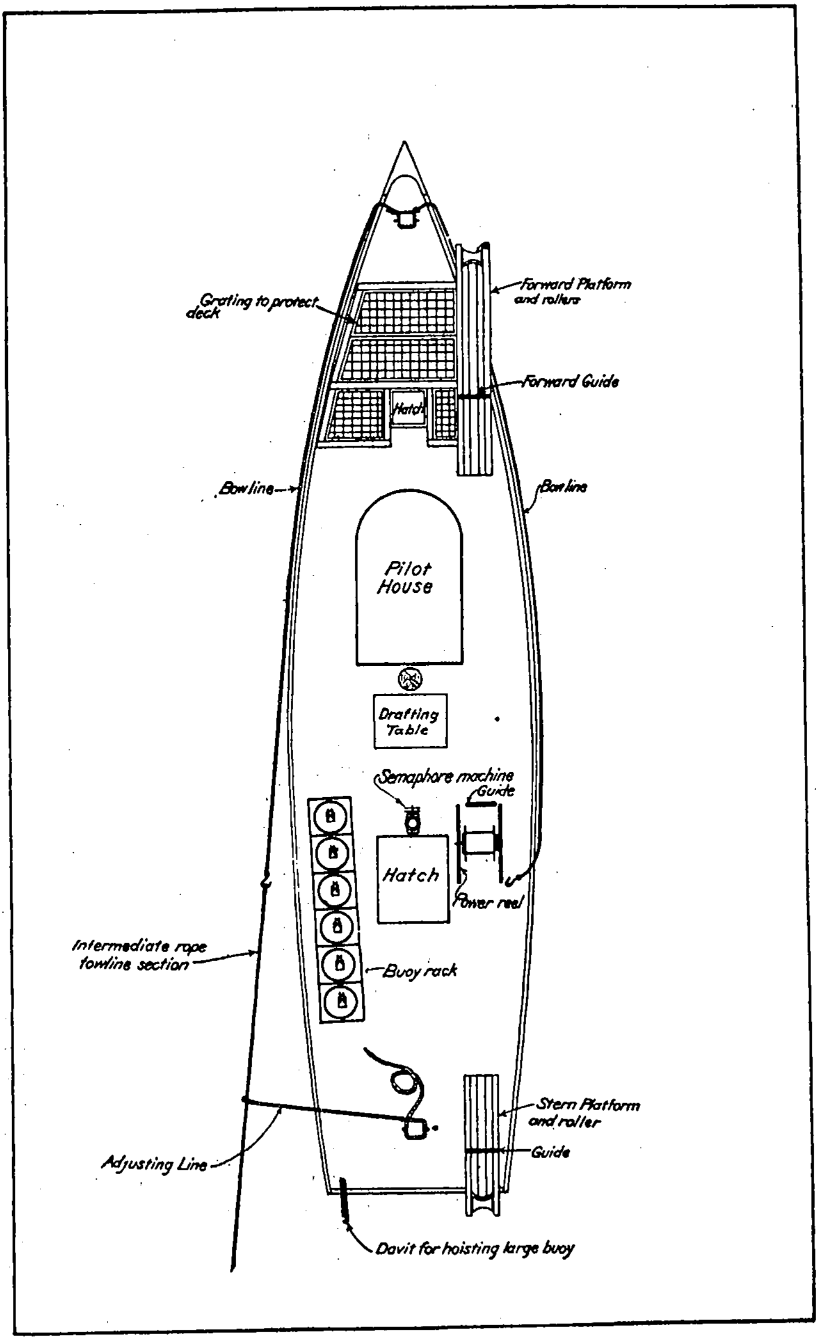


FIG. 5.—Arrangement of equipment on guide vessel

diameter of from 6 to 12 inches, increasing to from 10 to 18 inches at the ends, depending on the size of the vessel.

To prevent the wire from passing over sharp corners, curved horizontal and vertical outboard fenders of pipe or hardwood are installed on the forward platform. For protection of floats, the forward platform should be padded with old rope or coir matting. At a distance of about 3 feet back from the after roller and 6 feet from the forward roller inverted U-shaped guides of 1-inch pipe or solid iron are provided to prevent the wire, when slack, from flying off the platforms. A similar guide is installed just forward of the winch.

An automatic winder, based on the principle of the sewing-machine bobbin winder, has been devised to distribute the wire evenly on the winch drum when taking in the drag. While this apparatus is not essential its use tends to prevent the wire from catching under the fittings when setting out drag with resulting delay or possible damage to the wire.

On moderate-sized launches a wire-rope bowline is provided on each side. This line is made fast at the bow and entends to a point about 10 feet aft of amidships. A steel hook is spliced to the after end of each bowline for connecting the towline. An adjusting line of 1¾-inch rope with a sweep hook at one end extends from the towline to the stern of the towing vessel and is used to distribute the towing strain and to lift the towline clear of the propeller when necessary. If the drag catches on a shoal when working in a strong current, it is sometimes desirable to avoid excessive strains by detaching the towline immediately, and this may be necessary in order to avoid a collision with another vessel or for other reasons. It is therefore advisable to attach each bowline at the bow with a manila-rope strap that can be cut in emergencies. On larger towing vessels the towline can be attached to a bitt, a little forward of amidships on either side, by means of a slip line, to one end of which is attached a claw hook that will slip over the wire and bring up against the socket at the end of the towline.

The buoy rack is constructed of wood or of pipe and fittings to hold from five to nine small buoys. It should be designed in such a manner that the buoys can be set to the desired depth at the beginning of the day without removing them from the rack.

The launches should be equipped with an ample supply of swivels, shackles, and other fittings, pliers, chain books, buoy cranks, lead lines, etc. The guide vessel should carry several spare buoys, weights, bottom-wire units, and other parts.

The tender should carry a spare small buoy and weight, several bottom-wire units, spare fittings, lead line, drag tester, buoy cranks, grapnel, shoal-marking buoy, sextant, record book, and a copy of the signal code. On the New England coast a power lobster-pot hoist may be installed for removing such fishing gear from the path of the drag. On one of the tenders used by the survey a flexible shaft connected with the main engine by means of a differential clutch has been successfully used to transmit power to operate a sounding machine and adjust the length of the uprights.

When the drag is taken in, the floats sometimes strike against the forward platform and become detached, in which case the towing vessel passes them close by. There is also a possibility of floats being detached when the wire slides along a shoal, and in either case it is difficult to recover them with a boat hook or other means that may be available. For this purpose it is desirable to provide each towing vessel and tender with a strong landing net, having a hoop about 18 inches in diameter and a 10-foot handle. Such a net also will be found useful for passing records between boats and thus avoiding too close an approach in rough seas.

It is necessary to provide several small buoys of the anchor-buoy type for miscellaneous use such as buoying the end of a towline when detached, marking shoals temporarily, etc. For this purpose the pneumatic canvas buoy, described later in connection with the light-wire drag, is very satisfactory. These buoys are light and easy to handle, have great resistance against crushing, and will not damage the planking of any boat that might collide with them in a seaway.

The sounding tenders should carry lead lines, buoy cranks, marking buoy, sextant, record book, and signal code. All tenders should be provided with water-tight boxes for holding instruments.

OPERATION OF DRAG

When the drag is towed through the water it is obvious that a certain strip, bounded on either side by the paths of the large end buoys, which are directly over the ends of the drag, is covered; and that any obstruction between the end buoys extending above the plane described by the bottom wire will interfere with the progress of the drag (figs. 1 and 7). To survey a certain area, it is necessary to completely cover the area with a system of overlapping strips, with drags set at suitable depths, so that all obstructions therein will be discovered, or it will be proved that the area is free from such obstructions. For most efficient operation of the apparatus described in the preceding pages the following are necessary:

1. A trained organization of officers and men.
2. A system of control, including suitable instruments, for obtaining and plotting the paths of the drag and the locations of all obstructions found.
3. A complete signal system for communication between towing vessels and tenders.
4. A smooth sheet on which can be plotted the drag strips, obstructions found, and effective depths obtained; and one or two similar sheets, called boat sheets, for use on the towing vessels for directing the movements of the drag, depth changes, etc.
5. Tide predictions to show the approximate stage of the tide at any time and all available data regarding depths in the area to be surveyed.
6. A method for the complete recording of all operations, angles, etc.

ORGANIZATION

The usual party organization is as follows: Guide vessel, 2 or 3 officers, engineer, recorder, coxswain, line tender; end vessel, 1 or 2 officers, engineer, coxswain, line tender; tender, drag master, engineer; sounding tender, 1 officer, 1 engineer.

CONTROL SYSTEM

For drags up to 6,000 feet in length two methods of control are available. One method is known as "single-vessel control," by which the guide vessel, supplied with the only boat sheet used,

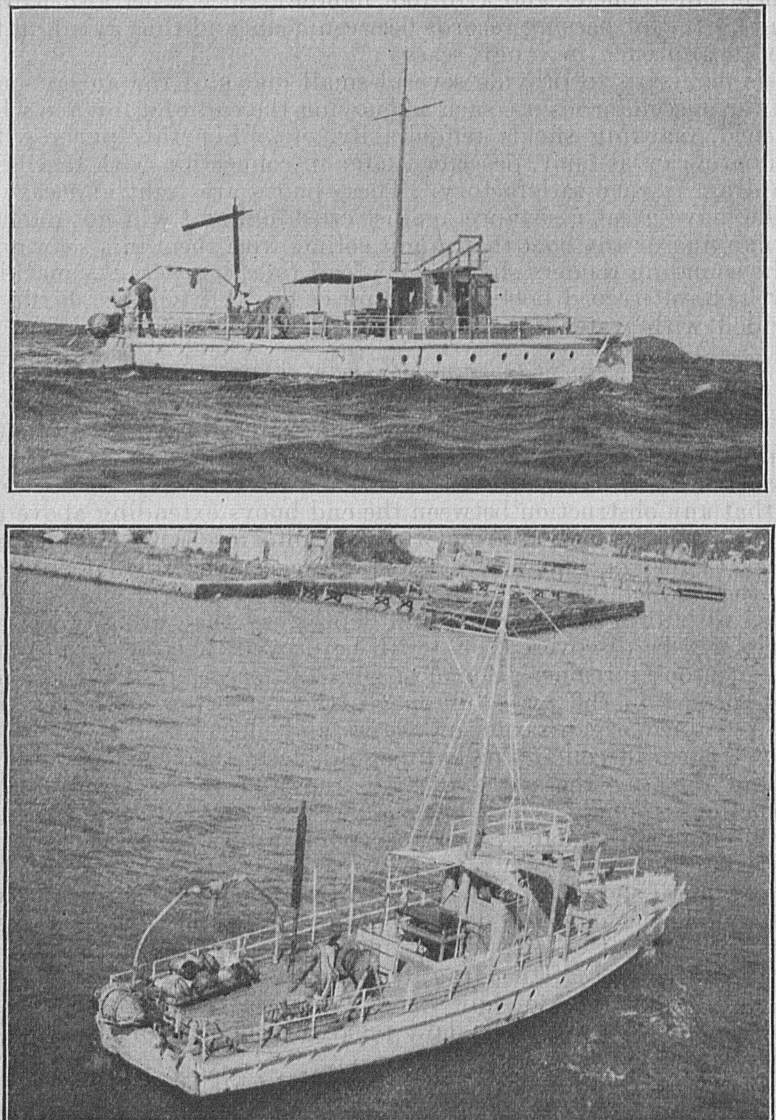


FIG. 6.—Wire-drag launch

obtains and plots the positions of both end buoys and directs, by signal, the movements of the end vessel. The second method is called "dual control," for which each vessel is supplied with a boat sheet, obtains and plots the position of the end buoy nearest to it, and directs its course in such a manner as to make the path of the buoy coincide with a prearranged line.

The single-vessel control method is shown in Figure 7. With four officers available, three are assigned to the guide and one to the end vessel. The position angles *R* and *L*, between located objects, are measured simultaneously with sextants by the first officer, who is in charge, and the third officer. The first officer then plots the position of the guide vessel by means of the standard three-arm protractor, while the third officer measures the angles *N′* and *F′*, the angles from one located object to the near and far large buoys, respectively. The first officer then uses a special instrument, called a wire-drag position protractor, to plot the position of the near large buoy by laying off its bearing and distance, the latter being the towline length (*O* to *N* in the diagram). While this work is going on the second officer signals to the end vessel and measures

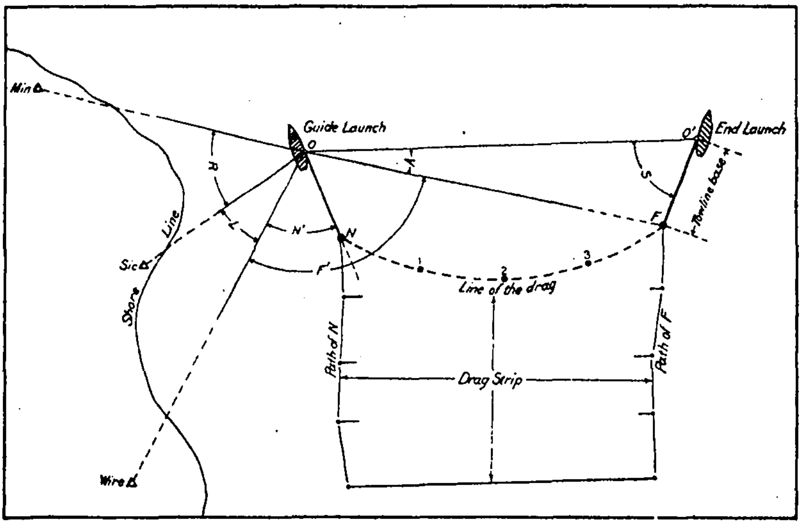
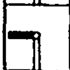
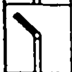
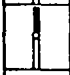
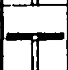
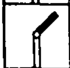
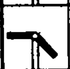
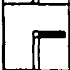
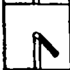
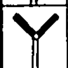
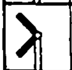
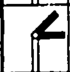
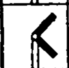
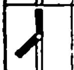
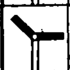
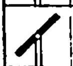
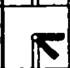
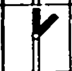
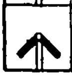


FIG. 7.—Guide vessel control system

the distance angle *A*, and the officer on the end vessel, on receipt of signal, measures the angle *S* and signals it, in degrees and tenths, to the guide vessel. Knowing the length of the towline base *O′* to *F* and the angles *A* and *S*, the second officer can compute the distance *O* to *F* on a special circular slide rule called a wire-drag computer, and the position of the far large buoy can be plotted with the position protractor. Only a short space of time is required by skilled observers to obtain a complete position. Positions are taken at regular intervals of from 2 to 10 minutes, depending upon the nature of the work, and successive positions of each buoy are connected by straight lines representing the paths of the buoys.

With this method of control all angles must be measured very carefully, and proper care must be taken to avoid obtaining the distance *O* to *F* under unfavorable conditions, as when the end vessel is heading nearly toward or away from the guide vessel. It is also best to introduce a factor of safety by using a base 2 or 3 meters less than the actual towline length. The towline base should be checked at least once during the season by observing simultaneous position angles on the end vessel.

Machine	Letter Number	Meaning	Machine	Letter Number	Meaning
	A 1	Take angle (to E.L.)		O	Out 10 degrees. (away from G.L.)
	B 3	Begin		P	Drag parted.
	C 5	Repeat last message, or angle.		Q 6	Dead line.
	D	Take up drag.		R	Turn back after next position, if "B" is not given before.
	E 7	Launches change ends of drag.		S	Stop.
	F	Far large buoy. Faster (to E.L.)		T	Anchor.
	G 9	Drag aground;Stop.		U	Attention. I understand.
	H 2	G.L. call letter.		V	Stopped by engine trouble.
	I	In 10 degrees, (towards G.L.)		W	Wait. Stop till further signal.
	J 4	Annul last message.		X 8	Lobster pots. Remove lobster pots.
	K	E.L. call letter.		Y	G.L.Small tender. Call letter.
	L	Slower.		Z 0	E.L. small tender. Call letter.
	M	Large Tender. Call letter.			Change letters to numbers or vice versa.
	N	Near large buoy.			Course follows in degrees from 0 to 360.

COMBINATIONS.

U-B	Connect drag by towing broken ends together.
U-C	Clear drag to continue line.
U-C-R	Clear drag to reverse line.
U-D	Disconnect drag. (to tenders only)
U-H	Underhaul drag to locate shoal.
U-M	Measure towline base.
U-R	When drag is parted, reverse and head in to aid tenders.
U-S	Send least water found on shoal.
U-T	Test drag depth.

FIG. 8.—Wire-drag signal code

Except in narrow channels the length of the towline need not be less than 300 feet with a 100-foot upper bridle on the end-vessel towline. For deep-drag work it is best to add a 100-foot unit to both towline and bridle, and for a 6,000-foot drag an additional unit should be used on the towline.

As it is sometimes difficult to see the far large buoy from the guide vessel it is usually desirable to attach a watch buoy so that it will tow 2 or 3 feet behind the large buoy. A convenient form of watch buoy is constructed with a bamboo pole having a flag at the top, a can lashed in the middle, and a weight at the bottom so that it will float upright.

With experienced officers the single-vessel control has many advantages and except in a few special cases will be found the more satisfactory method for all shoal-water work. The entire drag strip instead of a single buoy path line is shown at all times on the guide-vessel boat sheet; changes in plan of dragging, to meet changes in current, to avoid fishing gear or other surface obstructions, or to treat in the most economical manner any shoals that may be discovered, can be made without the delay incident to the exchange by tender of tracings and detailed instructions; and in general the entire operation of dragging can be supervised more closely by the officer in charge.

For drags over 6,000 feet long the angle A becomes very small and dual control is generally used. Two officers are assigned to each towing vessel and measure the position angles R and L and the angle to the nearest large buoy. Simultaneous positions on the two towing vessels are desirable, and as positions every 10 minutes are usually sufficient, it is customary on each vessel to take a position at the start of the line and then on the next and each succeeding even 10 minutes. Long drags are used only in deep water where more regular currents may be expected and where few shoals will be found, so that it is seldom necessary to deviate from plans made at the beginning of the day. There are a few cases in shoal-water work where dual control can be used to advantage. When working in very strong currents, for example, the drag will travel a considerable distance between positions and its course can be governed better by dual control, which also permits the full use of any ranges that may be available. As a general rule this method will also be more satisfactory in cases where the path of the large buoy nearest the end vessel skirts a shoal area or passes close inshore, involving frequent changes in course.

Three special instruments are used for plotting wire-drag work—the position protractor, the computer, and the buoy spacer. The protractor (fig. 9) consists of three rings, the lower one of which is of brass and carries the bearing surface and an extension arm. The upper ring, of German silver, is graduated to degrees (clockwise from 0 to 360° and counterclockwise from 0 to 180°) and is attached to the lower ring. Between the upper and lower rings a narrow brass ring, with two cross spokes at right angles, turns freely. One of the cross spokes carries the center, the index, and a removable scale corresponding to the scale of the sheet. To plot the position of a buoy, the center is placed over the boat position, the edge of the extension arm is placed over the position of the reference object, and the index is set to the angle, to the right or left of zero, corresponding to the bearing of the buoy. The position of the buoy is then plotted along the edge of the scale at the proper distance from the center.

The computer (fig. 9) is a circular slide rule consisting of two circular disks, two indicators, and a center clamp nut so arranged that

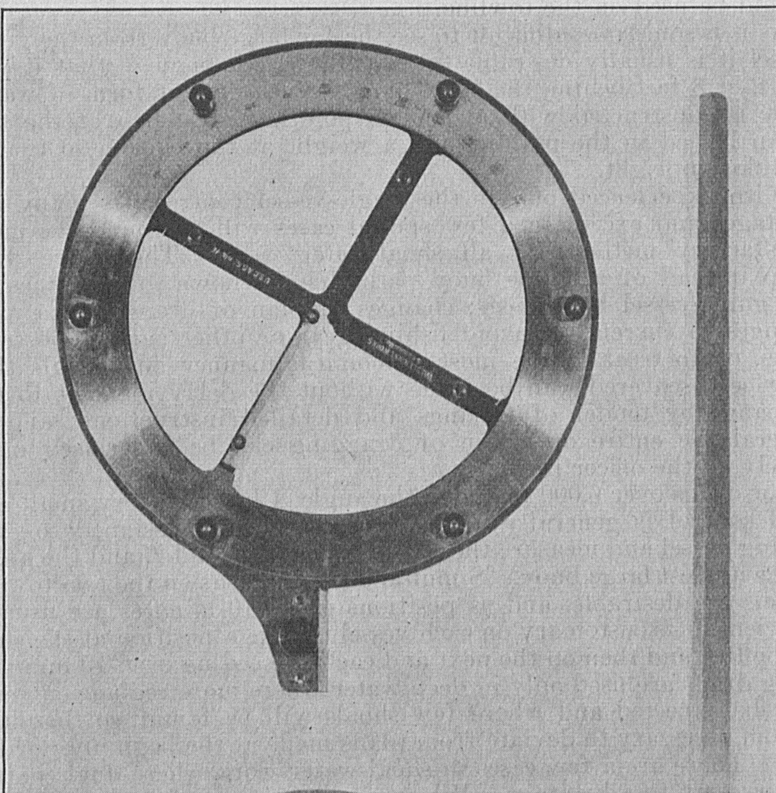


FIG. 9.—Wire-drag protractor and computer

the upper indicator can be clamped to the upper disk, leaving the lower indicator and disk free to rotate on a common center. Based on the fact that the sides of a triangle are proportionate to the sines of their opposite angles, the five concentric arcs are so graduated that the instrument can be used to compute the distance from the guide launch to the far large buoy when the angles and towline length, previously described, are known. All linear distances are given in meters. The method of operation (numbering the arcs from 1 to 5, from the center toward the outside edge) is as follows: Set upper indicator at proper length of towline base on arc 1 and clamp. Turn both until indicator is against the distance angle (angle *A*, fig. 7) on arc 5 for angles 5° 44′ or less and on arc 3 for larger angles. Holding the disks together with one hand, turn the lower indicator to the signaled angle (angle *S*) on arc 2. The distance is then given by the lower indicator on arc 4.

The buoy spacer (fig. 11) is used to show the position of each intermediate buoy and the line of the drag, which curves between the end buoys, at any time, as at the end of a line, when tidal changes alter the effective depth or when depth changes are made. The spacer used in the field consists of a celluloid strip about one-half inch wide, on which two full lines, at a suitable distance apart, depending on the scale and drag length, represent the end buoys. The space between these lines is divided into a suitable number of equal spaces, each representing a section, by shorter lines, each of which represents an intermediate buoy. To use this spacer it is only necessary to bend the strip so that it will curve in the proper direction with each end buoy line, touching the position of its corresponding buoy, as shown by the buoy path lines. The edge of the curve against the sheet will then show the line of the drag, while the position of each intermediate buoy will be indicated at the point touched by its corresponding line. A special strip must, of course, be provided for each standard length of section.

For office work a more accurate spacer has been devised and constructed of durable materials. This instrument consists of an arm rigidly attached at right angles to a strip on which a second arm, parallel to the first and provided with set and tangent screws, slides freely. The outer end of each arm is provided with a swivel plug for holding each end of a scale graduated in the same manner as the celluloid strip. The holder is of brass and the scales of thin steel or celluloid. This instrument can be set for any curve, and will lay on the smooth sheet at any desired position.

SIGNAL SYSTEM

For communication between towing vessels and tenders quite a number of signal systems are available, which include wigwag flags, whistle signals, semaphore, various submarine signaling devices, wireless telegraph, and radiophone. For most of the drag work of the Coast and Geodetic Survey combinations of the first three systems have been used, such as a semaphore on the guide vessel and flags on the other boats, whistles on both towing vessels, and flags on the tenders, etc. The convenience of oral communication by radiophone is obvious, but it is questionable whether or not the advantages of this method would justify the expense of installing and maintaining the necessary apparatus. Probably it could be used only on the towing vessels, so that a supplemental means of communicating with the tenders would be required.

For brevity in directing and recording operations a standard signal code has been adopted for all wire drag and sweep work. In this code the end buoy nearest the guide vessel is designated by the letter N, the large buoy nearest the end vessel by the letter F, while the intermediate buoys are numbered consecutively, beginning with the small buoy nearest the guide vessel as No. 1 (fig. 7). Each vessel and tender is assigned a letter and each standard operation or maneuver is represented by a letter or a combination of two letters.

For signals with flag or whistle the Morse code is used for letters and a special code for numbers. In preparing copies of the code for use in the field it is convenient to represent the dot by the numeral 1 and the dash by the numeral 2, as follows:

A - 1 2	J - 1 2 2 2	S - 1 1 1
B - 2 1 1 1	K - 2 1 2	T - 2
C - 2 1 2 1	L - 1 2 1 1	U - 1 1 2
D - 2 1 1	M - 2 2	V - 1 1 1 2
E - 1	N - 2 1	W - 1 2 2
F - 1 1 2 1	O - 2 2 2	X - 2 1 1 2
G - 2 2 1	P - 1 2 2 1	Y - 2 1 2 2
H - 1 1 1 1	Q - 2 2 1 2	Z - 2 2 1 1
I - 1 1	R - 1 2 1	
1. - 1	5. - 1 2	9. - 1 2 2
2. - 2	6. - 2 1	0. - 2 2 1
3. - 1 1	7. - 1 1 1	
4. - 2 2	8. - 2 2 2	

Short and long blasts of the whistle represent the numerals 1 and 2, respectively. With the wigwag flag the sender holds the flag in a vertical position, and facing in the direction that the message is to be sent, dips it 90° to his right and returns it to vertical for the numeral 1 and to his left for the numeral 2. The large tender is provided with a black flag for sending letters and a black-and-white flag for numbers, while the other boats use red flags for letters and red and white for numbers. With the semaphore the Navy code is used for letters and a special code for numbers. The wire-drag signal code, including the various semaphore positions, is shown in Figure 8. To avoid confusion all orders should be sent by guide vessel except in emergencies. If the end vessel requires the services of a tender, for example, it should so inform the guide vessel instead of calling the tender.

SMOOTH AND BOAT SHEETS

The smooth sheet is similar to the sheets used for all hydrographic work. It has a polyconic projection on a scale depending on the nature of the work. For shoal-water work scales of 1:10,000 and 1:20,000 are commonly used, while for deep water scales of 1:30,000 or 1:40,000 may be more suitable. The shore line and positions of all objects used for control are shown on this sheet. The guide-vessel boat sheet is a similar sheet with additions of a compass rose, having 10° divisions, a scale of statute miles, and complete data regarding soundings from previous surveys. These soundings are conveniently entered in feet with black ink, while depths on shoals found with the drag are later shown in red ink. The end-vessel boat sheet is usually made from a tracing of the guide-vessel sheet with the soundings omitted.

TIDAL AND HYDROGRAPHIC DATA

A curve, showing the predicted tides for some port near the work, is usually available, or this information can be obtained from the tide tables. The predicted heights of tide are used for setting the drag to obtain the desired effective depth while actual observations on a near-by tide gauge are used for the final reduction of the records. The various depths in the area to be dragged as shown by soundings are obtained from the charts and from bromide copies of original hydrographic sheets.

RECORDS

All operations, positions obtained, etc., are recorded for later work on the smooth sheet and for filing with this sheet as a permanent record of the work. For this purpose two records are used: One called the wire-drag record, for entry of all data pertaining to the drag operation, and the other, called the smooth sounding record, for entry of all information relating to shoals and other obstructions discovered. A separate set of records is kept on the guide vessel for each sheet. In addition to these two permanent records, memorandum records are kept on the end vessel and on the tenders. For single vessel control the officer in charge of the end vessel records each angle that he signals, together with the time, so that these angles, as received and entered on the guide vessel, can be verified. For dual control the position angles are recorded and copied later into the permanent record. Care should be taken also to record any occurrences, such as the temporary grounding of the drag near the end vessel, that might not be noted on the guide vessel. Each tender records all data obtained on shoals; depth changes, giving the time that the change started and ended, the new depth and the buoys involved; drag tests, etc. All entries relating to shoals are later copied in the smooth-sounding record, while other information is transferred to the wire-drag record.

The wire-drag record is kept in the double-page form shown on page 24.

On the first page of the first volume for each sheet are entered the names of objects used for control, the method by which they are located, and the short names assigned to them for convenience in recording. On the second page the party organization is given, with the name and duties of each member. The daily record then begins on the third page and continues through the first and succeeding volumes, one blank page being left at the beginning of each volume and after each day's work. Each day is designated by a capital letter in alphabetical order. A rubber stamp is provided for entering at the top of the left-hand page at the beginning of each day, the initial lengths of upright. In the case illustrated by the sample record page the uprights of the large buoy nearest the guide vessel and the first five small buoys were set at 45 feet and the remaining uprights at 48 feet. This stamp is used also whenever a depth change is made during the day, the blanks being filled in except for the times of starting and ending the change, which are obtained later from the tender record. A stamp for insertion of the

Form 411 WIRE-DRAG RECORD Sublocality 8

Locality *Coast of Massachusetts* *Boston Bay*

Year 1924 Month *June* Day of Month *14* Party No. *2* *B* day

Time of Start	Start at Buoy	End at Buoy	Length of Upright	Time of End
	N	*5*	*45*	
	6	*F*	*48*	

LENGTH OF DRAG *4000* FEET
" " SECTION *400* FEET
" " TOWLINE *100* METERS
WEATHER *Cloudy*
WIND *Lt. E'ly.*
SEA *Smooth*
LEFT FOR WORKING GROUNDS *7:30* MILES
REACHED WORKING GROUNDS AT *8:55*

Organization on page 2.
Tide gauge at Salem, Mass.

Position Number	Time Mer. 75 A. M. (h. m.)	Length of Upright (Feet)	Correction (Feet)	Drag Depth (Feet)	Red'n for Tide (Feet)	Effective Depth (Feet)		Objects	Angles		Distances in Meters Remarks Objects
L1	*9.15*	*45*	*0*	*45*	*2*	*43*		*Min*	*75-16*		
		48	*1*	*47*		*45*		*Life*			*Line begins*
								Wire	*32-26*		
	Drag	*tested -*	*No lift*	*of 3*				*Life*	*-19*		
			"	*" 8.*					*+32*		
									5202	*54.8*	*925*

Time of Start	Start at Buoy	End at Buoy	Length of Upright	Time of End
9 24	*3*	*F*	*36*	*9:42*

Position Number	Time	Length of Upright	Correction	Drag Depth	Red'n for Tide	Effective Depth		Objects	Angles		Remarks
*	*	*	*	*	*			* *	*	* *	*
L17	*10 30*	*45*	*0*	*45*	*1*	*44*		*Min*	*39-20*		
		36	*0*	*36*		*35*		*Sic*			*Line ends*
								Wire	*42-30*		
	Drag	*tested -*	*No lift.*					*Wire*	*-49*		*6" of 6*
									-120		*Wire -66*

11 06 *Sounding completed*
Unable to see signals - Fog
P.M. *Anchored on line.*
2 16 *Thick fog - Took up drag.*

NUMBER OF MILES *2.5*
" " ANGLES *100*
REASON FOR STOPPING WORK *Fog*
LEFT FOR HARBOR AT *2:36*
ARRIVED AT HARBOR AT *4:09*

data shown is entered at the top of the right-hand page and a statement as to the location of the tide gauge used must also be made.

When a position is obtained the position number and time are entered on the left-hand page. For single-vessel control the position angles, buoy angles, distance angle, signaled angle, and distance in meters are entered, as shown on the right-hand page, in the order named. For dual control the position angles and buoy angle are entered in the first angle column, leaving the second angle column and the right-hand column for later entry of the end-vessel angles and objects. Buoy angles are considered positive when the buoy is to the right of the object. Remarks relative to beginning and ending of lines, grounding on shoals, etc., are entered in the right-hand column or in the space between positions. At the end of each day a stamp is inserted for entry of the data shown.

The standard sounding record is used for a smooth record. Each day is designated by a small letter corresponding with the letter of the same date in the wire-drag record.

In wire-drag work various operations are being carried on by three or more vessels, and events, such as grounding, parting of the drag, etc., occur with more or less frequency. The most convenient and in many cases the only means of combining all of these in a satisfactory permanent record is by reference to the time when they take place. For this reason it is extremely important that the time used by the guide vessel be as correct as possible, that all other timepieces agree with the guide-vessel time, and that great care be taken to record correctly the exact time of any operation or incident. Knowledge of the exact time of obtaining each position is especially important.

DEPTH OF DRAG

Drag depths on the Atlantic coast are referred to the plane of mean low water and on the Pacific coast and in Alaska to mean lower low water. It is considered that an examination to a depth of 50 feet below the plane of reference is sufficient to safeguard surface vessels, while an examination to from 85 to 100 feet is necessary for submarines. The policy of the Survey is, therefore, to drag deep-water areas to 85 feet or over; to drag areas with depths between 100 and 50 feet to within 10 or 20 feet from the bottom; and to drag areas with depths of 50 feet or less to within about 3 feet from the bottom.

When the drag is towed through the water the bottom wire will usually lift slightly, due to the upward pull of the towlines and the resistance of the water. To obtain the upright length for a certain effective depth it is necessary to add to this depth the estimated amount of lift and the predicted height of the tide above the reference plane.

Long drags are usually set at one depth throughout, and if the general depth of water permits, depth changes may be avoided by setting the uprights for the maximum height of tide during the day. In open shoal-water areas fairly long drags can be used by setting the drag at different depths to conform to the bottom contours as shown by soundings. In this class of work frequent depth changes are necessary in order to allow for rise and fall of the tide, to conform to changing bottom contours, and to avoid shoals previously discovered. With a drag set at different depths the bottom wire of one or more sections will be inclined. To avoid the possibility of abnormal lift in certain sections of the drag due to upward pull of the wire of an inclined section or to loss of equilibrium, the following rules should be followed for this class of work.

1. The difference in length between adjacent uprights should not be greater than 2½ per cent of the length of section.

2. The uprights should never be set in such a manner as to have one or more deeper sections between two inclined sections leading to lesser depths.

In order to eliminate uncertainties, as to depths and paths of inclined sections, in the close examinations of rivers and narrow passages, the main channels should be covered, in so far as practicable, with short drags set at one depth throughout, using drags set at different depths only for relatively unimportant clean-up work near the edges of the channels.

SETTING OUT DRAG

Before reaching the working grounds the day's work is planned and a line is drawn on the boat sheet representing the proposed path of the large buoy nearest the guide vessel. A parallel line is drawn at a suitable distance to represent the path of the end-vessel large buoy. For dual control this line is transferred to the end-vessel boat sheet. When there is little current the most economical width of the drag path is about 90 per cent of the total length of drag. The heights of tide at hourly intervals are tabulated and the uprights are set for the desired depths. The length of upright and initial course (for single-vessel control) are signaled to the end vessel. It is always best to drag with the current if practicable. When dragging against or across the current, not only is progress retarded but there it likely to be considerable variation and uncertainty in the lift.

The towing vessels usually set out the drag while under way. Arriving at the starting point, the guide vessel heads, at slow speed, on a course about at right angles to the path lines. A supporting buoy is attached to the end of the bottom wire and it is passed overboard through the after guide. In setting out, the officer in charge maintains a general supervision and directs the course of the vessel, another officer operates the winch, the third officer assists with the buoys and checks each upright setting; the engineer operates the engine and steers, one man attaches floats, another attaches weights, and the remaining man tends the buoys. At each connection the winch is stopped while a float is attached. While setting out a section, the end of an upright is passed forward through the guide to a man who inserts the open staple of the weight, or a shackle, through the swivel at the end of the upright. When the last float of the section is attached the main engine is stopped, and at the next connection the winch is stopped while a weight, an upright, and a buoy are attached. The vessel then goes ahead, the upright is held until it uncoils, and the buoy is thrown overboard. These operations are repeated until all of the bottom wire is out. The large weight, upright, and buoy are then attached at the last connection, the weight is lowered overboard with a rope bight until the strain comes on the towline, and then lowered slowly with the winch until it is supported by the buoy. When everything is clear the vessel goes ahead again until the towline is set out, one or two floats being attached at each connection along the towline. The wire is then disconnected, the end of the towline is attached to the bowline on the side toward the drag, the adjusting line is attached, and the vessel is ready to start dragging. The various connections are shown in Figure 10.

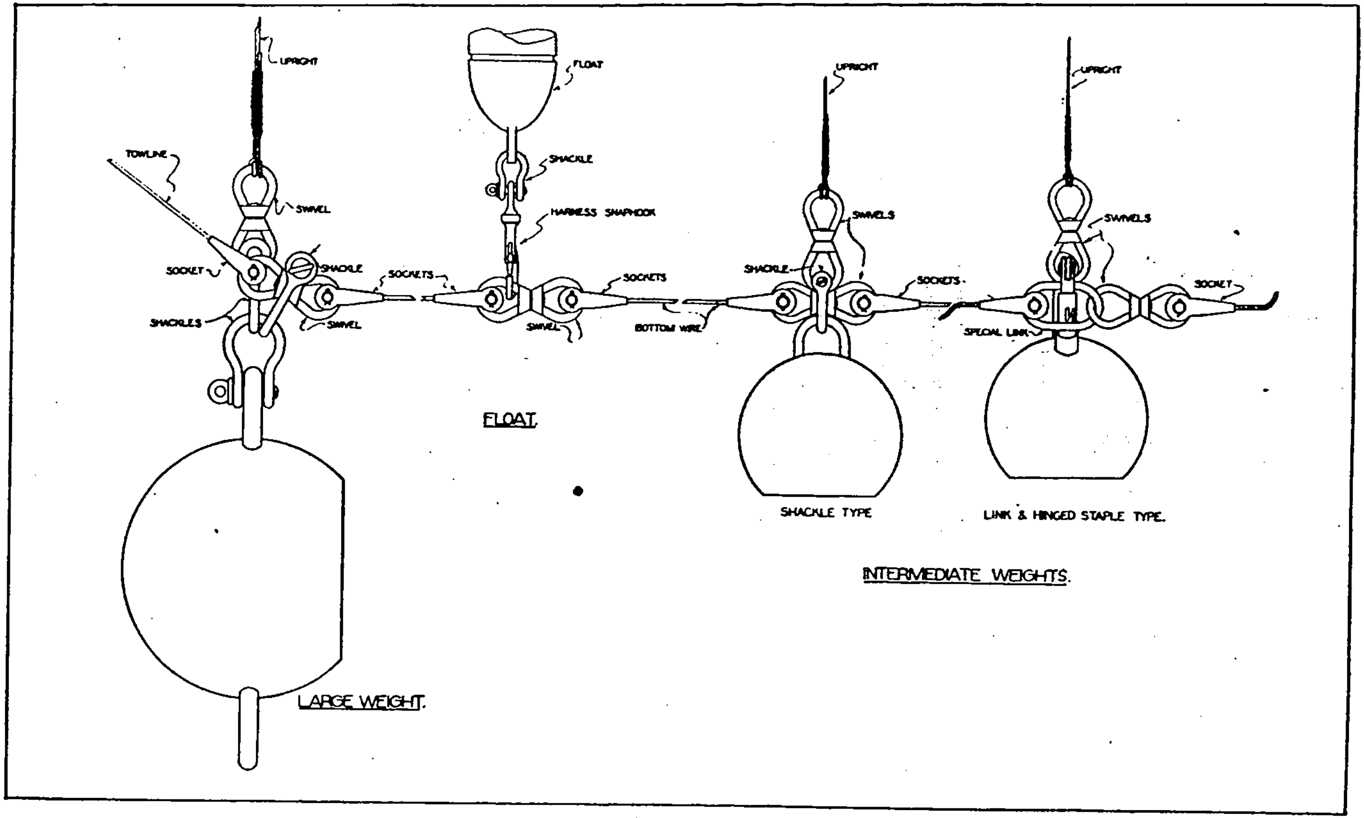


Fig. 10.—Methods of making connections

When, on larger vessels, the towline is secured to a bitt with a claw hook, it is advisable, as soon after setting out as possible, to lead the end of the wire remaining on the winch forward over the bow roller and then back, outside of everything, to a connection with the end of the towline. By slipping the claw hook the towline will lead to the bow and wire can be paid out from the winch to assist the vessel in turning or to relieve strain when the drag grounds.

After the guide vessel has set out about two sections of the drag, the end vessel picks up the end of the wire and connects it with the end of the wire on her winch. The part of the drag assigned to the end vessel is then set out in the same manner as on the guide vessel, after which the officer in charge signals the code letter B, signifying that his vessel is ready to start dragging. This launch carries two sections of bottom wire in a separate coil for use as an upper bridle when single-vessel control is used.

It is quite difficult to select a starting point so that the drag will be in exactly the proper position for starting a strip. For work close inshore it is usually practicable to set out the drag a little distance offshore and then tow it in to the starting point. In narrow channels and in shoal areas where there is considerable current it will usually be best to anchor the guide vessel on the path line and have the tender tow out the wire, stopping and starting on signal for the attachment of weights and floats.

In some localities conditions will be encountered that interfere considerably with setting out the drag, but it will be found that, with a little study, the above methods can be modified in such a manner that the drag can be set out under practically all conditions. For drag work in the East River, near Hell Gate, for example, it was necessary to contend with very strong currents in a narrow channel and heavy and almost incessant traffic. A 60-foot launch was used as a guide vessel, while the tender, equipped with a temporary wooden reel, towed the other end of the drag. The work was arranged so that the guide vessel towed the end of the drag nearest to shore and the following method was used to set out the drag. The guide vessel anchored on the buoy path line and passed the end of the wire to the tender, which, after drifting down with the current about 100 feet, was stopped by the brake on the guide-vessel winch. The tender then set out the end weight, buoy, and towline, and waited until there was a lull in the traffic and then started across the channel, while the remainder of the drag was set out as quickly as possible on the guide vessel.

In Portsmouth Harbor it was impracticable to anchor a launch in several places on account of rocky bottom and strong currents. The inshore end of the drag was towed by the end launch, and the entire drag, including the end-launch towline, was set out from the guide vessel. It was found that, with one end of the drag free, the guide vessel could start at a point in mid-channel a little above the beginning of the proposed drag strip, head directly into the current, and by frequent adjustments of speed set out the drag while under way, in such a manner that it extended along the mid-channel line with its lower end abreast of the starting point of the strip. After the set-out was completed the end launch picked up her towline and, heading up into the current slightly, started to tow her end of the drag inshore toward the starting point, while the guide vessel, still heading into the current, so regulated her speed as to drift slowly down and turn to the proper course, at a point abreast of the end launch, just as the latter reached the beginning of the inshore line.

DRAGGING

After the drag is set out the towing vessels proceed on their initial courses. At the beginning of a strip the line of the drag is represented by a straight line connecting the two end buoys, unless some part of it is ahead of such a line or the wire extends back in its regular bight. In both cases the full bight of the drag should be plotted, to decrease the area in the first case and to increase it in the latter. It is always questionable whether or not the drag curves astern unless it has been under way for a short time before the strip starts, as when the strip is resumed after clearing the drag from a shoal. The direction of the curve should be noted in the record, absence of a note indicating a straight line.

It is obvious that each vessel must head out from the path-line course when towing, the difference in course depending on conditions. When towing with little current, each vessel may head out 10 or 20°, while in strong currents the angle may be increased considerably. Towing speed is a very important factor and must be watched closely. The maximum practicable speed of drag is, of course, desirable, but excessive speed will cause abnormal lift and submerge the buoys so that depth changes can not be made. It has been found that a speed of 1½ miles per hour through the water is about the maximum that can be expected under ordinary conditions. After the first few days of dragging, by noting the speed of the drag, obtaining frequent tests, and watching the buoys closely, suitable and standard engine speeds can be determined for the different lengths of drag used. For straight drag strips the towing launches should keep station as nearly abreast of each other as possible. It should be noted, however, that the path lines need not be straight unless desired, for with the proper management the drag can be turned at any angle. As the drag proceeds, its position is obtained as often as required by the methods that have been described. After each position necessary changes in course to keep the drag on its path can be made. If a considerable change is necessary another position should be taken just as the change is made.

The amount of lift is determined by tests conducted from the tender. For this purpose a tester is used which consists of a galvanized-iron pipe, about three-eighths inch in diameter and 4 feet long, filled with enough lead to give the desired weight, attached to one end of a suitable length of three thirty-seconds inch aircraft cord that is graduated to feet in the same manner as the uprights. The tender stops a short distance ahead of the part of the drag to be tested and lowers the tester to a depth about equal to the upright length. When the wire strikes the pipe the tester is lifted until it clears the wire, the difference between the upright length and the reading of the tester when it clears giving the lift. The amount of lift will rarely exceed 2 feet and generally will be uniform over a drag set at one depth. For drags set at different depths the deeper sections frequently will lift about 1 foot more than the sections of less depth. The drag should be tested as frequently as practicable and the number of tests should be increased when towing against or across the current. Lifts over 3 feet are abnormal and usually due to excessive speed, difference in direction between surface and subsurface currents, or errors in setting the uprights. Unusual lifts should be investigated at once and reduced as soon as possible. If they are due to currents it may be necessary to redrag certain areas at a different stage of the tide. The probable reason for the lift should be noted in the record and if reduced by decreasing the speed of the towing vessels, the exact time of the change in speed should be noted. The most dangerous lifts are those caused by increase in speed for short periods due to poor engine control, for these may not be detected. After a few days of dragging the officers in charge of the towing vessels will become familiar with the sound of the engines for various speeds and be able to detect sudden variations. The engineers should also be impressed with the importance of watching engine speeds closely.

Depth changes are made by the tender on signal. Care must be taken to approach the buoys on the course that they are making and to keep headway on the tender so that it will not drag on the upright and lift the bottom wire. It should be noted that the time of changing any upright is the instant the operation starts when the depth is decreased and the time that the operation ends when the depth is increased. As it is customary to record the time for the first and last uprights affected and assume a uniform rate of change, undue delay at any buoy should be noted. In critical areas the tender may be instructed to record the time of change for each upright.

The drag-master, in charge of the tender, is responsible for considerable important work and should be the most experienced and skillful man in the party. After patrolling and testing the drag, he will be able to give the officer in charge valuable suggestions concerning towing speed, current conditions, etc. He should be trained to test the drag without instructions when there are indications, such as unusual behavior of the buoys, that there may be excessive lift.

The drag proceeds in this manner until a shoal is found, a proposed strip is completed, or the line is ended by accident. If tension is removed from the drag so that the wire may be lifted by the floats or by any other cause, the line must be ended in the record. If one of the towing vessels must stop for a brief period, the other vessel may proceed slowly and, by keeping tension on the wire, avoid ending the line. If the delay is likely to be lengthy, the tender may tow the disabled vessel while repairs are being made. If the drag parts, it may be connected by the tender while the towing vessels reverse and converge to lessen the strain on the drag. In some cases it may be expedient for one of the towing vessels to drop her towline and help tow the ends together, after which the line may be resumed. If the exact time of parting is not known, a sufficient number of positions should be rejected to be on the safe side. If a buoy starts to leak it may be supported until the end of the line by attaching one of the pneumatic buoys described later. In such a case the drag should be tested to make sure that the resistance of the two buoys is not causing undue lift.

When a strip is completed the drag may be taken up or reversed to cover an adjoining strip. To reverse the drag, the vessels stop, go astern a little, shift towline from one side to the other, and swing to the new course. The drag may be towed endways over to the start of the next strip or a course may be steered to work over gradually. In the first case the line ends and begins again, in the second it turns and continues. With dual control all details are arranged beforehand, but as soon as possible after reversing, the vessel that tows the overlapping end should receive from the other vessel a tracing from its boat sheet showing the actual location of the line to be overlapped. With single control the guide vessel directs all movements by signal. If, as is usually the case, the guide vessel is to tow the overlapping end, the procedure will generally be as follows: If the strip is to continue and work over gradually to its proper position, the guide vessel, before the last position, sends the code signal R followed by the new course in degrees. Immediately after the last position the towing vessels shift their towlines and swing around to their new courses. If the drag is to be towed endways the guide vessel sends the code signal R–O. Immediately after the last position the end vessel shifts towline and heads over toward the next strip on a course about at right angles to the path lines. The guide vessel also turns back and heads along the bight of the wire, selecting a speed that will keep her abreast of the end buoy and allow the end vessel to tow the entire drag. The bight will gradually straighten until the drag extends in a straight line astern of the end vessel, and as the drag straightens, the guide vessel shifts course to follow along the wire. On the way over the guide vessel signals the new course, and when the new path lines are reached sends the signal B. Both vessels then swing to their new courses and a position is obtained to start the line. As the drag is full length a distance angle is not required for the first position.

When covering an area with overlapping strips, the overlap at certain points may be insufficient, or small areas, called "splits," may remain uncovered, due to temporary loss of control, discovery of shoals, or drag failure. It is usually more economical to leave such spots until all of the work in the immediate vicinity is completed, for several of them may be close together, so that time can be saved by covering them with one set-out. It is very desirable, however, that each season's work be as free as possible from splits and insufficient overlaps so that this practice should be used with caution near the end of the season when bad weather may prevent the completion of all worked planned.

For work on scales of 1: 20,000 or larger a general overlap of buoy path lines equal to the length of one section of the drag may be considered as a standard; with fairly straight lines a decrease in overlap at a few points to one-half the length of a section is allowable, while all overlaps of less width are questionable. For work on scales of 1:30,000 and 1:40,000 the above overlaps should be increased 25 to 50 per cent. If the location of the path lines are at all uncertain, due to weak positions, the overlap of course should be increased.

It is very desirable, in order to minimize any uncertainty as to the location of the path lines and to reduce the number of splits and small overlaps, that the guide vessel tow the overlapping end of the drag whenever practicable. In covering splits and small overlaps it is desirable, if possible, that the approximate center of the drag pass over the areas in question and in no case should an end-buoy path line pass closer to the nearest bounding line of the area than the length of one section. In cases where the overlapping line is found to be approaching the previous line at such an angle that a decided change in course is necessary to avoid a split, it is very important that a position be obtained that will show the nearest approach of the end buoy to the previous line.

The above remarks apply only to the overlapping of well-determined buoy-path lines. When splits are being covered or when a strip previously dragged is continued with a new set-out, a second class of overlaps is formed by the line of the drag at the beginning or end of the line. In these cases the exact curve of the wire is not known and the width of the overlap should be equal, at least, to the length of two sections, assuming the most unfavorable position of the wire. For example, if the drag is being set out to cover a split, assume that from the first position of the end buoys the wire will extend full length in the shape of a V pointing toward the split and set out far enough from the split so that the point of this assumed V will be at least the required distance from the nearest point of the split.

MANAGEMENT ON SHOALS

When the drag proceeding with the current catches on a shoal the effect is noticed very quickly on the towing vessels. They lose headway, swing in from the path lines, and in a very short time the buoys will begin to line up and point toward the shoal. In many cases a loud humming sound, caused by the vibration of the wire, will be very noticeable on the vessel nearest to the shoal. If the drag grounds near the end vessel, the effects may be noted first on that vessel or the tender may observe the grounding while patrolling the drag. In these cases the vessel that first observes the grounding reports to the guide vessel.

A final position is obtained to end the line and the towing vessels stop. A final distance to the far end buoy, though desirable, is not essential, as its position is given by its bearing and the known length of the drag from the near end buoy around the shoal. An excellent check on the shoal position is obtained by observing and recording a bearing to the indicated position, with a note as to the number of the buoy nearest the shoal. This should be a standard procedure whenever practicable. (See last position of the sample page of record.)

The tender proceeds to the indicated location of the shoal and sounds with lead and line until it is reasonably sure that the least depth has been found. The drag tester will also give excellent results when used to develop shoals by sounding, especially if there is much current. The shoal is carefully described and located by position angles after which the drag is cleared and dragging resumed. If a sounding tender is available the drag is cleared as soon as a depth less than the upright length is found, the location of the shoal being marked temporarily by a buoy placed back of the wire. After the drag is cleared the sounding tender completes the examination of the shoal, picks up the marker buoy and rejoins the towing vessels. Position angles on shoals should be checked by an angle to a fourth object or by measuring the sum of the two position angles. The description of a shoal should be as complete as possible and should include the nature of the obstruction, its general shape and extent, and the surrounding depth.

On each tender the positions of soundings entered in the memorandum record are numbered consecutively, beginning with No. 1 for the first sounding of each day.

When proceeding against the current the action of the drag on a shoal is not so satisfactory. The buoys will not line up so quickly, and if the towing vessels stop the drag may drift back from the shoal. In this case it is usually best to modify the above procedure by towing at slow speed until the tender can place a buoy at the indicated location of the shoal.

The drag will sometimes catch on wreckage or other obstruction of such small extent that a sounding can not be obtained. In this case after a reasonable length of time the drag is cleared, a position is taken, and all available data are recorded, the upright length being regarded as the depth on the obstruction. This method, however, is not acceptable when the drag catches along an inclined section, as the depth of the bottom wire is not known. In this case the obstruction should be searched for again with a drag of uniform depth equal to the maximum depth that was first used. All obstructions of this nature should be redragged as many times as necessary, with successive decreases of about 3 feet in effective depth until the drag clears the obstruction.

It should be noted that a smooth, small-grained material such as mud, sand, or gravel, will not necessarily stop the drag, while rock or any hard obstruction will stop it instantly. The drag can be used to find mud or sand shoals by placing the buoys fairly close together and watching the drag closely, and even with the usual length of section there will usually be some indication of the existence of such shoals. Any indications of temporary grounding should be noted in the wire-drag record and later referred to in the sounding record. It is especially important that the number of the buoy or section where the grounding occurs and the time that the drag clears be included in this note. Lacking this essential information the cartographer who verifies the work on the smooth sheet has no choice but to reject the entire drag strip during the period that the drag was aground.

To clear the drag the tender usually lifts the bottom wire near the shoal, with a grapnel or by hauling in an upright, takes it across the bow, and goes ahead toward the shoal. The wire frequently comes clear during the process of underhauling, otherwise it is made fast at the bow and cleared by going ahead. If this method fails the wire may be disconnected and hauled clear or a portion may be abandoned. If the shoal is extensive the sounding tenders may hold up the wire at different points or the uprights may be shortened. In the latter case the uprights should be set at their original length as soon as possible after the drag is clear, all such operations being recorded in the same manner as the regular changes in depth. After the wire is clear the tender holds it up with a rope bight at the bow and signals to the towing launches to go ahead. When changing ranges or soundings show that the shoal is passed, the tender drops the wire and reports to the guide vessel so that the line can be started. Much time can be saved by systematic work on shoals, and standard exchange of signals between guide vessel and tender, similar to the following, should be used:

From—	Code	Meaning
Guide vessel	G	Drag is aground, proceed to indicated position of shoal and investigate.
Tender	U-C	Examination has reached point where drag can be cleared.
Guide vessel	U-C	Clear drag.
Tender	B	Have cleared drag and am holding up wire. Go ahead to tow drag over shoal.
Do	U-C	Drag has passed shoal; have let go of wire and line may be resumed.

While the drag usually can be cleared from shoals, time in some cases can be saved by taking it up. In some localities currents strong enough to submerge the buoys when the drag grounds will be encountered, and if one or two small buoys nearest the shoal start to go down it is usually only a matter of time before all of the small buoys will be forced under the surface. The buoys may be submerged far enough to crush them, considerable gear may be lost, there will be little indication of the location of the shoal, and it will be practically impossible to obtain satisfactory soundings. In such cases it is usually advisable to start taking in the drag at the instant the drag grounds, to search for the shoal only while taking in drag, and to examine the locality again at or near slack water.

All obstructions are later covered with a drag set from 2 to 4 feet less than the depth found to make sure that this is the least depth. For this work the requirements for overlaps of path lines and line of the drag are the same as for splits.

TAKING IN DRAG

To take in the drag each vessel stops and goes astern a little so that the end of the towline can be detached, hauled in over the bow roller, and connected with the wire on the winch. If the towline is already connected through to the winch, it is only necessary to slip the claw hook. The vessel then swings and heads toward the large buoy while the winch is operated at slow speed to take in the towline and large weight. When the strain of the weight comes on the towline the buoy will capsize and if the vessel is handled properly will come alongside on the starboard side. When the weight comes aboard it is detached and the buoy is hoisted with the davit. The vessel then heads along the line of the drag in such a manner that the wire leads a little off the starboard bow while the winch is operated at intermediate or high speed. The speed of the vessel should be regulated so as to relieve strain but not to overrun the wire. As each float and weight comes aboard the winch is stopped while they are detached by men at the bow. The small buoys are hauled aboard on the starboard side and placed in the rack. To avoid the necessity of transferring equipment, each vessel usually takes in the same amount of drag that it sets out. Otherwise both vessels take in drag until about one section remains and then one vessel disconnects the wire. After the drag is in, the floats and weights are carried aft in readiness for the next set-out.

The pins of the sockets on the bottom wire are secured by cotters, and as the wire is set out and taken in there is a tendency for these cotters to close and work out. It is therefore advisable, about once a week, to take up drag a little earlier at the end of the day and to examine the cotters and spread them if necessary. The swivels should also be inspected at this time to make sure that they turn freely. A more casual examination of the cotters may be made each time the drag is taken up.

SUPPLEMENTAL SOUNDINGS

In regions where few soundings have been obtained, additional soundings may be obtained from the large tender which sounds at various buoys as directed while the drag is under way and records the sounding, time, and number of the buoy at which the sounding is obtained. As the position of the buoys at any time can be shown on the sheet, each sounding so obtained can later be plotted in its proper position on the smooth sheet. Special instructions will be issued by the office if supplemental soundings are desired.

WORK ON EQUIPMENT

There is a sufficient amount of necessary maintenance work on the drag equipment to keep the party employed during periods when unfavorable weather conditions prevent field work. With a large vessel this may be done on board, but for a shore party a workshop and a covered space or wharf of sufficient length to permit stretching of bottom wire and uprights should be provided. This work is done under the supervision of the drag master, and includes the painting of floats and buoys with red lead for protection and to increase the visibility of the latter; repainting of uprights; preparation of new parts; general repair work on equipment and engines and the upkeep of the vessels.

A wire-drag party should be equipped with a complete set of carpenter and machine tools, including a grindstone, emery wheel, drill press, forge, anvil, and possibly a small machine lathe. A moderate supply of 15, 9, and 6 thread rope, tarred marline, paints and oils, etc., should also be carried on hand.

OFFICE WORK

The office work includes the necessary accounting in connection with the finances of the party, purchase of equipment and supplies, completion of records, and miscellaneous work. For a shore party a well-lighted room of sufficient size to hold two drafting tables, a desk, one or two tables, and a chart rack should be provided if practicable.

FIELD WORK ON RECORDS

The first step in the completion of records is the copying and copy checking in the permanent records of all data from the memorandum records. For single control the signaled angles are verified by comparison with the end vessel record. For dual control the end-vessel positions are entered opposite the corresponding guide-vessel positions, as shown by the time. If the two positions were not obtained at exactly the same time, the time of the end-vessel position may be entered just below the time of the guide-vessel position. All important notes in the end-vessel record that give any additional information should also be copied. All information in the tender records relative to shoals are transferred to the sounding record, and the wire-drag record must be examined carefully for notes of temporary grounding, etc., which are also transferred to the sounding record. Drag tests and times of depth changes are entered at the proper places in the drag record. The drag and tender records should be compared carefully to make sure that the stamp has been entered in the former for each depth change.

If soundings are obtained by more than one tender, there will be two or more memorandum records in which the position numbers are duplicated. In this case the position numbers in the memorandum records should be changed so that when copied in the smooth sounding record all positions of soundings obtained in any one day will appear in numerical order, beginning with No. 1.

In the "Remarks" column of the sounding record a note should be inserted opposite each position, showing the number of the drag position at which the grounding occurred. The above work should be done at the end of each day if practicable.

All soundings in the smooth sounding record are reduced to the plane of reference in the same manner as for ordinary hydrographic work.

To reduce the drag record the upright lengths are entered in the proper column at the beginning of each day, at the top of each page, and wherever altered by a depth change. The correction as shown by tests is entered opposite each upright length and subtracted to obtain the drag depth. If there is a correction for swell it should be noted by the officer in charge and should be added to the correction. For deep drag work a factor of safety may be introduced, at the discretion of the chief of party, by adding a foot or two to the lift shown by tests. Tidal reducers are entered in the same manner as for ordinary hydrographic work and applied to the drag depths to give the effective depths. If a tidal change occurs between two positions it is shown at the preceding position if it decreases the effective depth and at the succeeding position if the contrary is true. In the sample page of the record the reduction entries are underlined to distinguish them from the entries made during the course of the field work. All distances must be checked by recomputation.

The subdivision of the drag strips to show the various effective depths requires much time and care and every effort should be made to insure that the reading of the tide gauge corresponding to the reference plane, used to reduce the tide records, is correct, so that this work will not require revision.

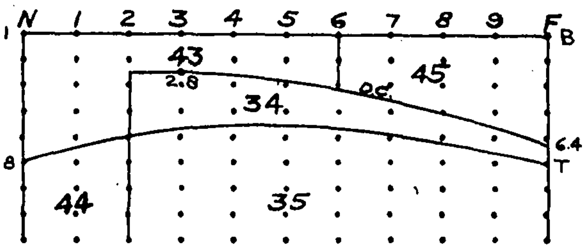
At the end of each day an effective-depth diagram is entered in the record. A stamp is provided for this diagram which is simply a graphic summary of the day's operations and effective depths. This stamp has 11 short vertical lines representing the paths of the maximum number of buoys used for shoal-water work, the lines being prolonged with a pencil to any desired length. In the preparation of effective-depth diagrams the following rules are to be followed:

1. The depth throughout an inclined section is considered to be the same as that of the shoaler adjoining section.
2. If the difference in length of the two uprights of an inclined section is greater than 2½ per cent of the length of the section, the depth of the deeper adjoining section is reduced to the maximum depth that will meet this requirement.
3. If the drag is set in such a manner that there are deep sections between two inclined sections, each leading to a lesser depth, the depth of the deep sections is reduced to that of the deeper adjacent section.

The diagram is prepared in the following form, which in this case corresponds with the sample page of the record.

DAY..8.. DRAG 4000..FT. SECTION.400..FT.

SMALL BUOYS...9... BIGHT ..—..........



The first horizontal line shows the initial effective depths, the letter *B* indicating the beginning of the strip. The section between buoys 5 and 6 inclines from 43 to 45 feet, its depth is considered to be 43 feet, and the path of buoy No. 6 is the dividing line between the two depths. The curved line marked *DC* shows the depth change from buoys 3 to *F*. The entry 2.8 on the path line of buoy 3 indicates that the change started when the drag had traversed 0.8 of the distance between positions 2 and 3, as shown by the time of start in the record. The horizontal line at this point between the path lines of buoys 2 and 3 indicates that, as the depth is decreased, the change extends to buoy No. 2 as soon as No. 3 is altered and that the path of No. 2 is the dividing line between the old and new depths. The entry 6.4 on the path line of buoy *F* indicates that the change was completed when the drag had traversed 0.4 of the distance between positions 6 and 7. The next curved line indicates a depth increase of 1 foot at position 8, due to a decrease in height of tide.

The entry of the data, in black india ink, called for on the cover labels of the wire-drag and sounding records completes the field preparation of the records. The permanent and memorandum records are forwarded to the office. The latter need no special preparation as they are used to investigate any discrepancies that may be found, and then destroyed.

WORK ON SHEETS IN THE FIELD

During the progress of the work all shoals, splits, and small overlaps should be clearly marked on the guide-vessel boat sheet, usually by ringing them with red ink or pencil. The plotting of the smooth sheet should be started as soon as possible after beginning field work and be kept up as closely as practicable with the field work. For this purpose the smooth sheet is protected by tracing cloth held securely in place, with small holes cut through over each control-object position on the sheet.

In plotting each day's work the first operation is to plot the positions of all shoals found during the day. If two or more positions evidently are on the same obstruction and so close together that all of the different soundings can not be plotted, only the position having the least depth need be retained. If there is any question in this matter, a decision should be obtained from the chief of party or other responsible officer. All accepted positions are then pricked through to the smooth sheet and marked with the proper number and day letter, using lower-case letters and ink of the color used for the drag work.

To plot the wire-drag work, a number of boat positions are plotted on the protective sheet with a three-arm protractor, after which the positions of the end buoys are plotted with a position protractor and pricked through to the smooth sheet. The successive positions of each end buoy are then connected by straight lines, using a pencil hard enough to indent the smooth sheet. Care must be taken to plot the buoy positions within a reasonable time after the boat positions lest the protective sheet change its position with relation to the smooth sheet. The protective sheet is then lifted while the path lines are drawn in pencil on the smooth sheet. The first, every fifth, and last positions of each drag strip are indicated by the proper number and day letter, using capital letters and ink of one certain color. These position numbers are entered only on the guide-vessel side of the strip.

Unless otherwise noted in the record, the line of the drag at the beginning of the strip is shown by a straight line connecting the first positions of buoys N and F. If there is a note in the record that the drag curves in a certain direction, the full bight of the drag should be drawn, with the buoy spacer, in the direction given.

If the drag is clear at the end of a strip, the full bight of the drag is shown in such a manner as to decrease the area covered. If the strip ends on a shoal the line of the drag may be represented by one or two straight lines, or by a combination of straight lines and curves, plotted in accordance with the best available information as to the position of the wire and with the following considerations:

1. That the line of the drag must extend back of all shoals found, having depths equal to or less than the effective depth of the drag.
2. That the total length of the line must represent a line of the drag with a length not less than the total length of the drag.

The next operation is the subdivision of drag strips to show the various effective depths obtained. This may follow closely the plotting of each strip or may be deferred until a considerable amount of work has been plotted. As there is usually some delay in the reduction of the records, and as the most valuable information obtained from the smooth sheet in the field is the existence of splits and small overlaps that do not appear on the boat sheet, the latter procedure is usually followed.

The method used to subdivide the drag strips is indicated in Figure 11. For changes due to tide the line of the drag is drawn with the spacer at the proper point. Depth changes are shown by connecting with a line the position of the first buoy involved at the

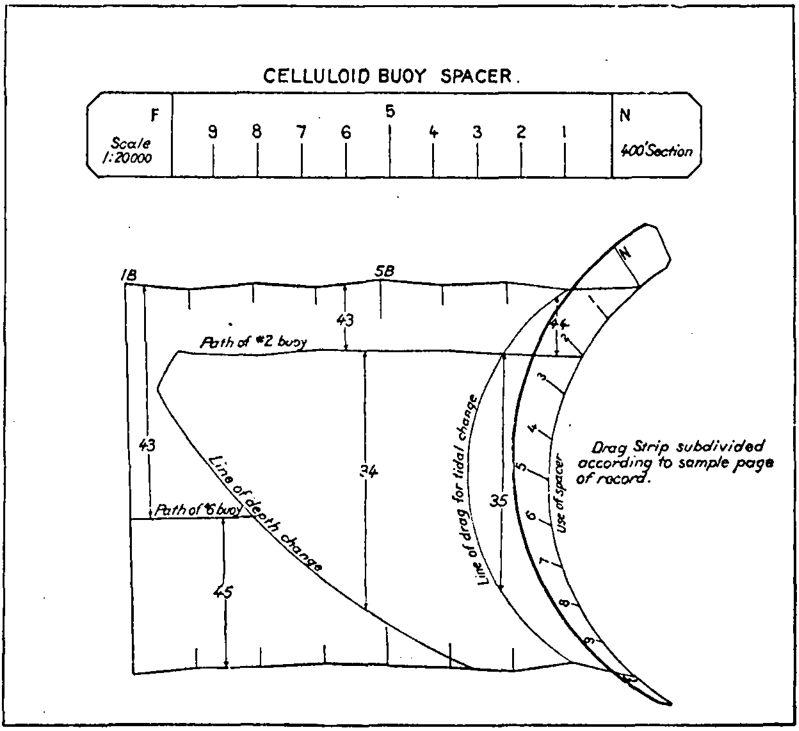


FIG. 11.—Buoy spacer and subdivided drag strip

time the change started and the similar position of the last buoy changed. If the change affects less than half the drag, the two positions are connected by a straight line. If more than half the drag is changed, it is best to locate the middle buoy involved at the time it was changed, assuming a uniform rate of change, and to connect the three points with a smooth curve. With a drag set at different depths the dividing lines are obtained by plotting the positions of the dividing buoys at each drag position and connecting succeeding buoy positions with straight lines.

After a strip is subdivided each subdivision is outlined with colored ink in accordance with the following color scheme, and with the rule that deeper areas are completely surrounded by a line of the proper color, while areas of less depth are surrounded by the proper color, except where they adjoin an area of greater depth:

19 feet and under	Brown.
20 to 29 feet	Yellow.
30 to 39 feet	Blue.
40 to 59 feet	Red.
60 to 79 feet	Purple.
80 feet and over	Orange.

Across each area one or more light lines, similar to the dimension lines of a working drawing, are extended with a space for a number representing the effective depth to which the area is dragged. These lines and numbers are also inked in accordance with the color scheme.

When the strips are inked, corresponding positions of the end buoys are indicated by short lines drawn from each toward the other. Each fifth position is indicated by slightly longer lines.

In shoal localities, where an area may be covered several times by drags set at different depths, the subdivision described above may be simplified by tracing each strip as it is plotted, subdividing the strip on the tracing and then transferring the subdivisions to the smooth sheet.

Effective depths are indicated by the above method with sufficient accuracy for all ordinary purposes. The dividing line between depths caused by a depth change is not shown exactly. As the depth of a section is decreased as soon as one upright is changed while it is not increased until both uprights are altered, the areas are actually divided by an irregular zigzag line. In critical areas the exact line of depth change may be plotted, but the operation is too laborious to use except in important cases.

The work described above, and the entry in pencil of all soundings for which positions have been plotted, complete the field work on wire-drag smooth sheets.

Rubber stamps covering each operation of reduction and plotting, with spaces for the initials of the persons performing and checking such operations, are provided for insertion at the end of each day in the record. Each operation should be performed very carefully and any discrepancies should be noted and referred to the chief of party. The requirements of the general instructions for field work, as to the necessary details on completed hydrographic sheets, should be followed in so far as they are applicable to wire-drag sheets. Each smooth sheet and corresponding boat sheet is forwarded to the Washington office, accompanied by a descriptive report, title sheet, table of statistics, and tidal data sheet, as required by the general instructions for all hydrographic sheets. The table of statistics is prepared in the following form:

Statistics, wire-drag sheet No. —

Date	Letter	Volume	Drag length	Positions	Miles, statute	Soundings
			Feet			
May 15, 1925	A	1	4,000	62	10.3	3
Total				609	125.6	15

VERIFICATION OF SMOOTH SHEETS

Upon receipt of the records and sheets in the Washington office the tidal entries are verified in the division of tides and currents. If any changes are made the corrections are carried through to the effective depths.

The plotting, subdivision, and inking of the drag strips are verified in the division of charts. Special attention is given to the plotting of path lines at points where there may be insufficient overlap and to the line of the drag at the beginning and end of each strip. The records are examined carefully to make sure that a strip ends in every case where there is a release of tension, as when both towing launches stop, when the wire is lifted over a navigation buoy, etc., and is not resumed until the wire is again under tension at its regular depth. It is in such cases that clear and complete explanatory remarks and exact time entries in the record are of the greatest importance. All cases of grounding are examined to make sure that the effective depth of the drag at the time of grounding, the depth found on the obstruction, its position by angles and with relation to the drag, and finally, the effective depth of drag that clears the obstruction, are all in logical relation; or that any discrepancies are explained clearly.

The wire-drag sheet is then examined in connection with the charts and hydrographic sheets of the area covered to make sure that the effective depths are sufficient and to ascertain if the drag has passed over without grounding on any spots where previous surveys or reports give depths less than the effective depth of the drag. As a general rule, unless there is uncertainty as to the effective depth, due to lack of tests, unusual lift at other points of the strip, etc., charted depths of this nature are considered to be disproved and are expunged from the chart.

As each strip is verified, the outlines of the various areas are traced in pencil on clear, heavy tracing paper, each in its proper position with relation to the projection on the sheet. If subsequent strips with greater depths cover all or part of the same area the outlines are modified accordingly so that the completed tracing shows the maximum effective depths obtained over the entire dragged area, as well as all splits and other defects. This sheet, which is the full size of the smooth sheet, is called the overlay sheet.

When the overlay sheet is completed it is carefully traced on vellum with inks in accordance with the color scheme. In each area a number in the proper color denotes the effective depth to which the area has been dragged. Splits are surrounded by hatchures conforming in colors to the limiting lines and have black arrows running to their centers. Insufficient overlaps are surrounded by black dots and are designated by black arrows. All soundings obtained by the drag party are plotted in black ink. At any grounding where a sounding is not obtained, as when the drag catches on wreckage or touches and slips over a sand or mud shoal, the effective depth of the drag, which is a depth on some part of the obstruction, is also plotted in black ink but is encircled in green ink to distinguish it from an actual sounding.

The completed vellum tracing is termed the "A and D (area and depth) sheet." As all overlaps, position numbers, and many of the curves are omitted, this sheet shows the final results of drag operations in a simplified and clear manner.

LIMITATIONS OF DRAG

The wire drag as described has been designed to meet all ordinary requirements. When unusually severe conditions are encountered it should not be used with the idea that it is infallible. The existence of such conditions should indicate the possibility of unusual behavior and every effort should be made to detect and remedy any unsatisfactory performance. When dragging with a heavy swell, for example, it is quite possible that excessive lift, due not only to lifting of the buoys by the swell but also to additional strain caused by the surging of the towing vessels, will result in the wire failing to hold on an obstruction projecting a foot or two above the depth to be verified, or even passing over it without touching. Likewise the use of unusually heavy vessels at both ends of the drag, or the action of strong or irregular currents, may cause similar uncertain action of the drag.

The wire drag has been developed by overcoming many obstacles of a similar nature and it is probable that additional problems can be solved by careful thought and experiment. Changes in equipment and methods that might be made in such cases include the use of heavier weights, longer towlines, setting the end uprights to a greater depth than the others, etc. In all such cases the difficulties encountered, the experiments made, and the changes recommended, should be described without delay in a special report.

THE LIGHT WIRE DRAG

INTRODUCTION

The apparatus described for the wire drag has been modified to provide survey vessels with a light wire drag for occasional use to investigate the shoal indications of ordinary hydrographic surveys and to examine anchorages, narrow channels, and other limited areas. Some parts of the wire drag, the buoys especially, require more storage space than is usually available on a survey vessel, and the apparatus in general is too heavy and elaborate for operation by the small hydrographic launches usually available. The various parts of the light wire drag are described below.

CONSTRUCTION

BOTTOM WIRE

The one-eighth-inch, 7-strand wire previously described, made up in 100-foot units and connected by sockets and one-fourth-inch drop-forged swivels is used for bottom wire.

LARGE AND SMALL WEIGHTS

The shape of the large weight, which weighs 75 pounds, is the same as shown in Figure 2. It is a lead casting with iron staples. A lead sphere 7⅛ inches in diameter, with a segment ⅞ inch high and 2⅓ inches radius removed, will have the required weight.

The shape of the small weight, which should weigh about 35 pounds, is shown in Figure 2. It is a lead casting with a solid iron staple. A lead sphere 5½ inches in diameter, with a segment ¾ inch high and 1⅞ inches radius removed, will have the required weight.

LARGE AND SMALL BUOYS

It is in the design of the buoys that the greatest change from standard wire-drag equipment is made. For this purpose a pneumatic canvas buoy, on the market as a fishing trawl buoy, is used. These buoys are spherical or pear-shaped and are built up of canvas strips treated on both sides with a special preparation to render them air-tight. Each buoy has a wooden head 8 inches in diameter and 1 inch thick, with a concave edge to which the canvas bag is attached with a cod-line seizing. This head is reinforced with a cross strip 1 inch thick and has a ¼-inch hole, closed by a plug wrapped with tarred oakum, for inflating the buoy. Tests of these buoys indicate that they will remain inflated without appreciable loss of air for several weeks and that no detrimental effect is caused by submergence to a depth of 36 feet for several hours.

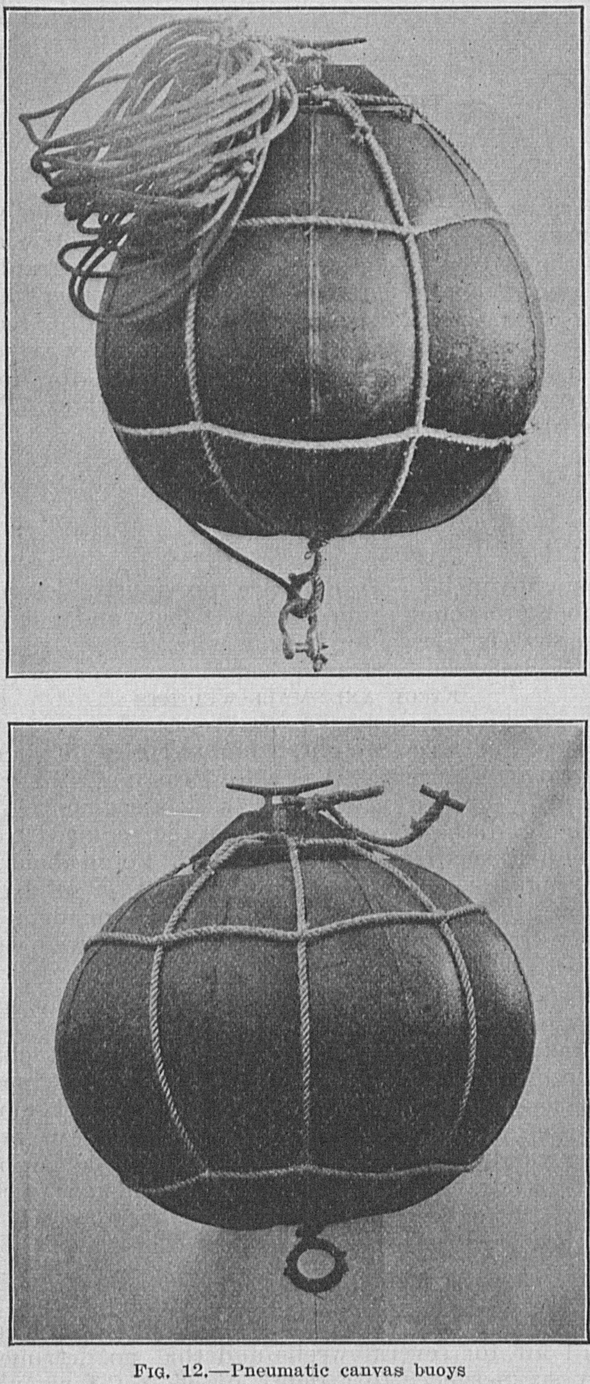


FIG. 12.—Pneumatic canvas buoys

An automobile tire hand pump may be used to inflate these buoys, and an air valve in the buoy head may be installed if desired.

These buoys are adapted for drag work by netting them with six-thread manila rope, attaching a 4-inch galvanized cleat to the crosspiece on the head with a wire seizing and providing a thimble at the lower end of the netting for an upright guide. Two stray lines should be attached to the netting on opposite sides of each buoy to hold it when changing the depth, and a short six-thread lanyard with oak toggle may be attached to the cleat to hold the spare upright when the maximum depth is not used. The buoys should be painted with red lead to increase their visibility. These buoys and the method of preparing them for drag work are shown in Figure 12.

Buoys 65 inches in circumference are used at the ends of the drag. When at rest in calm water one of these buoys will support a weight of 140 pounds. When dragging at a regular speed with 75-pound end weight, the buoy will be about 75 per cent immersed. The intermediate buoys are 60 inches in circumference; each will support a weight of 120 pounds and will immerse about 50 per cent when dragging. These buoys are obtainable in three larger sizes—70, 80, and 85 inches in circumference. It is probable that end buoys 85 inches in circumference and intermediate buoys 65 inches in circumference will give more satisfactory service on account of their additional reserve buoyancy.

FLOATS

The standard aluminum float is also used for this drag. The light wire drag, however, is not in constant use, and wooden floats will give more satisfactory service than for regular drag work due to the fact that their buoyancy can be maintained by drying them out frequently. Wooden floats should be made from well-dried cedar and should be designed for about 15 per cent excess buoyancy.

UPRIGHTS

No. 8 copper-centered lead line is used for all uprights. The uprights are cut to any maximum length desired and graduated in 10-foot intervals by attaching strips of tape or bunting in accordance with the standard color scheme. Each 10-foot interval may be divided into 1 or 2 foot sections by linen thread. The standard system for marking lead lines may be used if preferred. A one-fourth-inch swivel is attached to the lower end of each upright and an index correction to the graduation is provided so that the desired drag depth, with buoy immersed to its towing depth, is obtained when the proper mark is at the cleat on the buoy. The upright passes up through the thimble guide, around the buoy, and is made fast at any desired length by three or four half hitches on the cleat.

TOWLINES

The bottom wire is continued to form towlines in the same manner as for the standard wire drag. Four hundred feet is a convenient length for the towline. If an upper bridle is used, one end is shackled to the thimble guide on the end buoy.

54126°—25——4

LIST OF PARTS

It is considered that a drag 1,200 feet long with 300-foot sections will met all ordinary requirements. The following list gives the amount, weight, and cost of equipment for this length of drag with 70-foot uprights. A few spare wire units, floats, swivels, shackles, and snap hooks should be provided. The snap hooks should be tinned, and all other fittings are galvanized.

Article	Quantity	Weight, pounds	Cost
Bottom wire, 1/8-inch	[1]2,200	68	$25.00
Canvas buoys	5	50	25.50
Weights, 75 pounds	2	150	30.00
Weights, 35 pounds	3	105	30.00
Floats, aluminum	18	20	72.00
Lead line, No. 8, copper center	300	([2])	16.00
Air pump, hand, brass	1	4	4.50
Dynamometers	2	12	10.00
Sockets, special, open	40	12	16.00
Swivels, 1/4-inch	26	5	6.50
Shackles, screw anchor, 3/16-inch	9	2	2.00
Shackles, screw anchor, 1/4-inch	18	2	4.00
Snap hooks, No. 1, swivel eye	18	2	2.50
Thimbles, 2-inch	5	1	50
Cleats, 4-inch	5	2	75
Rope, manila, 6-thread	[3]40	5	1.00
Rope, manila, 3/4-inch	[3]70	12	2.75
	----------	452	249.00

With the buoys deflated the above equipment can be boxed or stowed in a container 2 by 4 feet by 21 inches.

[1] Feet. [2] In item 2. [3] Fathoms.

OPERATION

The light wire drag can be operated with any launches that are available. Ordinary hydrographic launches from 24 to 30 feet in length will do very well as towing launches, while a similar launch, or even a small dinghy equipped with a portable engine, can be used as a tender. A winch similar in design to the standard wire-drag winch but constructed of wood and turned by hand should be installed on the stern of one of the towing launches. The base of this winch should have a wooden roller on its after end, and the standards should be removable for convenience in stowing. The drum when removed from the standards may be used as a reel for storing the wire.

Each towing launch should be provided with a line of three-fourths-inch manila rope, made fast to the bow and long enough to reach the stern. The towline is attached to this bowline, which can be shifted to tow from either side of the launch. The usual adjusting line is provided. In order to standardize the engine speed of launches that are not used constantly it is usually advisable to introduce a dynamometer between the bow and tow lines. For this purpose a standard 400-pound ice scale may be used, being attached by its ring to the after end of the bowline, while its hook engages the end of the towline. A pull of 120 pounds will usually give the standard speed of 1½ miles through the water. There are indications that this drag can be towed at greater speed than the standard drag, without undue lift, but any increase in speed should be accompanied by careful tests of depth.

The drag is set out and taken in over the stern of the launch. These operations and the various connections are the same as for the standard drag, the uprights being attached by the shackle connection.

For dragging at relatively infrequent intervals, dual control will usually give more satisfactory results. Changes in depth are made by hauling in or paying out the uprights, the drag depth should be tested as often as possible and in general the methods given for wire-drag work should be followed as closely as practicable.

Separate wire-drag and sounding records should be kept for this work. If a limited amount of work is done in an area covered by an ordinary hydrographic sheet the drag work may be plotted on this sheet. If the work is extensive it may be plotted on a tracing of the hydrographic sheet or on a special wire-drag smooth sheet. Standard methods of recording and plotting should be followed in all cases.

THE WIRE SWEEP

INTRODUCTION

It has been stated that the maximum speed of the drag is about 1½ miles per hour, and for long drags this speed is, of course, decreased, due to the resistance of the additional equipment used. Drags over 6,000 feet are used principally to examine apparently clear water areas where very few, if any, obstructions may be expected. They are usually set at one depth, great enough to take care of the maximum tide that will occur. It is evident that if a long drag can be simplified by removing the floats, reducing the number of buoys, and using fixed-length uprights, so that hoists will not be required, the speed through the water can be considerably increased, either to cover more ground or to cope with adverse currents; that the apparatus can be set out and taken in very quickly; and that the cost of the equipment will be much less; all tending to expedite the work and decrease its cost. Such an apparatus will lack three properties of the drag; its depth will not be adjustable; with considerable distance between buoys, it will not indicate closely the position of any obstruction encountered; and the bottom wire will sag between supporting buoys to a depth considerably greater than the length of upright. As the first two are of little importance in long drag work, and as the variation in the depth of the bottom wire is always on the safe side, it is evident that such an apparatus might be used to advantage in cases where the general depths exceed by a sufficient amount the length of upright that must be used to verify any desired depth below the reference plane.

With modifications as outlined above in view, the survey developed the apparatus known as the wire sweep to meet the special conditions encountered in southeast Alaska and to expedite the work there. The outstanding features in this region are the narrow passages, with generally great depths extending close in to the shore, strong currents, confused at many points by sharp turns in the passages or by the junction at various angles of two or more passages; and the great amount of unfavorable weather. The advantages in such a region, of an apparatus that can be used with little regard for changes of current, that can be towed against a current of considerable strength, and that can be used to speed up the work during periods of favorable weather, are obvious, and the sweep was used so successfully that the estimated time required to complete the survey of the main steamer routes was reduced by at least two years. The sweep is used in conjunction with the drag, and replaces the longer drags wherever the general depth of water permits. In regions where its use is practicable it is usually necessary to provide for a drag only about 5,000 feet long for the survey of offshore shoal areas, clean-up work close inshore, and the examination of obstructions encountered by the sweep.

CONSTRUCTION

The bottom wire is the same as that used for the drag, three-sixteenths inch in diameter, with the special links omitted from the connecting swivels. The connections at 100-foot intervals are desirable not only in order that the wire may be used either for drag or sweep, but also for the reasons that they tend to prevent twists in the wire and render it easy to repair breaks or kinks in the bottom wire by removing a short length.

The 180-pound weights used for drag work are also attached at each end of the sweep, but no intermediate weights are used, as with floats removed the weight of the wire is sufficient.

Buoys and uprights are attached at each end of the sweep and at intervals of 2,000 or 2,500 feet. The buoys are the 55-gallon gasoline drums used for large buoys on the drag. They are fitted with the rounded wooden bottoms but do not have center pipes or hoists, the uprights being attached to eyebolts in the middle of the bottom. Fixed-length uprights are made up of the same wire used for the bottom wire. If the length is 100 feet or over, a standard unit is used with any length over 100 feet, provided for by a short additional upright of bottom wire or any suitable cable. A sweep hook is shackled to the lower end of each upright for attaching it to the bottom wire.

The towline is a continuation of the bottom wire similar to that used for the drag.

The total length of drag shown in Figure 1, assuming the length of section to be 600 feet, is 3,000 feet. The corresponding length of sweep shown above the drag diagram will give an idea of the simplicity of the sweep as compared with the drag and the amount of resistance that has been eliminated.

LENGTHS AND COST OF THE SWEEP

The length of the sweep depends on the width of the area to be surveyed and the equipment available. Sweeps from 10,000 to 20,000 feet long are used in Alaska for the deep areas some distance from shore, where the existence of obstructions is very unlikely, and a sweep about 7,000 feet long for the areas closer inshore, where a few shoals may be found, especially near the inshore end of the sweep. The latter is made up with two offshore sections of 2,500 feet each and one inshore section of 2,000 feet. After sweeping as close as possible to shore or to shoal areas the survey is completed with the drag. For covering splits and small overlaps a sweep 4,000 or 5,000 feet long is generally used. A sweep with only one section may be long enough in many cases, but it is usually more satisfactory to have at least one intermediate buoy in order to detect without delay any accident, such as parting of the bottom wire, to show the approximate curve of the wire, etc.

Aside from the bottom wire, fittings, and large weights that are also used for the drag, the sweep requires only a few gasoline drums with the rounded wooden bottoms and a sweep hook for each upright. The cost of these is small, and as the sweep replaces the long drags it is obvious that there is considerable decrease in cost of equipment due to the fact that it is not necessary to provide a large number of buoys, floats, etc., for the long drags. In regions where a drag about 5,000 feet long is all that will be required the total cost of equipment as shown on page 9 will be reduced about one half.

SPEED, WIDTH, AND DEPTH OF THE SWEEP

The most suitable speed for the sweep is usually about 3 miles per hour through the water. Suitable engine speeds for the sweep may be determined in the same manner as for the drag.

On account of the higher towing speed and the sagging of the wire between uprights, the effective width of the sweep is represented by a smaller percentage of the total length than for the drag. Any attempt to increase this width beyond a certain amount will result in decrease of speed and consequent loss of one of the important advantages of the sweep. Under general conditions the most suitable effective width is usually about 75 per cent of the total length of bottom wire, though this may vary from 65 per cent for the longer sweeps, being towed against the current, to 85 per cent for short sweeps proceeding with the current.

The length of upright depends on the depth to be verified and the maximum height of tide in the region of the work. For the work in southeast Alaska an examination to a depth of 85 feet below mean lower low water is desired and as the height of tide rarely exceeds 20 feet an upright 105 feet long is required. In order to provide a factor of safety, however, an upright 110 feet long is used. There is accordingly a margin in the depth of the bottom wire at the point of attachment of the upright of 5 feet at high tide and 25 feet at low tide, while the depth of the wire between uprights is considerably greater.

As the minimum depth of the bottom wire minus an amount equal to the highest tide and an allowance for lift is considered to be the effective depth of the sweep, information as to the exact depth at various points along the wire is not essential. It is important, however, to make sure that there is no excessive lift at the points of attachment of the uprights and to obtain a general idea of the amount of sag in the wire, so that the minimum depth of water in which the sweep can be used may be determined. It is impracticable to test the sweep by the method used for the drag. On account of the deep bight of the wire and speed of the sweep, it is difficult to place the tender so as to test at a certain point; the depth of the sweep is much greater than the drag and there is a tendency for the tester to foul the bottom wire at the higher speed. However, by using a sounding lead instead of a pipe and by increasing the number of tests in a section, a fairly good idea of the depth of the wire can be obtained. Instead of trying to test at a certain point, the tender should obtain several tests at different points and locate these tests either by estimating the distance from a buoy at the instant the tester strikes the wire, or by raising a flag for simultaneous bearings from the towing launches. To test at definite points along the wire a device called a test buoy may be used. This consists of about 200 feet of three thirty-seconds-inch aircraft cord graduated to feet with a sweep hook at one end and a 15-gallon oil drum at the other. When the sweep is set out the cord is attached at any desired point and trails behind the sweep, its upper end being supported on the surface by the buoy. To make the test the tender picks up the buoy, runs ahead, takes in the slack cable, and when over the wire, hauls taut to read the depth. To test at the point of attachment of an upright the cord is made fast to the upright sweep hook and care must be taken in setting out to prevent the cord from fouling the upright. Any desired number of tests may be made with the tester while only one for each set-out can be made with the test buoy. Frequent tests of the sweep are not essential, one or two during the season being sufficient.

Tests of the sweep that have been made to date indicate the following:

1. That with 2,500-foot sections and 110-foot uprights, the depth of the wire in the center sections of a long sweep may be as great as 180 feet, decreasing to 150 in the middle of the end sections, with a slight decrease in general depths for shorter sweeps while a reduction in length of section to 2,000 feet decreases the maximum depth of the sweep to about 150 feet.

2. That the end weights may lift as much as 25 feet due to the increase in towing speed, while there is little, if any, lift at the intermediate buoys.

3. That a sweep with 2,500-foot sections can not be used in depths less than about 35 fathoms, but that for work in depths slightly less than this the sections may be shortened to 2,000 feet.

4. That a modified sweep might be used to advantage in depths between 20 and 25 fathoms, using sections about 800 feet long with 15-gallon oil drums for intermediate buoys.

The lift at the ends of the wire does not have much effect in sweep work. With a depth of 85 feet at the end and 150 feet in the middle of an end section the wire will reach a depth equal to the upright length about 500 feet from the end weight. The bight of the sweep is so deep that several hundred feet of wire tow almost directly behind the end buoys so that an ordinary overlap will take care of the end lift. In cases where the sweep line runs so close to shore that drag work is not required the depth of 500 feet of wire nearest the shore may be considered uncertain to a minimum depth of 85 feet. On account of the depth of the bight, however, the width of this uncertain strip usually will be too narrow to plot.

OPERATION OF SWEEP

The towing vessels and equipment previously described are also used to operate the sweep. Two minor additions to the operating equipment are desirable. The sweep is taken in at much higher speed than the drag and considerable water comes aboard on the wire, being thrown off when the wire winds on the drum of the winch. As a protection for the man operating the winch a detachable guard of sheet iron should be provided at the rear of the drum. The other addition is a small wooden hand reel to carry the uprights.

A tender is sometimes useful in sweep work to carry data between the towing vessels, etc., but these occasions are so infrequent that, unless the sweep is to be tested, it is usually more economical to assign the tender to other work. In regions where few soundings have been obtained the tender may be used to advantage in obtaining additional soundings in areas where later drag work is to be done.

The method of setting out the sweep is similar to that for the drag, with the exception that, as stops are necessary only to attach the end weights, the vessels proceed at much higher speed. This speed is not only desirable in order to reduce the time of this operation but it is also necessary to prevent the wire from sinking considerably below its towing depth and possibly catching on the bottom. A launch may proceed at approximately full speed, but larger vessels, on account of greater momentum, may adjust speed to the necessity for a quick stop in case of an accident, such as the wire catching under a fitting on the drum. To compensate for slower speed, a larger vessel is able to exert a more even strain on the wire. The guide vessel buoys the end of the wire, passes it overboard, and goes ahead very slowly until the end vessel picks up the end and connects it with the wire on her winch, after which both vessels set out at their regular speed. The units are carefully counted as they go overboard, and as the point of attachment of an upright is neared a buoy with upright attached is put overboard and towed astern until the number of units in a section are out. As the last unit leaves the drum the sweep hook is slipped over the wire and the buoy released. The upright can slide along the wire, but is confined within a limit of 100 feet by the fittings on the ends of the unit. Lenth of towline should be 500 feet for launches and 600 feet for larger vessels. For the latter, if the distance from the towing bitt to the stern is 100 feet or over, a convenient arrangement is to keep one unit attached on each side at all times. The forward end of the unit is attached to the bitt with the claw hook while the after end is secured temporarily near the stern, so that, instead of setting out 600 feet of towline and then hauling it forward to the bitt, 500 feet can be set out and then connected near the stern with the unit already in place.

After the sweep is set out the general procedure is about the same as for the drag, dual control being used. There is one important difference between the drag and sweep, however, that always must be considered at the beginning of a strip. Unless the sweep is set out at very high speed and without delay, the wire will sink below its towing depth, and if the towing vessels start at too great speed the resistance of the water against the lifting of the wire will tend to submerge the buoys, so that they may be crushed. The towing vessels therefore must always start at slow speed and increase very gradually to regular speed. The buoys must be watched constantly, and if one starts to submerge the nearest vessel must stop at once until the buoy appears again. After observing these precautions for a short time the wire will reach its towing depth and it will be difficult to submerge the buoys at any reasonable speed. In setting out the sweep there is always a possibility that the wire may sink far enough below its towing depth to reach bottom, and it is obvious in such a case that the best chance to clear the wire is by a vertical lift without horizontal strain. It is therefore advisable in most cases for the vessels to tow away from each other at right angles to the path lines until the strain on the wire and the behavior of the buoys indicate that the wire has reached its approximate towing depth. A launch may then change quickly to the path line course, while a larger vessel should start swinging a little earlier. As the sweep will then be fairly well stretched, it is evident that one vessel, at least, will be considerably outside the path line course. Instead of heading in sharply and possibly removing tension from the wire, a vessel outside its path line should select a course that will work in gradually and reach the path line after two or three positions.

Unless an accident occurs or the wire strikes an obstruction the sweep then proceeds until the strip is completed, after which it may be taken up or reversed to cover an adjoining strip. To reverse the sweep, the vessel on the side of the next strip should change course quickly and increase her speed slightly to tow the sweep over to the new starting point while the other vessel reverses her course and heads along the line of the wire, adjusting speed to keep abreast of her end buoy. If an accident such as parting of the wire occurs it is usually best to take up the sweep and start over again. The time required to take up and set out the sweep is so short in comparison with the drag that time is usually wasted in attempting any other procedure. If both vessels stop, the line does not necessarily end as in drag work for there is nothing to lift the wire, but such a delay must be brief or the wire will sink to the bottom. For straight strips it is important that the towing vessels keep station abreast of each other. This not only gives the greatest possible area for a certain effective width but also increases the maneuvering ability of the towing vessels. The standard overlap for fairly straight lines is the length of one section of the sweep. Other overlaps should be in the same proportion as for the drag. There should be a minimum overlap of about 1,000 feet where drag and sweep strips join.

If the sweep encounters an obstruction the effects are about the same as with the drag, but are not noticed so quickly on account of the slack in the wire and the small number of buoys. The end buoys usually trail nearly astern of the towing vessels and the swinging of an end buoy away from this position toward the center of the sweep is usually the first indication of grounding. Except in one special case the standard procedure is to take up the sweep at once and examine the area later with the drag. The vessel that clears the wire may obtain a few soundings when the wire extends vertically up from the obstruction, but any further attempts at development usually are a waste of time. The special case occurs when the sweep grounds at or near an end section, and under this condition time usually can be saved by the following operations: The vessel farthest from the obstruction heads away from it and reduces speed as much as possible while keeping steerage way and strain on the wire. The other vessel takes in the wire until it clears, turns immediately, resets ahead of the obstruction, and resumes towing. When the set-out is completed the first vessel changes course and works back gradually to her path line. The vessel that takes in the wire records the time that the end weight starts to lift, the number of units taken in, the approximate position of the grounding, any soundings that may be obtained, and the time that the resetting is completed. These operations leave a split in the strip that is bounded by the line of the sweep at the time the end weight lifts, the line of the sweep at the time the resetting is completed, and the path of the buoy remaining in the water nearest the grounding between its positions at the two times mentioned.

The method of taking in the sweep is the same as for the drag. After the end weights are aboard the winches are operated at high speed and stops are made only to unhook the uprights.

RECORDS AND OFFICE WORK

The standard wire-drag record and the methods of recording dual control are also used for sweep work. At the beginning of the day the fixed length of upright is shown at the top of the left-hand page. The length of section, recorded on the right-hand page, shows whether the drag or sweep is used. There is one point, however, that must be specially considered for sweep work. There are some cases, as when one vessel takes in wire to clear the sweep while the other vessel continues towing, when one vessel will take more positions than the other. If the guide vessel takes fewer positions a sufficient number of blank spaces must be left in the record for later entry of the additional end vessel positions.

As only the minimum depth of the sweep is considered there are no reductions to be made in the record. The work is plotted in the same manner as a long drag and the sweep strips are outlined with orange-colored ink, no depth numbers being shown. A note is placed on the smooth sheet stating that all areas outlined in orange, unless otherwise noted, are swept to a minimum of 85 feet, or whatever the effective depth may be.

COST OF DRAG AND SWEEP WORK

The costs of wire-drag and sweep work vary through a wide range and are affected by numerous conditions. On the coast of New England, for example, fishing gear, such as lobster pots and trawls, interferes with the work and must be removed. To effect this, it is necessary to divide the area to be surveyed into small sections and to examine each section separately. When a section is to be examined its corners are buoyed and fishermen are notified, so that they can remove their gear. This procedure prevents the planning of work to take advantage of different weather and current conditions and adds greatly to its cost. Likewise, in narrow channels, the length of drag is limited, and in many cases the currents are so strong as to prevent work except at or near slack water. In all regions the cost increases with the number of shoals that are found. With average conditions the cost of combined drag and sweep work will vary from $75 to $100 per square mile. Surveys of limited areas where current and other conditions are unfavorable may cost as much as $1,000 per square mile.

OTHER FORMS OF DRAG

While the elaborate apparatus, operating equipment, and special launches described in the preceding pages have been developed for the purpose of increasing the efficiency and consequent economy of drag and sweep work, it should be remembered that the principle of the drag or sweep is very simple and is always available to the hydrographer. Lacking special equipment, a drag can be improvised for work of small extent by using material at hand, such as telephone or sounding wire, oil cans, sounding leads, etc., and operated in fairly good weather from whatever launches are available. Several other devices have been used by the United States Coast and Geodetic Survey and by other surveying organizations to supplement lead-line surveys, and a few of these devices are decribed briefly below.

SUBMARINE SENTRY

The submarine sentry consists of a wooden trough, called a kite, suspended by a towing wire from a small winch on the deck of a vessel. The kite is provided with a trigger, and the towing wire is made fast to a bridle in such a manner that the kite is towed at a certain distance below the surface, depending on the length of the wire used. If an obstruction is encountered the kite trips and rises to the surface, while a bell on the winch rings, due to release of tension on the towing wire. This apparatus is used to warn a vessel when approaching shoal water, but it may be used also to a limited extent in surveying. For this purpose it is towed back and forth over an area to be surveyed, the obstructions encountered being examined with the lead and line. While shoals may be found with this device, there is, of course, no assurance that all or any great proportion of shoals in the area have been discovered.

THE PIPE DRAG

The pipe drag consists of an arrangement of iron pipe, pipe fittings, and guys by which a pipe a little longer than the beam of a ship is suspended athwartships in a horizontal position at any moderate distance below the ship. A pipe is attached on each side of the ship and extends down to support the horizontal pipe. The strip covered by this apparatus is very narrow, and some repairs are usually necessary whenever an obstruction is encountered.

THE CHANNEL SWEEP

The channel sweep is used to verify depths in channels. It consists of a heavy iron rail suspended at any desired distance below one or two barges. The barges are towed slowly along the channel and the uprights are watched closely for evidence of grounding.

THE SINGLE-VESSEL SWEEP

A device called the single-vessel sweep has been used to a considerable extent by the British Admiralty. Two sled-shaped wooden floats, each provided with a small iron air tank to increase its buoyancy, are used. Each float is provided with a sheet-iron rudder attached at an angle in such a manner that when the floats are towed astern of a vessel with separate towlines the rudders force the floats away from each other. A weight of about 35 pounds is suspended from each float by a cable upright of suitable length, and the two weights are connected by a third cable. When this apparatus is towed through the water the floats sheer off from each other and stretch the third cable in a horizontal position similar to the bottom wire of the drag. The Swedish Hydrographic Office uses a similar device, called a sentry sweep. In this apparatus kites similar to those used for submarine sentry replace the weights. When the bottom wire strikes an obstruction both kites are detached so that they float to the surface and remain anchored on the shoal by the bottom wire.

THE MARLINE SWEEP

This sweep was used by the Coast and Geodetic Survey to supplement the wire drag in searching for submerged trees and snags in Lake Washington. It was found that when the wire drag was used for this purpose it was almost impossible to clear the wire without considerable loss of equipment. To operate the marline sweep lead lines were lowered from each of two small pulling boats, and the leads were connected with from 100 to 150 feet of tarred marline. The buoyancy of new marline just balances its weight in the water, so that its behavior is practicaly the same as the bottom wire of the drag with floats attached. The small boats proceeded slowly at a suitable distance apart until the marline caught, after which the leads were raised, a round turn taken with the marline, and a buoy attached to the two ends, thus marking the obstruction. Each tree and snag found and marked in this manner was removed later by a snag boat and, after it was considered that all such obstructions had been removed, the area was examined with the wire drag to make sure that none had been missed.

In operating any of the devices just described it will usually be helpful to place several temporary buoys for reference points in the area to be examined. In surveying small areas with overlapping strips reasonable assurance of suitable overlap may be obtained by having a tender mark the path line of the edge of the strip that is to be overlapped by dropping small marker buoys at frequent intervals. The next strip is run so that the end of the apparatus passes inside of this buoy line, the tender preceding the towing vessel and picking up the buoys just before the drag reaches them.

On account of short length and other limitations of these devices, their use for surveying is usually a time-consuming and costly process. Except in a few special cases it is believed that the use of the wire drag and sweep as developed by the United States Coast and Geodetic Survey will be much more satisfactory and economical.

APPENDIX

SPECIFICATIONS AND INFORMATION REGARDING WIRE-DRAG EQUIPMENT

Bottom wire.—The use of strand wire was suggested by John A. Roeblings' Sons Co. of Trenton, N. J. This firm can furnish any quantity of wire desired, and it is also obtainable from other manufacturers of wire and wire rope. It is usually ordered in continuous lengths of 5,000 feet wound on a wooden reel and packed for shipment.

Specifications (small wire).—Steel strand wire, 1/8 inch diameter, 7 wires, double galvanized, extra high strength, approximate breaking strength 1,830 pounds.

Specifications (large wire).—Steel strand wire 3/16 inch diameter, 7 wires, double galvanized, extra high strength, approximate breaking strength 3,990 pounds.

Large weight.—The large weights can be made by any iron foundry.

Specifications.—To be a cast-iron sphere with one flat surface, with dimensions as shown in Figure 2. A 3/4-inch iron rod bent to form two staples to be cast in the weight as indicated.

Small weight.—The small weights with locking staple can be made by any well-equipped machine shop. If a solid staple is used the weights may be obtained from an iron foundry.

Specifications.—Body of weight to be a cast-iron sphere with one flat surface, with dimensions as shown in Figure 2. A 3/4-inch round steel rod to be bent to the shape shown and cast in the weight. A section of galvanized iron pipe, 3/4-inch inside diameter, to be inserted in the weight as indicated and cut at the top to the shape shown. A hinged arm of round steel, 11/32 inch in diameter, to be attached to the bent steel rod with a pin as shown. This hinged arm to be fitted with a ferrule of 1/2-inch brass pipe, slotted as shown. A steel plug with upper end 11/32 inch in diameter to be soldered into the galvanized pipe in the weight. The entire arrangement to be such that with the staple closed, there will be a clearance of 1/8 inch between the lower end of the hinged arm and the top of the steel plug; that when a pin in the hinged arm engages the left-hand slot in the ferrule, the staple is locked; and that when the pin engages the right-hand slot the ferrule may be lifted so that the hinged arm swings open freely.

Buoys.—The 55-gallon galvanized-iron gasoline drums used for large buoys and the 15-gallon black iron oil drums used for small buoys are standard articles and may be obtained from manufacturers or oil dealers. The following method for installing a center pipe in the small drum has been used with good results. The same method is used for the large buoys with necessary increases in the sizes of the materials used.

Installation of central pipe.—The following materials are required for each small buoy:

1. One 15-gallon oil drum, diameter 15 inches, length from 20 to 22½ inches.
2. One piece one-half inch, double strength, black iron pipe, 2½ inches longer than the drum, threaded outside 5 inches on one end and 3 inches on the other.
3. One iron plate 2½ by 5 inches, one-eighth inch thick, with center hole just large enough to slip over pipe, and 10 one-fourth inch holes spaced evenly around the edge.

4. One iron plate, 2½ by 5 inches, one-fourth inch thick, with holes corresponding in position to those on the first plate. Center hole to be threaded to fit pipe threads; holes along edge to be threaded for one-fourth inch stud bolts.

5. Two lock nuts to fit pipe thread, two washers to fit over pipe, 10 stud bolts, one-fourth by one-half inch, and small piece of three thirty-seconds inch rubber packing for gaskets.

The following steps of the operation are given in the order that they are performed:

1. In the center of one end of the drum drill a round hole of the same diameter as the outside of the pipe. In the center of the other end cut a rectangular hole 1¼ by 2¾ inches. Lay one of the plates over this opening, mark and cut holes for the stud bolts.

2. Screw one lock nut as far as it will go on the end of the pipe having the 5-inch thread, follow with a washer, and then insert the pipe with this end first through the rectangular hole and out through the round hole as far as possible. About 5 inches of threaded pipe will then protrude through the end of the drum having the round hole, the washer and nut will be brought up against the inside of this end, and the remainder of the pipe will be inside the drum.

3. Insert the plate with the threaded holes through the rectangular opening, work it into place and secure it loosely with two of the stud bolts. Holding the pipe by the protruding end, shove it back until the 3-inch threaded end enters the threaded hole in the plate; then turn pipe until this end projects about 1 inch out through the plate.

4. Remove stud bolts holding plate in place, insert the blade of a large screw driver into this end of the pipe, and shove pipe back until the washer is again brought up against the inside of the end of the drum. The pipe will now be in the same position as at the end of the second step, but the plate will be screwed on the 3-inch threaded end of the pipe and the screw driver handle will protrude through the rectangular opening.

5. Bring the pipe and drum to a vertical position resting on the end of the screw-driver handle, hold the upper end of the pipe, press down on the drum and turn it counterclockwise. Friction between end of drum, washer, and nut will cause the nut, which should be well oiled, to unscrew and rise with the drum on the pipe until the plate brings up firmly against the inside of the lower end of the drum. The pipe will now be in its proper position, held in place by an interior nut and washer at one end and a plate at the other.

6. Place remaining plate over the pipe, with a well-leaded gasket underneath, and secure it with the 10 stud bolts that pass through the holes in the outside plate and end of drum, and screw into the holes in the interior plate. Screwing a gasket, washer, and lock nut down as far as possible on the other end of the pipe completes the operation.

The pneumatic canvas buoys used for the light drag are a foreign product and, so far as known, are not manufactured in the United States. Under the trade name of "Hercules" brand, canvas buoy, they are obtained by dealers in this country from O. Nielssen & Son, Bergen, Norway. They are obtainable from the Pacific Marine Supply Co., and the Norby Supply Co., Seattle, Wash., and possibly from dealers in marine supplies in other ports.

Buoy hoists.—Buoy hoists can be made by any well-equipped machine shop.

Specifications (large buoy hoist).—Construction and dimensions to be as shown in Figure 13. Frame to be of three-sixteenths-inch steel plate, cut and bent as shown. Two seven-eighth-inch steel shafts, each with a five-eighths-inch squared end, to be fitted through the frame as shown. Lower shaft to be provided with a screw eye near its center for attaching cable. A brass ratchet to be keyed to the upper shaft outside the frame, as shown, so that its teeth when engaged by a dog will prevent the shaft turning counterclockwise. Two brass spur gears to be keyed to the two shafts as shown. The upper gear to be solid and approximately 3 inches in diameter, the lower to be cored out for lightness and approximately 10 inches in diameter. Gear teeth to be in proportion of 1 to 4. Disks on lower shaft to be of brass and fastened in place by set screws through their collars. A thrust bearing to be provided between each gear and the frame. A collar with set screw to be provided on each shaft outside the frame and on the end opposite the gears to hold the shafts in place. A brass dog swinging on a pin to be provided to engage the ratchet and lock the hoist. A hole 2 inches in diameter to be provided in the base of the frame as shown. Top of frame to be braced with a rod with inside and outside nuts, as shown.

Specifications (small buoy hoist).—Construction and dimensions of various parts and assembly to be as shown in Figure 13. Frame to be one-fourth-inch steel plate, cut and bent as shown. Shaft to be of steel with one end squared to five-eighths inch, as shown. Ratchet and dog of brass to be provided as shown; dog to be provided with a spring pin to engage a hole in the frame and lock the dog against the ratchet. Washers and collars to be of steel. Drum to be made up of two galvanized plates and an oak center. Oak center to be carefully turned to the dimensions given. Shaft hole to be exactly centered and ends squared at right angles to the hole. Each plate to be attached with three screws; screws in opposite plates to be staggered. Drum to be securely keyed to the shaft.

Floats.—Aluminum floats can be obtained from various manufacturers of aluminum goods. Satisfactory floats have been obtained from the Aluminum Goods Manufacturing Co., of Manitowoc, Wis., and the Aluminum Co. of America, Pittsburgh, Pa. Wooden floats can be obtained from any woodworking shop. They should be waterproofed by immersion in raw linseed oil, maintained just under the boiling point, for about 20 minutes. After drying for several days, the oil bath should be repeated.

Specifications (aluminum floats for one-eighth inch wire).—Shape and dimensions to be as shown in Figure 2. To be a hollow aluminum float, cylindrical in shape, with an outside diameter of 3½ inches and a length of 17½ inches. Material to be aluminum plate, 98 to 99 per cent pure, 0.05 inch thick, (No. 16, B. & S. gauge). To be stamped in two sections approximately equal in length, the open end of each section to have a quarter-round exterior bead. Each section to be strengthened by four one-eighth inch corrugations extending inward and all the way around the float, as shown. The open end of each section to be closed by welding in a round plate, three-sixteenths inch thick, rounded to fit tightly into the flaring end of the section. After closing ends in this manner, the two sections to be joined by welding. A bale of aluminum, seven-sixteenths inch wide and one-fourth inch thick, to be securely welded with pure aluminum to one end of the float as shown. Each float to withstand submergence in sea water to a depth of 150 feet without filling with water, leakage, denting, or crushing.

Specifications (wooden floats with 15 per cent buoyancy for one-eighth inch wire).—To be of well-dried white cedar, length over all, 20½ inches; maximum diameter, 4 inches. To be turned to stream-line shape as follows: Two inches of end to be rounded, next 11½ inches to have full diameter, remaining 7 inches to be tapered to a rounded end 2 inches in diameter.

Uprights.—The various materials for uprights can be obtained from manufacturers of wire rope and cable.

Specifications (large upright).—To be of galvanized aircraft cord, with 1 center strand and 6 outside strands, each strand to have 7 wires. Diameter to be one-fourth inch, approximate breaking strength to be 5,800 pounds.

Specifications (small upright).—To be galvanized aircraft cord, 6 strands of 7 wires each and a cotton center. Diameter to be three thirty-seconds inch, approximate breaking strength to be 780 pounds.

Specifications (small upright).—To be of galvanized-wire rope of plow steel. To have 6 strands of 19 wires each and a hemp center. Diameter to be three-sixteenths inch.

Sockets.—The sockets used for wire-drag work were developed by John A. Roebling's Sons Co., of Trenton, N. J., and so far as known can not be obtained from other dealers.

Specifications.—Special, double-galvanized, drop-forged, open sockets, with pins and cotters, for —— diameter wire. (Give size of wire and drawing as in fig. 2, using the proper set of dimensions for the wire used.)

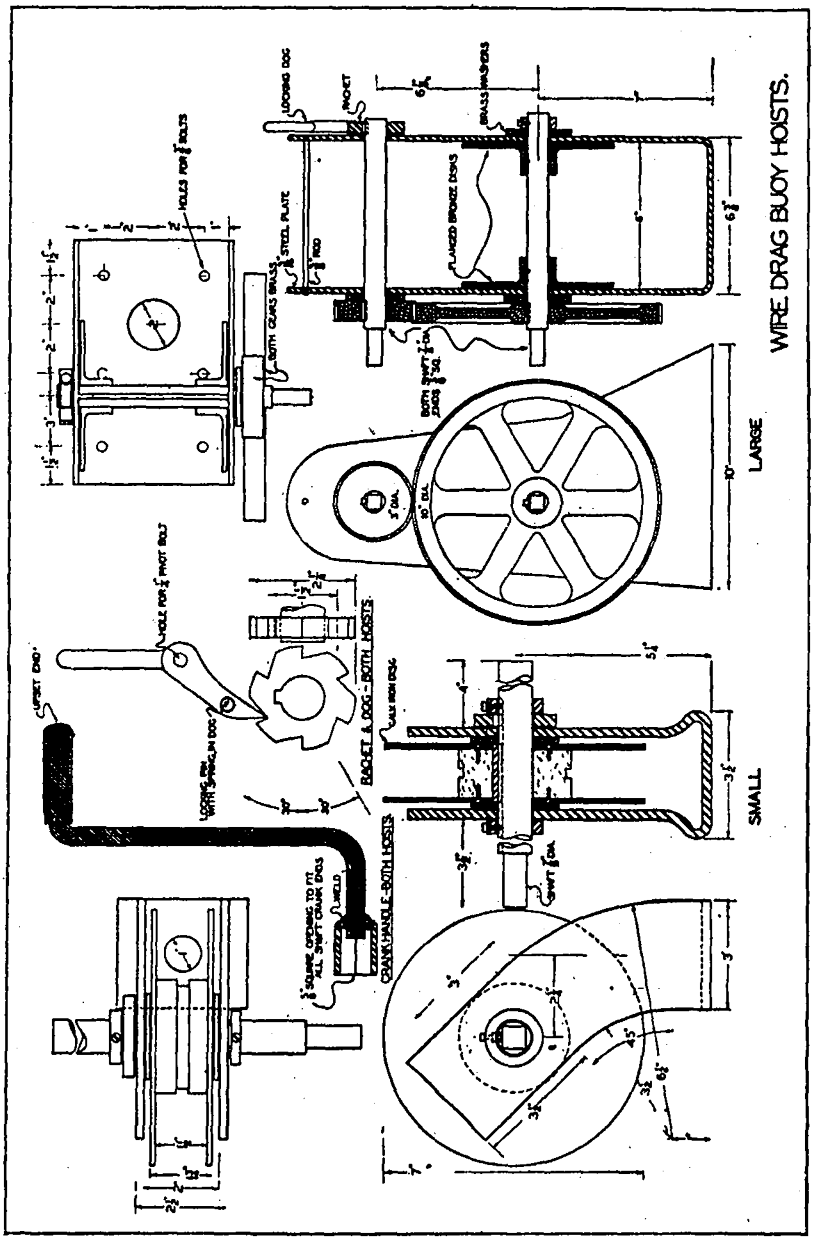


FIG. 13.—Large and small buoy hoists

Power winch.—Drawings of the power winch installed on one of the special wire-drag launches are given in Figure 14. This winch is driven by a gasoline engine installed in the hold of the launch. The design may be modified somewhat to meet various conditions.

If the engine must be installed on deck, for example, it may be desirable to shift the sprocket to the inboard and the brake to the outboard side of the winch. On one of the launches used by the survey the height of the standards has been reduced about one-half with some advantages. It is desirable to provide removable handles on the flanges of the drum for use in case of engine failure. The winch should be bolted securely through the deck and leveled with wedges, if the deck is cambered. The winch and the forward and after platforms should be aligned carefully.

There is no standard design of the power plant, as this depends on the construction of the various parts used. It is the usual practice to secure a used automobile transmission and clutch of substantial construction, connect it with the engine shaft, and provide a sprocket for transmission of power to the winch through a sprocket chain. This adaptation can be made easily by a skilled mechanic. The gear shift, clutch, and brake levers should be installed so that they can be operated from the rear of the winch but are out of the way of the wire passing on or off the winch drum.

Specifications.—Design and dimensions of power winch to be as shown in Figure 14. The two standards to be of wrought-iron angles, 2½ by 2½ by ⅜ inch, bent or cut and welded as shown and cut at bottom to form plates for bolting winch through deck. Standards to be connected and braced with two strips of wrought iron as shown. Two bearings for 1⅜-inch shaft to be bolted to the standards as shown. Flanges of drum to be of ⅝-inch iron, 23½ inches in diameter. Barrel of drum to be formed with six straps of wrought iron, 2 by 5/16 inch, keyed into the flanges. Barrel of drum to be braced by an interior disk, as shown. A 6½-inch collar to be bolted to each flange and keyed to the shaft. Brake drum, 12 inches in diameter and 2¼ inches wide, similar to brake drum of an automobile, to be securely bolted to one drum flange. Brake band to be of steel, 2 inches wide to be lined with asbestos brake lining. One end to be made fast to the standard and the other to a lever about 14 inches long arranged on a fulcrum in such a manner that a pull from the rear of the winch will apply the brake. A cast-steel sprocket as shown to be bolted to the other flange. Teeth to fit standard automobile truck chain and sprocket to be set out from flange so that chain will clear the flange.

Rubber stamps.—The standard rubber stamps used for the records of wire-drag work have been assigned stock numbers as follows:

Stamp No. 6.—For insertion in wire-drag record at the beginning of each day. Blanks for length of drag, section, and towline; weather, wind, and sea; time of leaving for and arrival at working grounds.

Stamp No. 7.—For insertion in wire-drag record at beginning of each day and wherever a depth change occurs. Blanks for time of beginning and end of depth change, buoys effected, and length of upright.

Stamp No. 8.—For insertion in wire-drag record at end of each day. Blanks for miles run, angles obtained, reason for stopping work, and time of leaving for and arrival at headquarters.

Stamp No. 9.—For insertion in wire-drag record at end of each day. Blanks for initials of person checking entry of data from memorandum records and of the persons who enter and check the distances, correction, drag depth, reducers, effective depth, and effective-depth diagram.

Stamp No. 10.—For insertion in wire-drag record at end of each day. Blanks for initials of persons who perform and verify the operations of plotting the positions, tracing drag strips, rejecting positions, subdividing areas, transfer and inking, and comparison with chart.

Stamp No. 11.—For insertion in sounding record at end of each day. Blanks for initials of persons who enter and check data from memorandum records, tide reducers, and reduced soundings; and for initials of person who plots the soundings.

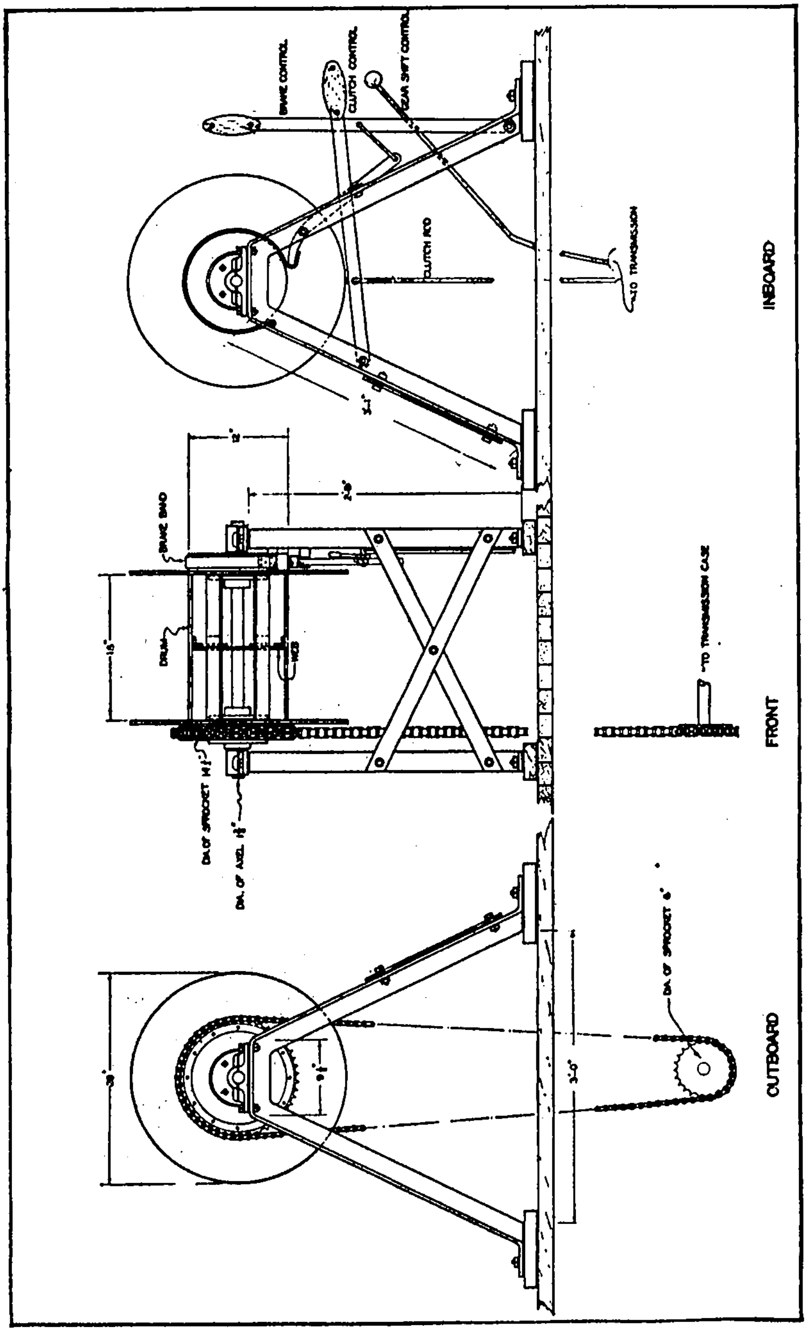


FIG. 14.—Power winch

Stamp No. 13.—For insertion in wire-drag record at end of each day. For entry of effective-depth diagram.

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