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AIR-CURTAIN FISHING FOR MAINE SARDINES

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SUMMARY

Since its initiation, nearly a century ago, the Maine sardine industry has been dependent upon passive types of gear--weirs and stop seines--for the capture of its basic raw material, the Atlantic herring (Clupea harengus harengus). Such gear, although effective in capturing inshore schools and in incorporating the necessary provision for holding the live fish for several days, is not effective in coping with the schools when, as often happens, they remain in deeper water offshore. Failure of the herring to move inshore has often resulted in cannery supply shortages.

Realizing the need for a more active and far-reaching type of gear, the U. S. Bureau of Commercial Fisheries began, in 1955, to experiment with other types of gear. Research activities were largely based on the premise that, since the herring are easily-frightened fish, a device that would frighten them might also be used to drive or guide the fish from deep water to the areas where they could be taken in the weirs and stop seines. In the past three years, the usefulness and effectiveness of an air-bubble curtain for driving and guiding the herring has been demonstrated to the industry, and at least 12 air-curtain units have now been constructed by members of the Maine industry.

Essentially, the air-bubble curtain consists of several lengths of $\frac{1}{2}$- to $\frac{3}{4}$-inch-diameter polyethylene pipe, weighted to lie on or near the sea bottom, and from which columns of bubbles escape through $\frac{1}{64}$-inch holes bored in the pipes at regular intervals. Air is supplied by a shipboard compressor. The bubble curtain is used to surround the fish and slowly draw them to the seines, or to otherwise direct them in the direction of the weirs and seines by cutting across their normal path of movement.

BACKGROUND

The Maine sardine industry began in the 1870's when the Franco-Prussian War restricted the supply of Russian and French sardines to the United States. New York importers searched for a supply of sardines to be packed in the style known as Russian sardines, which were described by Goode (1887) as "small herring packed in spices and vinegar." The importers became interested in the large schools of Atlantic herring (Clupea harengus harengus) that occurred each summer in the vicinity of Eastport and Lubec, Maine, i.e., the Passamaquoddy and lower Bay of Fundy area, and after initial experiments, they concluded that the fish could be properly processed and canned as Russina sardines.

In 1875, 200 to 300 cases of the fish were packed in Eastport, and during the next few years there was a rapid expansion of the industry. By 1880, nineteen canneries were in op-

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eration and packed $800,000 worth of sardines, including Russian sardines, anchovies, and sardines in oil, mustard, spices, and tomato sauce (Earll 1887). By 1886, the number of canneries had increased to 45--the approximate number processing sardines in recent years.

The conventional methods of catching sardine-size herring--stop-seining and weir-fishing--are restrictive and confine fishing operations to very shallow waters. Limitations of these methods, combined with natural fluctuations in abundance, often cause shortages in the herring supply, and result in cannery shutdowns and associated instabilities in the sardine industry. Fishing-gear research by the U. S. Bureau of Commercial Fisheries has been directed toward increasing the range and effectiveness of Maine sardine fishing gear to diminish the effect of supply shortages.

FISHING METHODS

Stake-and-brush fish weirs or traps were originally used for catching the small herring. The earliest were probably copies of Indian traps used in the Passamaquoddy Bay area.

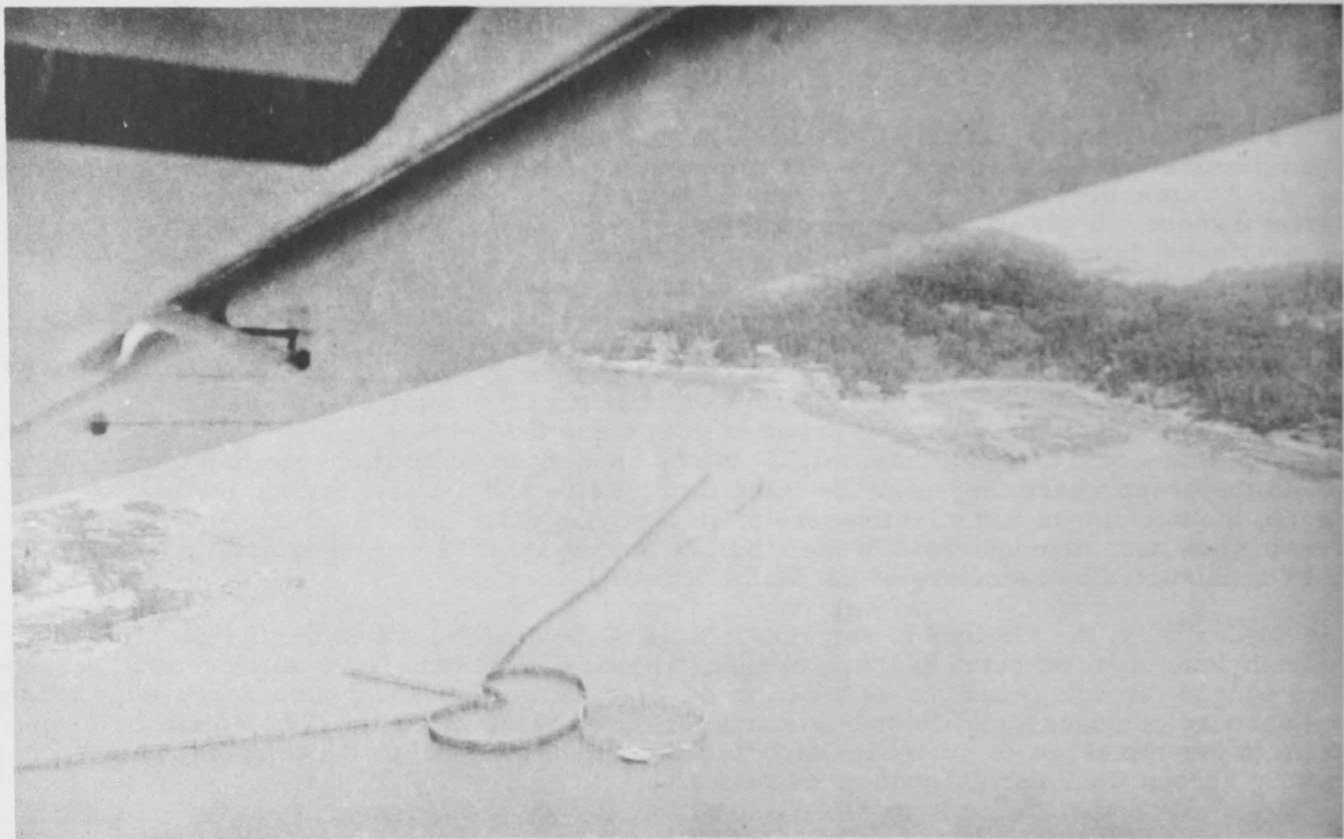

Fig. 1 - Typical weir and holding pocket or "parlor" used for catching Maine sardines.

Weirs of similar design are used to this day, although the modern weirs are constructed of much longer stakes or pilings that are driven into the mud with cotton or nylon nets stretched and fastened over them. Seines were tried early in the fishery also; but this method became extremely unpopular among weir operators, and laws were passed in the 1800's to prohibit seining. These laws have since been repealed and a "drag seine" or "stop seine" is the dominant type of gear now used for catching Maine sardines. The stop seine is a straight piece of netting of approximately 1-inch mesh size (stretched measure) made up in sections 100 fathoms long and 7 to 10 fathoms deep. One to ten 100-fathom lengths of this gear are used to "shut-off" the mouth of a cove or small bay after the herring schools have migrated into the cove. A set of 200 to 500 fathoms is the most common.

Stop-seine gear is very efficient in that it catches 100 percent of the herring available when schools can be located inside suitable coves or on shallow beaches. Over 60 percent of the 1947 catch was taken with stop-seine gear (Scattergood 1949), and at the present time approximately 84 percent of the Maine herring catch is being taken in stop seines (Power 1958).

As effective as sardine-weir and stop-seine methods are for catching the small herring, they have a common and serious deficiency. Both methods are passive and are completely dependent upon migrations of herring to the shallow-water fishing sites. During late spring, summer, and fall, schools of herring usually migrate from the deeper waters of the open ocean and the bays up into the smaller coves on what is generally believed to be a feeding migration. It is during these movements that the opportunity for catching the herring is presented. Often, however, herring schools fail to run inshore far enough to be caught with stop seines or weirs. They can frequently be located (even when fishermen inshore are actively seeking fish and sardine processors are standing by in their idle plants) lying in the deeper waters of the larger bays and inlets along the coast, where they remain sometimes for periods of weeks, but fail to make the anticipated migrations up into the shallow waters. A situation of apparent scarcity often exists, therefore, when in actuality plenty of herring are to be found along the Maine coast.

Stop seines and weirs, despite their shortcomings, have remained the sole gear used for taking herring for sardine processing because they perform an essential function that other types of gear cannot; they hold herring alive for periods of up to one month without serious loss of quality or total weight. The fish must be held alive for two reasons:

(1) to allow their intestines to clear of food and fecal matter; and
(2) to provide live storage of the fish until it is possible for the canneries' carrier vessels to pick them up for processing.

Since the sardines are packed whole except for removal of the head and gills, it is essential, in the interest of producing a palatable product, that the live fish be held for a period of from several hours to several days to completely clear the intestines of the fish.

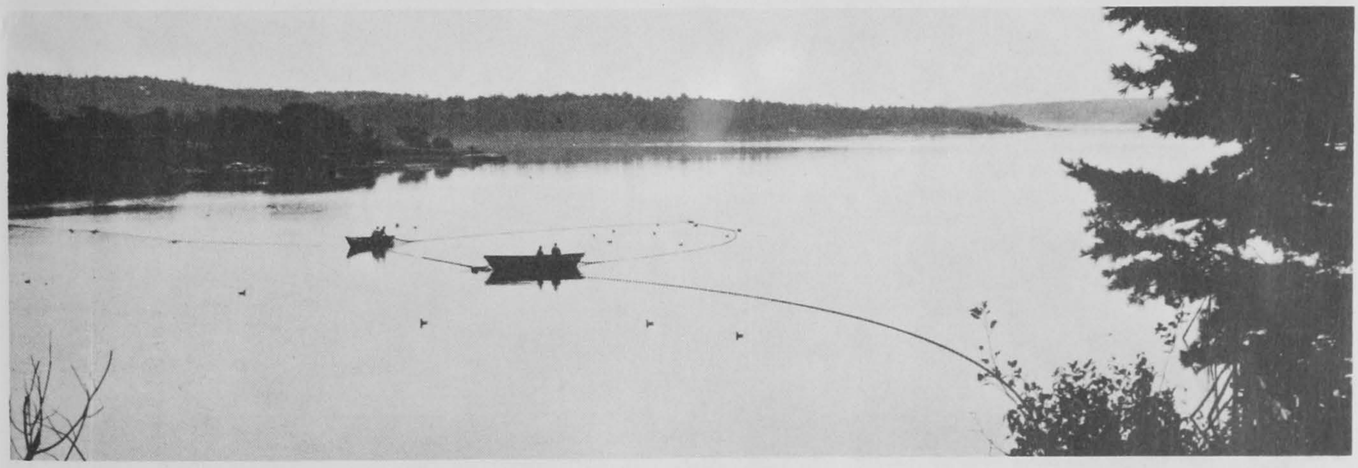

Fig. 2 - Set of Maine sardine stop-seine gear. The fishermen are attaching a holding pocket into which the small herring will be allowed to swim at the next low tide. This is accomplished by sinking the floatline of the stop seine where it adjoins the pocket.

Thus the present conventional fishing methods provide the essential feature of holding the fish alive for as long as is necessary and convenient, but they impose rather drastic restrictions on the areas in which fishing operations can be prosecuted. Owing to a high tidal range (which averages over 18 feet between high and low tides at Eastport, Maine) and consequent rapid tidal currents, stop-seine fishing is limited to depths of approximately 36 feet at low tide. Weir fishing operations are likewise restricted to shallow-water areas, as it is impractical to drive weir stakes in water depths of much over 30 feet at high tide. The herring fisherman, whether he is a weir operator or a seiner, is, therefore, in the position of waiting for the herring to come to him rather than being able to go out and seek the schools of fish wherever they may occur.

GEAR EXPERIMENTS

The Bureau's Maine Herring Exploration and Gear Research Project was set up in 1955. Part of its directive was to study the sardine fishing gear to see if improvements were possible. It was recognized that a more active and aggressive method of catching the young herring was needed. There was a need to extend the sardine gear from the very restricted, shallow-water, inside locations to at least the deeper water of the open bays and into the areas of more rapid tidal flow occurring in the channels between the many islands and peninsulas of the Maine coast. It was believed that since the herring is a very skittish and easily-frightened fish and that since schools of them are often driven by predator fish, an apparatus that would set up a commotion in the water could possibly be used to frighten and thus guide or drive herring from inaccessible locations to favorable seining sites. To set up a controlled disturbance, experiments with a curtain of air bubbles discharged at the water's bottom were started in the fall of 1957.

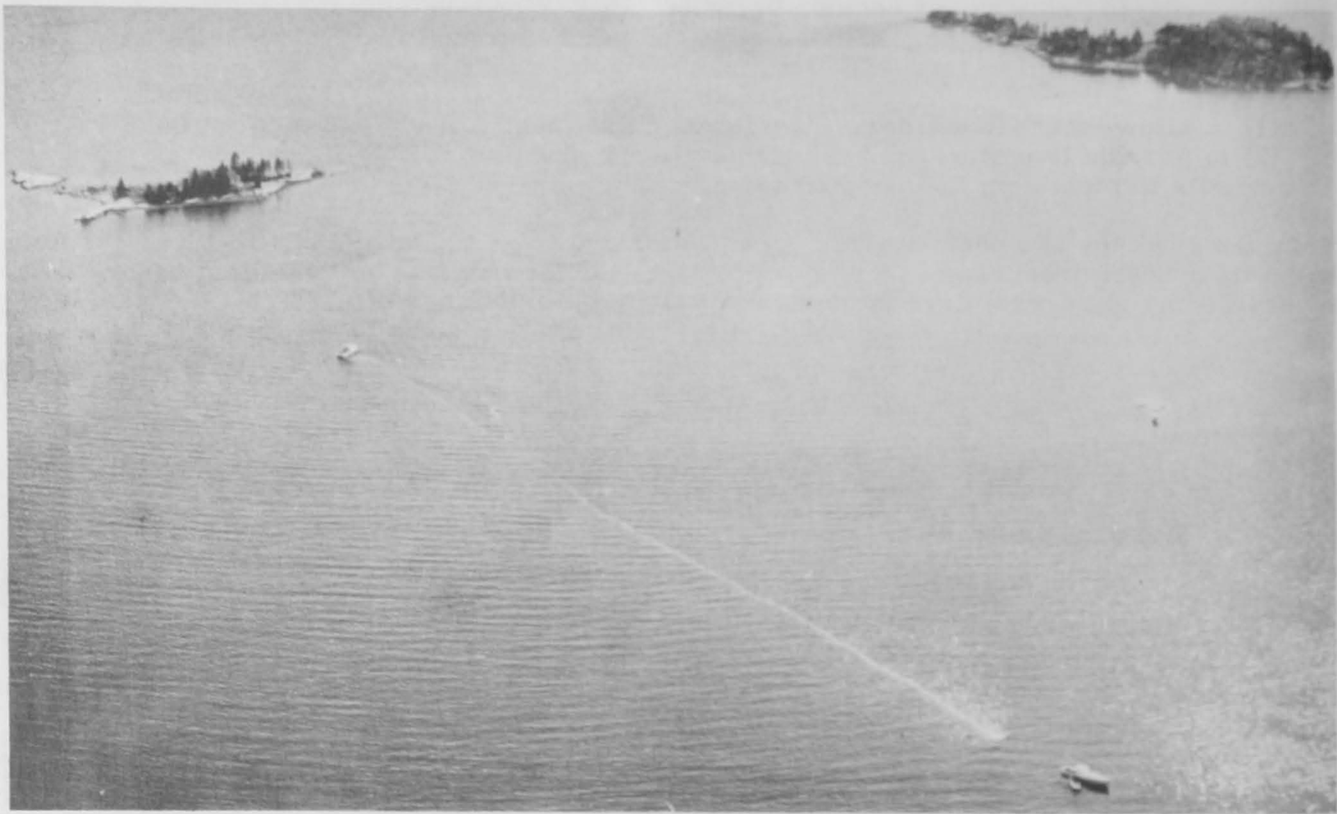

Fig. 3 - Photograph of a 200-fathom-long air-bubble-curtain in Boothbay Harbor.

The initial equipment used in these trials consisted of:

(1) a 500-foot length of 1-inch diameter polyethylene plastic pipe, perforated at 1-foot intervals with $\frac{1}{32}$-inch holes and weighted with lead to make it sink to the ocean floor; and

(2) an air compressor unit consisting of a 132 cubic-foot-per-minute air compressor coupled to a driving engine. Air from the compressor was led into the perforated pipe

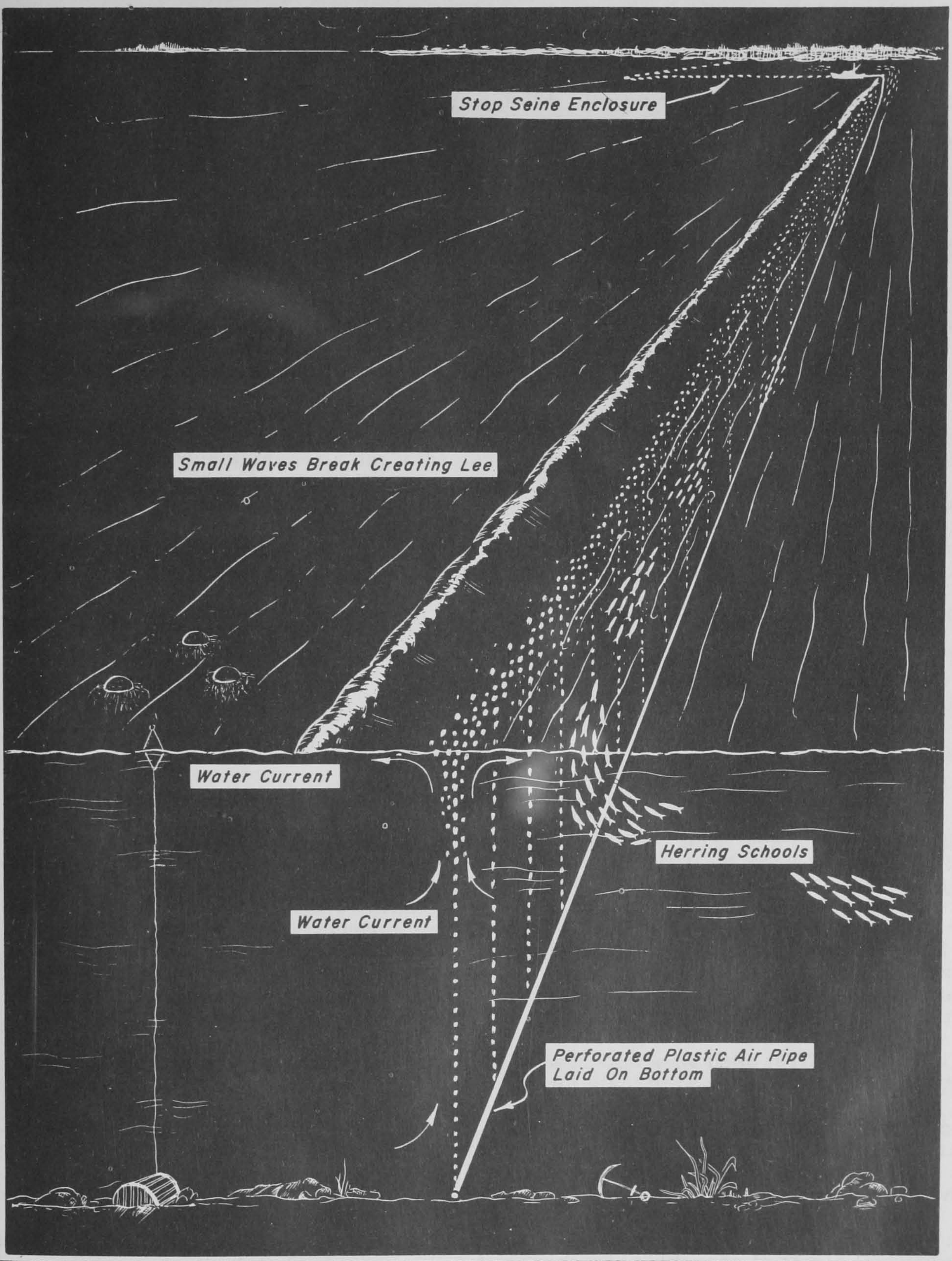

Fig. 4 - Diagram of air-bubble curtain, showing the method of diverting herring schools into a stop-seine enclosure.

lying on the bottom and was discharged through the smaller holes, setting up a wall or curtain of air bubbles rising from the bottom to the surface. 1/

The gear was tried out during the fall of 1957, first on impounded herring and later upon herring schools in their natural state. These initial experiments demonstrated that it was possible to guide and drive herring with this type of apparatus.

During the fall of 1958, an extended air-bubble curtain of 1,200-foot length was tested in Casco Bay near Portland, Maine. At that time, schools of herring were located by aerial observation as they swam through Diamond Island Roads channel, although no catches had been made for several weeks from the stop-seine sites located on each side of the channel. For a period of two weeks, herring schools were watched in the Diamond Island Roads area; yet none of them approached close enough to the shore to be exploited by the stop-seine fishermen.

Working in cooperation with the fishermen, Bureau personnel laid the 1,200-foot air-bubble curtain diagonally out into the Diamond Island Roads channel with one end attached to the fishermen's seines and the other end extending well beyond the center of the channel. When the herring schools began to move down the channel, as was usual during the late afternoon and early evening, they encountered the air-bubble curtain, and rather than pass through it, swam along it and were led shoreward into the shallow water and eventually into the stop-seine enclosures of the fishermen. The offshore end of the air-bubble curtain was then swept ashore forming a loop which was gradually closed. By pulling the entire polyethylene pipe ashore the enclosed fish were driven into the stop-seine sets. This operation was repeated for six nights over a 2-week period, as the Bureau worked with different seine crews, and each action (with one exception) was successful in catching fish that to all appearances could not have been caught in conventional stop-seine gear. Only one set of the gear, made without benefit of aerial observation, was abandoned during this period without a catch of fish, when herring schools failed to materialize as expected.

It was noted during these trials that if the herring were crowded too closely, or were badly frightened, they would pass through the air bubbles to freedom. It was concluded, therefore, that the movement of the plastic pipe must be accomplished slowly and smoothly when the fish are being driven. When the herring have a choice of paths they will avoid passing through the air discharge and thus can be led or driven to points of capture.

USE OF AIR-BUBBLE CURTAIN IN SARDINE FISHERY

The air-curtain gear was introduced to Maine sardine fishermen in 1958 and 1959 by means of progress reports, demonstrations, and assistance to fishing crews interested in setting up their own units. Advice and help have been given to one cooperating sardine company in constructing an experimental 2,000-foot-long unit. This installation utilizes a 196-cubic-foot-per-minute compressor and discharges air through $\frac{1}{64}$-inch (0.0156")-diameter holes in $\frac{3}{4}$-inch and $\frac{1}{2}$-inch polyethylene pipe. Air pressure at the compressor was held at approximately 70 pounds per square inch. Although fish were very scarce in the most eastward section of the Maine coast, where this unit was used in 1959 some valuable catches were made.

The unit was first used as a weir lead to guide herring schools from deeper water at the center of a cove over to the weir installation adjacent to the bank.

Schools retreating at ebb tide from the shallow inner end of the cove encountered the air curtain, followed along it, and were led to the weir entrance. In their continuing search for an unobstructed escape route to deep water they moved through the weir entrance passage and were captured.

In another location, herring schools were found to be lying near the mouth of a cove but during several nights of searching and observation they remained at depths beyond the reach

1/A carburetor device was installed to add chemical irritants to the compressed air to assist in driving the herring; and a supply of carbon dioxide, formaldehyde, and tear gas was procured for use in the air discharge, but use of these materials did not prove necessary.

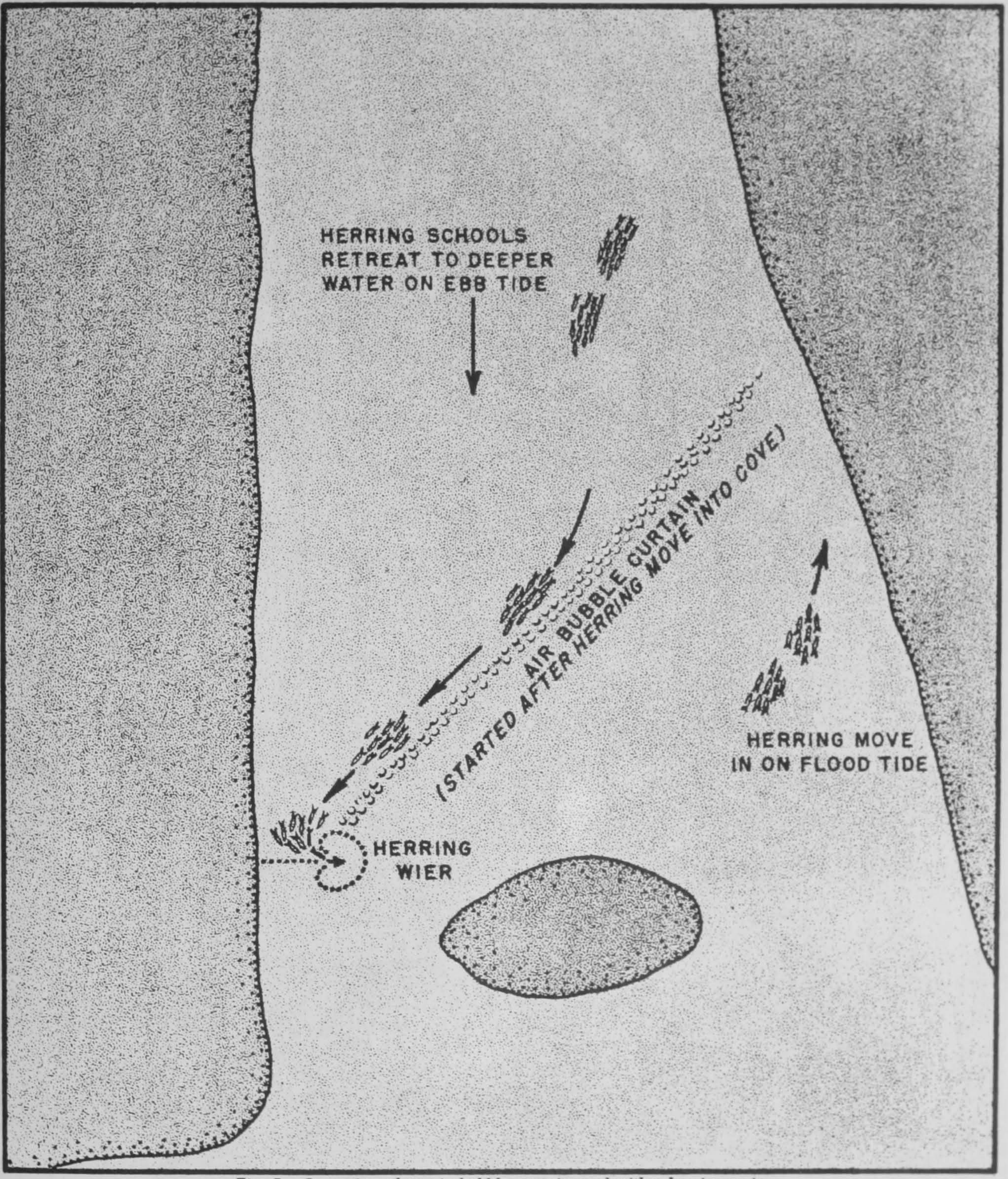

Fig. 5 - Operation of an air-bubble curtain used with a herring weir.

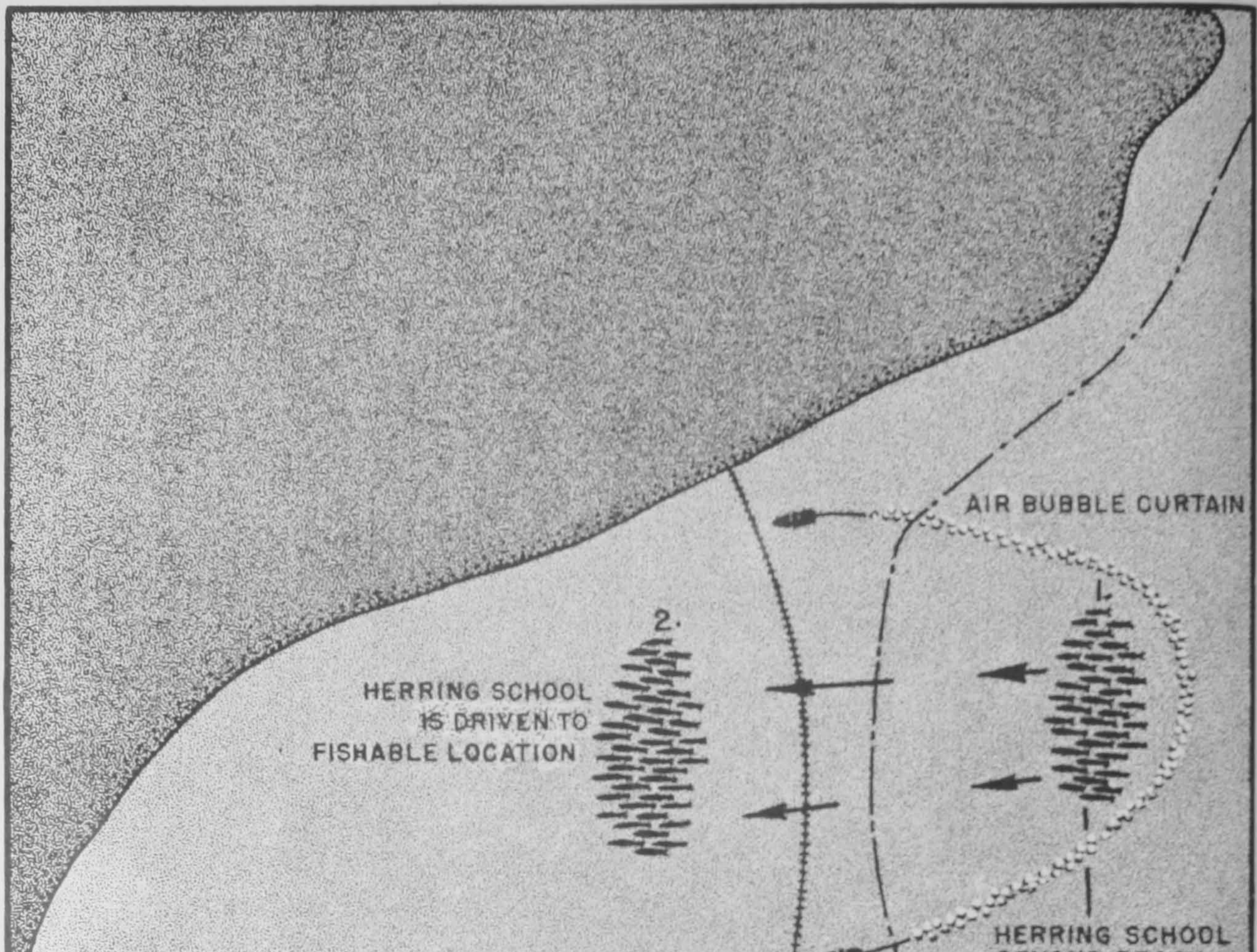

Fig. 6 - Diagram showing the air-bubble curtain as it was used to drive herring schools to a seining site from water depths beyond the range of stop-seine gear.

of stop-seine gear. Since this was an area of smooth bottom, the polyethylene pipe was looped around a part of the school and towed shoreward, driving the herring into the cove to a point where they could be enclosed with a stop seine.

A seine crew also used air-curtain gear in the Casco Bay area near Portland to take fish from areas beyond the reach of their seines. During one week of short herring supply in the 1959 season, most of the herring delivered to Portland, Maine, canneries came from catches made with air-curtain gear in the Casco Bay location.

In all, a dozen or more air-curtain units have now been installed by fishermen in Maine and New Brunswick. At least four of these were used in actual operations during the 1959 season, and good catches were made in at least three areas where conventional gear would have been of no use. Other units were not used during the 1959 season, owing to the scarcity of herring schools. It is expected that, with six or more new, well-designed units now going into operation, the method will be applied with increasing effectiveness in the 1960 and succeeding seasons.

ASSEMBLY METHODS

The appendix lists the materials needed to complete a 400-fathom and 250-fathom air-bubble curtain. Reference to the appendix will aid understanding of assembly methods and facilitate construction. The following abbreviations are used throughout this section and in the appendix:

(1) psi. - pounds per square inch (air pressure).
(2) cfm.- cubic feet per minute (of air).
(3) hp. - horsepower.
(4) rpm. - revolutions per minute.

AIR COMPRESSOR: The heart of air-curtain equipment is the air-compressor-engine unit. In choosing an engine to drive the compressor it is most important to select one of sufficient horsepower to run the compressor continuously. For this reason one must be concerned only with the continuous shaft or brake horsepower. The internal top speed horsepower ratings of engines listed by many manufacturers should not be considered in making this selection since this rating is much higher than can be supplied under working conditions.

Whether the compressor is belt-driven or direct-driven, the maximum rated rpm. of the compressor should be reached when the engine is running at its best continuous operating speed. Engine and compressor speeds may be easily regulated by adjusting the pulley sizes using the formula

$$\frac{\text{engine speed (rpm\ )}}{\text{compressor speed (rpm.)}} = \frac{\text{pitch diameter of compressor pulley}}{\text{pitch diameter of engine pulley}}$$

If the compressor is direct-driven, the operating speed of the engine must match that of the compressor.

SAFETY AND EXHAUST VALVES: At the air outlet of the compressor a safety valve and air pressure gauge should be installed. Also at this point a pressure relief valve must be installed on a T fitting in the main air line to allow the compressed air to exhaust freely into the open atmosphere as the compressor is started. This exhaust valve should be closed slowly after the compressor has been started to gradually increase the pressure of the air delivered to the preforated plastic pipe lying at the sea bottom. The plastic pipe will be full of water at the start of the operation, and the water must be forced out gradually by closing the exhaust valve to increase the pressure. The safety valve should be mounted in another T fitting adjacent to the exhaust valve and should be set to open at the maximum compressor pressure or the maximum plastic pipe rating (75 psi.), whichever is lowest.

AFTERCOOLER: The compressed air should be piped, preferably with steel pipe, from the compressor to an aftercooler. If any hose connections are made in this run only a good grade of steam hose or heat resistant compressed air hose of 100 psi. or higher pressure rating should be used, and all connections should be doubled clamped and securely fastened. The aftercooler should be constructed of corrosion-resistant metal and should be of sufficient capacity to cool 196 cfm. of air compressed to 80 psi. pressure down to within 10 degrees of the cooling water. If a larger compressor supplying a greater volume of air is used, the size and cooling capacity of the aftercooler must be correspondingly increased.

An alternative method of cooling the compressed air is to pipe it through copper tubing that is kept overboard and submerged in the sea water in the "keel cooler" fashion. One cooler of this type made up with five 6-foot lengths of $1\frac{1}{2}$-inch copper tubing joined together with 180° return-bend fittings has worked quite satisfactorily with a 130-cfm. compressor. An advantage of this method is that no water pump or hoses are needed for cooling the air. A similar type of cooler using a total length of 45 feet of $1\frac{1}{2}$-inch copper tubing would be sufficient for cooling air from the 196 cfm. compressor.

POLYETHYLENE PIPE SECTIONS: The undrilled 100-foot length of 1-inch plastic pipe should be connected to the outlet of the aftercooler as a lead-in section to the drilled lengths. The drilled sections should then be connected in the order listed in the appendix. These sections may be connected by means of insert couplings and stainless-steel hose clamps. Metal (brass or galvanized steel) insert couplings should be used rather than the plastic type, because the metal types have thinner walls and provide a larger inside diameter for air flow. Insert couplings are available also as reducing couplings for changing the diameter of plastic pipe.

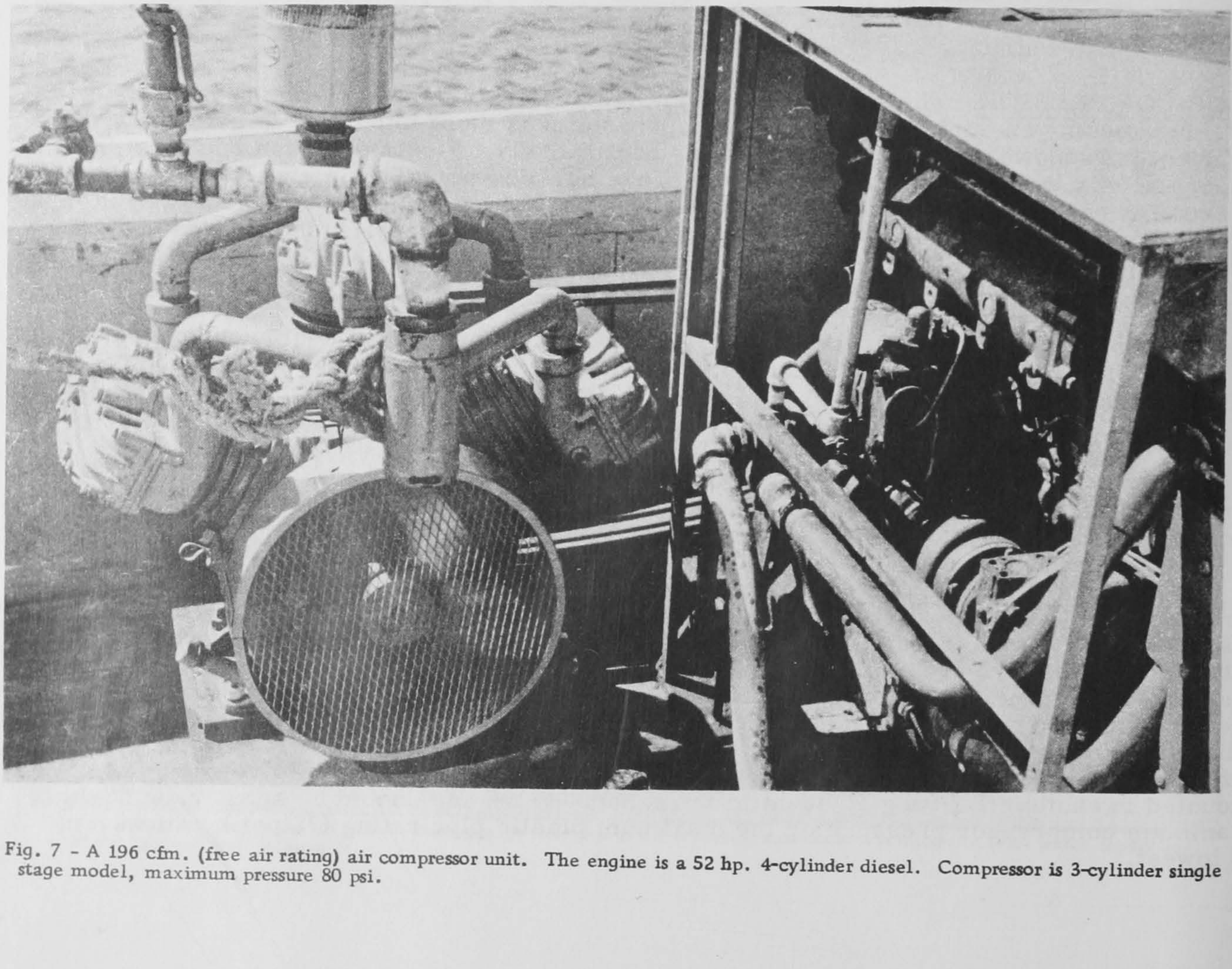

Fig. 7 - A 196 cfm. (free air rating) air compressor unit. The engine is a 52 hp. 4-cylinder diesel. Compressor is 3-cylinder single stage model, maximum pressure 80 psi.

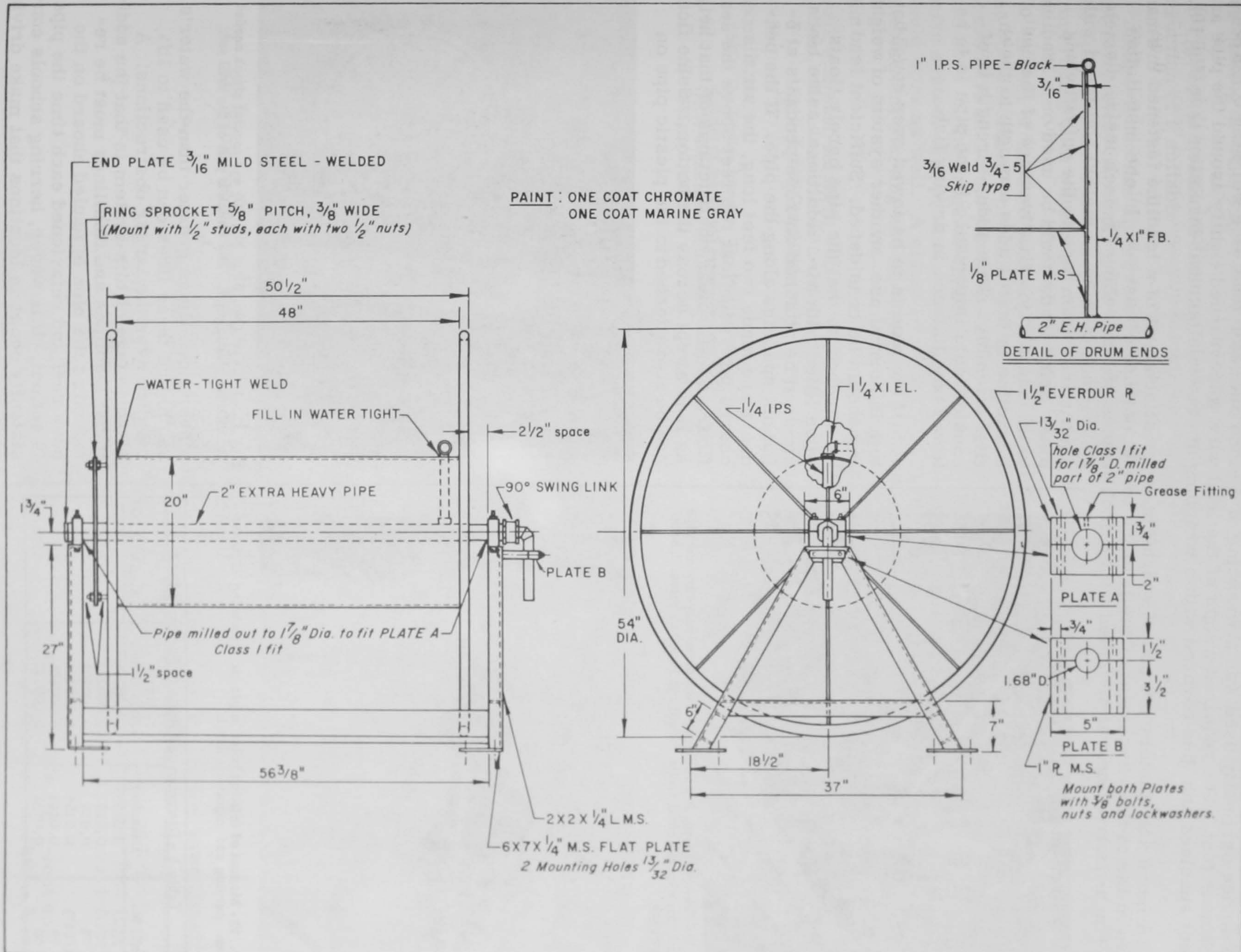

Fig. 8 - Drawing of plastic pipe reel for handling 400 fathoms of air-curtain equipment.

WEIGHTING PLASTIC PIPE: The plastic pipe must be weighted to sink it to the bottom. The device originally used was a wrapping of $\frac{3}{16}$-inch diameter lead wire weighing 0.125 pound per linear foot. The required weight of the lead wire was wrapped tightly around the pipe at 4-foot spacings and then covered with a wrapping of plastic electrical insulation tape (fig. 10).

A more satisfactory method of weighting is the attachment of a leadline fastened in a manner similar to the attachment of the leadline to the footrope of a seine. In one installation, a $\frac{3}{16}$-inch-dacron line was weighted with 6-inch lengths of lead tubing ($\frac{5}{16}$-inch inside diameter and $\frac{9}{16}$-inch outside diameter) and taped with plastic insulation tape to the polyethylene pipe. Seine leads could be used on a leadline in the same way. An advantage of the use of a leadline is that it adds strength to the entire assembly. This added strength is of considerable importance if the pipe is to be towed any distance in driving fish.

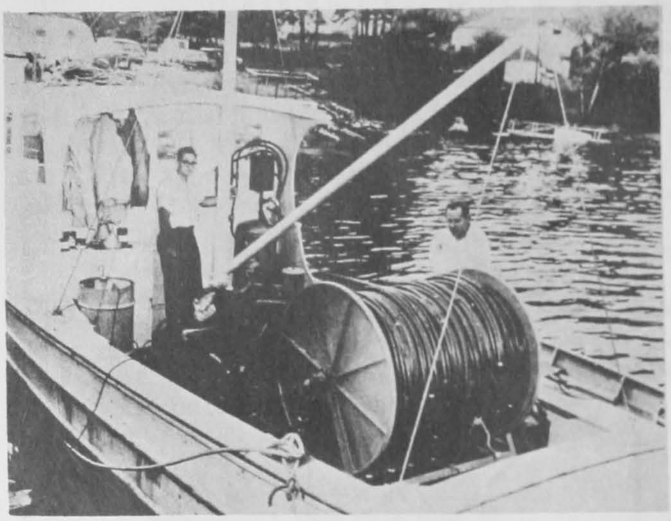

Fig. 9 - Hose reel with 200 fathoms of weighted polyethylene pipe ready for experimental trials aboard the Bureau's research boat *Blueback*.

If the pipe is to be towed over rough bottom in normal use, another system of weighting should be considered. Sufficient lead may be attached so that the pipe barely floats when filled with air. Additional seine leads can then be attached on rope pendants at 5-fathom spacings along the pipe. If the pendants are made two feet long, the air discharge pipe will float two feet above the sea's floor and will clear obstructions of that height as it is swept across the bottom. Seine floats can be also attached to the plastic pipe on longer lines (lines greater than the water's depth) and these lines can be used to lift the pipe over the larger obstructions. A disadvantage of this system is that the additional leadlines and floatlines must be removed as the pipe is hauled aboard on the hose reel and refastened each time the pipe is set out. If however, herring schools consistently occur in locations that make driving

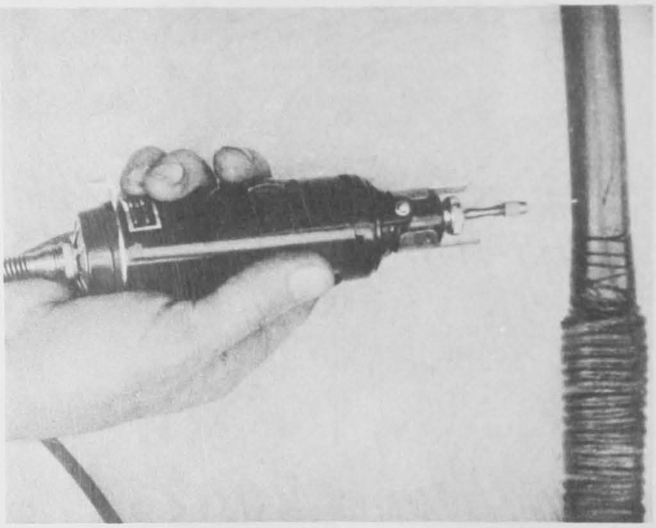

Fig. 10 - Method of drilling holes in plastic pipe using 27,000-rpm. carving and engraving motor.

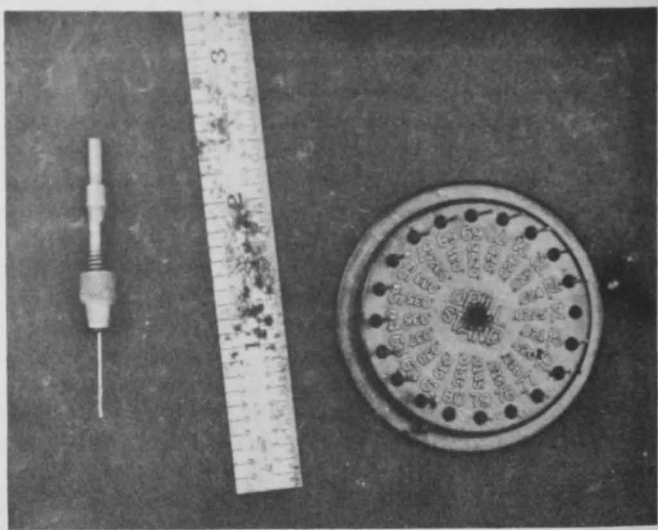

Fig. 11 - Drill set (No. 61 to No. 80) and special chuck needed for drilling plastic pipe. The chuck is part of the drill set.

Table 1 - Diameters and Areas of Numbered Drills

Drill No.	Diameter	Area Square Inches	Area x 10,000
76	0.020"	0.000314	3.14
77	0.018	0.000254	2.54
78	0.016	0.000201	2 01
(1/64")	0.0156	0.000191	1.91
79	0.0145	0.000165	1.65
80	0.0135	0.000143	1.43

them over a rough area necessary for capture, it would be well-worth the added time required for making a set to rig the leads in this fashion.

A reel is needed for setting and hauling the plastic pipe. General information on the construction of a suitable reel is presented in figure 8.

Experience has shown that air connections through the reel as shown in the diagram are not completely necessary, but that they do ease the work of hauling the pipe aboard, because the air pressure can be kept applied during the hauling process thus keeping the plastic pipe from filling with water.

A reel of another design, or of other material (such as plywood), might serve as well as the one described--provided it has sufficient capacity. The reel should be power driven if possible to make the job of hauling the pipe aboard fairly fast and easy. A hydraulic drive was used on the original experimental model and was found excellent, but any other good drive system of approximately 5-horsepower capacity, geared to turn the reel 30 to 60 rpm., would work as well. A clutch must be provided on any mechanical-drive system to allow intermittent starting and stopping of the reel.

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APPENDIX: EQUIPMENT LIST

A. EQUIPMENT FOR A 400-FATHOM AIR-BUBBLE CURTAIN

1. Compressor: Capacity 196 cfm. or higher (free air rating). Pressure rating 80 psi. or higher.

2. Compressor engine: Gasoline, 30 to 50 continuous brake hp., or shaft hp., air or water cooled.

3. Aftercooler: Compressed-air pipe-line aftercooler, capable of cooling 196 cubic feet per minute of air to within 10°F., of the temperature of the cooling water.

4. Exhaust valve: One-inch-diameter pipe size.

5. Safety valve: Set to open at 75 psi.

6. Air-pressure gauge: Containing a 0-150 psi. scale.

7. Polyethylene plastic pipe: Pressure rating, 75 psi.

   First Section: 100 feet, 1-inch-diameter, undrilled and unweighted, attached between aftercooler and drilled sections.

   Second Section: 100 fathoms, 1-inch-diameter, drilled at 1-foot spacings with No. 80 drill, weighted with 8 ozs. of lead per foot (to sink completely to bottom). Leads can be attached 2 lbs. per 4-foot spacing.

   Third Section: 100 fathoms, $\frac{3}{4}$-inch-diameter, drilled at 1-foot spacings with No. 79 drill, weighted with 0.3 lbs. lead per foot (to sink). Lead can be attached 1.5 lbs. per 5-foot spacing.

Fourth Section: 100 fathoms, $\frac{3}{4}$-inch-diameter, drilled at 1-foot spacings with No. 78 drill, weighted with 0.3 lbs. lead per foot (to sink).

Fifth Section: 100 fathoms, $\frac{1}{2}$-inch-diameter, drilled at 1-foot spacings with No. 78 drill, weighted with 0.2 lbs. lead per foot (to sink).

8. Hose Reel: Revolving drum 4 feet long, 54-inch-diameter with 20-inch-diameter core. This may be of wood or metal construction and should be power driven for easiest operation (figs. 10 and 11).

9. Self-priming $\frac{3}{4}$-inch-pump: (neoprene impeller type) to supply cooling water for after-cooler, belt driven by compressor engine or other engine.

B. EQUIPMENT FOR 250-FATHOM AIR-BUBBLE CURTAIN

1. Compressor: 130 cfm. or higher rating, 80 psi. or higher maximum pressure.

2. Compressor engine: 25 hp. gasoline engine, continuous shaft hp., or 15-hp. electric motor.

3. Aftercooler: Pipe-line aftercooler of sufficient capacity to cool 130 cubic feet per minute of air to within 10°F. of the temperature of the cooling water.

4. Exhaust valve

5. Safety valve

6. Air pressure gauge: 0-150 psi. scale.

7. Polyethylene plastic pipe: 75 psi. pressure rating:

First Section: 100 feet, 1-inch-diameter, undrilled and unweighted attached between aftercooler and drilled sections.

Second Section: 100 fathoms, $\frac{3}{4}$-inch-diameter, drilled at 1-foot spacings with No. 80 drill and weighted with 0.3 lbs. of lead per foot of length.

Third Section: 100 fathoms, $\frac{3}{4}$-inch-diameter, drilled at 1-foot spacings with No. 79 drill and weighted with 0.3 lbs. of lead per foot of length.

Fourth Section: 50 fathoms, $\frac{1}{2}$-inch-diameter, drilled at 1-foot spacings with No. 78 drill and weighted with 0.2 lbs. of lead per foot of length.

8. Hose Reel: Revolving drum 3 feet long, 54-inch-diameter with 20-inch-diameter core, otherwise as described above for 400-fathom unit.

9. Self-priming $\frac{3}{4}$-inch-pump: (neoprene-impeller type) for aftercooler water.

C. SPECIAL TOOLS FOR DRILLING PLASTIC PIPE

Special small drills, chuck and drill motor are needed for boring the very small holes in the plastic pipe. A high-speed motor from a carving and engraving set was found to be most satisfactory for this use. A set of drills, No. 61 through 80 and a special small chuck to adapt the drill motor chuck to the small drills (figs. 10 and 11 and table 1) are also needed. These tools can likely be obtained from a hobby shop, a well-stocked hardware store or a mail-order house.