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HYDRAULIC MODEL INVESTIGATION ON THE DEVELOPMENT PLANS FOR ALCÂNTARA-SANTOS QUAYS

Study made for ADMINISTRAÇÃO GERAL
DO PORTO DE LISBOA

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CONTENTS

HYDRAULIC MODEL INVESTIGATION ON THE DEVELOPMENT PLANS FOR ALCÂNTARA-SANTOS QUAYS

1 - THE PROTOTYPE

Alcântara-Santos quays (Fig. 1) are located on the north bank of the Tagus estuary about 10 km east of the mouth of the estuary (Fig. 2). They are integrated in the main dock system of the Port of Lisbon and are the principal quays used by steamers.

The Tagus estuary extends from S. Julião to about 90 km upstream, where the head of tidal propagation is located. It comprises an area of about 34.000 ha. of wetted surface.

Tides occuring in the estuary are of the semi-diurnal type. Along the area under study they range from 0.70 at neap tides to 4.10 m at spring tides. The tidal prism is estimated to be 700,000 cubic meters for spring tide. The mean freshwater inflow is 300 m^3/sec. but it varies from some 50 m^3/ sec in summer to more than 1.200 m^3/sec. in winter.

Salinity at the entrance of the estuary is about 33 ppt. As the estuary is considered well mixed for the first 15 km, salinity gradient between surface and bottom can be considered not significant for the purpose of the present study as the speed of currents does not undergo appreciable changes.

2 - PURPOSE OF THE INVESTIGATION

Recently, the Port of Lisbon Authority (Administração Geral do Porto de Lisboa-A.G.P.L.) has been faced with a serious problem concerning the Alcântara-Santos quays as several subsidences of the ground occurred under the platform of the quays. A considerable extent of those vital quays was then put out of operation, which prompted the A.G.P.L. to undertake the construction of proper works.

Three options were possible, which will hereafter be designated by plans, A, B, and C (Fig. 3):

- Plan A is the base plan. It consists in maintaining the present layout and in rebuilding the ground after consolidation of the works.
- Plan B aims at enlarging the present platform of the quays reclaiming from the estuary an area with a uniform width of 80 m over a length of 1200 m.
- Plan C proposes to enlarge the platform of the quays by reclaiming an oblique area with a width ranging from 20 m on the east side to 180 m on the west side.

Apart from other aspects of the feasibility study, it is important to know what could be the possible hydraulic effects of both plan B and C. Thus, A.G.P.L. requested the Laboratório Nacional de Engenharia Civil (LNEC) to undertake an investigation study on the existing hydraulic model of the Tagus estuary in order to know those possible effects.

3 - THE SCALE MODEL

The hydraulic model of the Tagus estuary existing at the LNEC (Fig. 4) was commissioned some years ago by Administração Geral do Porto de Lisboa and Directorate-General of Harbours. This model was to be used for studying the many hydraulic problems likely to appear in future since the port of Lisbon is having an increasing development.

The model reproduces the whole estuary from the entrance to the head of the tidal propagation. It also reproduces an appreciable area of the Atlantic ocean extending to some 15 km away from the entrance and to 30 km along the coast.

The model was constructed to linear scales, model to prototype, 1/500 horizontally and 1/70 vertically, therefore having a geometric distorsion of about 7. From these basic ratios it follows that other scales will be: velocity 1/8.37, time 1/59.76, discharge 1/292,835 and volume 1/17,500,000. With these scales one

Fig.1 - Overall view of the Alcântara - Santos quays and the bridge over the estuary

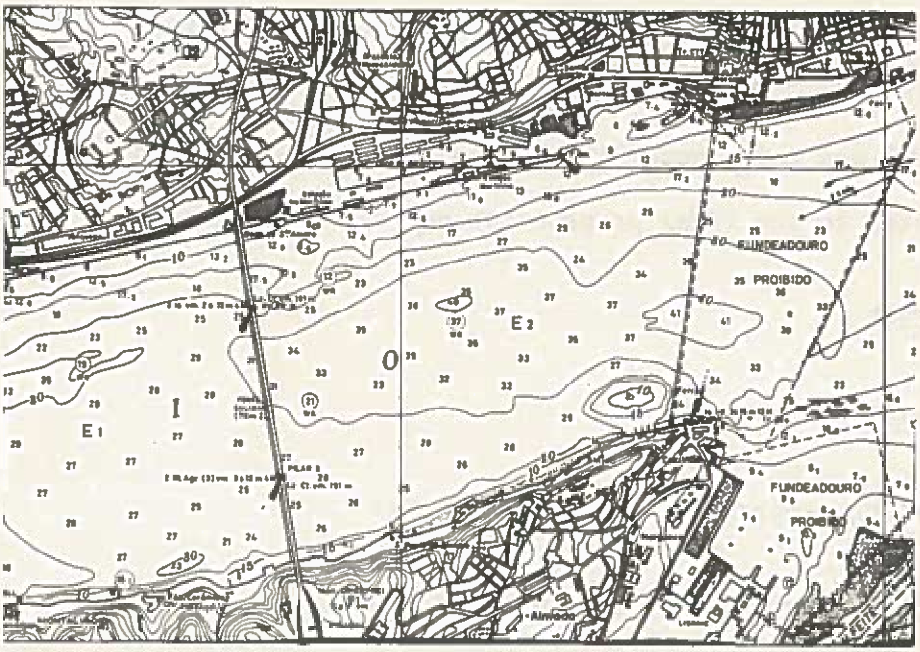

Fig.2 - Area under study showing the location of the Alcântara -Santos quays and of the bridge

prototype mean tidal cycle of 12h and 25 min is reproduced in the model in 12min 28sec.

The salinity is not reproduced in this model as the velocities of currents induced by gradient densities seem to be unimportant for most of the problems now existing in the estuary.

The model is equipped with the necessary appurtenances to reproduce and measure all pertinent phenomena such as tidal elevations, current velocity, freshwater inflow, waves and sediment distribution. Apparatuses (Fig. 5) used include a tidal generator, tidal recorders and tidal gages, a serpent type wave generator, wave sensors, current velocity meters, freshwater measuring weirs, bottom profiles, sensors and records, and photographic equipment.

The reproduction of tidal action in the model is accomplished by means of an automatic tide generator with a feedback control so that the model is selfregulated. Tides are programmed by means of cams which may accept from one to four different tides at a time.

Current velocities are measured by miniature current meters of the Kent type, which are frequently calibrated in a test velocity tank. Records of measurements are also obtained.

The model was built according to hydrographic surveys and it has already been calibrated to the tidal propagation and freshwater inflow.

4 - MODEL TESTS

4.1 - Program

The testing program was outlined to show:

- current velocity values at selected places;
- current pattern induced by the three proposed plans in the immediate vicinity of the quays
- other pertinent features such as tidal elevations changes, scour and

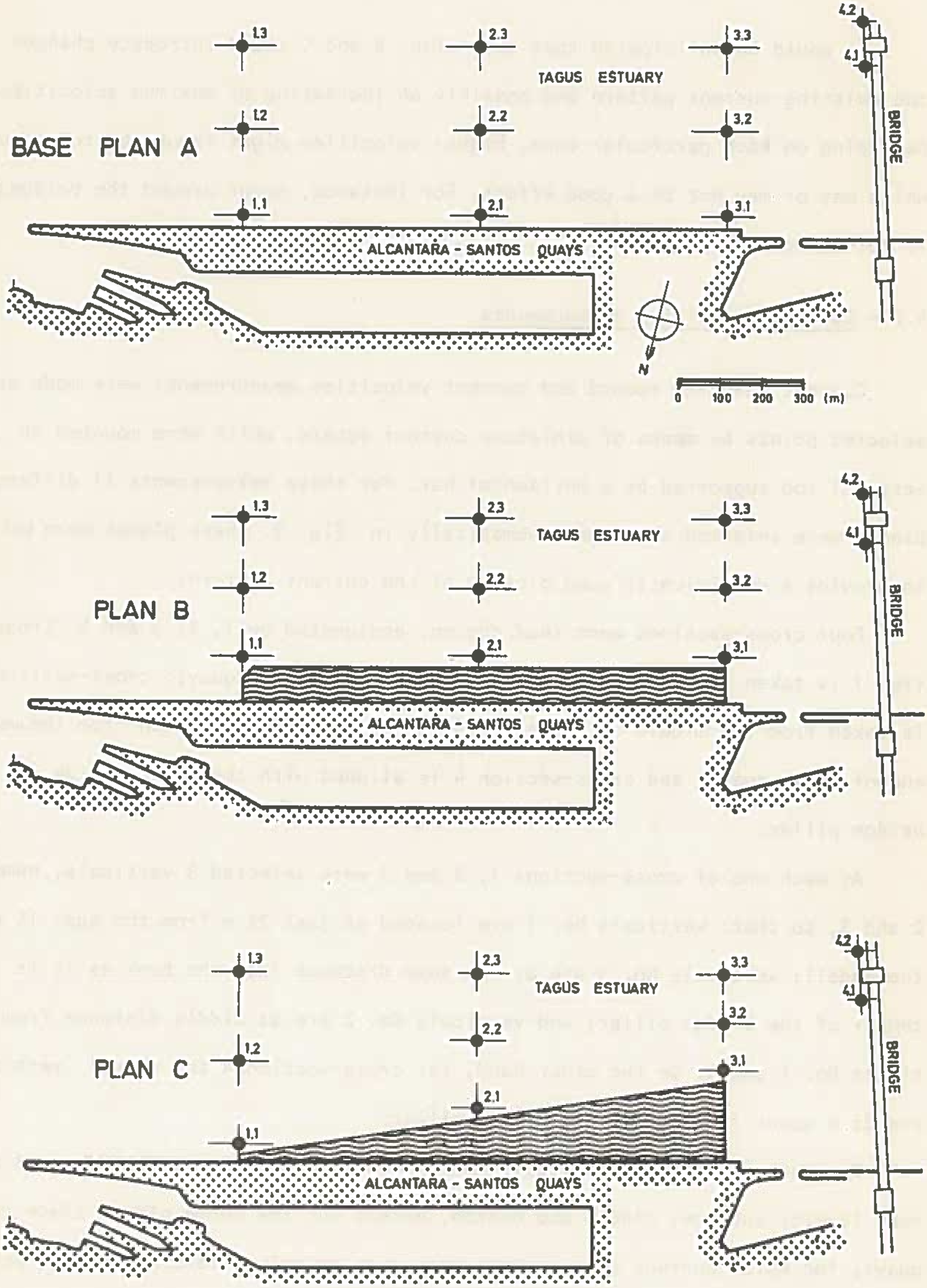

Fig. 3 - LAYOUT FOR PROPOSED SOLUTIONS

shoaling effects, etc.

It could be anticipated that both plans B and C would introduce changes in the existing current pattern and possibly an increasing of maximum velocities. Depending on each particular case, higher velocities might favour bottom scours which may or may not be a good effect. For instance, scour around the bridge pillar is not convenient.

4.2 - Current velocities measurements

Current velocity record and current velocities measurements were made at selected points by means of miniature current meters, which were mounted on a vertical rod supported by a horizontal bar. For these measurements 11 different places were selected as shown schematically in Fig. 3. These places were believed to provide a sufficiently good picture of the current patterns.

Four cross-sections were thus chosen, designated by 1, 2, 3 and 4. Cross-section 1 is taken from the eastern end of both plan B and C quays; cross-section 2 is taken from the middle of those quays; cross-section 3 is taken from the western end of those quays; and cross-section 4 is aligned with the eastern side of the bridge pillar.

At each one of cross-sections 1, 2 and 3 were selected 3 verticals, named 1, 2 and 3, so that: verticals No. 1 are located at just 25 m from the quay (5 cm in the model); verticals No. 3 are at the same distance from the bank as it is the center of the bridge pillar; and verticals No. 2 are at middle distance from verticals No. 1 and 3. On the other hand, for cross-section 4 the chosen verticals are 25 m apart from both sides of the pillar.

For each of those 11 verticals measurements of currents were made at 3 different levels: surface, middle and bottom, except for the three places close to the quays, for which current measurements were made at only 2 levels (surface and bottom).

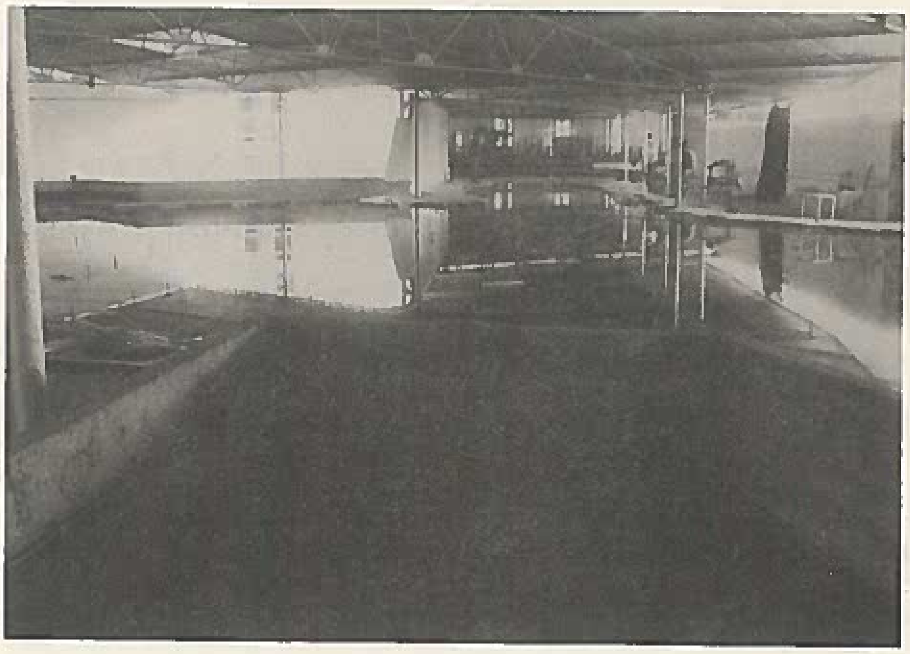

Fig.4 - Partial view of the area under study taking from the inner part of the model of the Tagus estuary

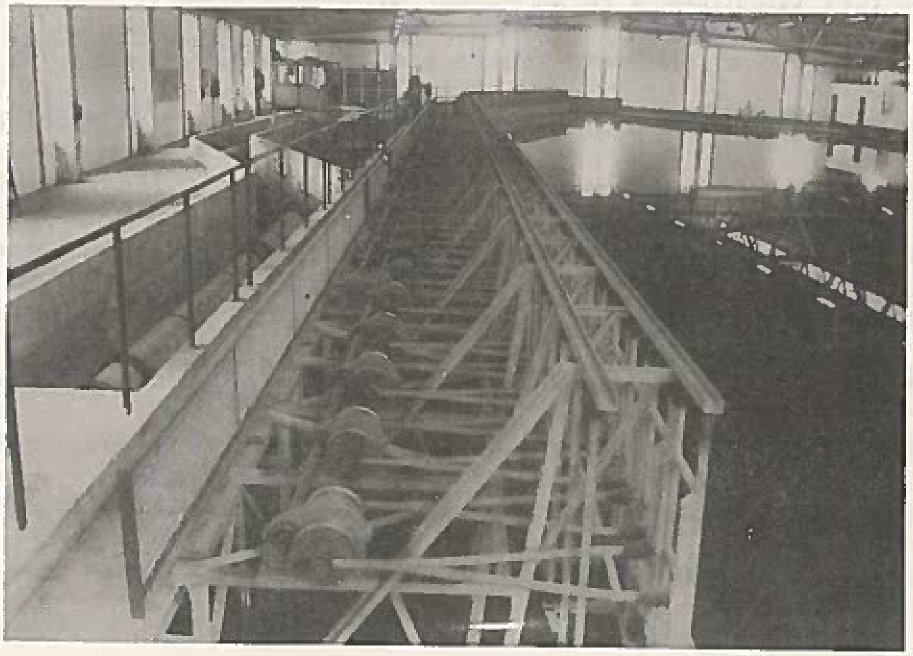

Fig.5 - Wave and tidal generator equipment of the scale model

This means that measurements were made at 30 different points.

In order to evaluate the influence of the tidal range, tests were made for 3 different semi-diurnal tides, named M_1, M_2 and M_3 with local range of, respectively, 3,95 m, 3.53 and 3,17 m.

Finally records were made for each one of plans A, B, and C.

Altogether a total of: 30 points x 3 tides x 3 plans = 270 current records were made.

From these records were computed the maximum ebb and flood current velocities, which are shown in plates 1, 2 and 3 (pages 15 to 20).

It has to be said that each one of the computed velocities is the mean of at least 3 consecutive tidal cycles records. This means that, altogether, 1620 measurements were made.

4.3 - Surface current direction photos

The patterns of surface current directions may accurately be shown by means of chrono photographies.

To use this technique a large number of square bits (1 cm x 1 cm) of white papers were spread over the water surface of the model.

Photos were then shot from the ceiling structure of the model along an entire cycle for the highest tidal range, that is, for tide M_1. The time intervals between photos were of 1/2 minute, which corresponds very closely to half-an-hour prototype. The time for each exposure was about 5 seconds, which allows the photos-film to show current directions, though it cannot be used for current measurements.

Appendix A shows the entire collection of photos obtained, ordered in each plate for each half-an-hour prototype. In these photos P.M. stands for "preia-mar (high water level), and B.M. stands for "baixa-mar" (low water level). The number just below P.M. or B.M. means the time in hours elapsed since the previous high or low water time.

A total of 26 x 3 = 78 photos was taken.

5 - TEST RESULTS

5.1 - Current velocities

The results of the measurements made with the miniature current meters are presented in tables 1, 2 and 3. These are only the values considered most important and so they refer to the mean maximum velocities measured at each one of the 30 selected points during either the ebb or the flood phase.

Moreover, as already said, an equal number of records was made, which would make it possible to analyse many other aspects, as for instance the variability of the current velocities, the gradient of velocities in time and space, etc.This study would take time and is not presented now as it does not appear to be vital for the purpose of the present report, which is to supply the A.G.P.L with the main conclusions on the hydraulic behaviour of the proposed plans.

Let us summarize the analysis of the values presented on tables 1, 2 and 3:

- the maximum velocities for the ebb currents are always considerably higher than those for the flood currents. Records would show that for flood phases velocities remain close to maximum for a relatively long time, while for ebb phases maximum velocities are obtained only for short periods. This gives consistency to the results as the water running upstream must balance the water running downstream.
- With few exceptions velocities decrease, as expected, from the surface to the bottom for any given vertical. This means that hydrographic irregularities of the estuary are sufficient to introduce turbulence in the model water even if, as is the case, there is no salt water in the model. This phenomenon seems to show that the model is accurate.
- Comparison between the results obtained for the three tidal cycles shows that velocities increase with the tidal range.
- The highest velocities are observed as a rule in the points away from the

quays, except for vertical 3.1, located close to the western end of the quays as proposed in plans B and C.

- Particularly important are the measurements made at vertical 3.1. For the highest range tide M_1 the maximum ebb surface velocities are 1.70 m/sec for base plan A, 2.05 m/sec for plan B, and 2.40 m/sec. This is taken as a rather significant effect from the layout of plan B and, specially, of plan C.
- Results for verticals 4.1 and 4.2, which stand close to the bridge pillar, show that ebb velocities tend to increase with plan B and more with plan C, but not as much as could be expected. Thus, for vertical 4.1 mean maximum velocities for plan A, B and C are 2.55, 2.57 and 2.48 m/sec, respectively, for tide M_1; 2.33, 2.32 and 2.43 m/sec for tide M_2; and 1.75, 1.72 and 1.90 m/sec for tide M_3. For vertical 4.2 mean maximum velocities are 2.53, 2.67 and 2.77 m/sec for tide M_1; 2.30, 2.40 and 2.50 m/sec for tide M_2; and 1.73, 1.73 and 1.98 m/sec for tide M_3. The meaning of these results is not clear, as they present fluctuations. It is believed that such fluctuations are closely related with the great turbulence created by the flow around the bridge pillar, and this would require another type of investigation. Anyway, for the present purpose, it is important to retain that plan B seems better than plan C as far as the velocities around the bridge pillar are concerned.
- Another interesting aspect of the results is the lower flood velocities alongside the quays walls produced by plan B and particularly by plan C. This is better understood by inspection of the cronophotographs referred to below, where it can be seen that these plans create a shadow area over that zone, thus reducing velocities.

5.2 - Current patterns

The cronophotograph collection presented in this report is self explanatory as photos on each page present, for each one of three plans: A, B, and C, the surface current pattern for the same time step (pages 21 to 46).

Before interpreting these photographs it is important to note that the low water level, that is, "baixa-mar" (B.M.), is the low water level at Cascais.

Thus, by the time those photos begin, water in the area under study is still running downstream. The low slack water in this area occurs nearly half-an-hour later than low water level time at Cascais, and then currents reverse. A similar effect occurs for the high water level (P.M.) and the related slack water. Much could be said of these photos. Let us summarise it:

- Both plans B and C induced changes in the current paths in the vicinity of the proposed enlarged quays, as could be expected.

  However, changes are considerably greater with plan C.

- For flood phase the main changes consist either of large eddies developed just after the low water slack time - when currents reverse-or in the current pattern alongside the quays. Again plan C is the one which more strongly disturbs the existing conditions, due to the oblique shape of the quays and to the greater width of the western end of the quay. Thus just at the beginning of the flood current - half-an-hour after low water at Cascais - - a large eddy, propagated from seaward, develops around the bridge pillar so that for a while a somewhat strong cross current impels the water toward the middle estuary, instead of along the bank. This is an important disturbance effect. Besides, alongside the quays another eddy appears just at the beginning of the flood phase and remains there all along this phase. This happens for plan C but not for plan B as with this plan the eddy alongside the quays only remains for a while.

- It is known, from current meters measurements, that velocities reach the highest values for ebb currents. Current patterns photos show that water tends to be directed towards the bridge pillar. This happens to a much lesser degree with plan B, but is evident with plan C. As a result, velocities around the bridge pillar increase with plan C. Also, it is important to stress that such currents could endanger the safety of the pillar, because, if a ship happens to be out of control when manoeuvering by the quays, these currents would favour a collision between the ship and the pillar.

Another important aspect revealed by flood current patterns is that a permanent eddy is formed alongside the bank just seaward of the western end of the quays. This eddy produces still waters which greatly favour sediment settlements, thus increasing shoaling in the adjacent dock of Santo Amaro. This effect is much higher with plan C than with plan B.

6 - CONCLUSIONS

Based on the analysis of model tests, the following conclusions are drawn:

a) - For ebb currents, plan B does not introduce appreciable effects on the highest velocities existing with base plan A. On the contrary, plan C causes a variable increase of up to 15 to 20 cm/sec (10 to 15%) in the highest velocities observed around the bridge pillar and at the measurements points of the western cross-section.

b) - For flood currents there are no significant increases in the maximum velocities either with plans A, B or C. Besides, plan C produces during the entire flood phase a shadow area just alongside the quay walls and this causes maximum velocities at the eastern side of the quays (points 1.1 and 2.1) to be smaller than those with base plan A.

c) - Surface current direction photos show that plan B does not introduce great changes in the current pattern although it tends somehow to develop the eddies that are always formed when currents reverse by slack times.

On the contrary, photos with plan C depict clearly that large eddies are formed by slack times and then propagate upstream and downstream with most disturbing effects on prevailing current patterns shown by plan A. Besides, plan C produces during the entire flood phase a shadow area just alongside the quays walls thus originating there a permanent large eddy with weak current velocities.

d) - For both plans B and C a permanent shadow area is created in the inner corner just seaward of the western end of the quays. That shadow area originates a permanent eddy with relatively still water that will favour sediments to settle, thus increasing the tendency towards shoaling in the adjacent Santo Amaro dock. Again, plan C seems to be the worst solution.

e) - For the sake of safety of the bridge, it is worth pointing out that surface current direction photos show that for most of the ebb phase plan C seems to favour water to be impelled from the area in front of the quays directly towards the bridge pillar. This means that a ship manoeuvering in that area would tend to be impelled to hit the pillar.

All these conclusions may be summarized as follows:

- Plan B does not introduce significant changes in the existing hydraulic conditions as exibited by base plan A.
- Plan C causes the highest current velocities to increase and to develop large moving eddies which disturb the prevailing current directions and generate two permanent eddies — one alongside the quays walls and another at the inner corner of the western end of the quays, which favour sediments deposits.

Lisbon, Laboratório Nacional de Engenharia Civil, January 1977

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MODEL TEST DATA

MAXIMUM VELOCITIES (m/sec) FOR TIDE M_1

TABLE 1

POINT		PLAN A		PLAN B		PLAN C	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
1.1	S	1.95	1.20	1.90	1.30	1.90	0.85
	B	1.90	1.20	1.90	1.25	1.80	0.85
1.2	S	2.20	1.40	2.25	1.45	2.20	1.40
	M	2.15	1.45	2.15	1.45	2.25	1.40
	B	2.15	1.30	2.05	1.25	2.10	1.20
1.3	S	2.35	1.50	2.35	1.45	2.35	1.50
	M	2.25	1.40	2.15	1.40	2.30	1.45
	B	2.00	1.35	2.00	1.30	1.90	1.30
2.1	S	1.90	1.15	1.75	1.10	1.60	0.75
	B	1.80	1.15	1.80	0.90	1.50	0.70
2.2	S	2.30	1.40	1.95	1.35	2.25	1.30
	M	2.25	1.45	2.15	1.30	2.20	1.40
	B	2.15	1.40	2.10	1.20	2.10	1.50
2.3	S	2.35	1.45	2.30	1.40	2.40	1.65
	M	2.30	1.35	2.20	1.45	2.30	1.75
	B	2.05	1.30	2.00	1.05	2.20	1.40

1 of 2 sheets

MODEL TEST DATA

MAXIMUM VELOCITIES (m/sec) FOR TIDE M_2

TABLE 2

POINT		PLAN A		PLAN B		PLAN C	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
1.1	S	1.70	1.25	1.70	1.20	1.70	0.95
	B	1.70	1.15	1.70	1.20	1.70	0.90
1.2	S	1.95	1.25	1.80	1.25	1.95	1.30
	M	1.95	1.35	1.90	1.35	1.95	1.30
	B	1.80	1.10	1.75	1.10	1.90	1.20
1.3	S	2.15	1.40	2.05	1.30	2.15	1.30
	M	2.05	1.30	1.90	1.30	2.05	1.30
	B	1.80	1.20	1.80	1.10	1.80	1.15
2.1	S	1.70	1.10	1.65	1.05	1.75	0.80
	B	1.65	1.10	1.65	1.05	1.45	0.75
2.2	S	2.05	1.30	1.90	1.15	2.10	1.15
	M	2.10	1.45	1.90	1.25	2.10	1.25
	B	2.00	1.20	1.85	1.10	1.85	1.50
2.3	S	2.15	1.30	2.10	1.20	2.20	1.50
	M	2.10	2.5	2.00	1.30	2.05	1.50
	B	1.95	1.15	1.85	1.00	1.95	1.20

1 of 2 sheets

MODEL TEST DATA

MAXIMUM VELOCITIES (m/sec) FOR TIDE M_2

TABLE 2

continued

POINT		PLAN A		PLAN B		PLAN C	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
3.1	S	1.65	1.25	1.95	1.45	2.10	1.25
	B	1.65	1.10	1.80	1.35	2.05	0.95
3.2	S	2.10	1.30	2.10	1.40	2.25	1.45
	M	2.10	1.35	2.00	1.30	2.15	1.45
	B	1.95	1.15	1.85	1.10	1.85	1.05
3.3	S	2.20	1.45	2.10	1.30	2.05	1.40
	M	2.10	1.35	2.10	1.30	2.35	1.45
	B	2.05	1.05	1.85	1.00	2.25	1.25
4.1	S	2.45	1.75	2.45	1.75	2.50	1.65
	M	2.20	1.40	2.40	1.75	2.50	1.55
	B	2.35	1.65	2.10	1.30	2.30	1.55
4.2	S	2.30	1.75	2.50	1.70	2.60	1.80
	M	2.30	1.60	2.45	1.60	2.50	1.55
	B	2.30	1.30	2.25	1.20	2.40	1.55

Legend: S - Surface

M - Middle

B - Bottom

MODEL TEST DATA

MAXIMUM VELOCITIES (m/sec) FOR TIDE M_1

TABLE 1

continued

POINT		PLAN A		PLAN B		PLAN C	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
3.1	S	1.70	1.20	2.05	1.40	2.40	1.35
	B	1.75	1.15	1.95	1.25	2.25	1.00
3.2	S	2.15	1.45	2.20	1.55	2.50	1.60
	M	2.30	1.55	2.20	1.40	2.40	1.70
	B	2.10	1.50	2.10	1.15	1.95	1.10
3.3	S	2.45	1.55	2.40	1.45	2.45	1.55
	M	2.35	1.60	2.30	1.55	2.60	1.65
	B	2.25	1.25	2.10	1.05	2.40	1.30
4.1	S	2.60	1.40	2.70	2.05	2.75	1.95
	M	2.45	1.85	2.70	1.90	2.70	1.85
	B	2.60	1.95	2.30	1.60	2.60	1.65
4.2	S	2.60	1.95	2.75	2.00	2.90	2.05
	M	2.50	1.95	2.70	1.90	2.30	1.95
	B	2.50	1.50	2.45	1.55	2.60	1.60

Legend: S - Surface

M - Middle

B - Bottom

MODEL TEST DATA

MAXIMUM VELOCITIES (m/sec) FOR TIDE M_3

TABLE 3

POINT		PLAN A		PLAN B		PLAN C	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
1.1	S	1.50	1.25	1.50	1.15	1.35	0.85
	B	1.50	1.20	1.45	1.05	1.30	0.85
1.2	S	1.65	1.20	1.65	1.20	1.65	1.20
	M	1.60	1.15	1.60	1.15	1.65	1.20
	B	1.60	1.10	1.45	1.10	1.40	1.10
1.3	S	1.85	1.25	1.80	1.15	1.75	1.15
	M	1.80	1.15	1.70	1.10	1.70	1.10
	B	1.65	1.15	1.60	1.10	1.55	1.05
2.1	S	1.45	1.10	1.40	0.70	1.40	0.85
	B	1.40	1.05	1.35	0.80	1.30	0.85
2.2	S	1.60	1.20	1.60	1.05	1.65	1.00
	M	1.60	1.15	1.55	1.05	1.55	1.15
	B	1.55	1.10	1.43	0.90	1.20	1.20
2.3	S	1.75	1.15	1.75	1.05	1.60	1.30
	M	1.70	1.15	1.65	1.05	1.65	1.20
	B	1.50	1.05	1.55	0.90	1.55	1.00

1 of 2 sheets

MODEL TEST DATA

MAXIMUM VELOCITIES (m/sec) FOR TIDE M_3

TABLE 3

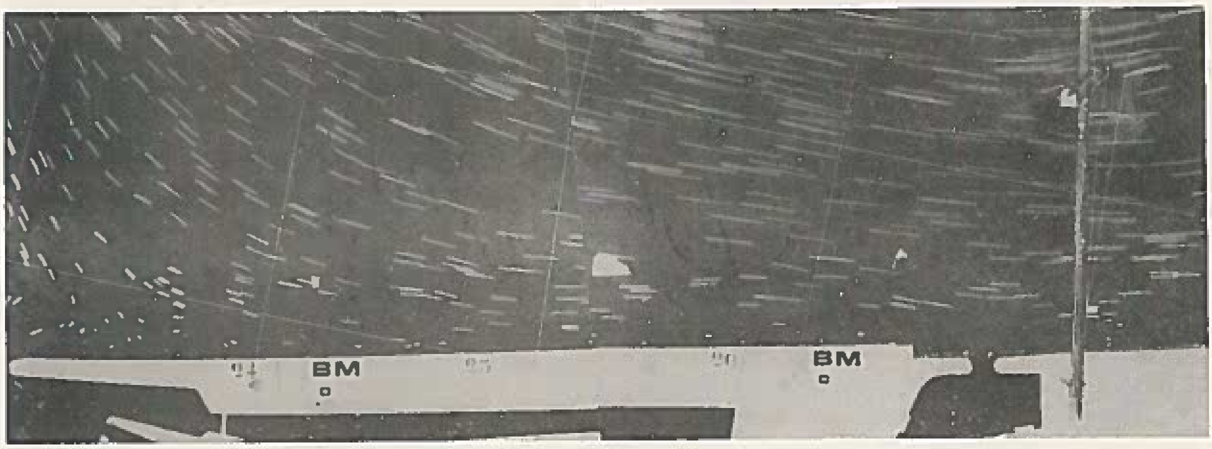
continued

POINT		PLAN A		PLAN B		PLAN C	
		Ebb	Flood	Ebb	Flood	Ebb	Flood
3.1	S	1.50	1.15	1.55	1.20	1.55	0.95
	B	1.35	1.05	1.45	1.25	1.60	1.00
3.2	S	1.65	1.10	1.60	1.10	1.75	1.20
	M	1.60	1.20	1.65	1.10	1.75	1.20
	B	1.55	1.10	1.55	1.00	1.65	0.95
3.3	S	1.80	1.15	1.70	1.05	1.85	1.30
	M	1.70	1.05	1.75	1.10	1.85	1.25
	B	1.60	0.95	1.60	0.85	1.80	0.95
41.A	S	1.75	1.25	1.80	1.40	1.90	1.35
	M	1.75	1.25	1.75	1.40	1.90	1.25
	B	1.75	1.20	1.60	1.20	1.90	1.15
42.A	S	1.75	1.40	1.80	1.45	2.00	1.45
	M	1.75	1.40	1.75	1.30	2.10	1.40
	B	1.70	1.15	1.65	1.15	1.85	1.15

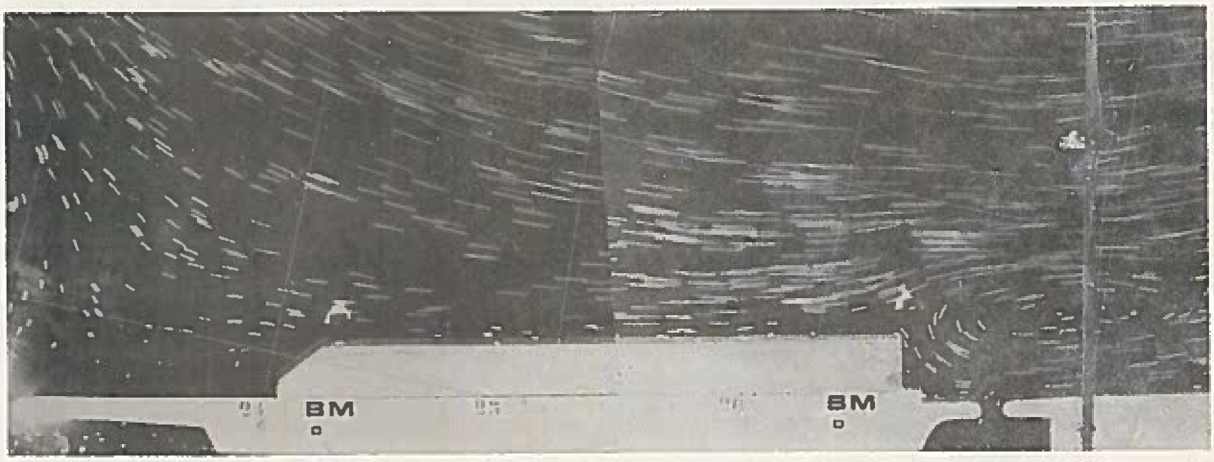
Legend: S - Surface

M - Middle

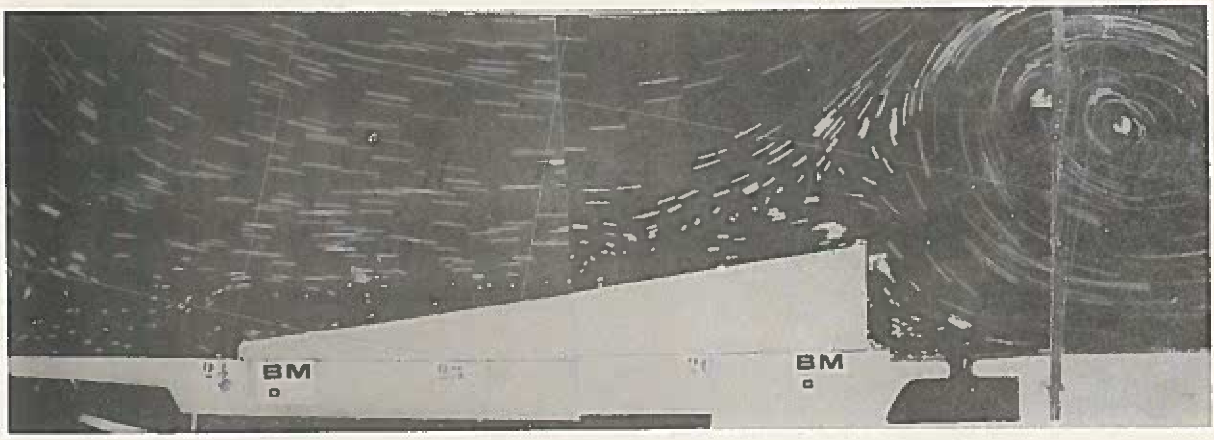
B - Bottom



BASE PLAN A

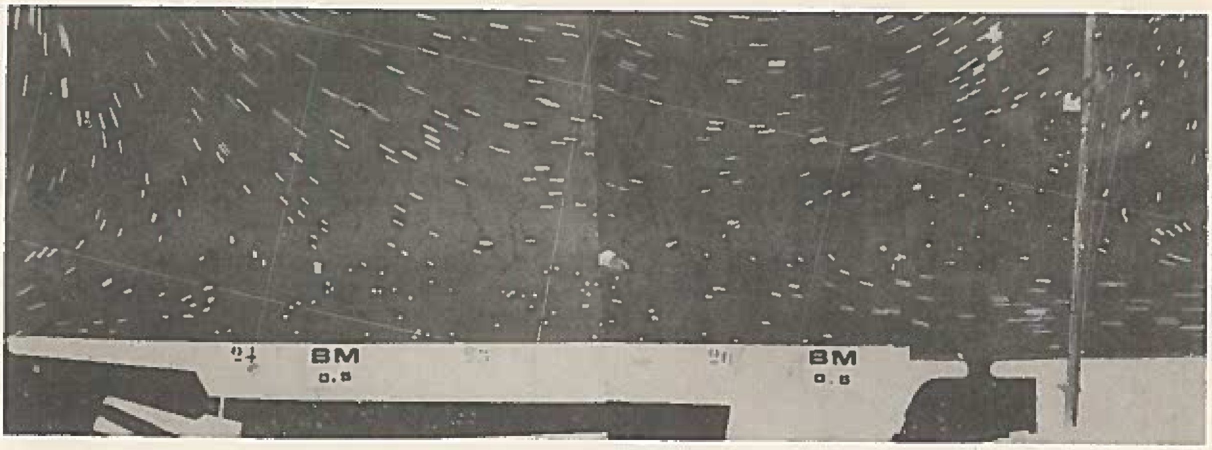


PLAN B

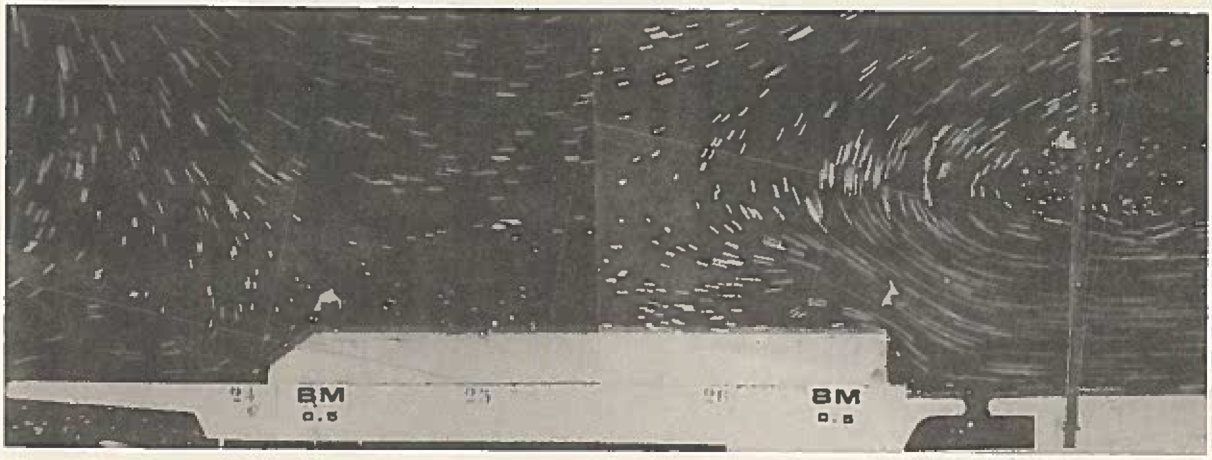


PLAN C

Effects of plans A, B and C on surface currents



BASE PLAN A



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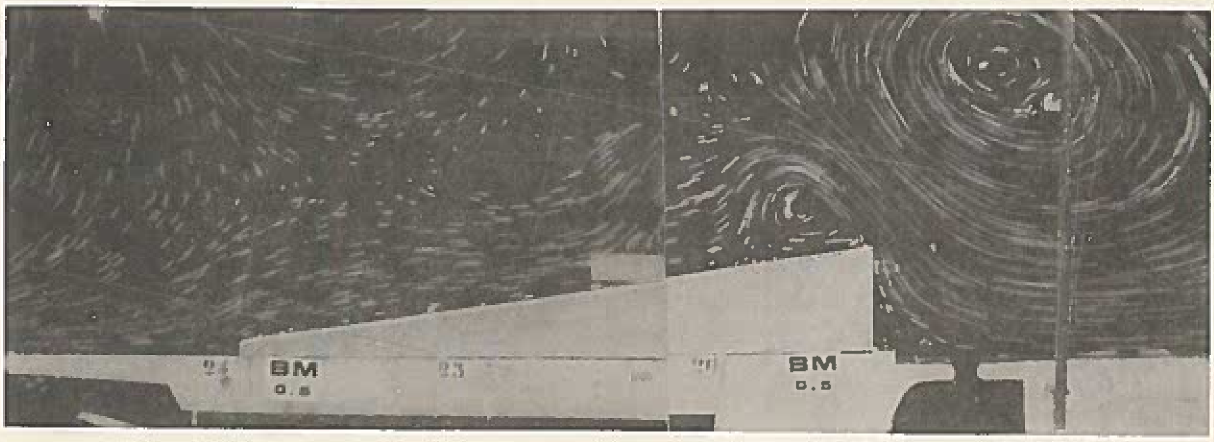
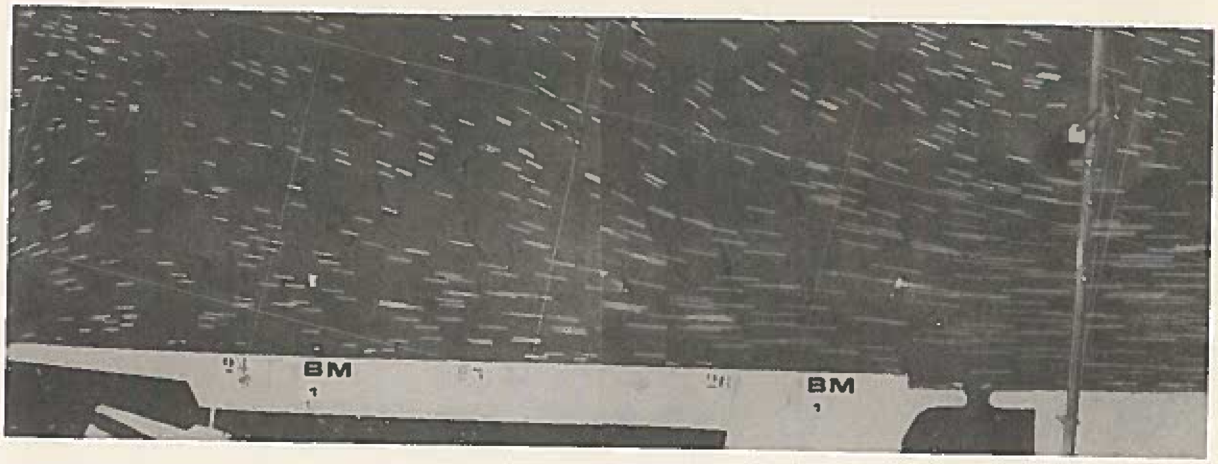


PLAN C

Effects of plans A, B and C on surface currents



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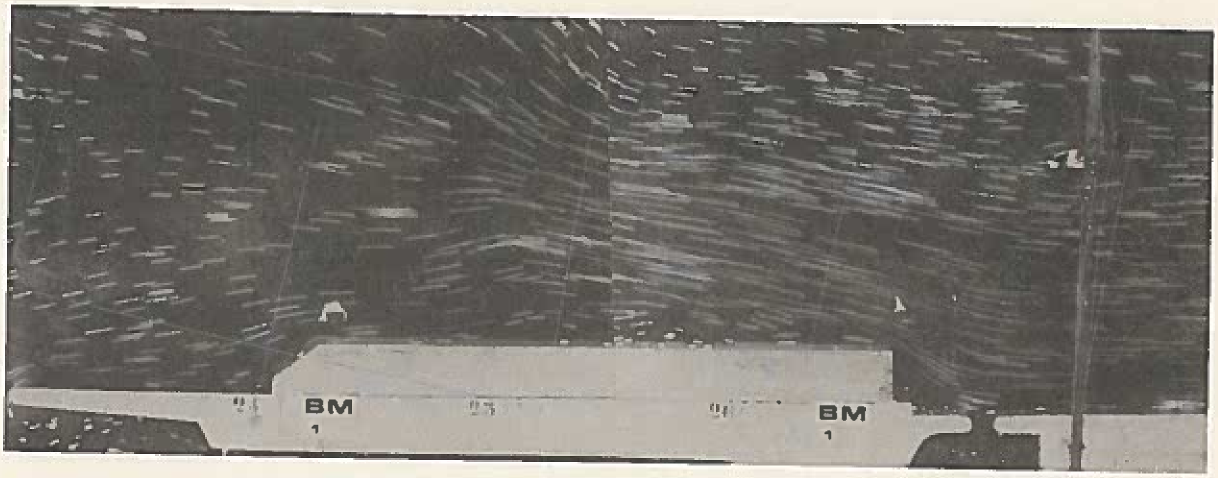

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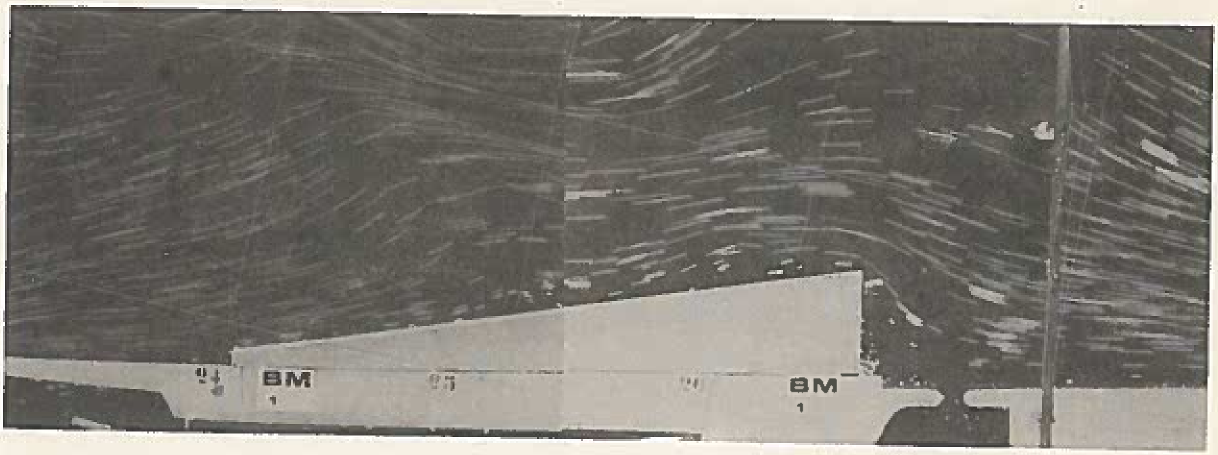
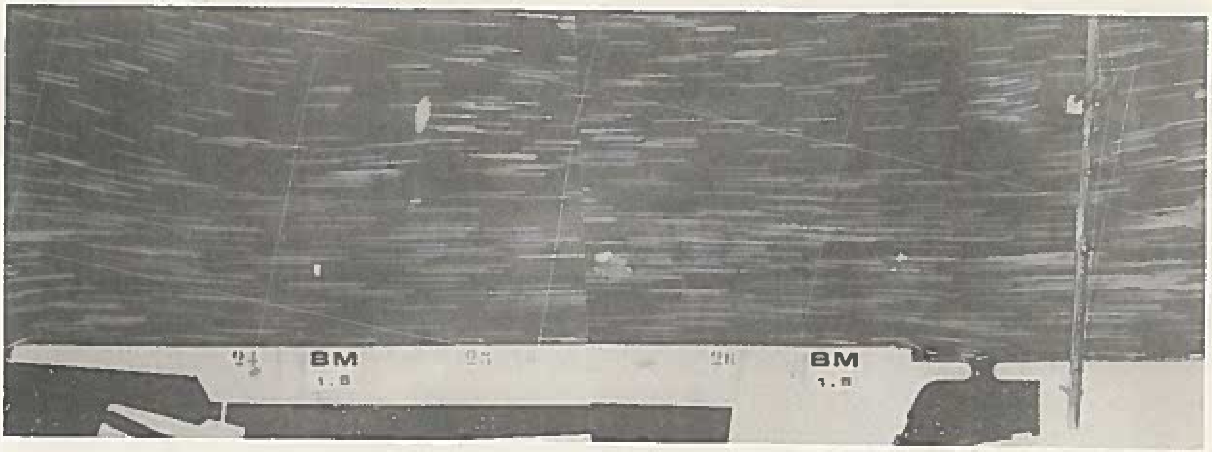


PLAN C

Effects of plans A, B and C on surface currents



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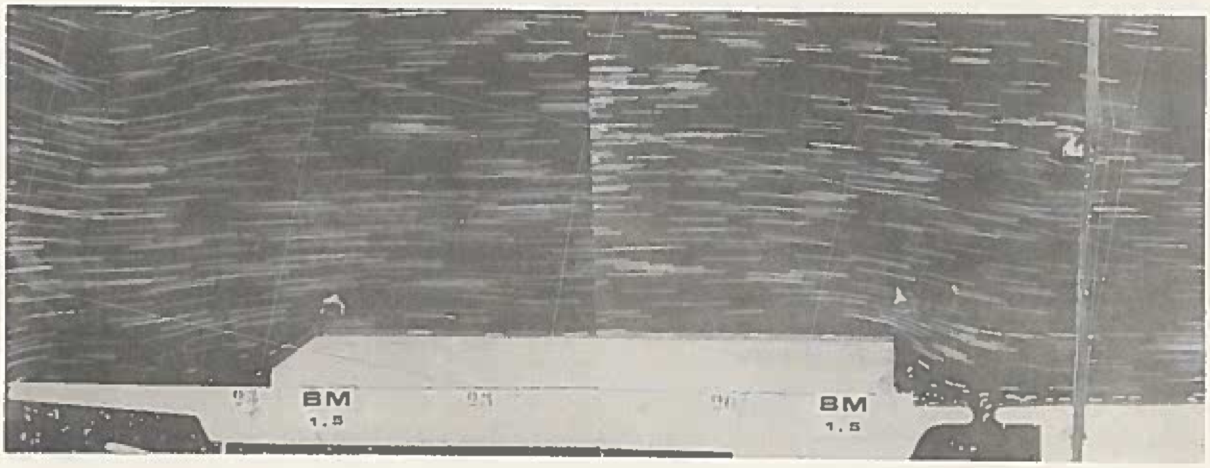

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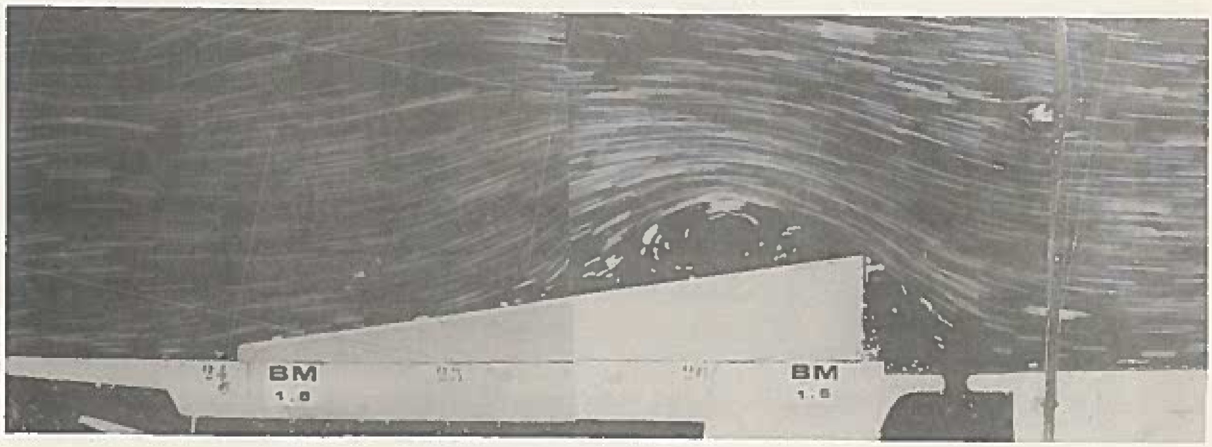
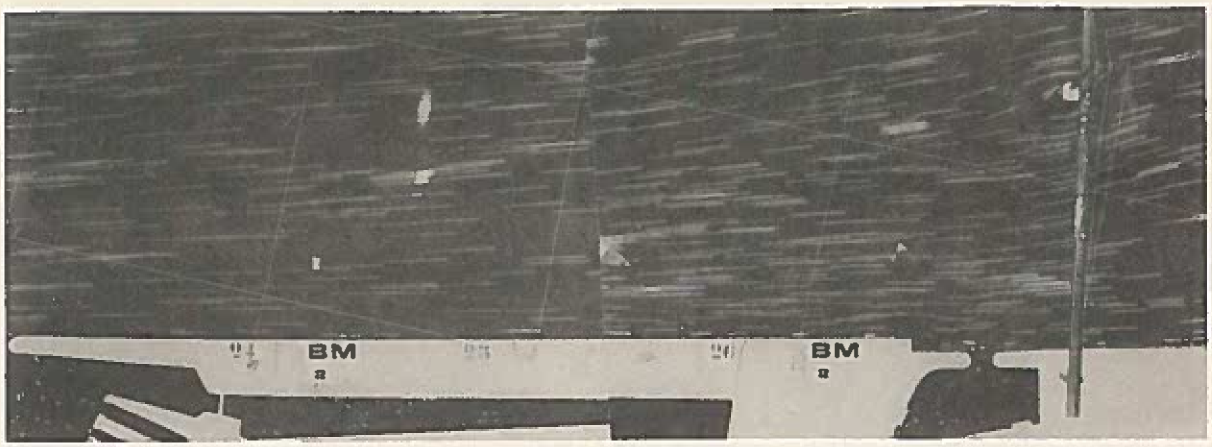


PLAN C

Effects of plans A, B and C on surface currents



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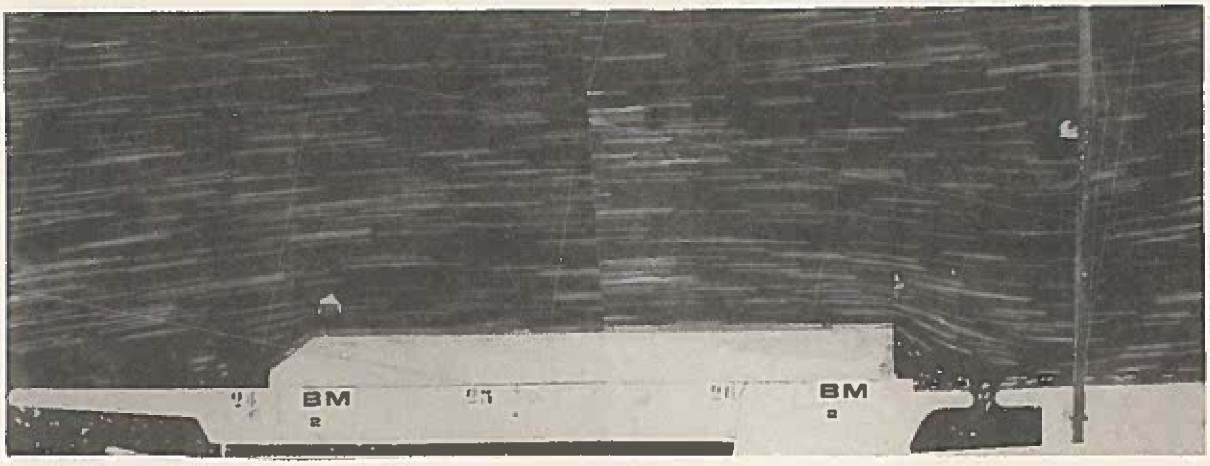

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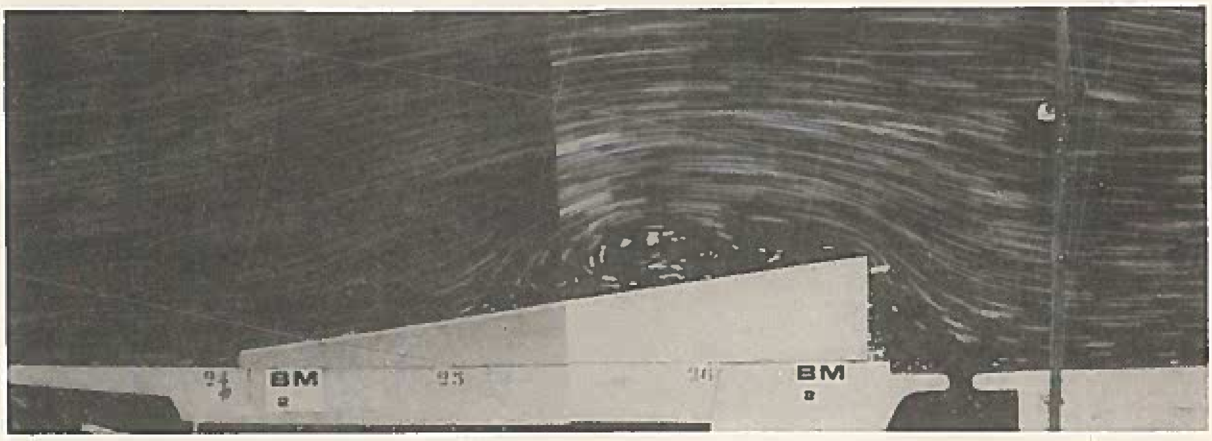
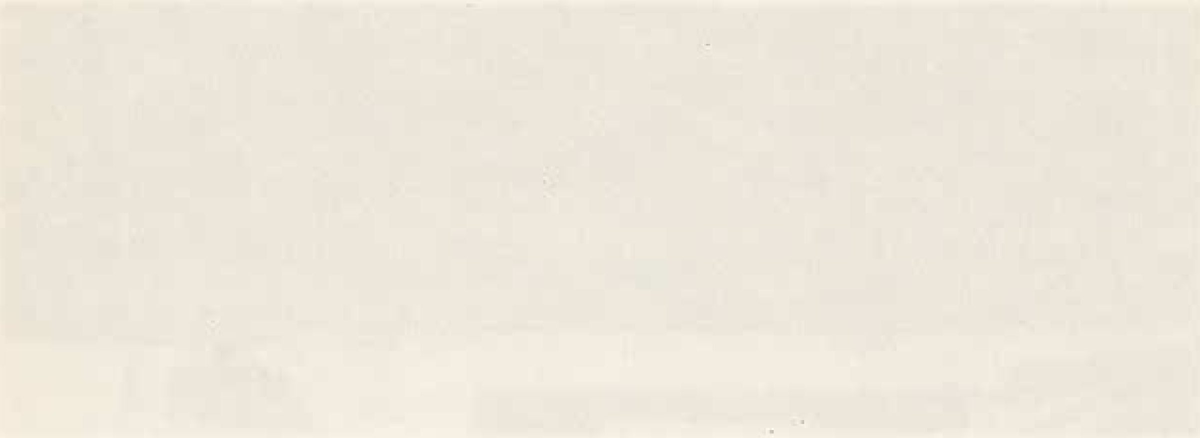
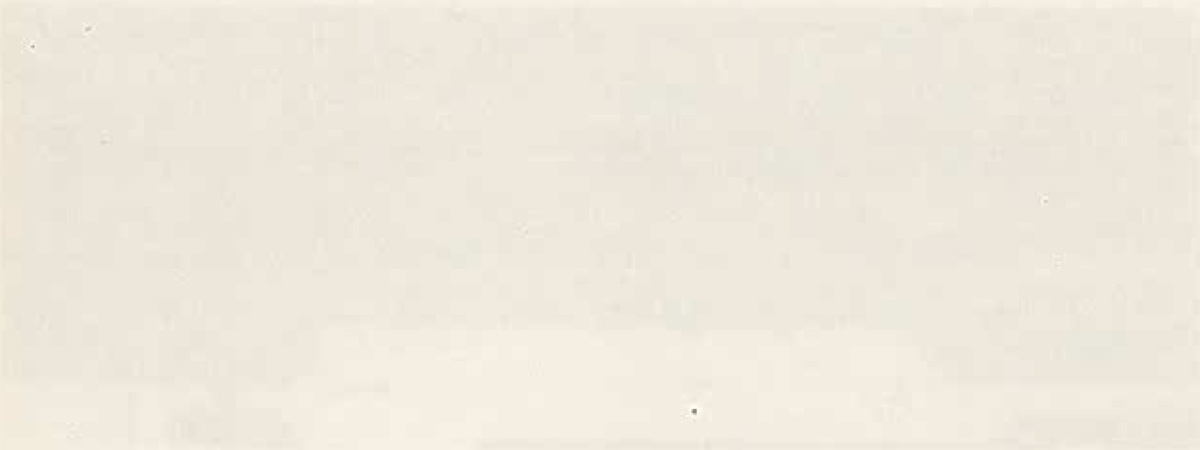
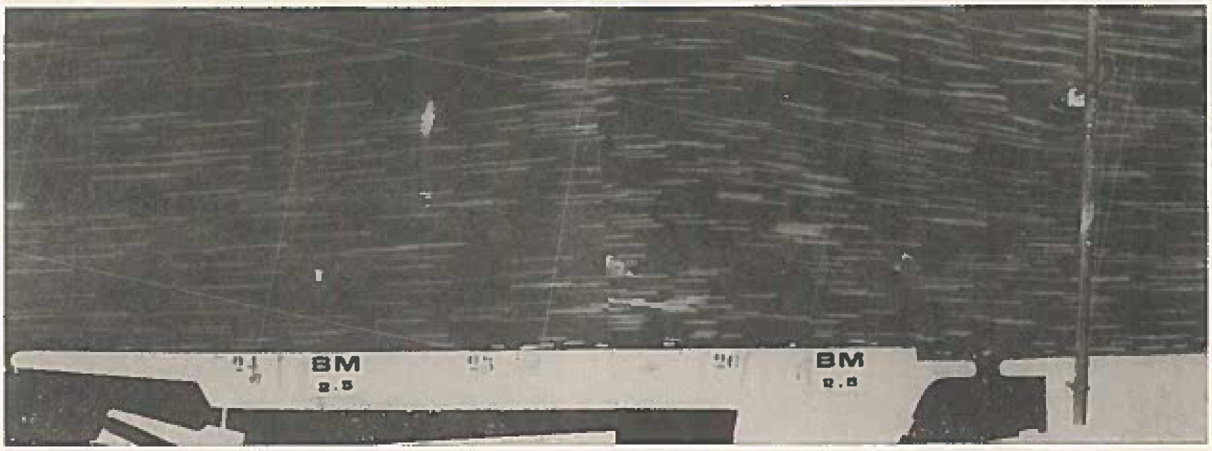


PLAN C

Effects of plans A, B and C on surface currents







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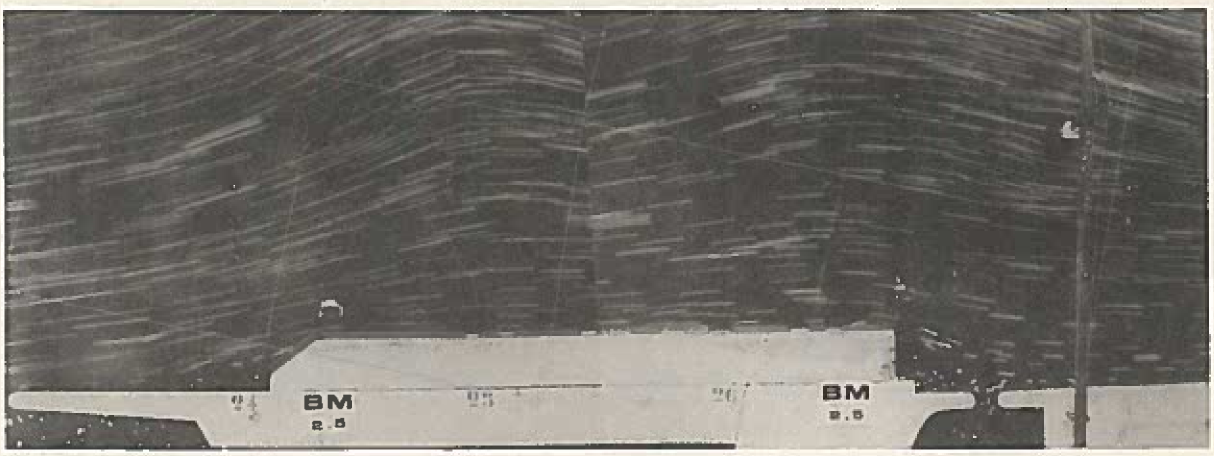

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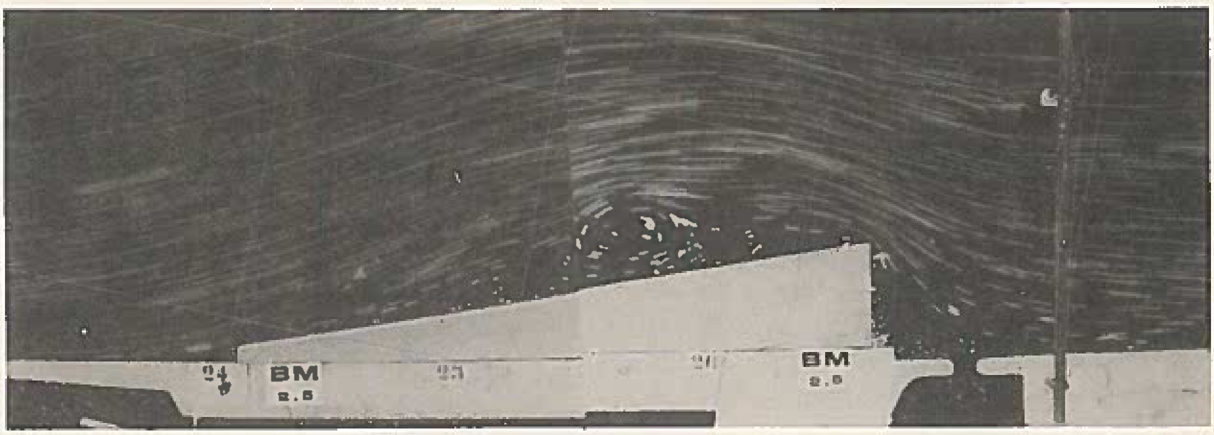
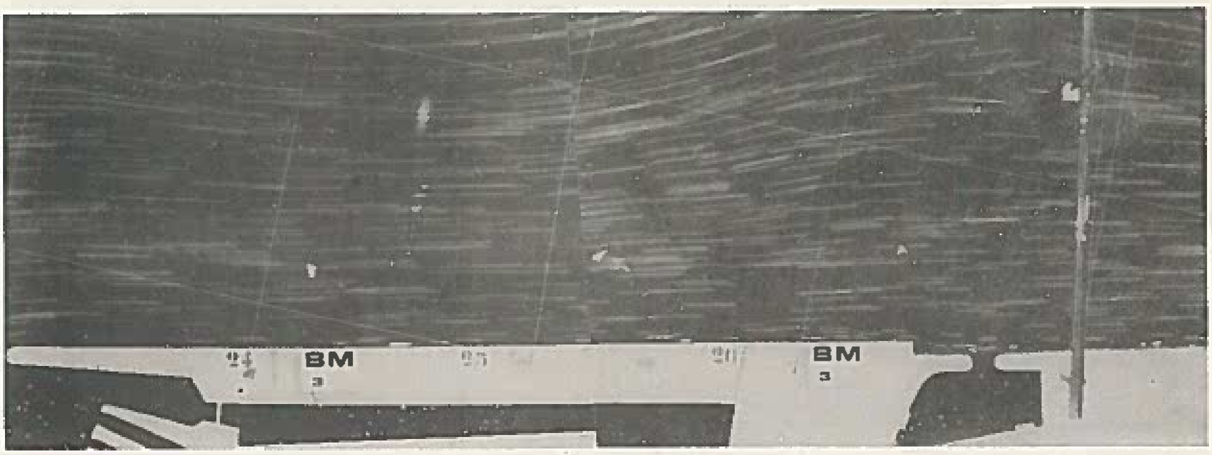
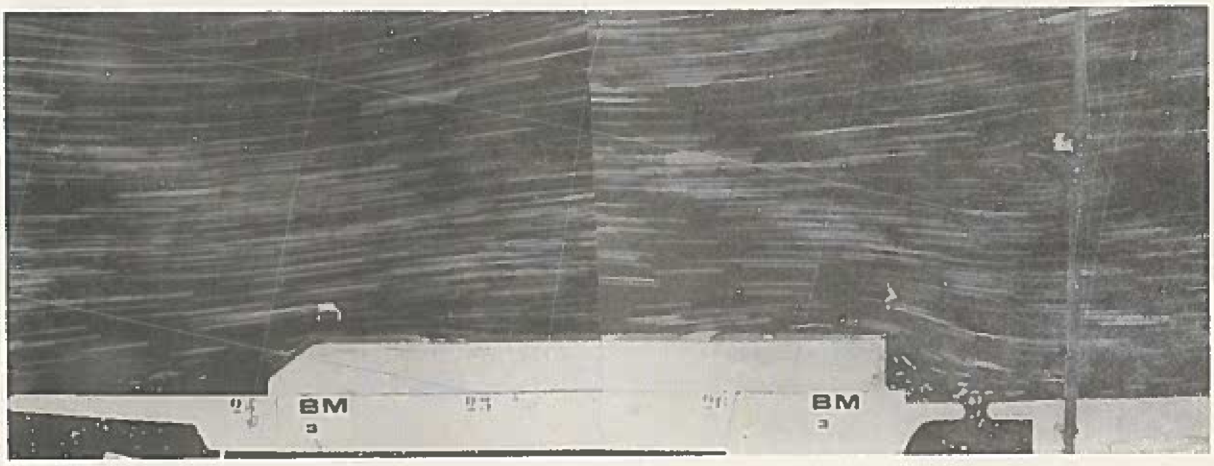


PLAN C

Effects of plans A, B and C on surface currents



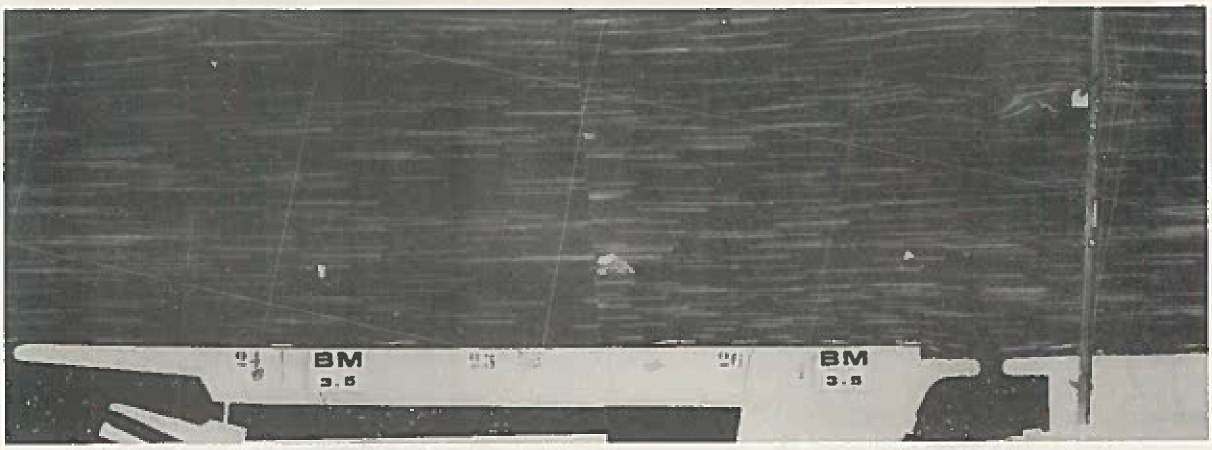
BASE PLAN A



PLAN B

PLAN C

Effectrs of plans A, B and C on surface currents



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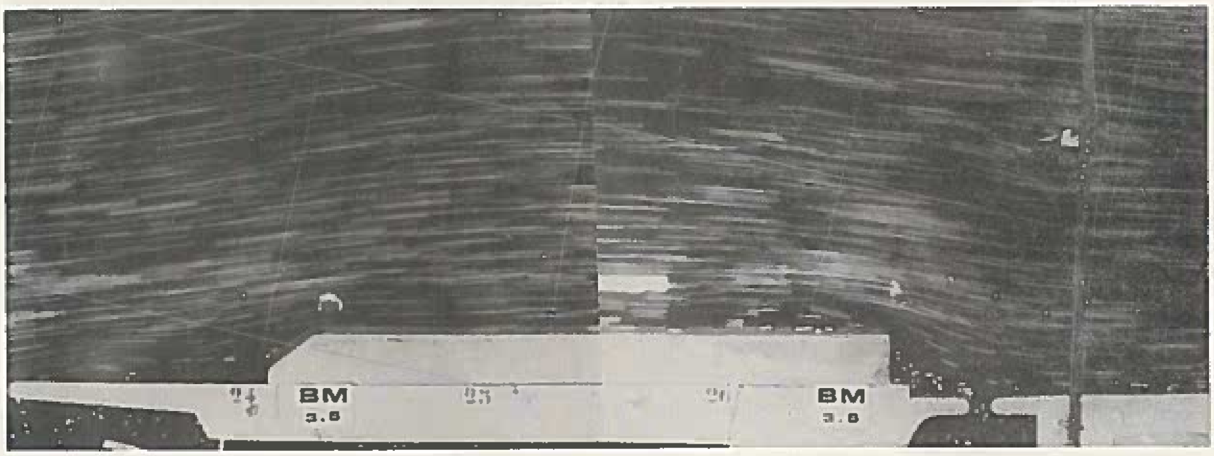

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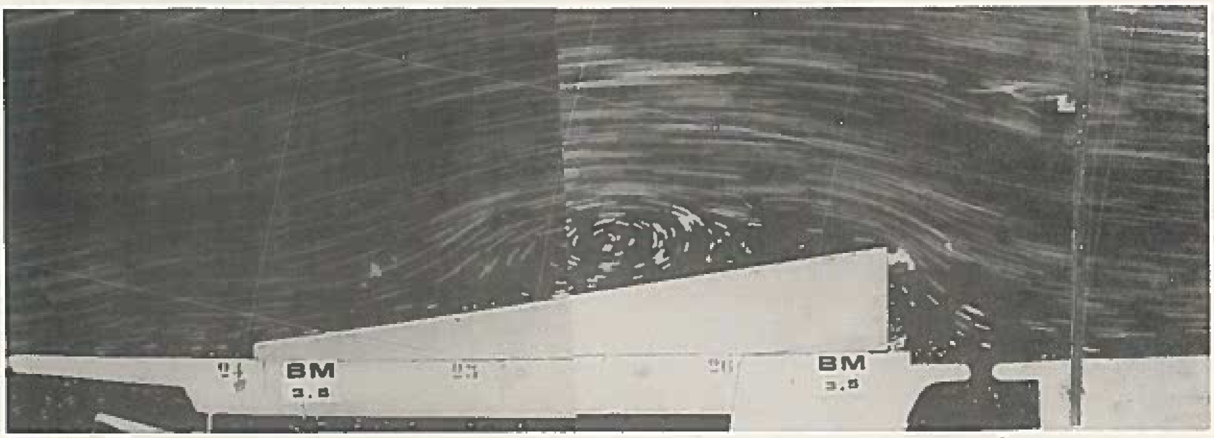
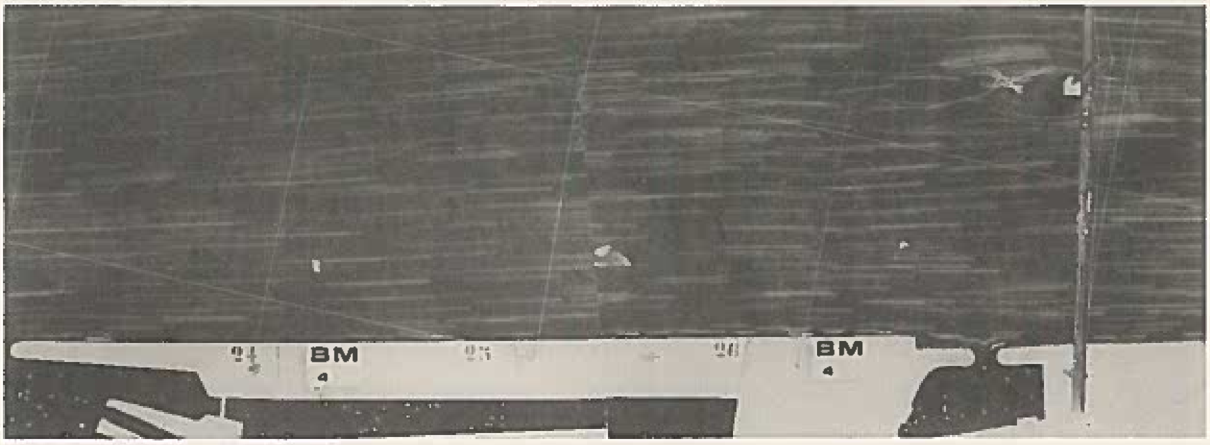
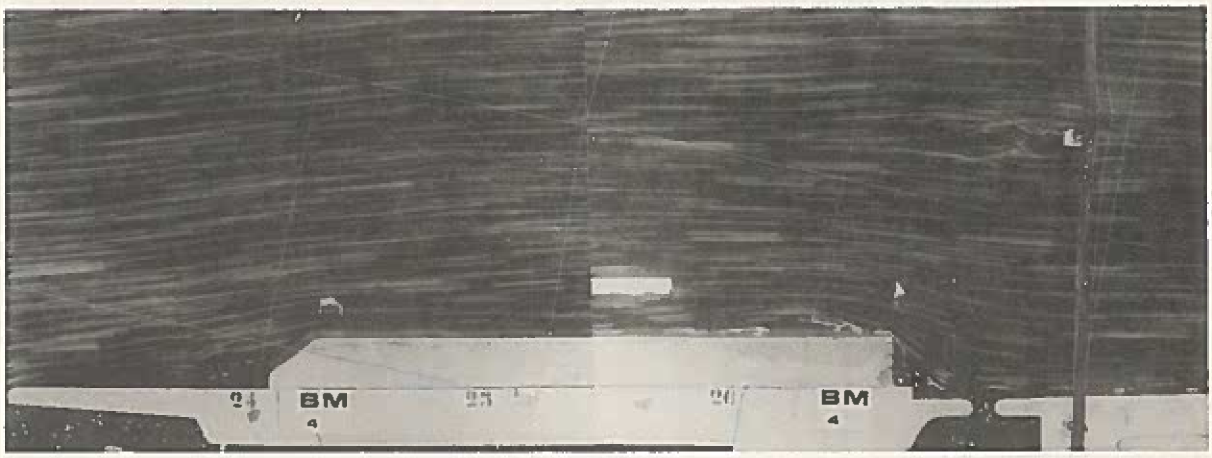


PLAN C

Effects of plans A, B and C on surface currents



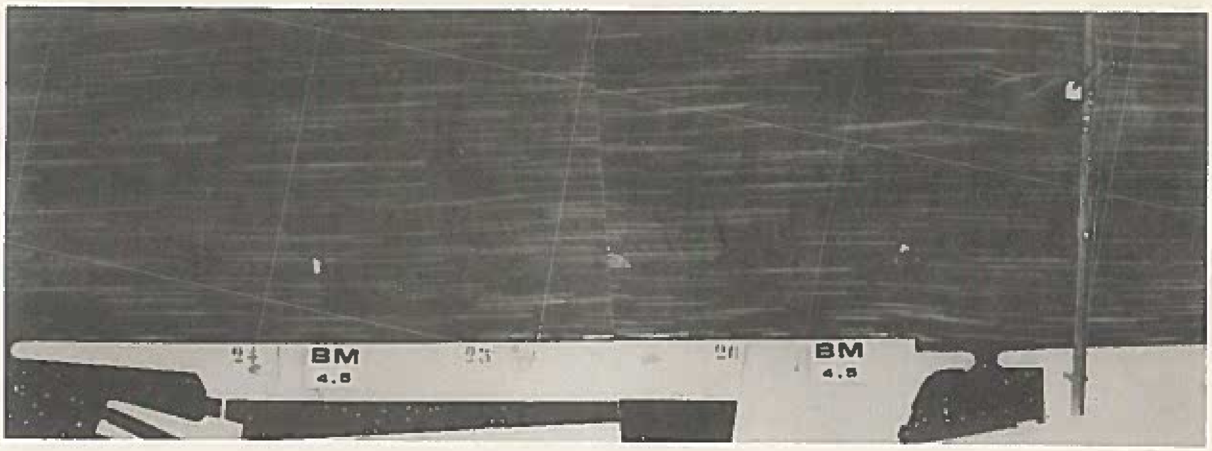
BASE PLAN A



PLAN B

PLAN C

Effects of plans A, B and C on surface currents



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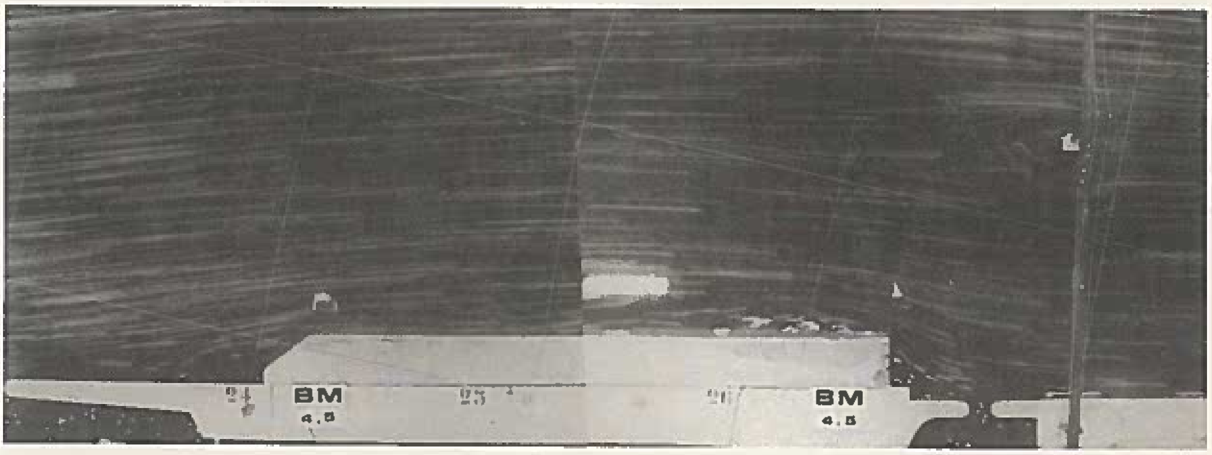

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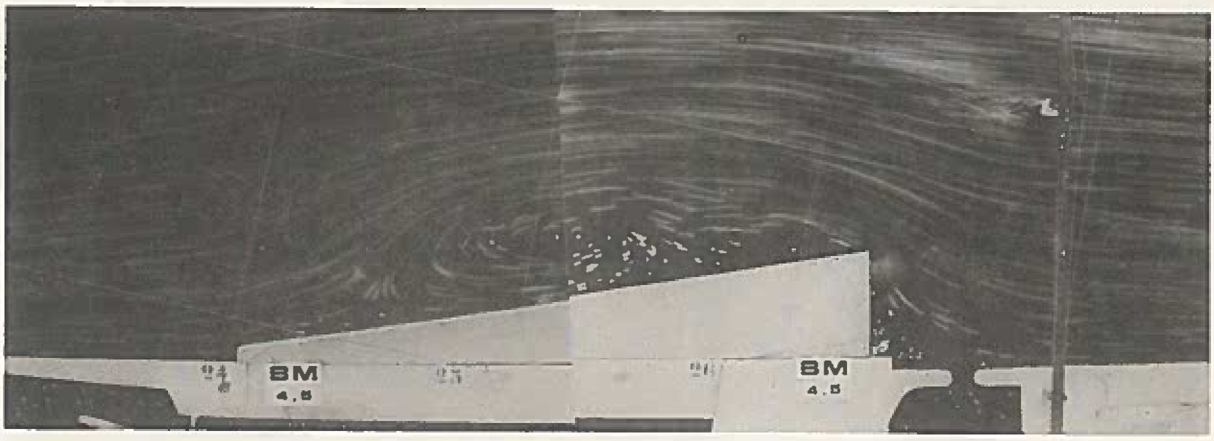
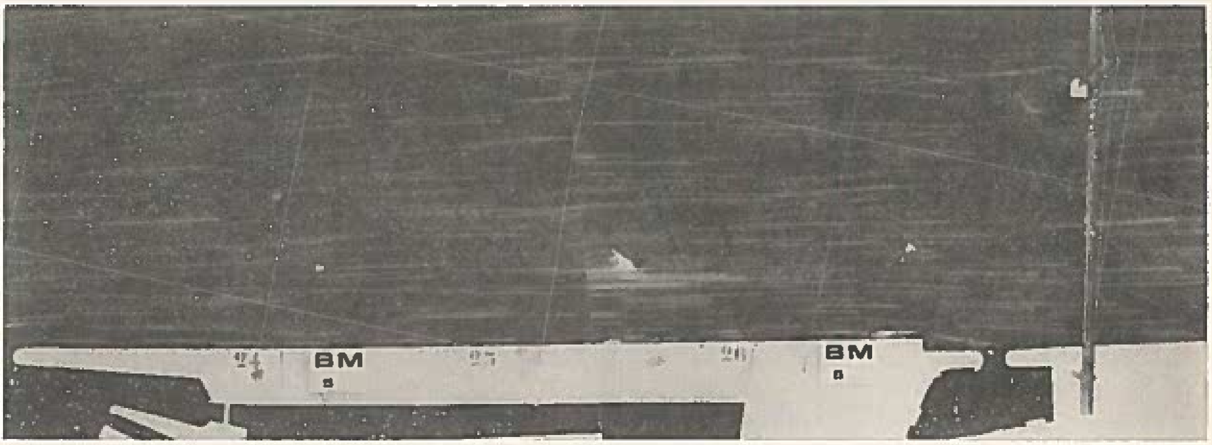


PLAN C

Effects of plans A, B and C on surface currents



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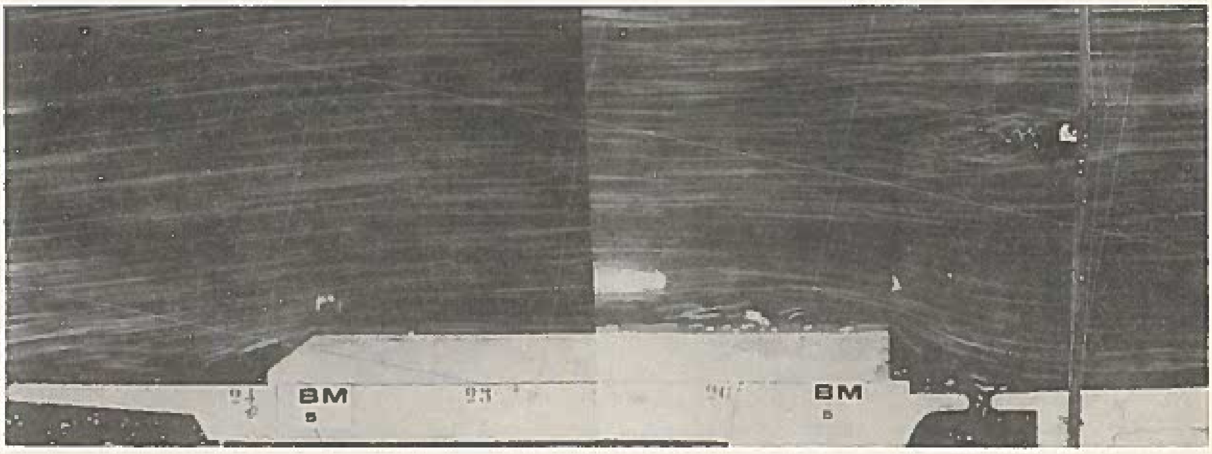

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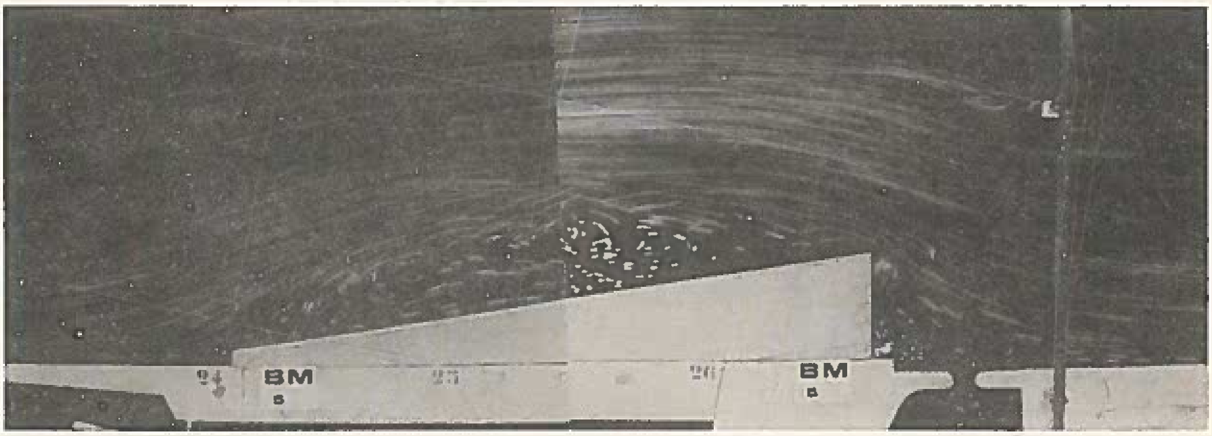
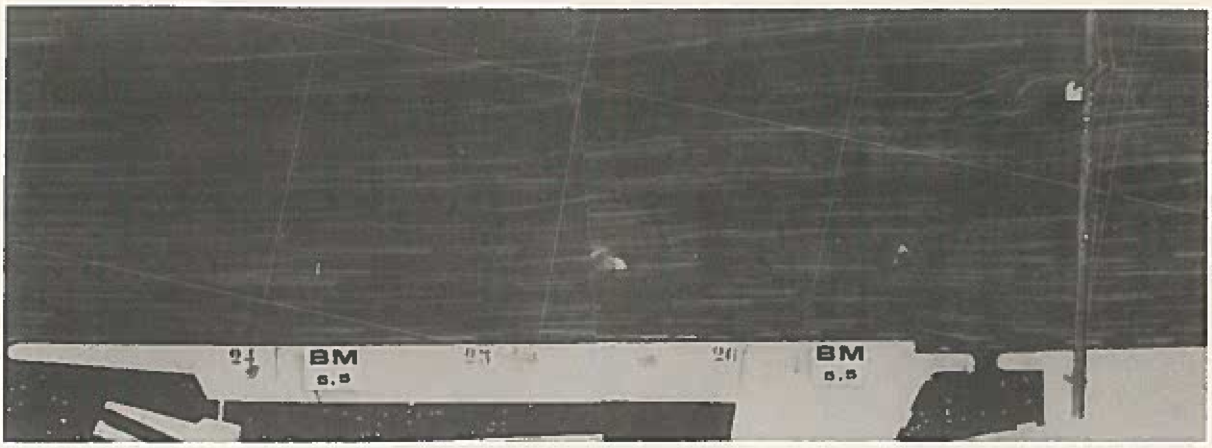


PLAN C

Effects of plans A, B and C on surface currents



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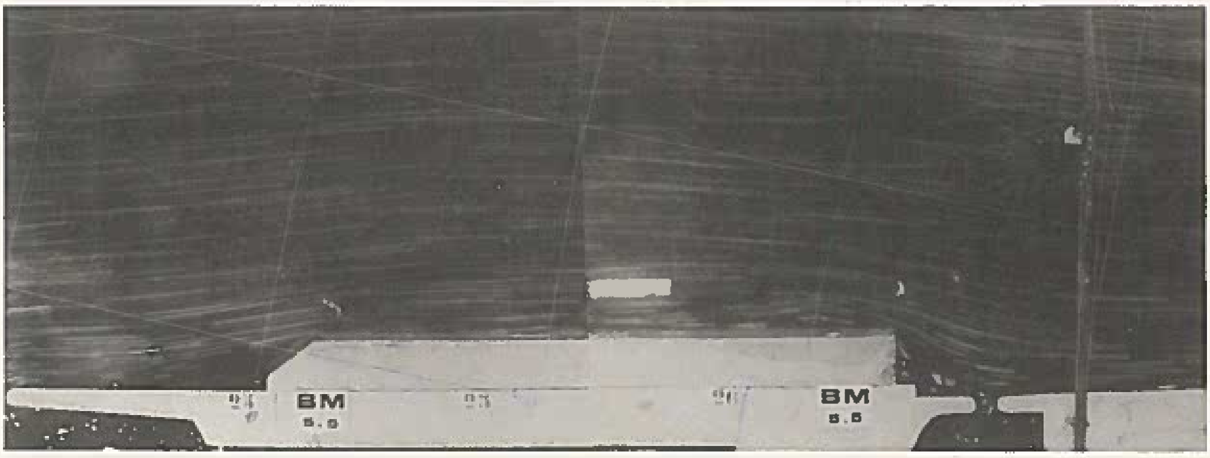

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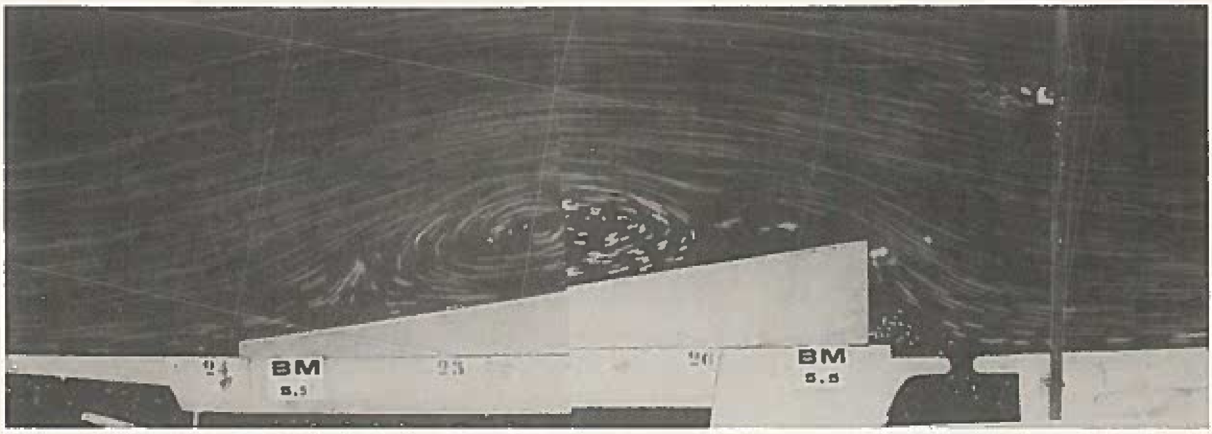
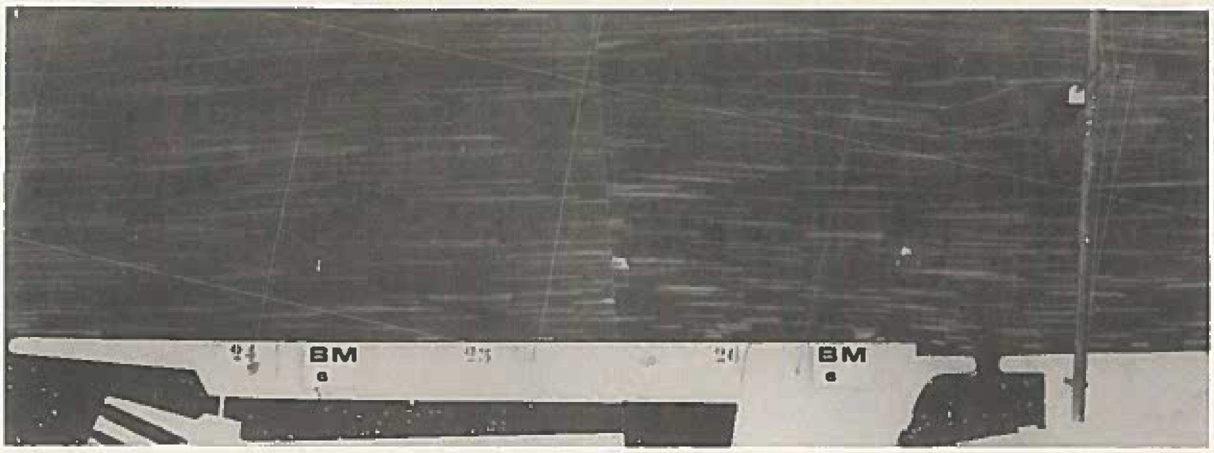


PLAN C

Effects of plans A, B and C on surface currents



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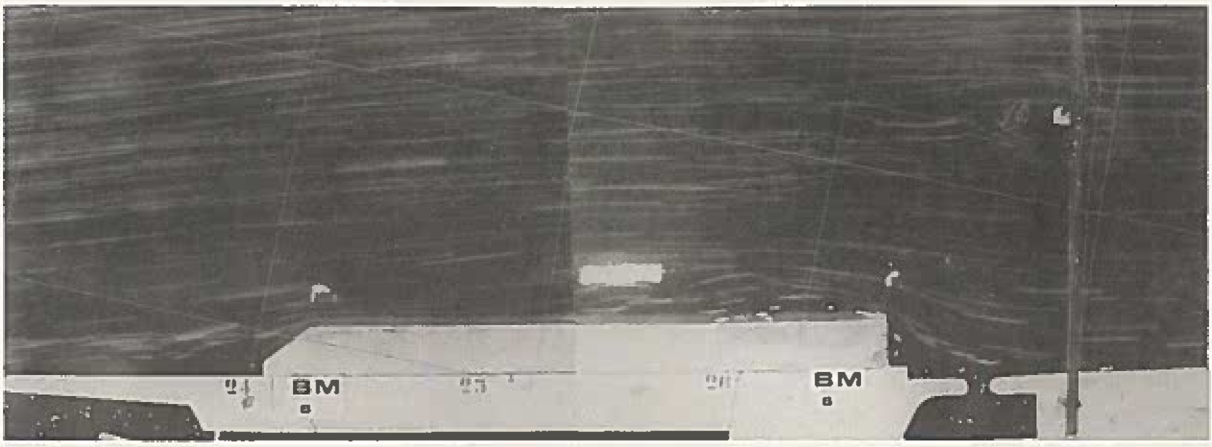

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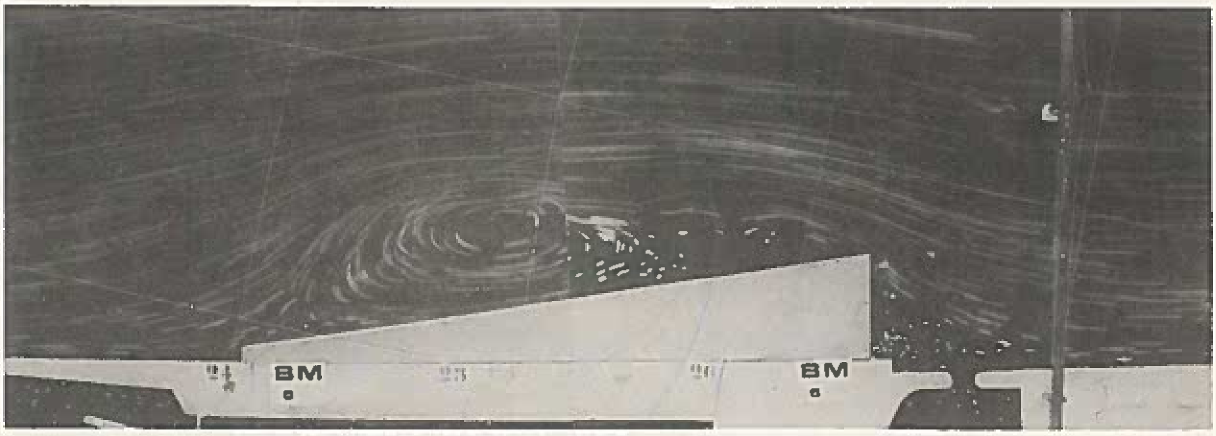
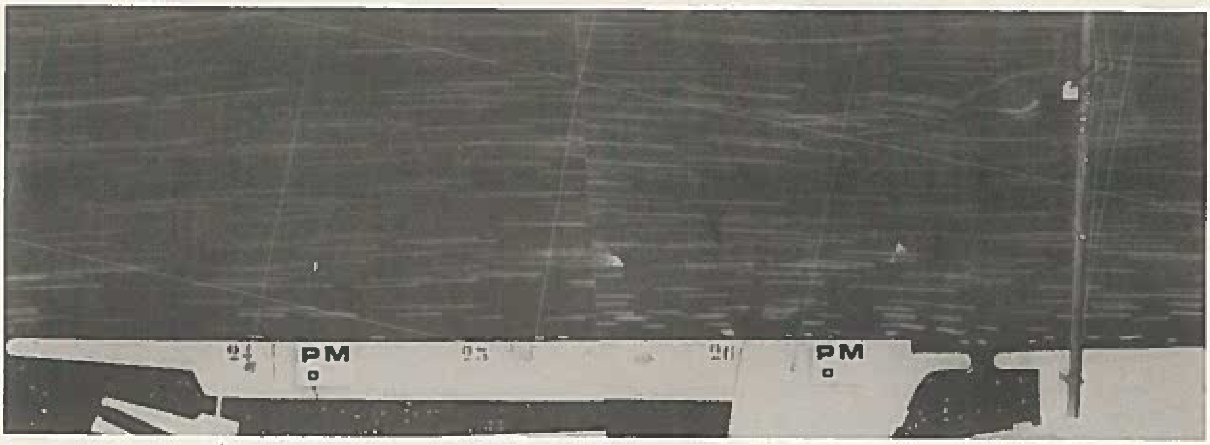


PLAN C

Effects of plans A, B and C on surface currents



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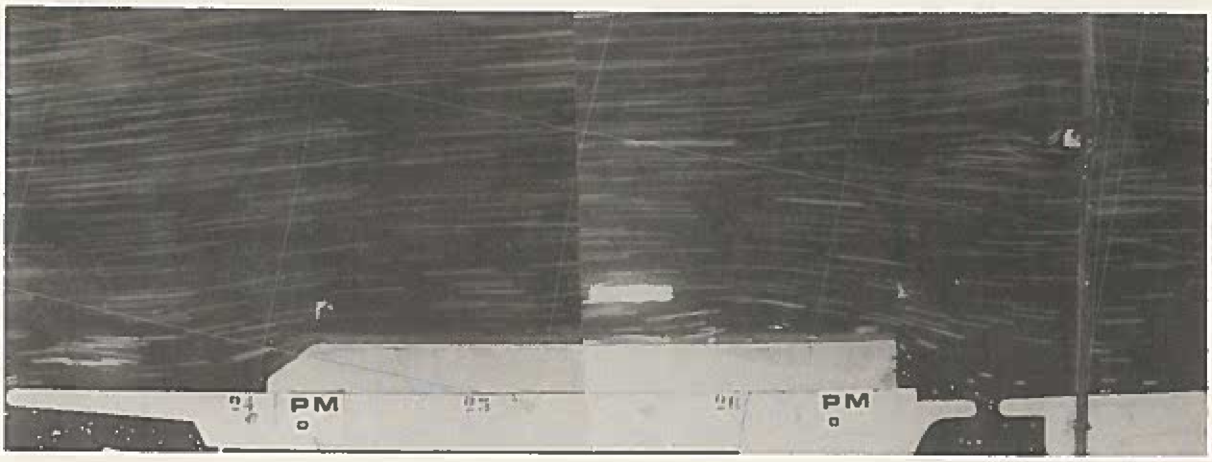
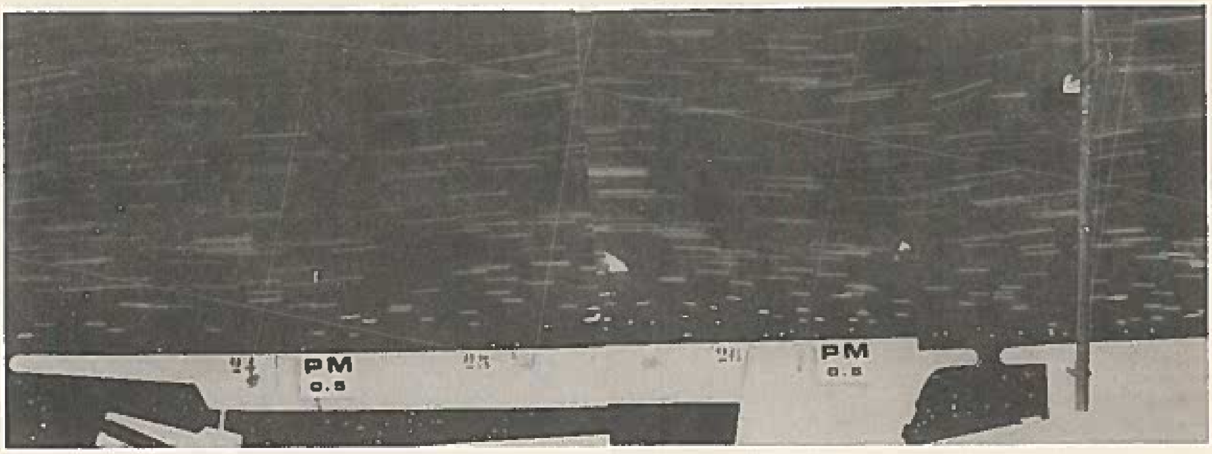


PLAN B

PLAN C

Effects of plans A, B and C on surface currents



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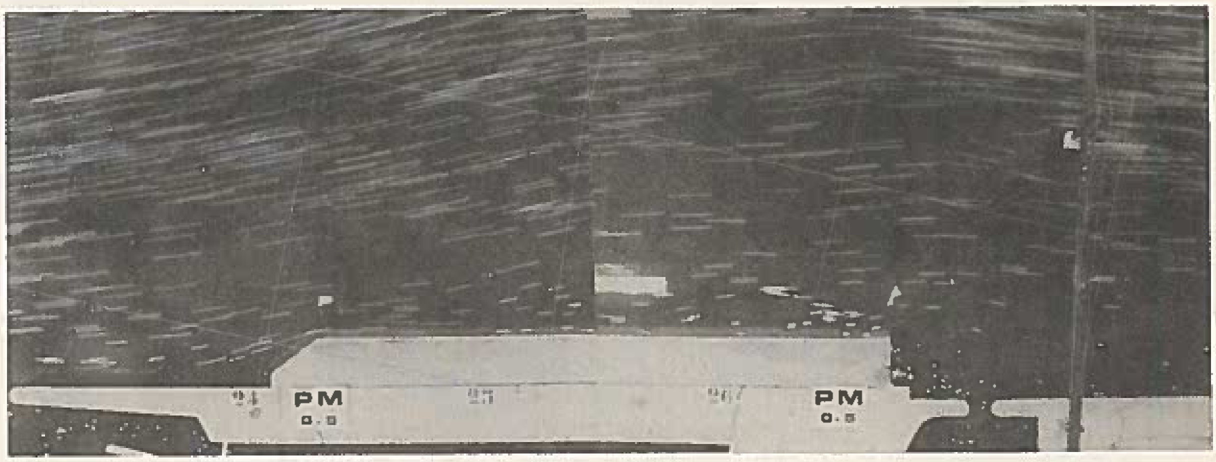
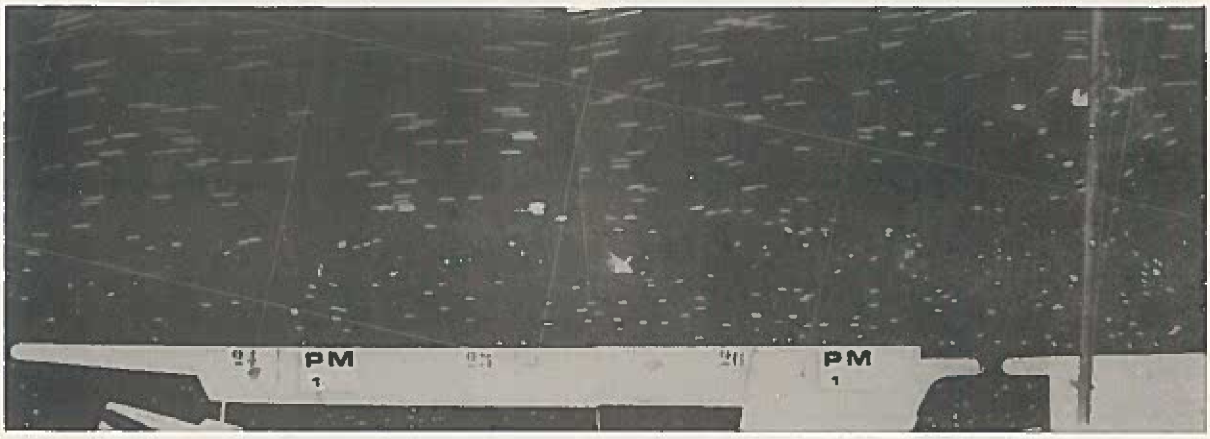


PLAN B

PLAN C

Effects of plans A, B and C on surface currents



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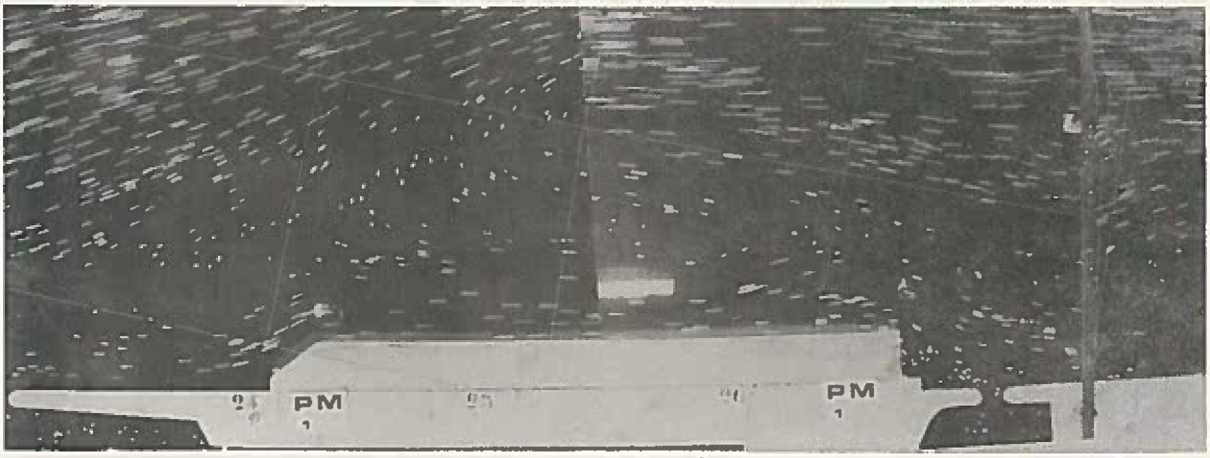
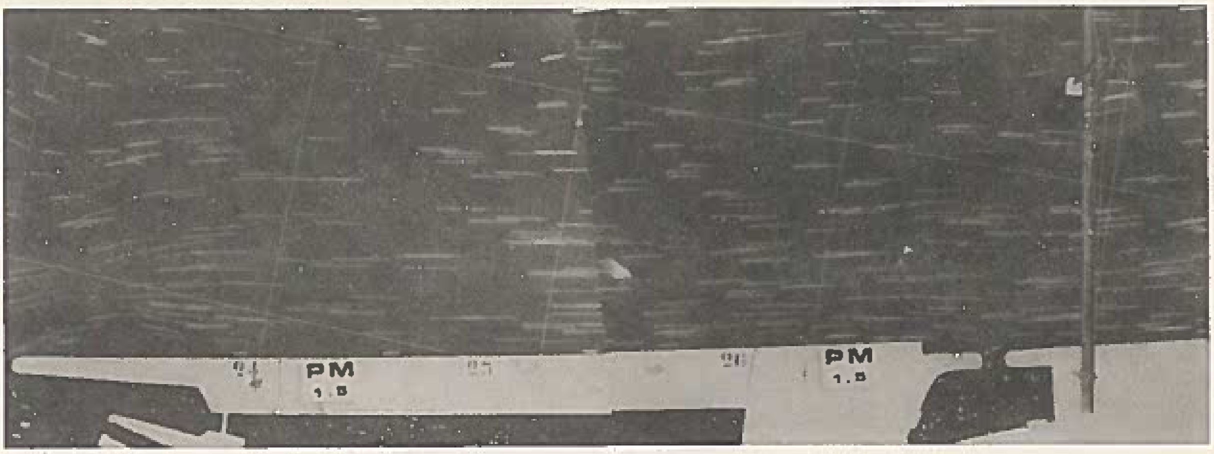


PLAN B

PLAN C

Effects of plans A, B and C on surface currents



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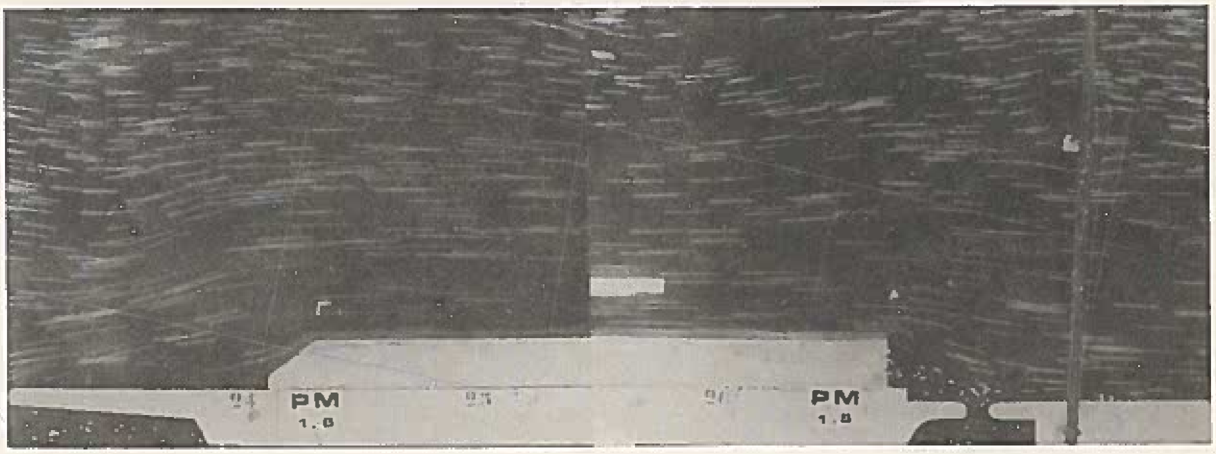

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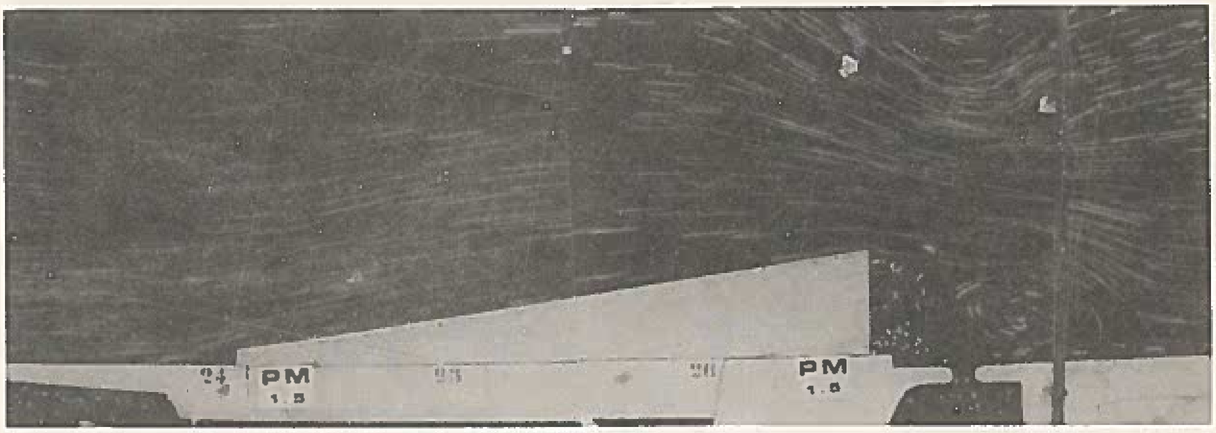
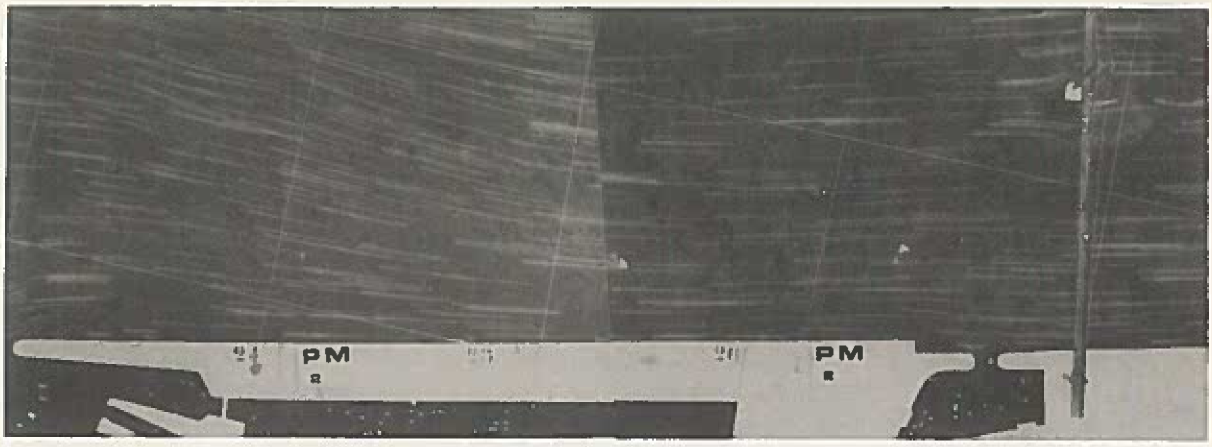


PLAN C

Effects of plans A, B and C on surface currents



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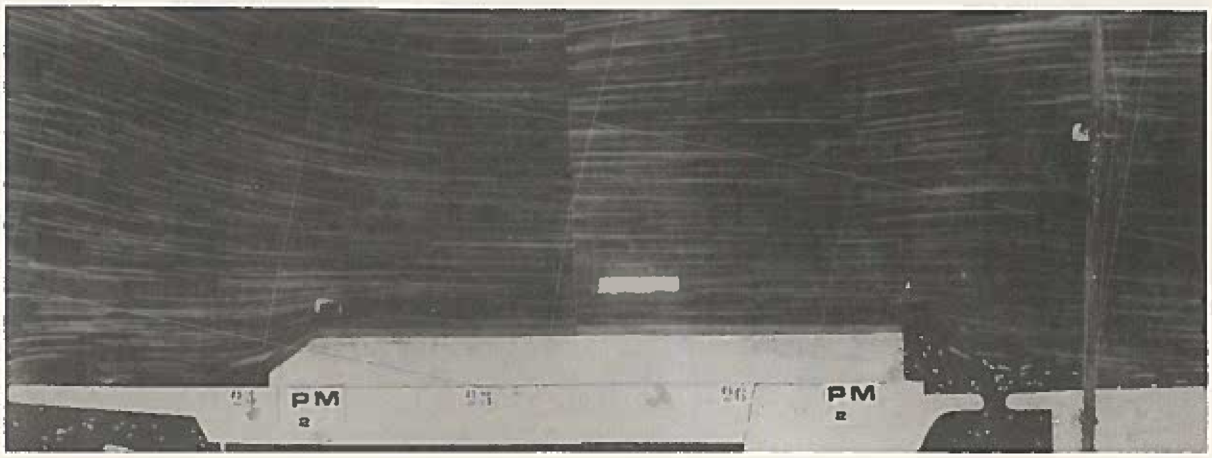
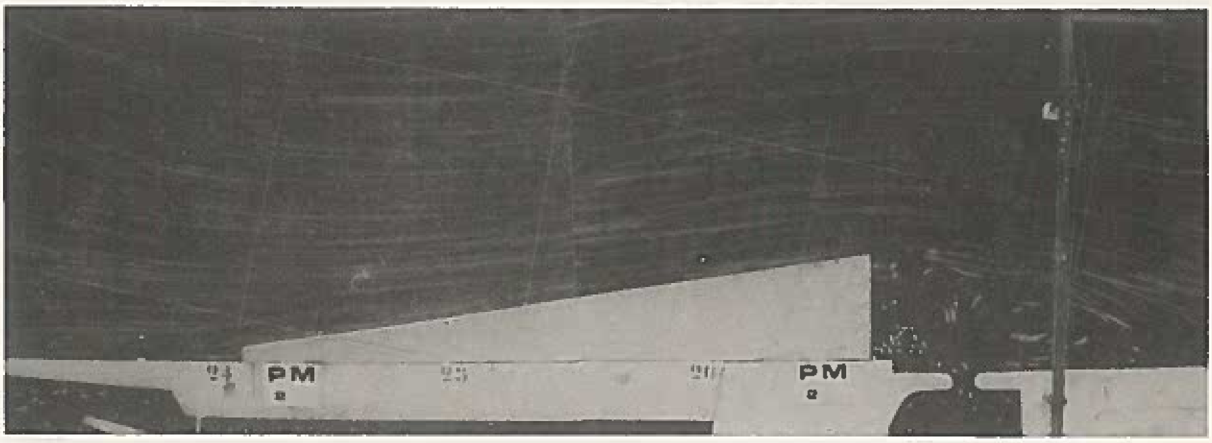
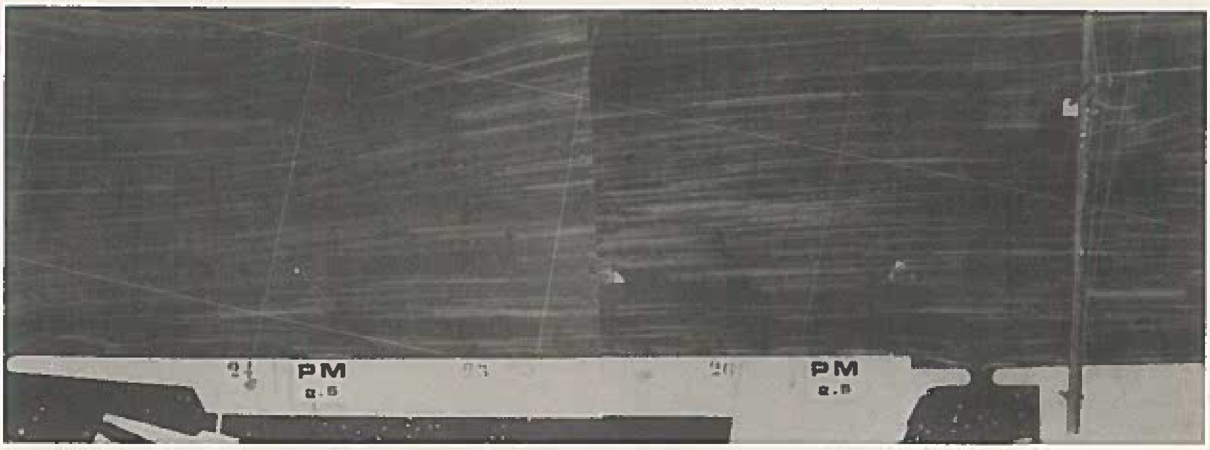


PLAN B



PLAN C

Effects of plans A, B and C on surface currents



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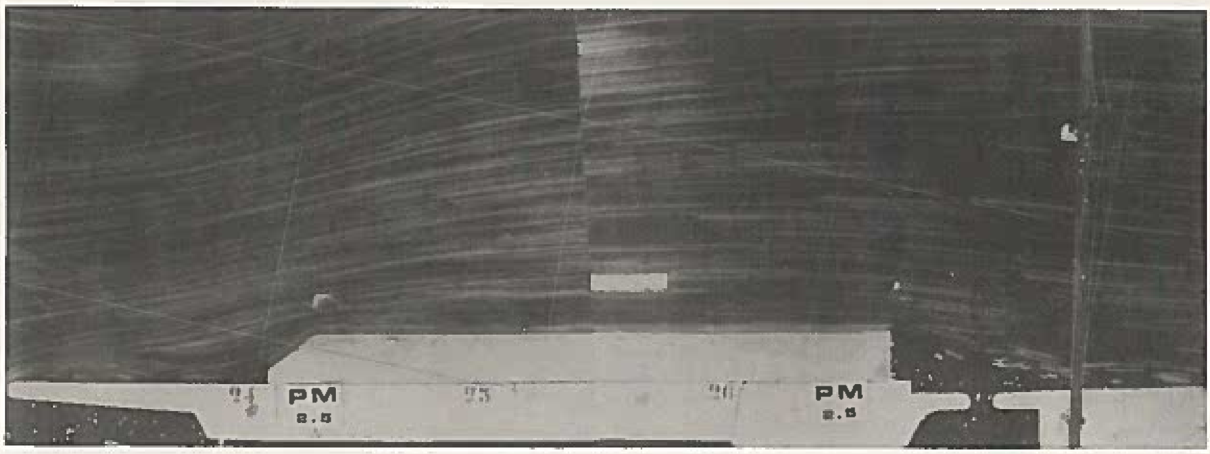

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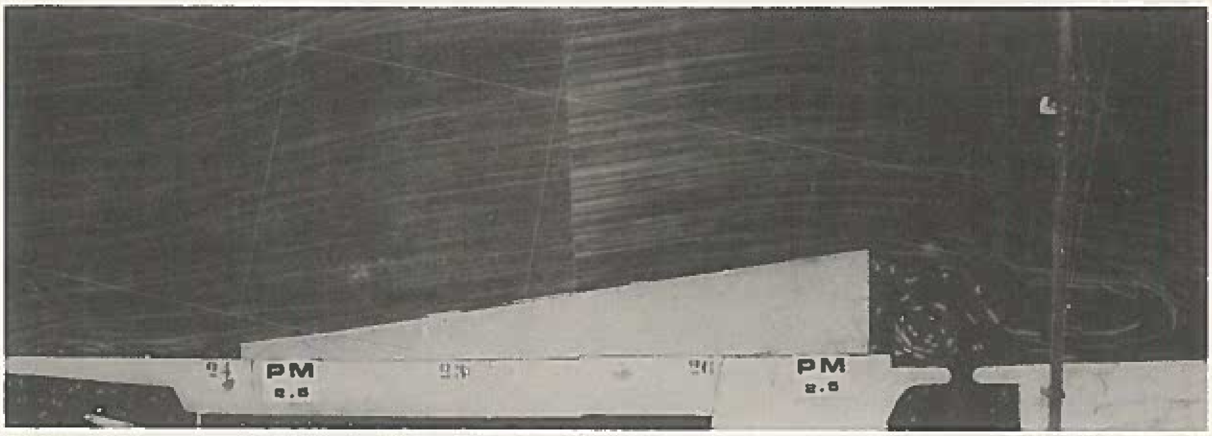
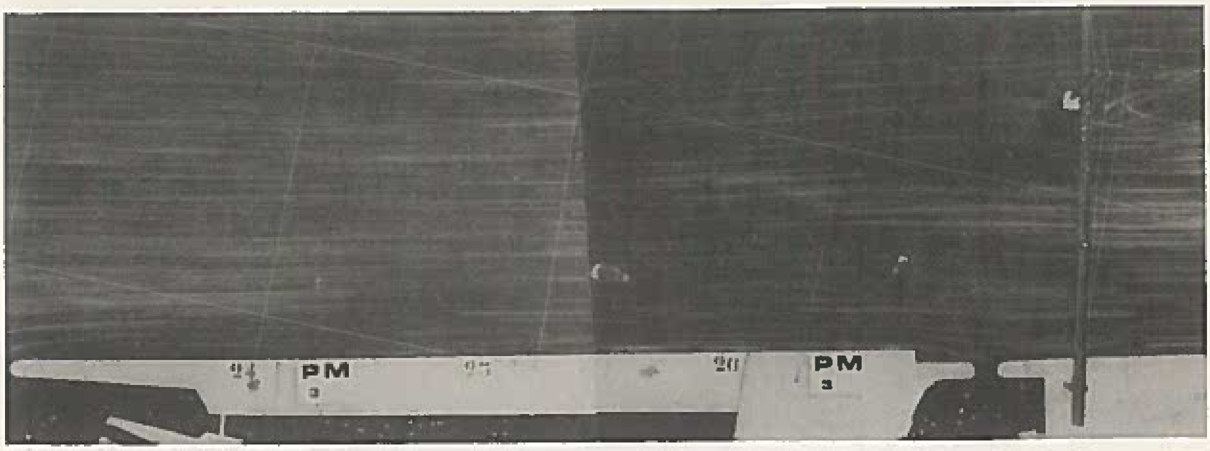


PLAN C

Effects of plans A, B and C on surface currents



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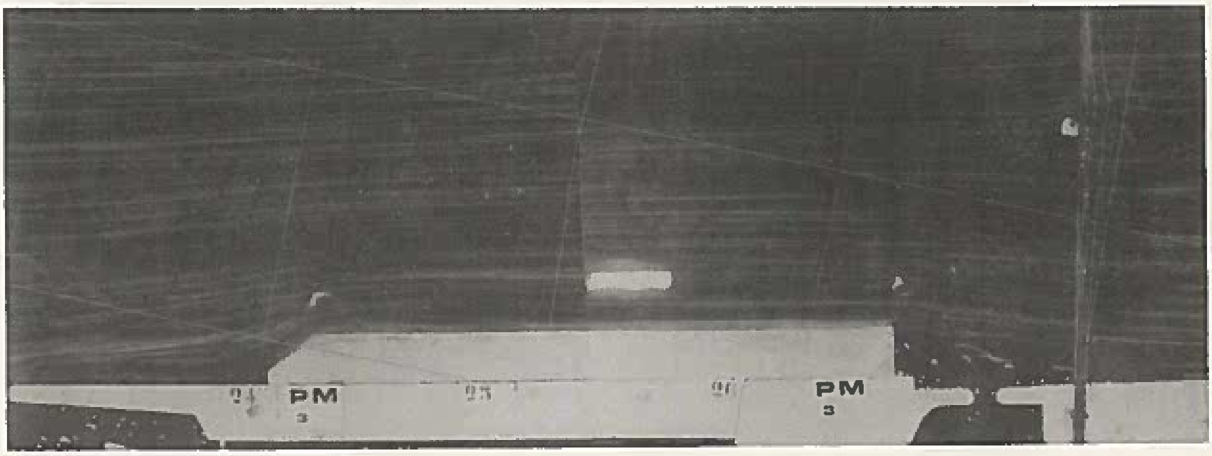

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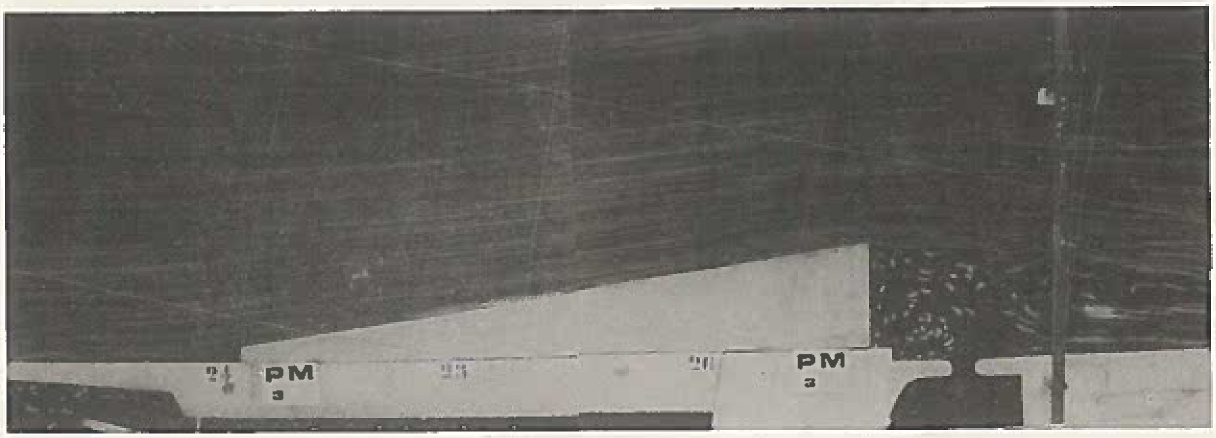
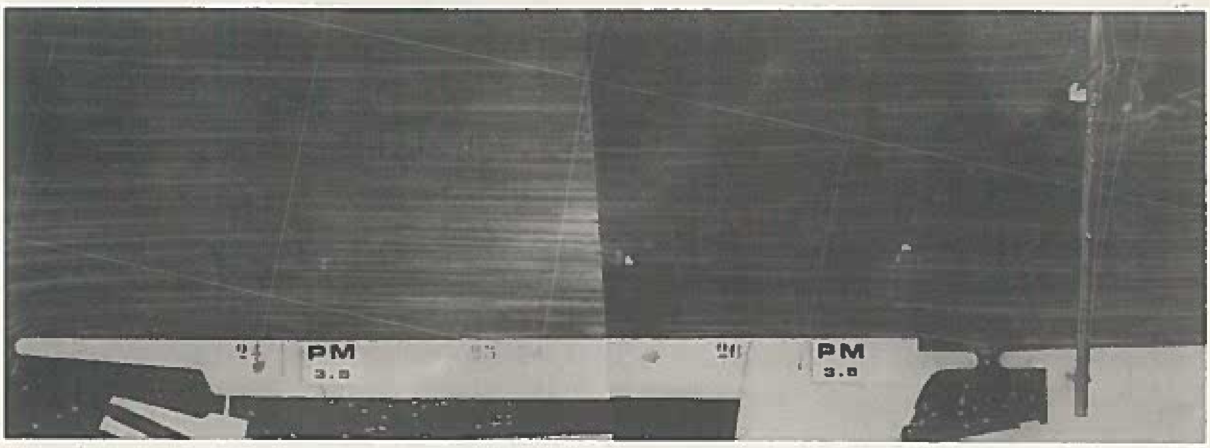
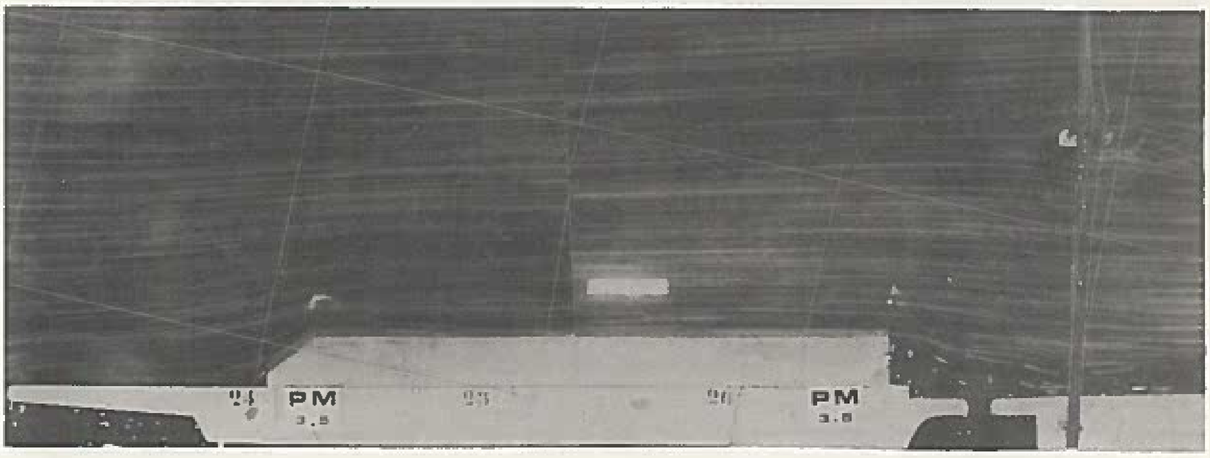


PLAN C

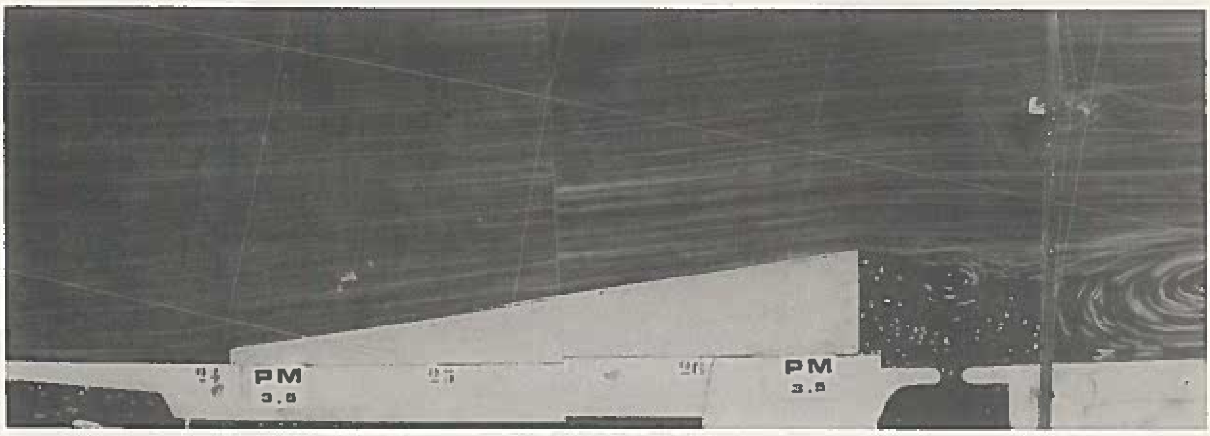
Effects of plans A, B and C on surface currents



BASE PLAN A

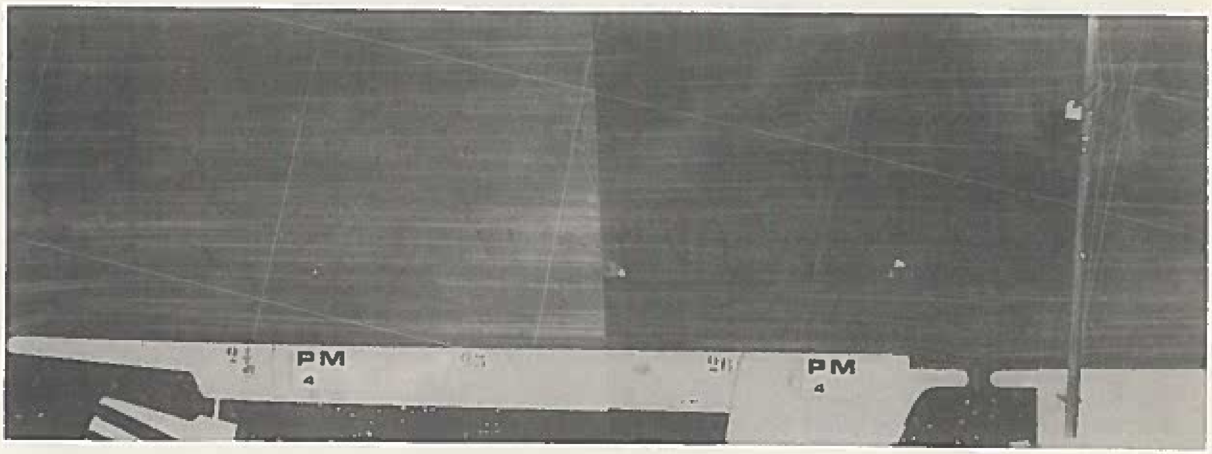


PLAN B

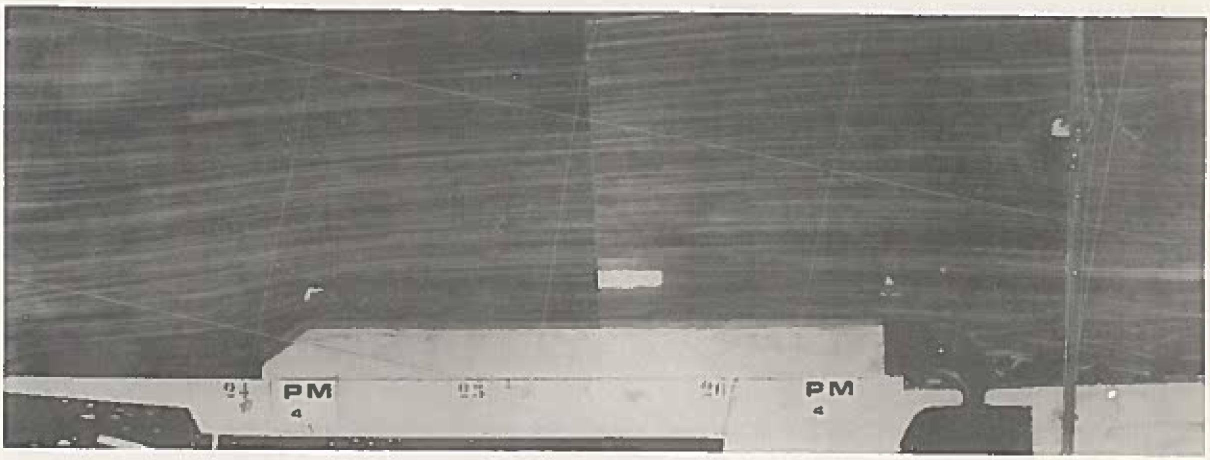


PLAN C

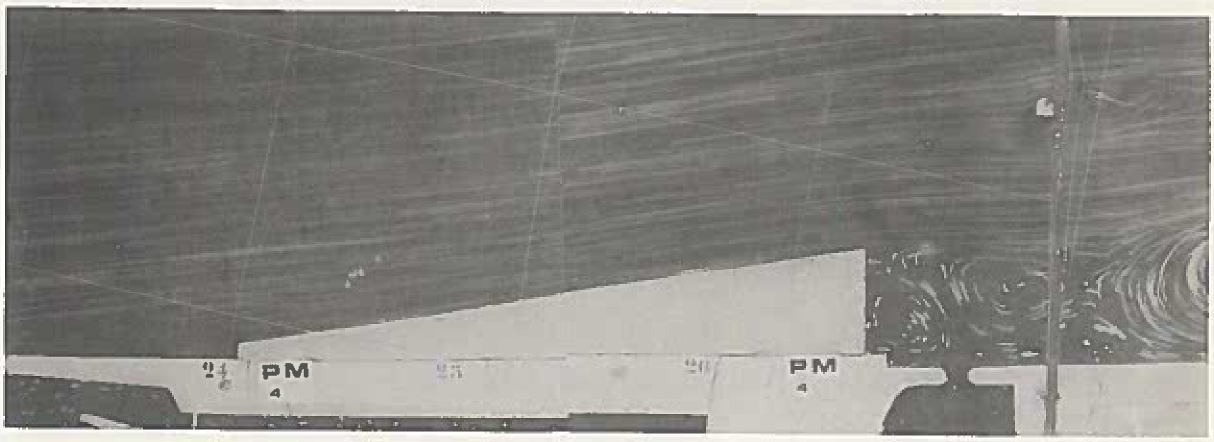
Efects of plans A, B and C on surface currents



BASE PLAN A

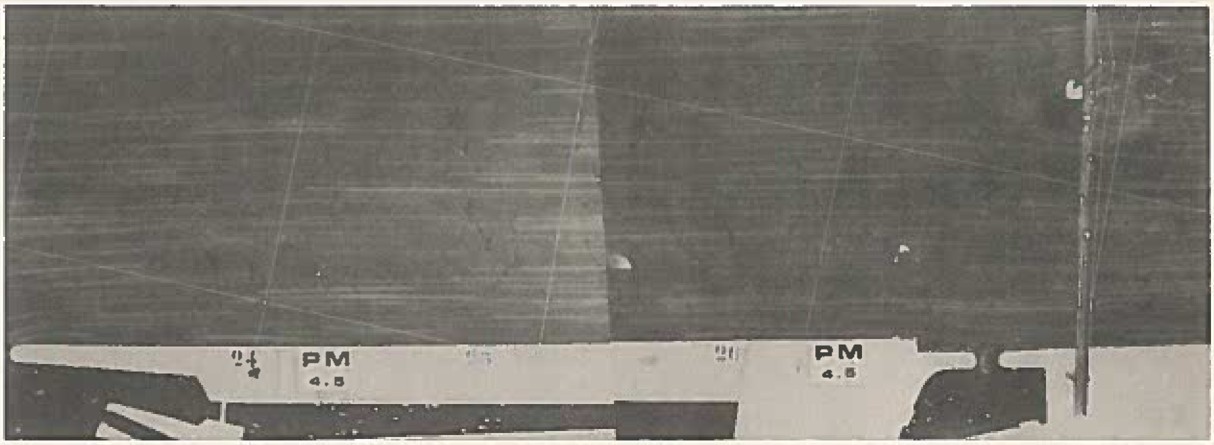


PLAN B

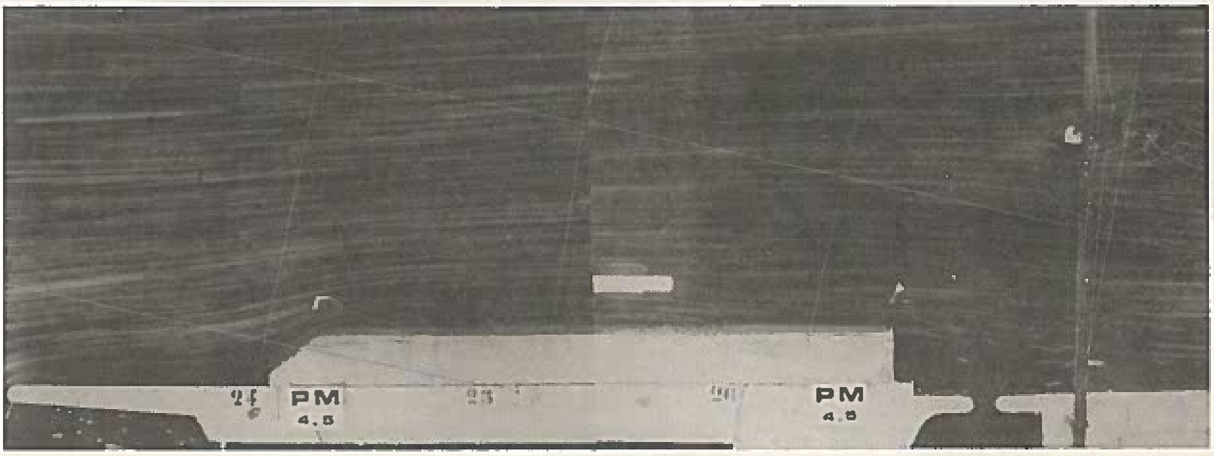


PLAN C

Effects of plans A, B and C on surface currents



BASE PLAN A



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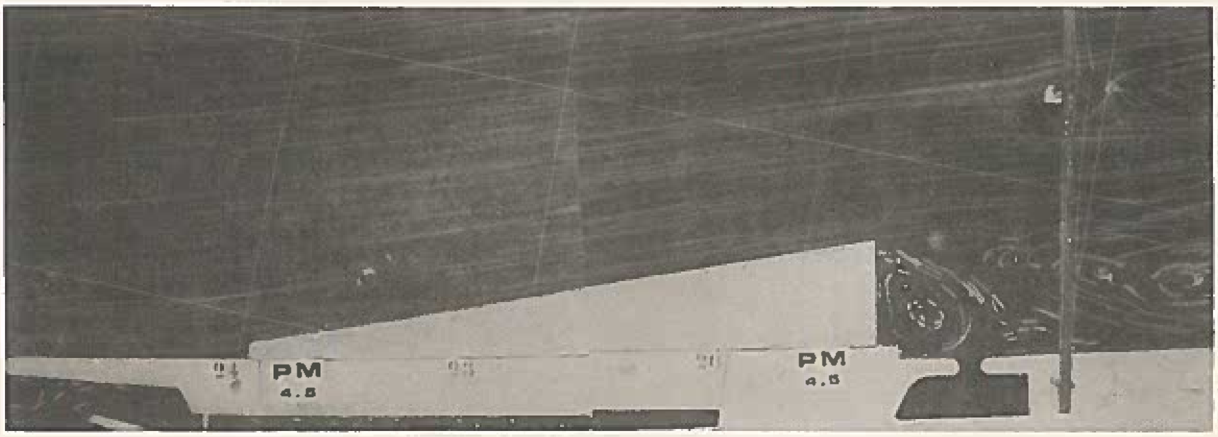
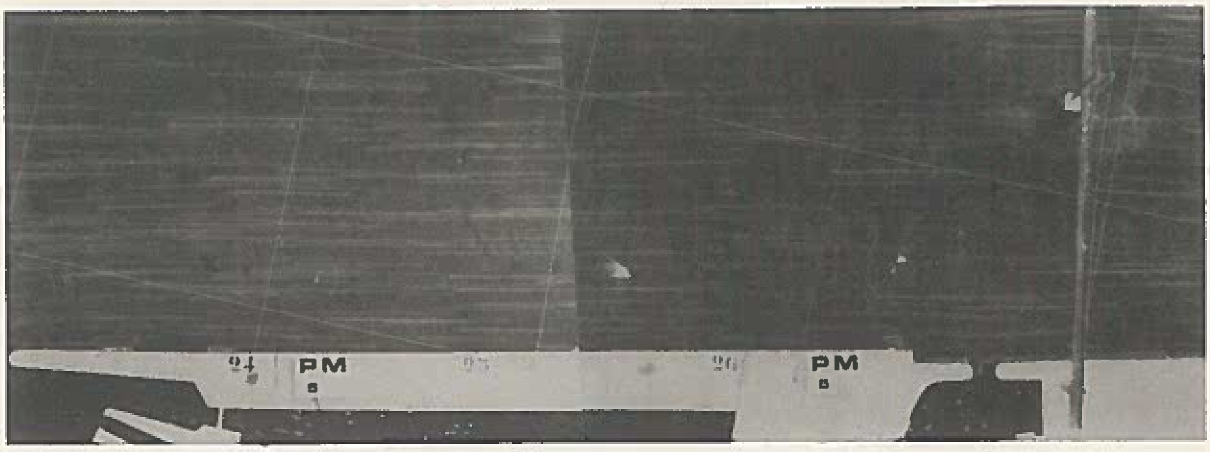
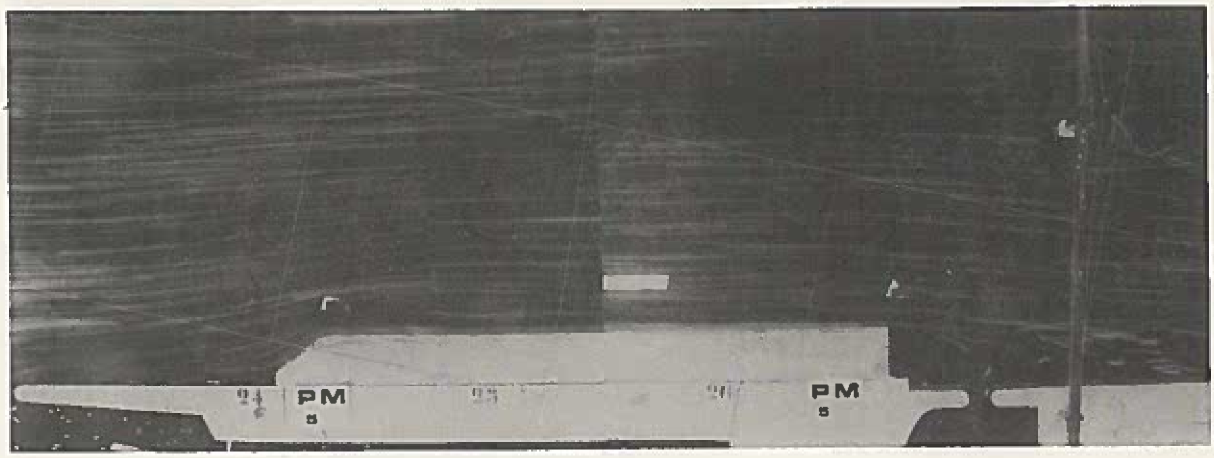


PLAN C

Effects of plans A, B and C on surface currents



BASE PLAN A



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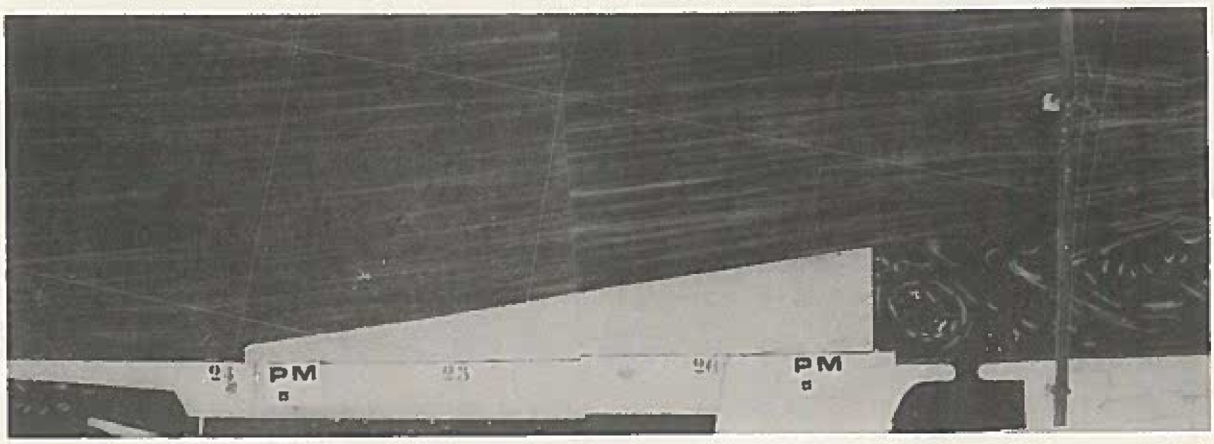
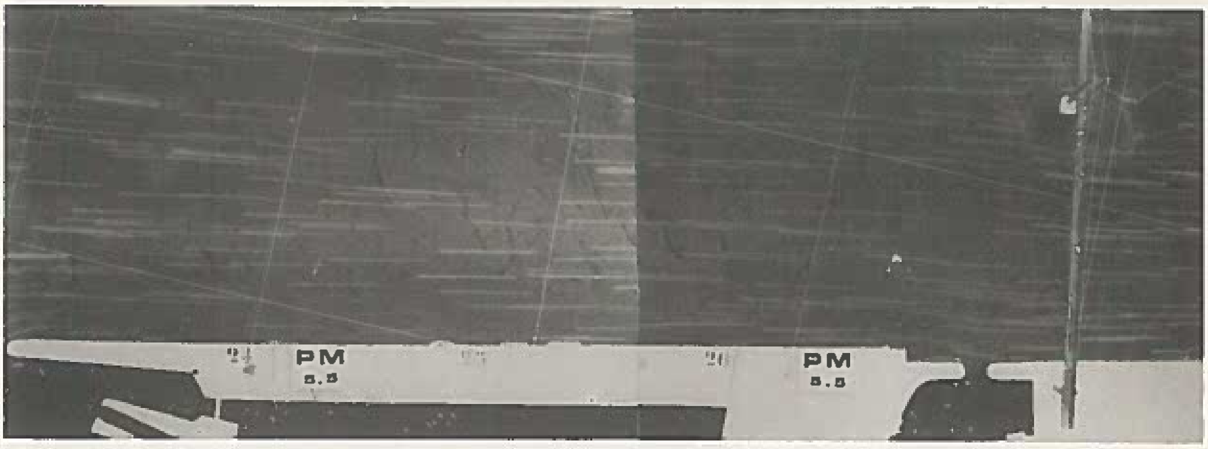
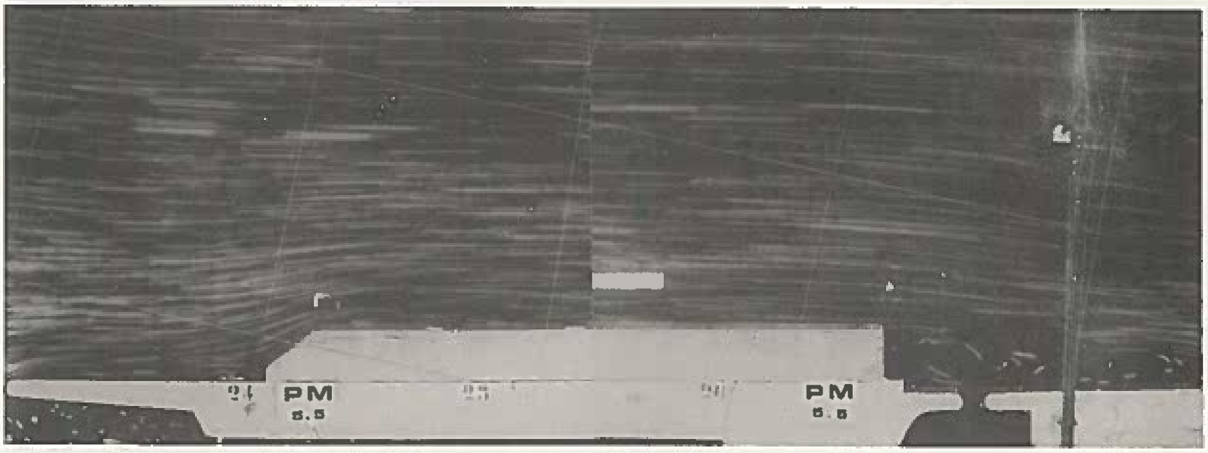


PLAN C

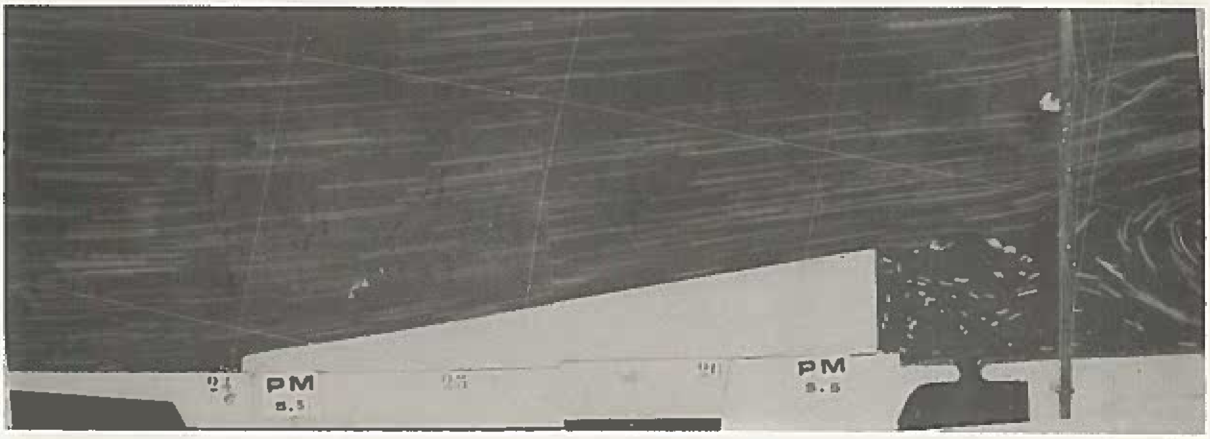
Effects of plans A, B and C on surface currents



BASE PLAN A

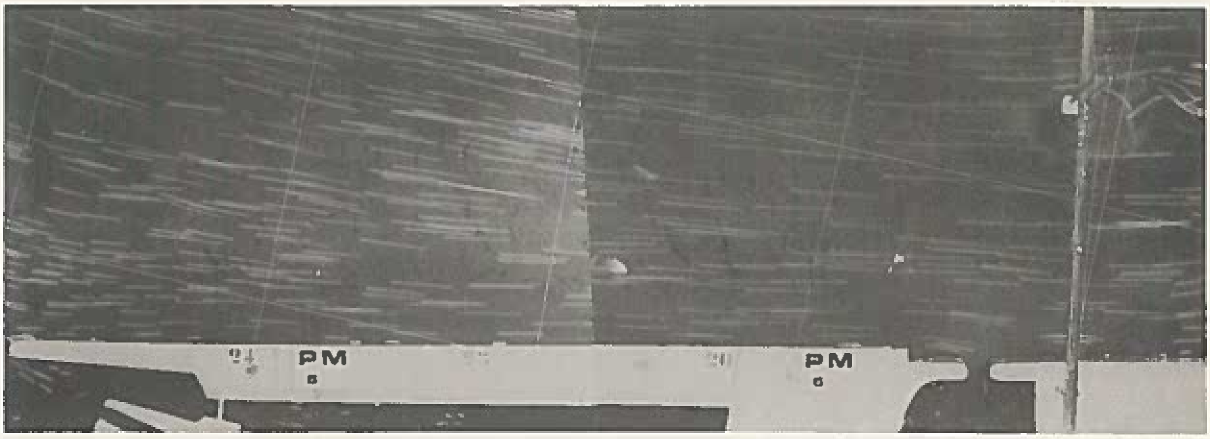


PLAN B

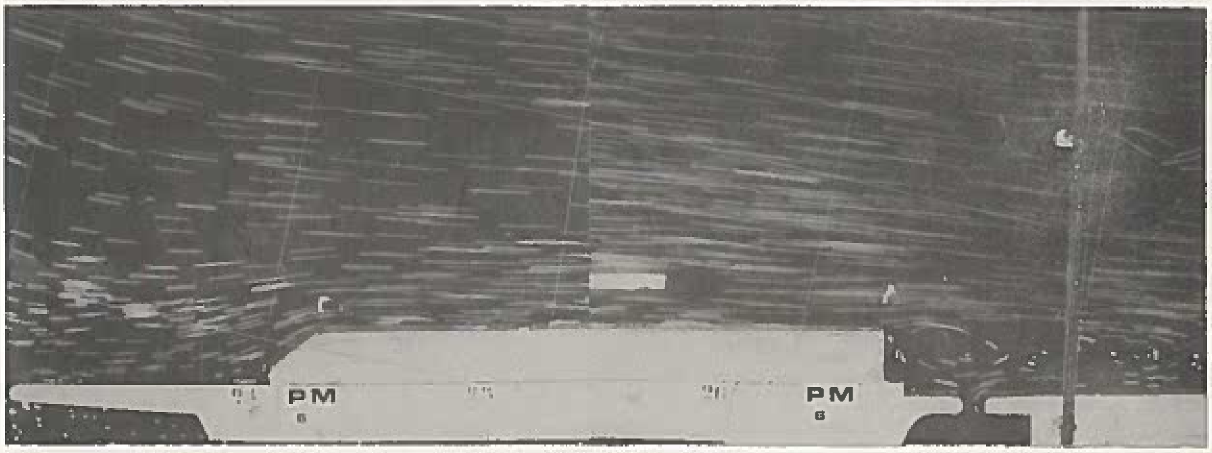


PLAN C

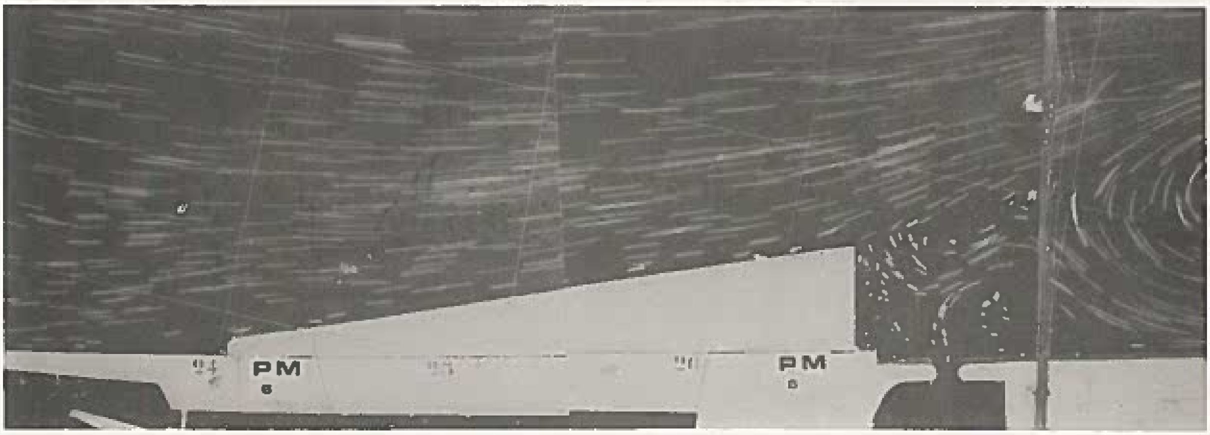
Effects of plans A, B and C on surface currents



BASE PLAN A



PLAN B



PLAN C

Effects of plans A, B and C on surface currents