20 November 1935

NRL Report H-1219
NRL Prob. H-48

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

SHIP CAMOUFLAGE - REDUCTION OF VISIBILITY OF PERISCOPE FEATHER WITH DYE.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
Washington, D.C.

No. of pages: Text - 10 Plates - 9

Authorization: C&R let. L1/NPL4(F)N/C of 25 June 1935.

Date of Tests: August through October 1935.

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Distribution:
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Experiments with an imitation periscope pushed in front of a motor boat showed: (a) that showering a water solution of black dye down on to the top of the "feather" produced an effective darkening of the "feather", and (b) that introducing the dye solution into the water below the surface was less effective.

With the dye solution ejected from a small ring nozzle attached to the periscope tube a few inches above the feather, 6 gallons of dye solution per minute were required when the periscope speed was 7 knots.

It is calculated that for a destroyer moving at 24 knots, roughly 1000 gallons of dye solution per minute would be required to darken the wake.

CHAPTER I

INTRODUCTION

1. AUTHORIZATION The investigation of the camouflage of ships was authorized by a letter from the Bureau of Construction and Repair, L1/NP14 (F)N/C of 25 June 1935, with attention directed to three items: (1) low visibility of surface craft, excepting submarines; (2) breaking up of straight lines by means of paint; and (3) the use of dye to conceal the feather of the periscope of a submerged submarine.

It may be mentioned that a recent opinion of Naval aviators was that under average conditions the feather is the first evidence of a submarine which an aviator sees.

2. SCOPE OF THE PRESENT REPORT The first phase of the ship camouflage investigation resulted in the preparation of a report entitled "Preliminary Report on Low Visibility Camouflage of Ships", Naval Research Laboratory, 18 September 1935, in which were outlined specific experiments dealing with items (1) and (2). The experiments are now being carried out with ships at sea. The report further stated that in the case of item (3) experiments would be performed on the Potomac River at this Laboratory with an imitation periscope tube pushed in front of a motor boat to determine the effectiveness of dye in reducing the visibility of the periscope feather. The present report describes these experiments and offers recommendations for further pursuit of the problem.

CHAPTER II

THE RING NOZZLE EXPERIMENT

1. The Ring Nozzle Experiment - The ring nozzle experiment was the last of a series of fourteen experiments with various methods of dye ejection. It gave the best results and of all the nozzles tried was perhaps the nearest approach to a nozzle which could be installed on a real periscope. It is therefore described first. However, since the subject is new and various questions may arise, it is thought to be of value to put on record in Chapter IV a number of the preceding experiments.

2. Experimental Details - The imitation periscope consisted of a metal pipe of 2-1/2 inches external diameter, held in a vertical position by two supports 5 feet long projecting out from the bow of a motor boat. The arrangement is shown in Plate 1a. The pipe extended about two feet below the surface of the water, and when the motor boat was underway at a speed of 6 to 8 knots the pipe ploughed up the water to produce a "feather" about a foot high similar to that of a submarine periscope. It will be recalled that a real periscope is circular in cross section, of diameter 2-1/2 inches at the point where it intersects the surface of the water.

In Plate 1a may be seen the 12 gallon tank from which the dye flowed through a rubber tube, of internal diameter 3/4 inch to the nozzle.

Water soluble anilene dyes were used which were black in concentrated solution. In dilute solution one was a brownish black and another a purplish black. There was no perceptible difference in their effectiveness due to tint. Actually the purple black dye, Dupont "Nigrosine", was used in most of the experiments simply because there was a sufficient stock on hand. A saturated solution of the dye was used; this required about 1/30 pound or 1/2 ounce of dye per gallon of water. In the ring nozzle experiment about 6 gallons of dye solution per minute were ejected, which meant about 3 ounces of dye per minute, or a few cents worth of dye per minute, since the cost of the dye was less than one dollar a pound.

The ring nozzle is shown in Plate 2. It was a brass, hollow ring of square cross section, 5/8 inch on a side, with a tube for connecting to the rubber tube leading to the dye tank. The nozzle was fitted on the periscope tube about 18 inches above the surface of the water and hence a few inches above the upper spray of the feather, as shown in Plate 1b. The lower face of the ring was perforated with 71 holes 1/16 inch in diameter. The dye solution flowed out of the holes in streams down along the periscope tube and mingled with the spray and foam of the feather. When the dye tank was about 6 feet above the nozzle and open to atmospheric pressure, the pressure at the nozzle was about 3 pounds per square inch. In this case the dye solution flowed out at a rate of about 6 gallons a minute.

3. Results - The effect on the periscope feather of the dye solution flowing out of the ring nozzle is shown by the photographs of Plates 3 and 4 which were made during two runs, one run without dye and one run with dye. The experimental data for Plates 3 and 4 were:

October 23, 1935 1:30 P.M.
Sunny, no breeze, Potomac River oily calm.
Speed of boat, 7 knots.
6 gallons of dye solution per minute (requiring 1/2 ounce or 3 cents worth of dye per gallon, or about 20 cents worth of dye per minute).

It is seen from Plates 3 and 4 that the dye solution rendered the white spray and foam of the feather a dark color and lowered the visibility of the feather. Plates 3 and 4 were for a calm surface of water. The reduction of visibility occasioned by the dye was more pronounced when the surface of the water was ruffled by a breeze because a ruffled surface is darker than a calm surface. The appearance of the feather with and without dye in breezy weather is shown in Plates 6, 7 and 9. The pictures of these plates were taken when other nozzles were being used (see Chapter III) but the effects with the ring nozzle were similar; it happened that no pictures were taken of the ring nozzle in breezy weather.

Various observers watching the feather at distances from 1/10 to 1/2 mile agreed that the dye lowered the visibility of the feather and estimated that the dyed feather would rarely be picked up beyond 1/2 mile at sea in breezy weather.

The dye from the feather flowed into the wake of the motor boat and left a dark streak near the surface which remained visible for about 5 minutes. It is believed that the dark streak would not be particularly visible at sea and that it would not increase appreciably the visibility of the periscope feather scene at sea.

Experiment showed that the effect of the dye became negligible when the rate of ejection was reduced below 3 gallons per minute of saturated solution. It was concluded that the rate of ejection could not be reduced much below 6 gallons per minute without too great diminution of the feather coloration, as long as the speed was 7 knots. At lower speeds the feather is smaller and less dye is necessary; no quantitative experiments were made on this point.

Adding salt to the dye solution produced no visible chemical changes, so that the effects at sea of the dye on the feather would be expected to be the same as those on the Potomac River.

4. Practical Difficulties - If the ring nozzle were operated on a periscope at sea, a difficulty might arise due to waves. Suppose that the nozzle were placed on the periscope 12 inches below the optical opening at the top of the periscope, which is normally 4 to 6 feet above the average level of the surface of the water. Due to sea swell the water surface, and hence the feather, would move up and down the periscope, so that the distance from the nozzle to the top of the feather might vary by several feet. At the greater distances it might happen that the dye would not fall down on the feather in a way to produce the desired coloration. Whether this hypothetical difficulty would turn out to be of importance can not be said.

A not improbable difficulty might be that some of the dye solution splashes over the window of the periscope and obscures the view through the periscope.

It is beyond the province of this report to attempt to suggest a practical installation of the dye apparatus on a submarine.

CHAPTER III

EARLY SERIES OF EXPERIMENTS

1. Experiments with Holes in Periscope Tube

Experiment a - The lower end of the periscope tube was closed and 80 holes, 1/32 inch in diameter, were bored through the periscope tube in a section of the tube from 12 inches above the surface of the water to 6 inches below the surface. The rubber tube from the tank of dye was connected to the upper end of the tube. The dye flowed out of the holes at the rate of about 2 gallons per minute into the foam of the feather, but there was not enough dye to produce much darkening of the feather. Pictures of the experiment are shown in Plate 5. The data of the experiment were:

September 27, 1935 10:00 A.M.
Sunny, breeze 4 knots, 6 inch waves on river.
Speed of boat, 7 knots.
2 gallons of dye per minute.

Conclusion - It was concluded that for a periscope speed of 7 knots the rate of ejection of dye of 2 gallons per minute was too low.

Experiment b - 80 holes, 1/16 inch in diameter, were bored in the periscope tube in a section of the tube from 12 inches above the surface of the water to 6 inches below the surface. The dye solution was introduced into the top of the tube, and the rate of ejection was about 6 gallons per minute. The dye caused an effective darkening of the periscope feather. The results are shown in Plates 6 and 7. The experimental data were:

October 1, 1935 10:00 A.M.
Sunny, breeze 10 knots, 10 inch waves.
Speed of boat, 7 knots.
6 gallons of dye per minute.

In the course of the runs of this experiment the motor boat ran through an occasional larger wave which caused the water surface to move up and down the imitation periscope. When the water surface rose above most of the holes in the tube, the dye did not color the feather effectively.

Conclusions - It was concluded that for a periscope speed of 7 knots the rate of ejection of dye of 6 gallons a minute was effective in darkening the feather, and that the method of ejecting the dye through holes in the periscope tube would probably only be successful in a very smooth sea and not in waves.

It was observed that the dye which flowed out of the holes above the water surface and which therefore fell down on the foam and spray of the feather after the foam and spray had begun to be formed produced an effective darkening of the foam and spray. Whereas the dye which flowed out of the holes below the surface and hence into the water before the foam and spray were formed, did not produce an effective darkening. The reason was due to

the successful spreading of the dye solution amid the foam and spray in the one case and to the lack of successful spreading in the other case; the success in the one case arising from the mechanical dissemination of the dye, and the lack of success in the other case arising from the slowness of diffusion of one liquid into another. In more detail, the dye solution which tumbled down on to the top of the water near the periscope tube actually fell into a disturbed region of splashes, foam and spray, and the disturbance of these was sufficient to scatter the solution pretty well over the region. The dye solution which emerged from the holes below the surface was swept into rapidly moving (relative to the periscope), but not broken, currents of water. The dye from each separate hole made a separate narrow streak in the current of water. The current of water, or a portion of it, rose to the surface and broke into foam to form the foam and spray of the feather, but the streaks of dye did not diffuse and disseminate sufficiently through the feather.

Rule - From the foregoing observations the rule may be stated: In order to color effectively with dye solution the foam and spray made by an object moving through the surface of water, the dye should be sprayed on to the region of the water surface where the foam and spray have just begun to form; it is less effective to introduce the dye solution into water ahead of the disturbing agent.

This rule may be regarded as the only important result of the entire series of experiments of the present report.

2. Experiments with Shower Nozzle - In view of the results of the preceding experiment it was decided to shower the dye solution down on to the top of the feather with a shower nozzle. Photographs of the shower nozzle are shown in Plate 8. The end of the nozzle was 2-1/2 inches in diameter and was perforated with 70 holes 1/16 inch in diameter. The nozzle was fustened to the after side of the periscope tube about 18 inches above the surface of the water and hence a few inches above the upper spray of the feather. Pictures of the feather with the shower nozzle are given in Plate 9 which show that considerable darkening of the feather was produced. The data of the experiment were:

October 16, 1935 11:00 A.M.
Sunny, breeze 10 knots, 12 inch waves.
Speed of boat, 7 knots.
6 gallons of dye solution per minute.

Conclusions - It was concluded that with a periscope speed of 7 knots and with the shower nozzle on the after side of the periscope ejecting 6 gallons of dye solution per minute, an effective darkening of the periscope feather was produced.

Repeating the experiment with the shower nozzle lashed to the fore side of the periscope tube did not yield as uniform darkening of the feather as in the case of the nozzle on the after side.

In these experiments, just as in the case of the ring nozzle experiment,

Chapter II, the dye solution made a dark streak in the wake of the motor boat which persisted for about 5 minutes.

CHAPTER IV

REDUCING THE FEATHER BY STREAMLINING THE PERISCOPE

Concerning the possibility of reducing the periscope feather by streamlining the periscope, a number of questions were asked of officers of the Construction Corps. The questions and answers are:

Question 1 - Can the periscope feather be reduced by streamlining the periscope?
Answer: Yes

Question 2 - How would this be done?
Answer: By giving the periscope a "tear drop" cross section.

Question 3 - Are there conceivably any great practical difficulties in suitably installing a periscope with such a cross section on a submarine?
Answer: No.

Question 4 - Why have periscopes not been streamlined?
Answer: Probably the visibility of the feather has not been regarded as sufficiently disadvantageous as to induce consideration of streamlining.

CHAPTER V

COLORING THE WAKE OF SHIP WITH DYE

In regard to the old suggestion that the visibility of the wake of a ship be reduced by darkening with dye, the data of the present periscope experiments permit the following calculation. The surface area of the periscope feather for a speed of 7 knots was about 6 square feet, and to color this required 6 gallons of dye solution per minute. Assume the foam region near the stern of a destroyer moving at 24 knots is 300 square feet in area. Since the dye coloration is essentially a surface effect, the necessary rate of dye ejection is directly proportional to the speed and to the area to be covered. Hence for the assumed destroyer case the rate is

$$6 \times \frac{24}{7} \times \frac{300}{6} = 1000 \text{ gallons per minute.}$$

This appears to be a fairly large quantity of dye solution.

The calculation supports the conclusion that, even if the difficult problem were solved of distributing properly the dye solution over the foam of the wake of a ship, a considerable quantity of dye solution would be required to produce an effective darkening of the wake.

CHAPTER VI

RECOMMENDATIONS

It is recommended:

(1) That further consideration of the problem of reducing the visibility of the periscope feather be referred to those personnel most experienced in submarine affairs.

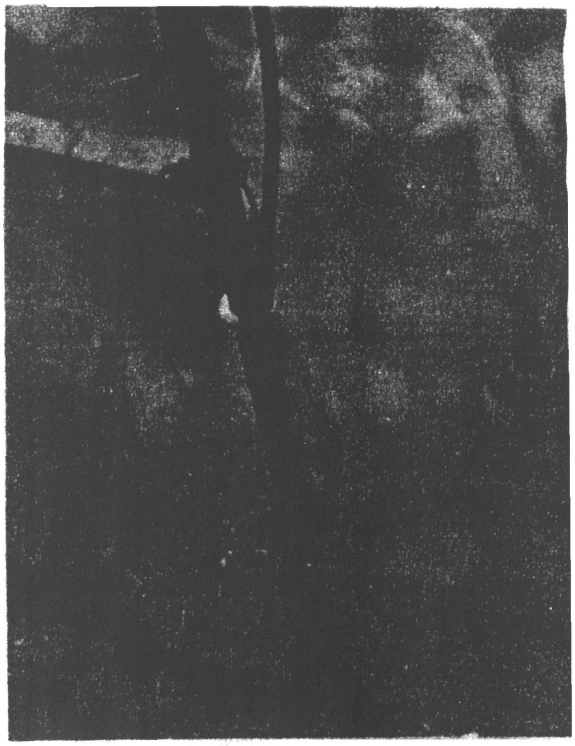
(2) That they consider whether streamlining the periscope promises a practical means of feather reduction.

(3) That they consider whether, in the light of the foregoing experiments, coloration by dye offers a practical means of feather visibility reduction.

(4) That, if experiments with streamlining be instigated, these be initiated at, say, the Model Basin of the Washington Navy Yard rather than at this Laboratory. Such experiments would involve: (a) development of streamlined cross-section, and (b) consideration of means of installation on a submarine.

(5) That, if experiments with dye coloration be continued, these be carried out on submarines at sea with observation from the surface and from the air.

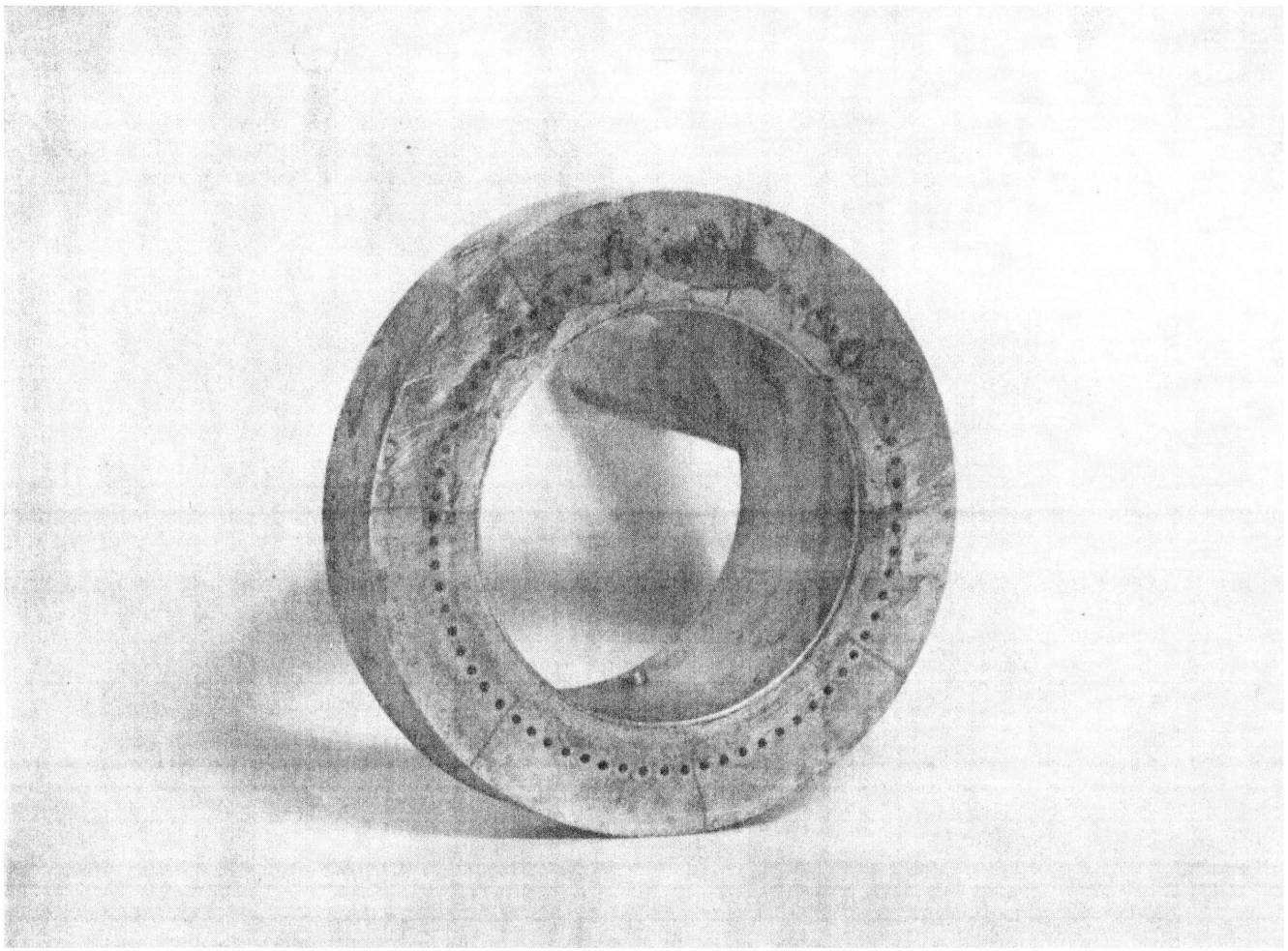
a. BOAT, PERISCOPE, AND DYE TANK.



b. RING NOZZLE ON PERISCOPE.

IMITATION PERISCOPE ON BOW OF MOTOR BOAT.

PLATE 1.



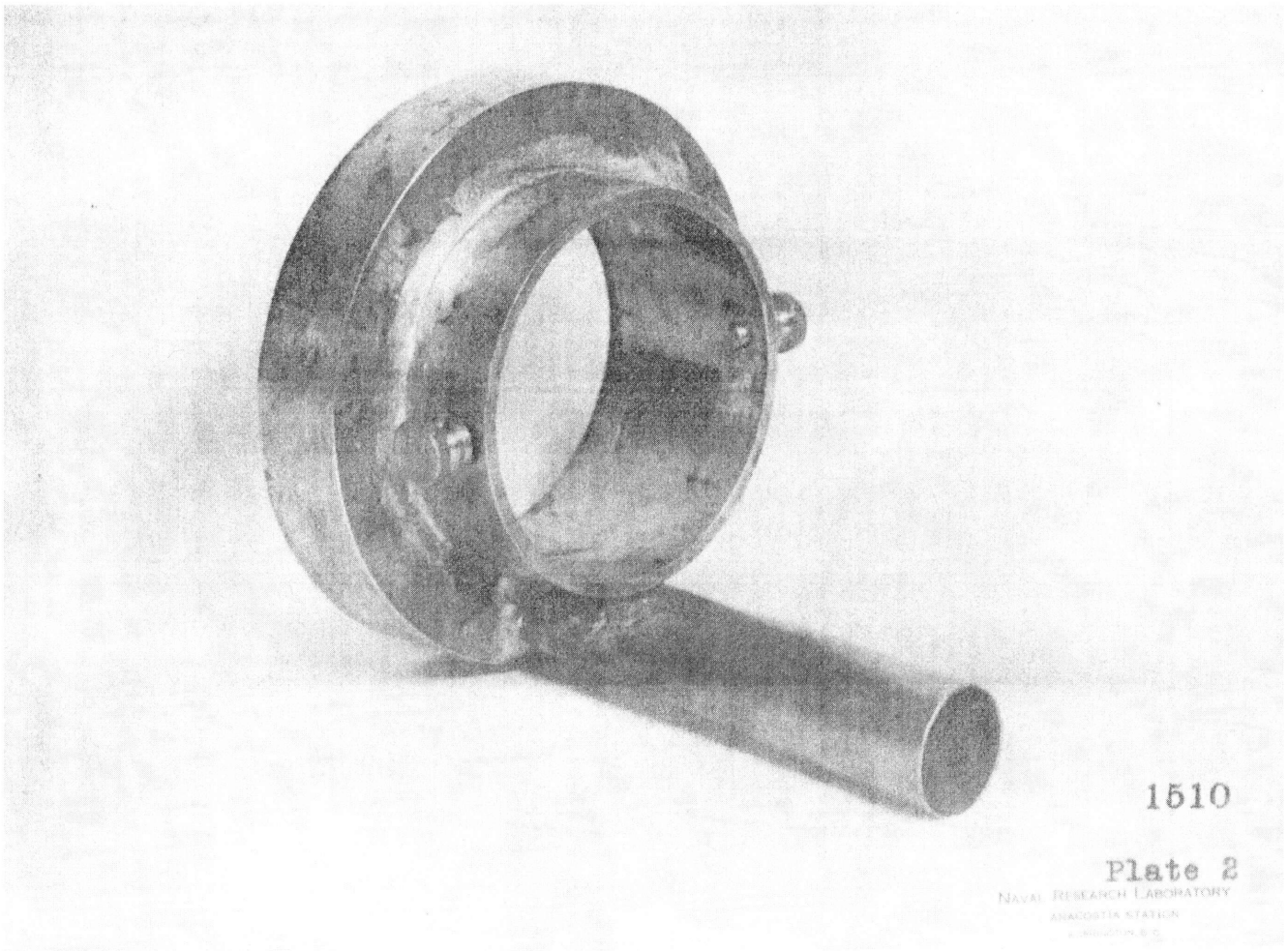


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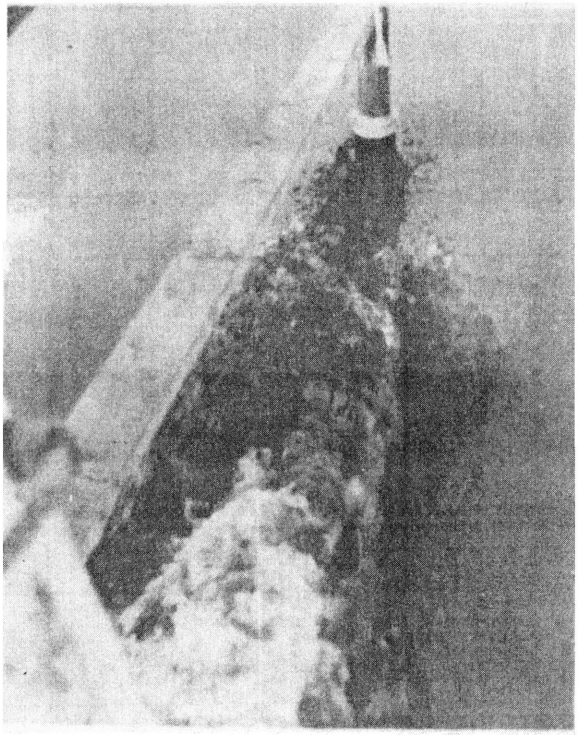
Plate 2

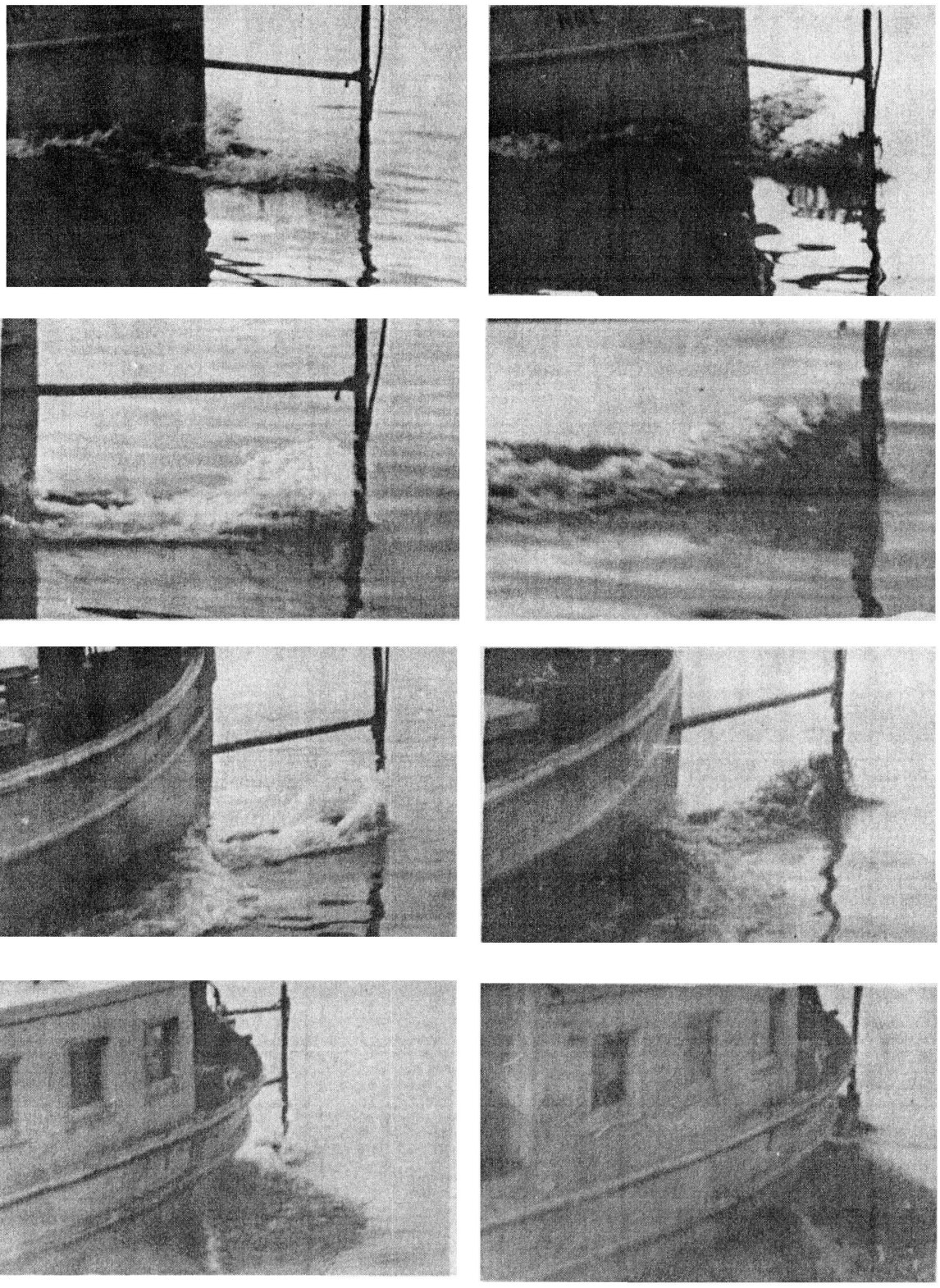
WITHOUT DYE



WITH DYE

RING NOZZLE EXPERIMENT, VIEW OF FEATHER FROM ABOVE.

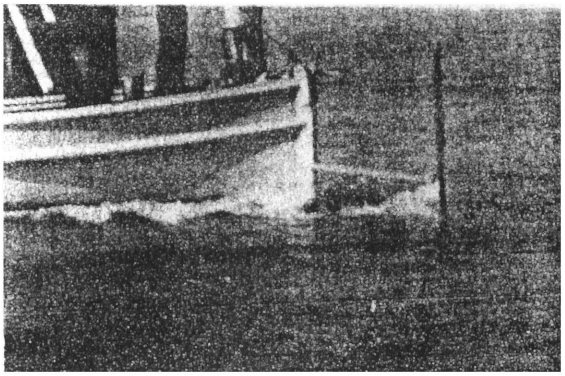
PLATE 3

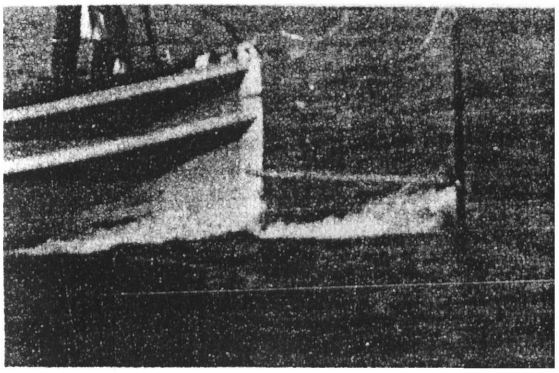


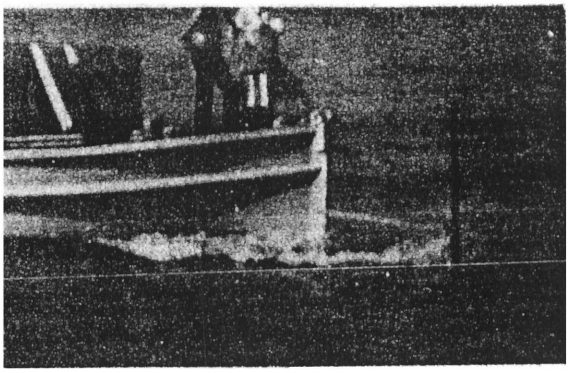
WITHOUT DYE WITH DYE

RING NOZZLE EXPERIMENT, SIDE VIEWS OF FEATHER

PLATE 4





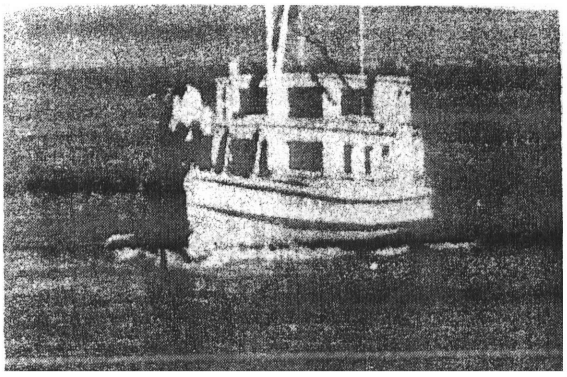
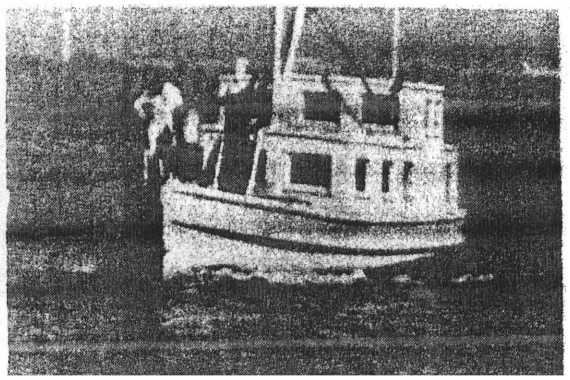
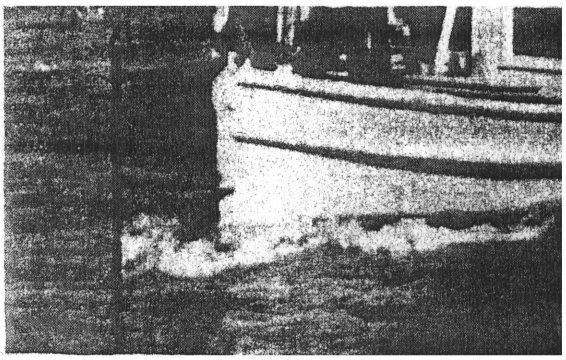
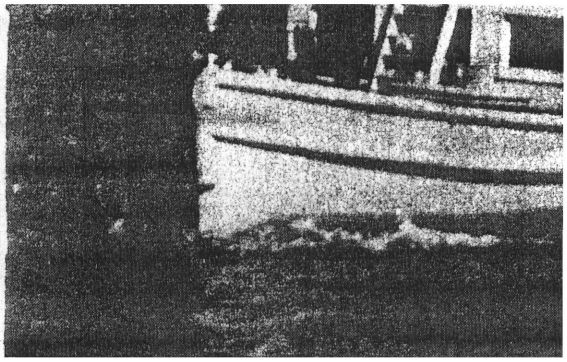
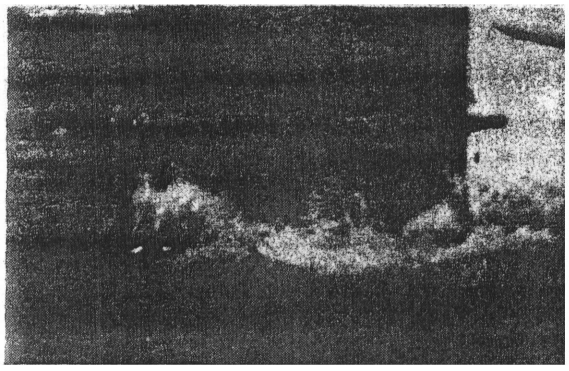
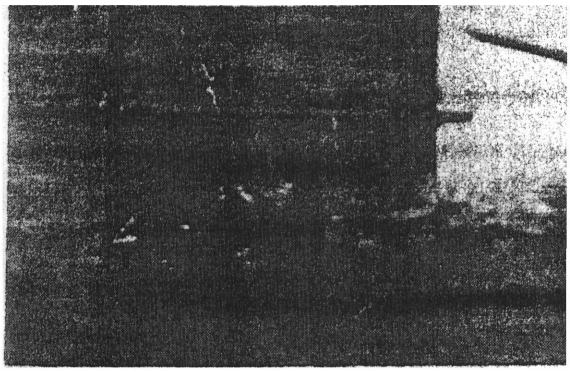
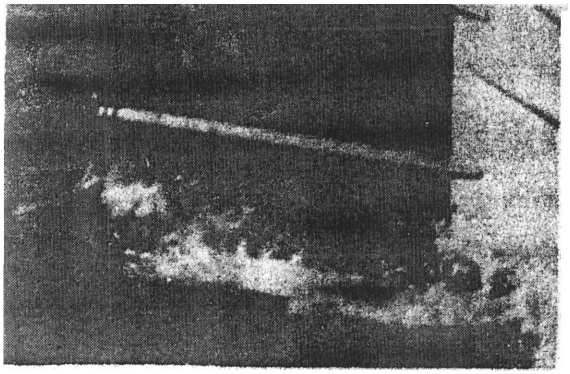
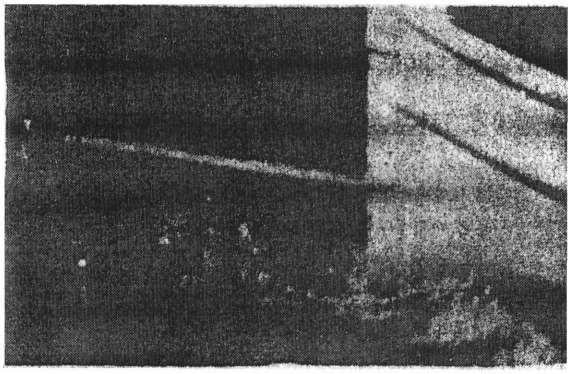


WITHOUT DYE

WITH DYE

EXPERIMENTS WITH HOLES IN TUBE, RATE OF FLOW OF DYE 2 GALLONS PER MINUTE.

PLATE 5

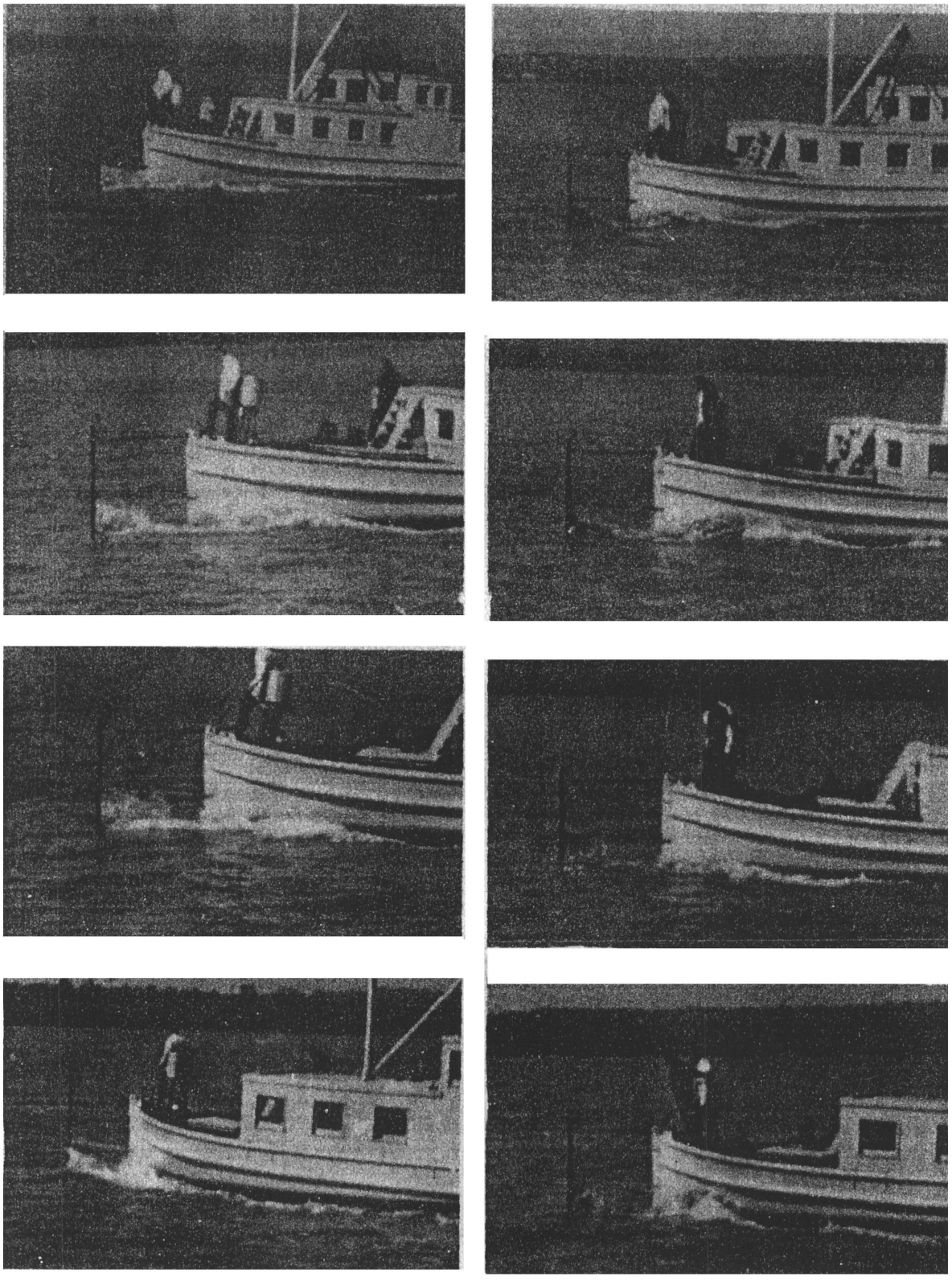









WITHOUT DYE

WITH DYE

EXPERIMENTS WITH HOLES IN TUBE, RATE OF FLOW OF DYE 6 GALLONS PER MINUTE. NEAR VIEW.

PLATE 6

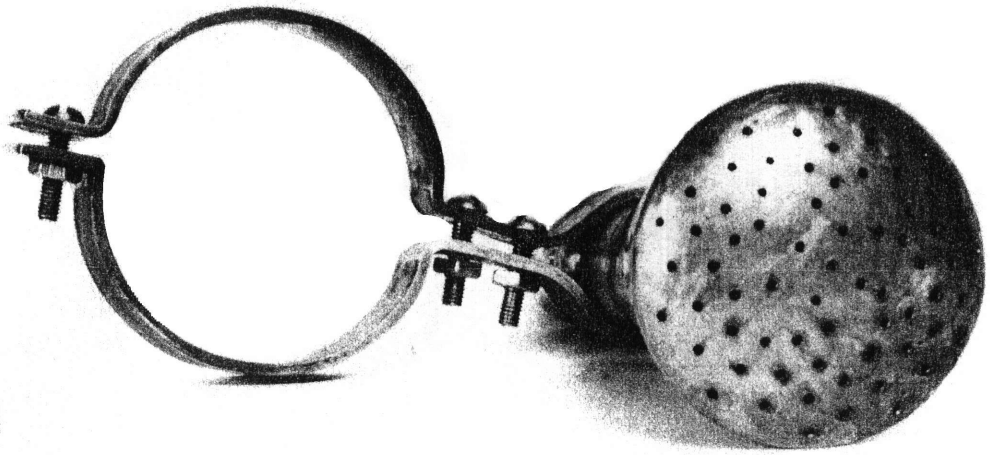


WITHOUT DYE

WITH DYE

EXPERIMENT WITH HOLES IN TUBE, RATE OF FLOW OF DYE 6 GALLONS PER MINUTE, DISTANT VIEW.

PLATE 7



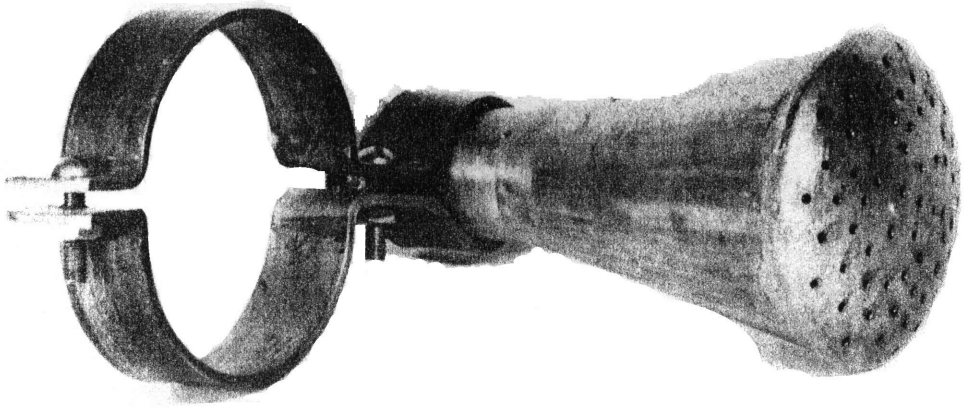


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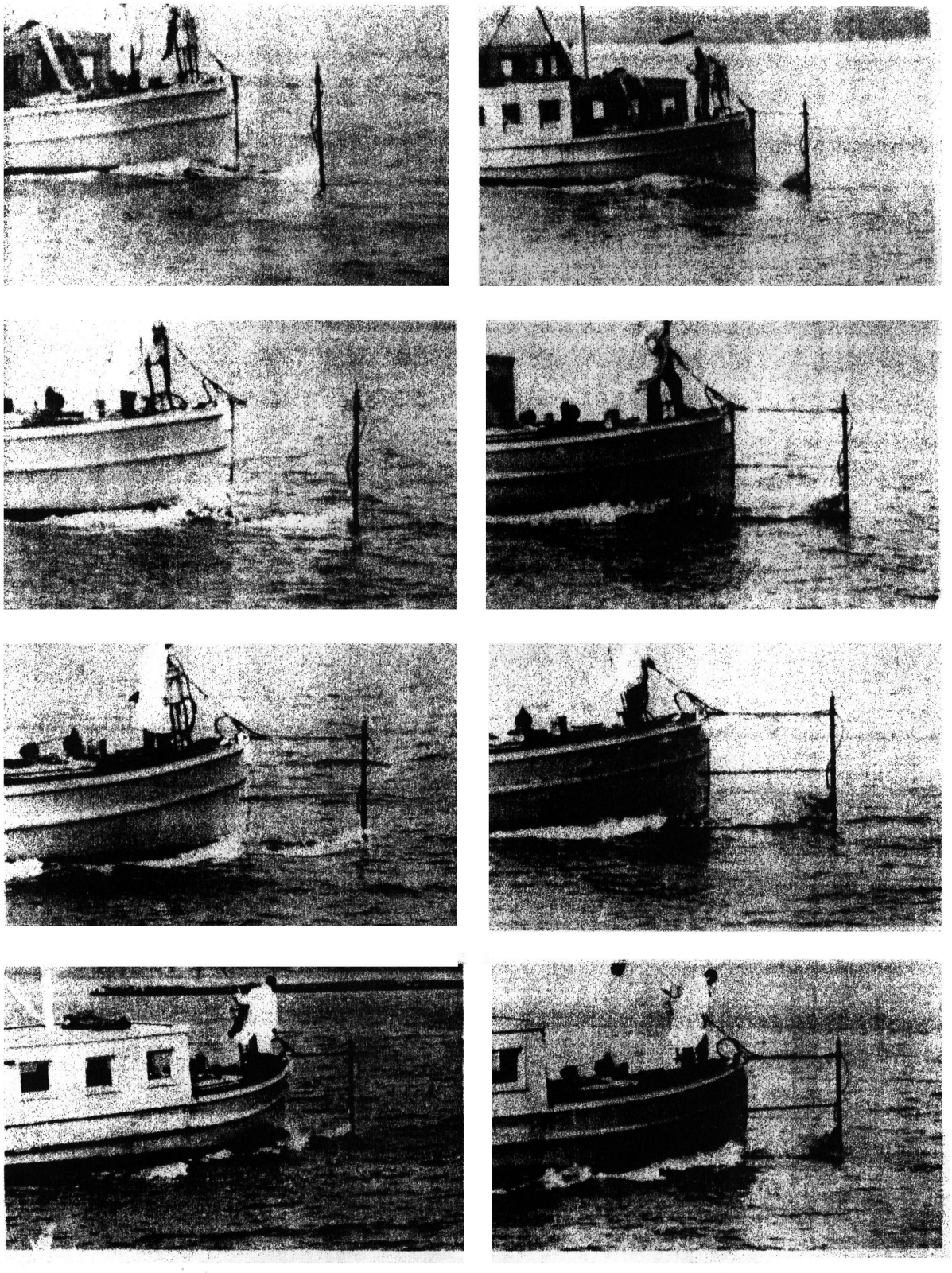
Plate 8



WITHOUT DYE

WITH DYE

EXPERIMENTS WITH SHOWER NOZZLE, RATE OF FLOW OF DYE 6 GALLONS PER MINUTE.

PLATE 9