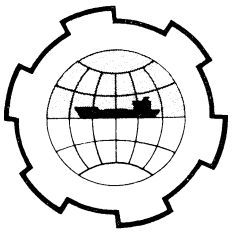
PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY



ICE COVER PREVENTION BY MEANS OF AIR BUBBLES, NARSSAQ, GREENLAND.

E. Hulgaard & Torben Sørensen
Civil Engineers, Partners.

Hostrup-Schultz & Sørensen
Consulting Engineers

Copenhagen
Denmark

INTRODUCTION

The climate in the coastal regions of southwestern Greenland is such that ice covers are not formed locally in the sea or in the outer parts of the deep fiords. Only in the inner parts of the narrow fiords and in highly sheltered coves in the fiords do continuous ice covers form during the winter.

This fact has often in general terms been attributed to the effect of the sheltering from wave action, the idea being that the presence of waves would tend to prevent the formation of ice sheets.

The tendency for sheltered regions to become covered with ice presents the harbour engineer with a dilemma:
Should the harbours be placed in the sheltered areas, where long periods of closure due to ice may be expected, or should they be placed in exposed conditions, where damage to vessels on account of wave disturbance may occur?

However, there is a possibility that the tendency for formation of ice covers may be governed partly or primarily by other factors than the degree of sheltering from wave action. The upper end of the fiords is always the site of the mouth of a river, and the same applies to many of the small bays that are attractive from the point of view of wave protection. In Greenland, where the frequency of calm weather is very high, in order of 2o per cent, there is therefore a strong likelihood that in these

regions a density stratification plays an important part in providing conditions that are favourable for the formation of a local ice cover. In so far as this is the case there is also a possibility of preventing ice formation by means of vertical mixing arrangements, such as air bubble induced circulations.

THE NARSSAQ HARBOUR

Narssaq is a small village in the southernmost part of Greenland, located at the middle of one of the long narrow fiords typical for this part of the island (FIGS. 1 and 2.) At a certain distance landward of Narssaq the fiord freezes up regularly every winter, whereas the fiord in the region just off Narssaq normally is open throughout the winter season.

The bay, called the Industry Bay, (FIG. 3) facing south, has no more tendency for freezing up than the open fiord at Narssaq, but is exposed to quite violent wave action in southerly storms, which has resulted in fishing vessels anchored in this bay being torn loose from their anchors and thrown ashore. This bay is therefore not very suitable for the construction of wharf facilities for fishing vessels.

Just northwest of this bay lies the so-called Colony Bay, which is 8oo m long and 2oo m wide. The water depth is 5-1o m and the tidal range is about 2 m.This was the original harbour used by the first settlers in this village. This bay is very well protected from wave action, but freezes up every winter. The ice cover always begins to form at the landward end of the bay, at which a small stream discharges averagely 75 litres per second during the winter. The ice cover is broken up and carried away several times each winter in strong northeasterly gales. If the ice formation could be prevented or significantly reduced this bay would offer excellent possibilities for construction of harbour facilities for fishing vessels.

FIELD INVESTIGATIONS

During the winter of 1964/65 regular measurements of water salinity and temperature were made in a number of points in


84°
81°
78°
75°
72°
69°
66°
63°
60°
57°
THULE
BAFFINS BAY
GREENLAND
DISKO
EGEDESMINDE
CHRISTIANSHÅB
HOLSTEINSBORG
SOENDRE STROEMFJORD
SUKKERTOPPEN
ANGMAGSSALIK
ICELAND
GODTHÅB
FREDERIKSHÅB
FIG 2
NARSSAQ
JULIANEHÅB
KAP FAREWELL
0 200 400 600 800 1000 KM

FIG. 1

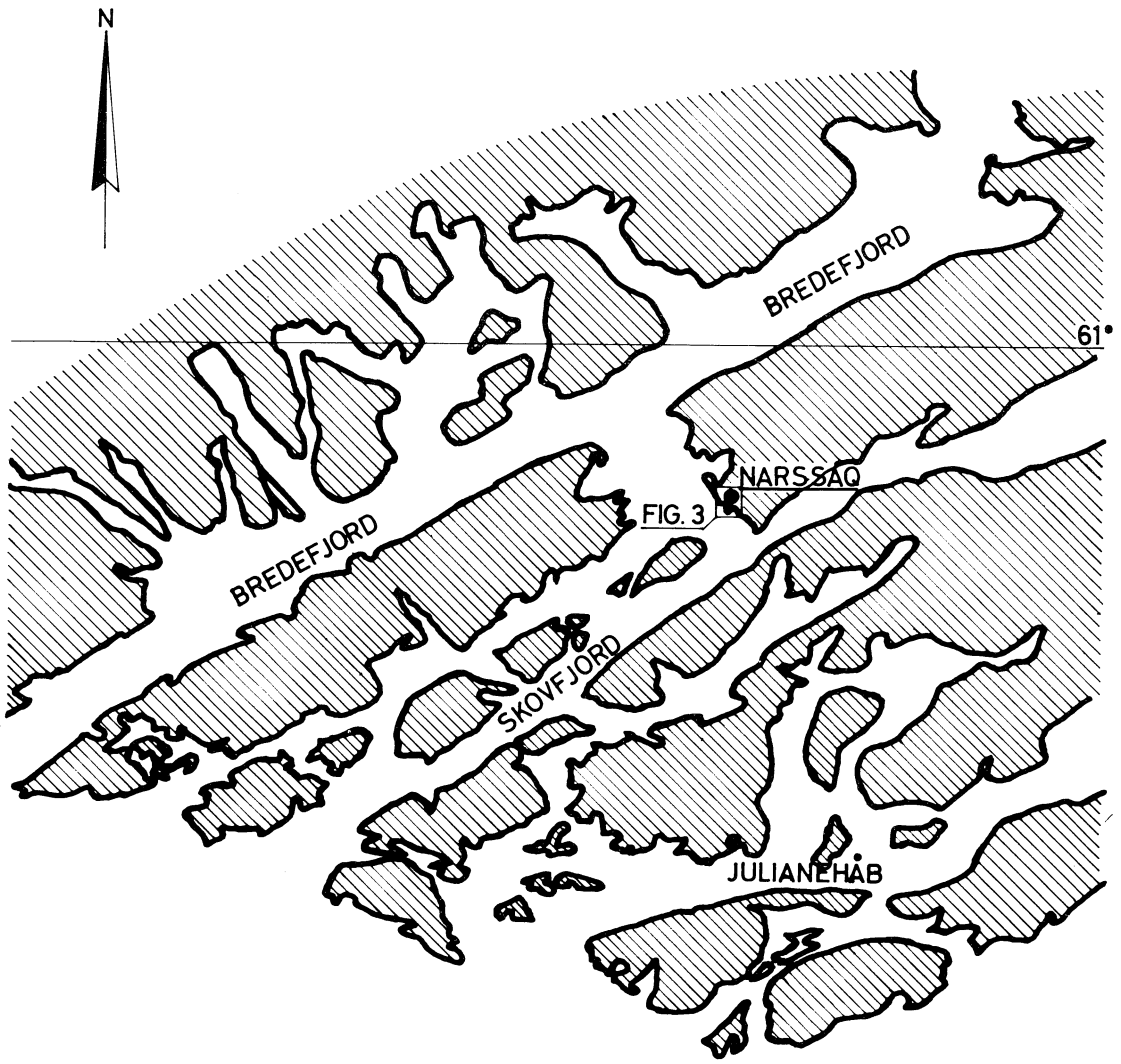

N
BREDEFJORD
61°
NARSSAQ
FIG. 3
BREDEFJORD
SKOVFJORD
JULIANEHÅB
60°30'
5 0 10 20 30 KM

FIG. 2

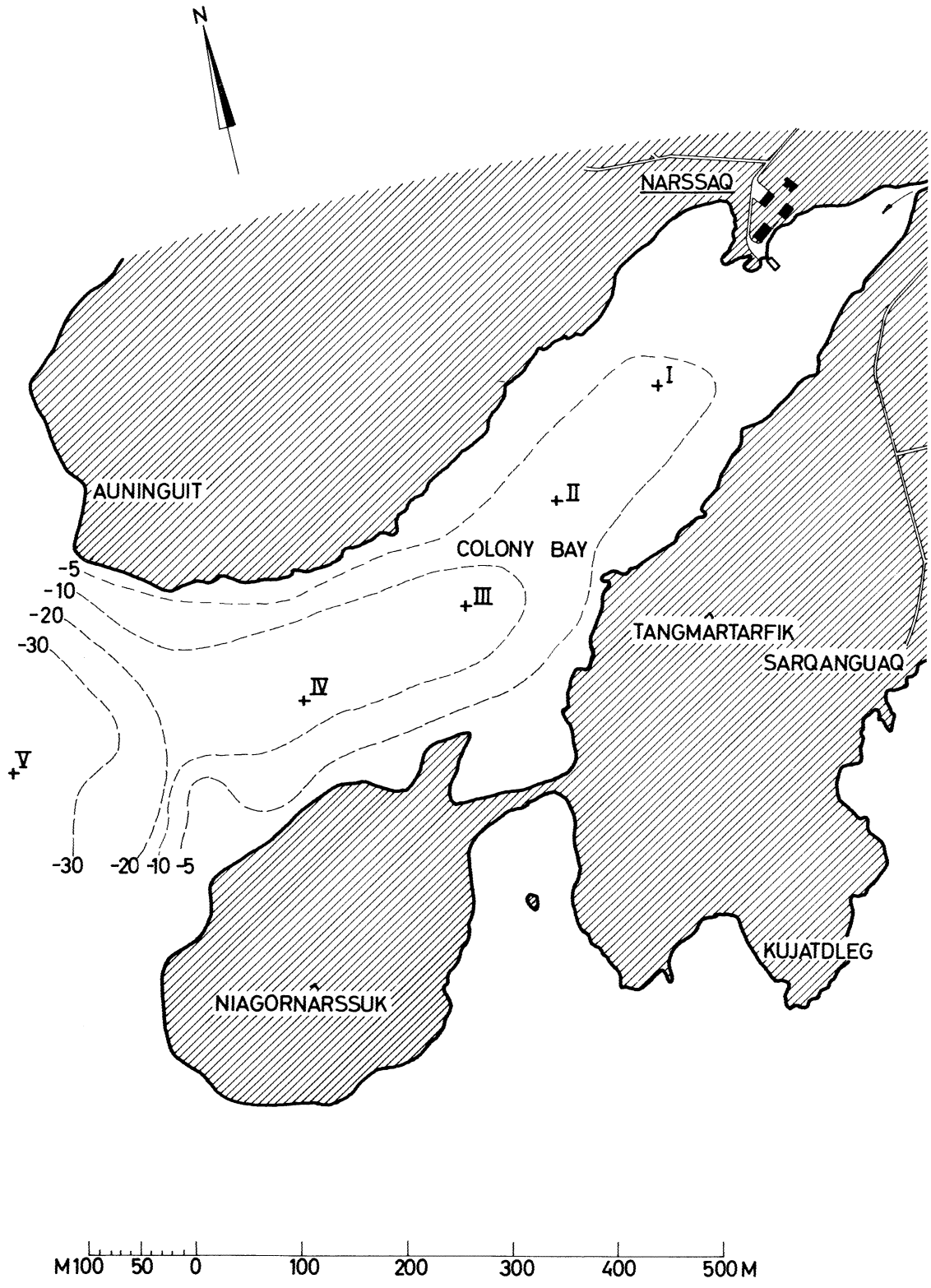

N
NARSSAQ
AUNINGUIT
COLONY BAY
I
II
III
IV
V
-5
-10
-20
-30
-30 -20 -10 -5
TANGMÂRTARFIK
SARQANGUAQ
KUJATDLEG
NIAGORNÂRSSUK
M100 50 0 100 200 300 400 500 M

FIG. 3

the bay (FIG. 3) and at several depths below the water surface. At the same time the air temperature and wind conditions were observed for comparison with existing statistics, and the formation of ice in the bay was observed.

FIG 4. shows the variation during the winter period of the salinity at the surface (So) at points I,III and V.
It is obvious that during the first 2 months the salinity at point I is lowest, but later there is no clear difference.

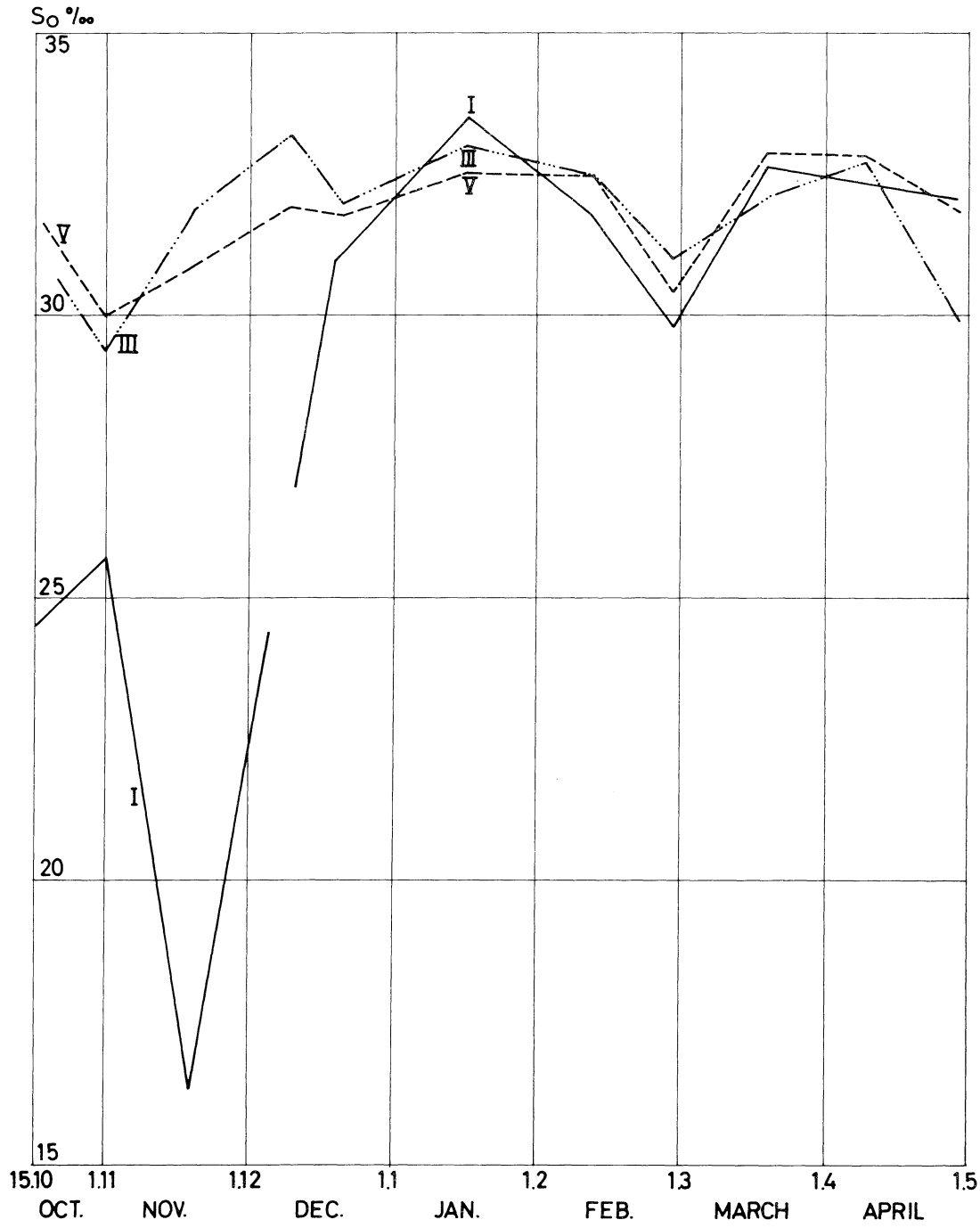
FIG 5. shows the variation of the difference between the salinity at 5 m depth (S5) and at the surfase(So). It is seen, that S5 normally is greater that So and some times the difference is very pronounced.

FIG 6. shows the extent of the ice cover the temperatures of the air and the mean temperatures in the verticals at points I, II and V. Until the 2o. February the water in the inner part of the bay (point I) is coldest. After this date it is changed. Also from this date the water at the surface is warmer than at the bottom.

The climate conditions during the winter 1964-65 were not very far from normal, but the ice cover was broken up about 6 times in northeasterly gales, and the maximum thickness of the ice was low, about 15 cm.

THE BACKGROUND OF THE EXPERIMENT.

The water with the lowest salinity is found at the surface and since the unit weight of the surface water is then lower than that of the underlying there is no natural tendency for the water to be mixed. An artificial mixing may in these circumstances be expected to reduce the tendency for formation of an ice cover by preventing the generation of a stable thin surface layer, which can easily be cooled to temperatures below freezing point. For the period until the 2o. February an artificial mixing will in addition increase the temperature of the surface water.
To further examine this possibility an experiment involving artificial mixing by means of air bubbles was conducted from 3o.Oct.



SALINITY AT THE SURFACE : S_o

FIG. 4

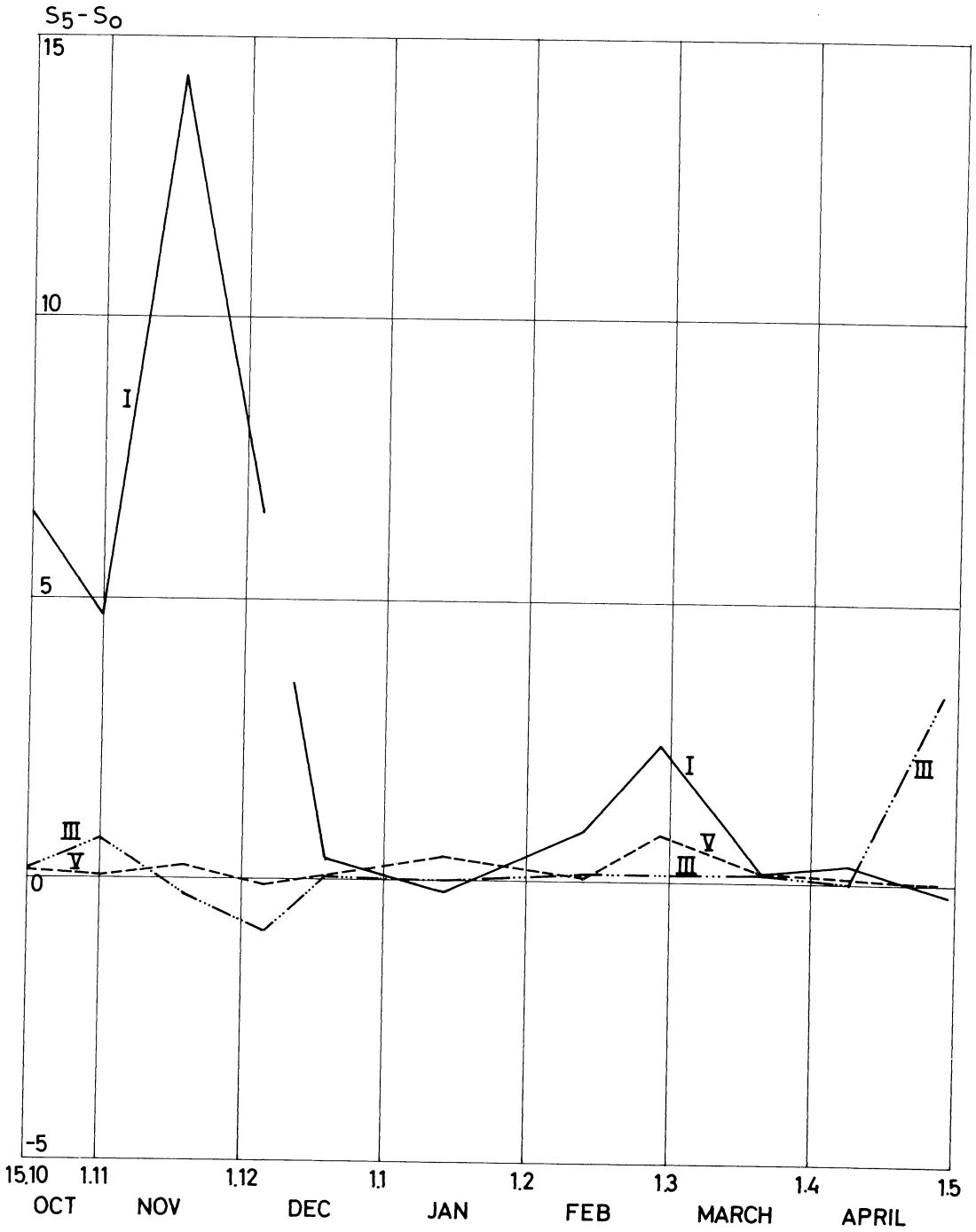

$S_5 - S_0$
15
10
5
0
-5
I
III
V
15.10
1.11
1.12
1.1
1.2
1.3
1.4
1.5
OCT
NOV
DEC
JAN
FEB
MARCH
APRIL
SALINITY AT 5M DEPTH (S_5) ÷ SALINITY AT THE SURFACE (S_0)‰

FIG. 5

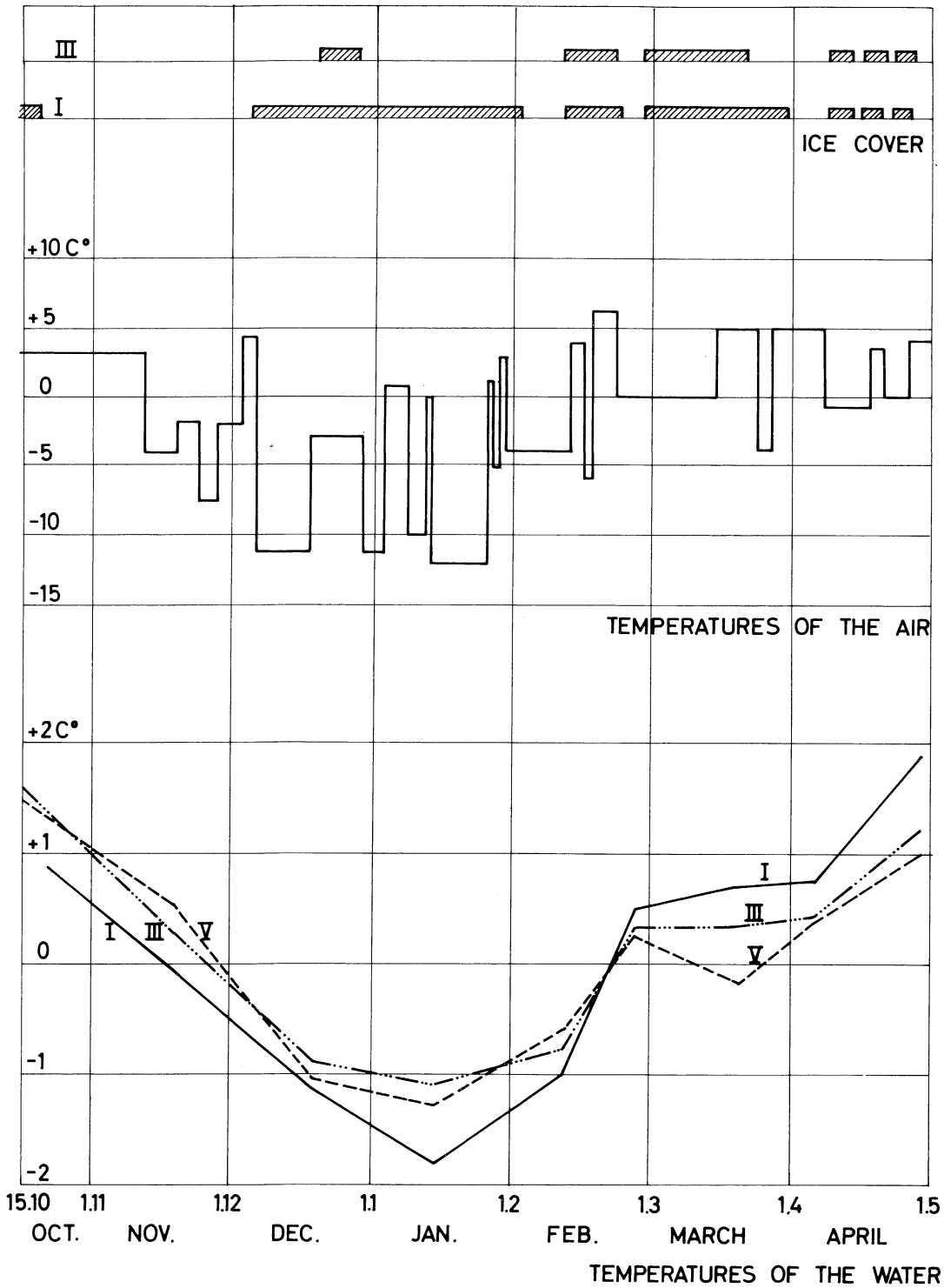

III
I
ICE COVER
+10 C°
+5
0
-5
-10
-15
TEMPERATURES OF THE AIR
+2 C°
+1
0
-1
-2
I
III
V
I
III
V
15.10
1.11
1.12
1.1
1.2
1.3
1.4
1.5
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
TEMPERATURES OF THE WATER

FIG. 6

1966 to 27. February 1967.

AIR BUBBLE CIRCULATION EXPERIMENT

Two 1" plastic tubes with o.6 mm holes spaced 2 metres apart were placed on the bottom at the inner end of the bay, and air was supplied to the tubes from a standard compressor with a capacity of 4,5m^3 per minute. (FIGS.7 AND 8).

During periods with comparatively light general ice cover holes in the cover with a diameter of 1 - 1.5 m were formed over each hole in the tubes. When the temperature dropped to about -1o° C the open holes were reduced to about o. 5 m diameter or were in some cases completely closed. However, it was always clear that the ice was significantly thinner above the tubes than elsewhere.

This is considered to be of great importance, because the ice cover in this case is more easily broken up in northeasterly gales.

CONCLUSION

It is considered that the experiment, which was not designed to keep the bay open, but only to investigate the possibilities of the air bubble method, did suggest that a very significant improvement in ice conditions under circumstances such as those obtained at Narssaq may be achieved by means of a properly designed air bubble arrangement. When combined with frequent traffic of vessels in the harbour it appears very probable that an air bubble arrangement could provide entirely acceptable navigation conditions throughout the winter period.

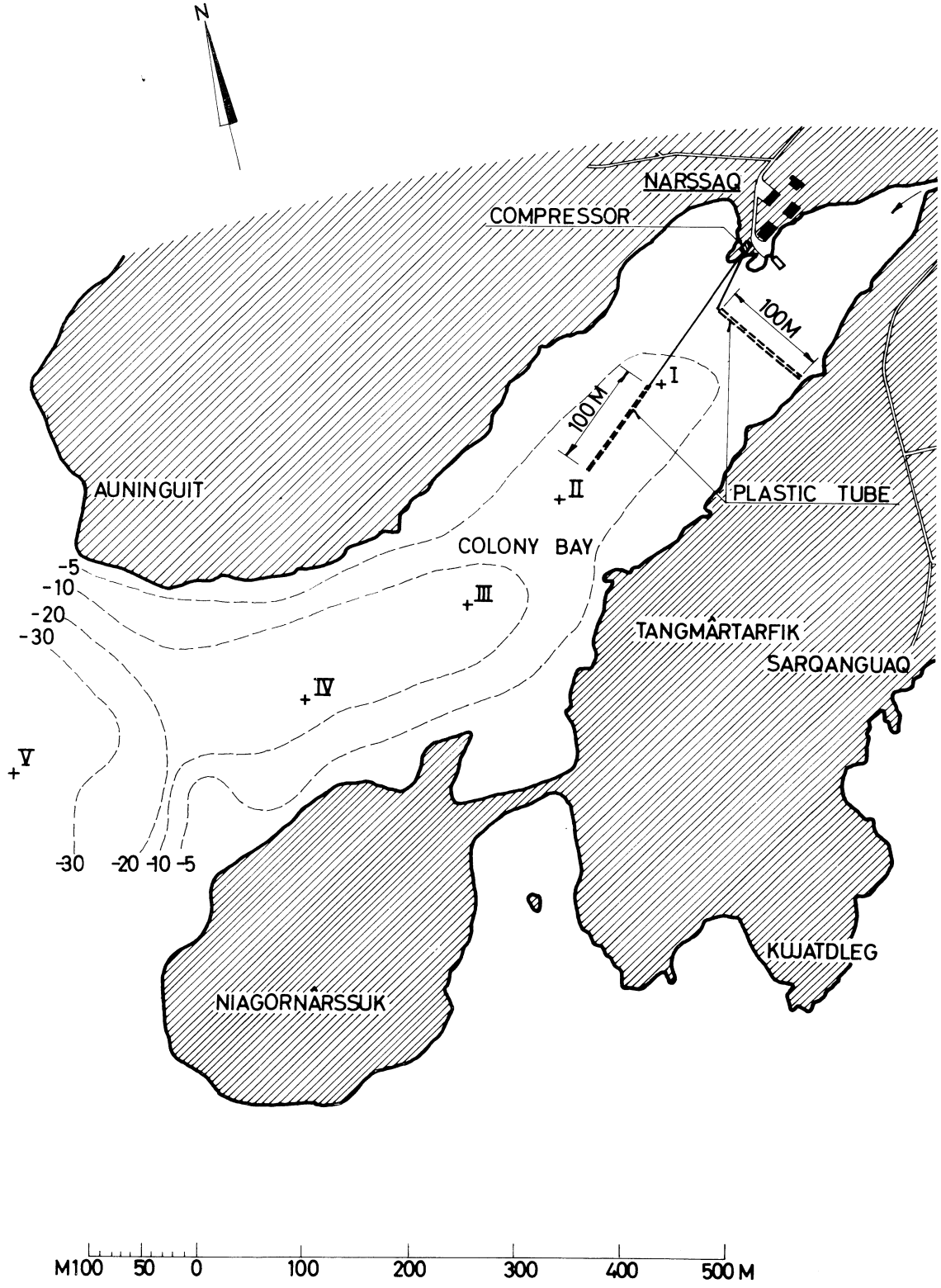

N
NARSSAQ
COMPRESSOR
100M
100M
I
II
III
IV
V
AUNINGUIT
PLASTIC TUBE
COLONY BAY
-5
-10
-20
-30
TANGMÂRTARFIK
SARQANGUAQ
-30
-20
-10
-5
KUJATDLEG
NIAGORNÂRSSUK
M100
50
0
100
200
300
400
500 M

FIG. 7

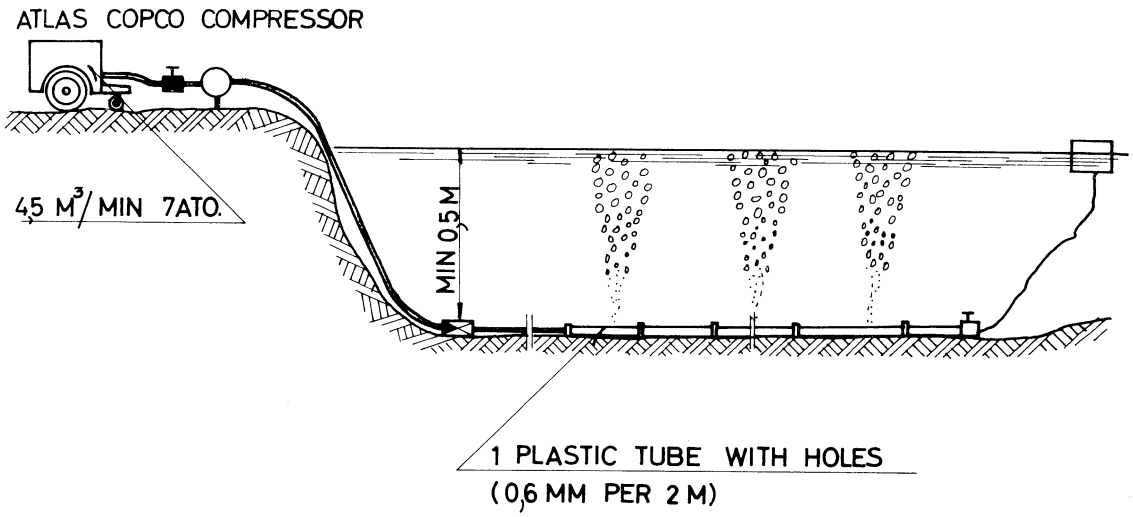

ATLAS COPCO COMPRESSOR
4,5 M³/MIN 7ATO.
MIN 0,5 M
1 PLASTIC TUBE WITH HOLES
(0,6 MM PER 2 M)

FIG. 8