PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

LONG PERIOD WAVE PHENOMENA IN JAKOBSHAVN HARBOUR BAY, GREENLAND

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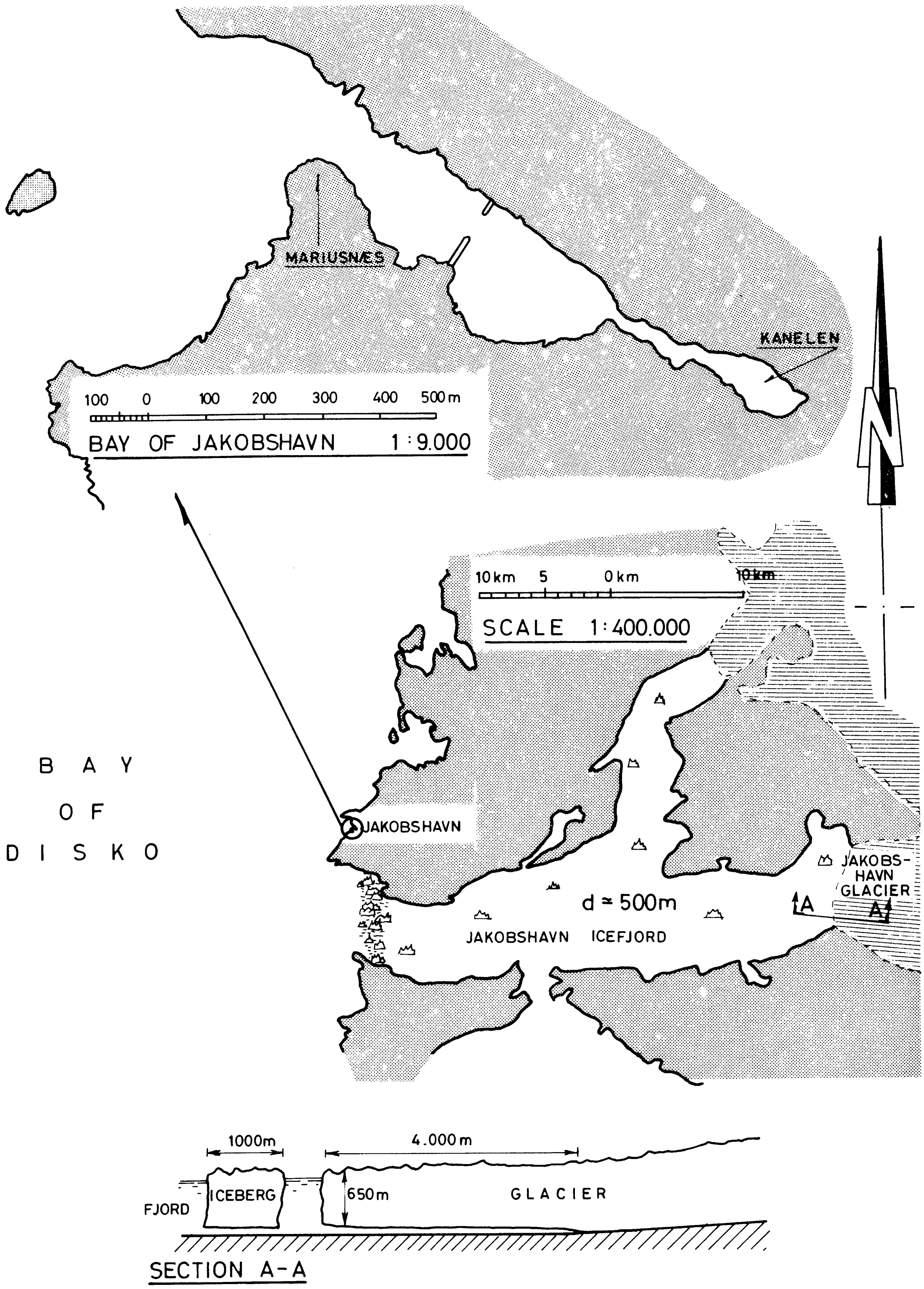
INTRODUCTION

Long period waves are known to cause adverse effects in harbour basins when the period of the incoming waves approaches one of the natural oscillation periods of the basin. Usually the origin of the long period waves is not easily detected, but in the present case it is known that the long period waves originates from icecalvings, and it has been shown that the harbour bay responds violently to these oscillations [1] , [2] .

Jakobshavn Harbour Bay is located in the southern part of the Disko Bay in West Greenland in the vicinity of one of the most productive glaciers in Greenland. The inner part of the bay forms a natural harbour with depths of 6-7 m, and is used by a fleet of shrimp cutters and pleasure boats. The boats have hitherto been moored to single moorings, but as a result of the establishment of a shrimp processing plant, the fleet has grown to a point where the available space no longer is sufficient for this type of mooring system.

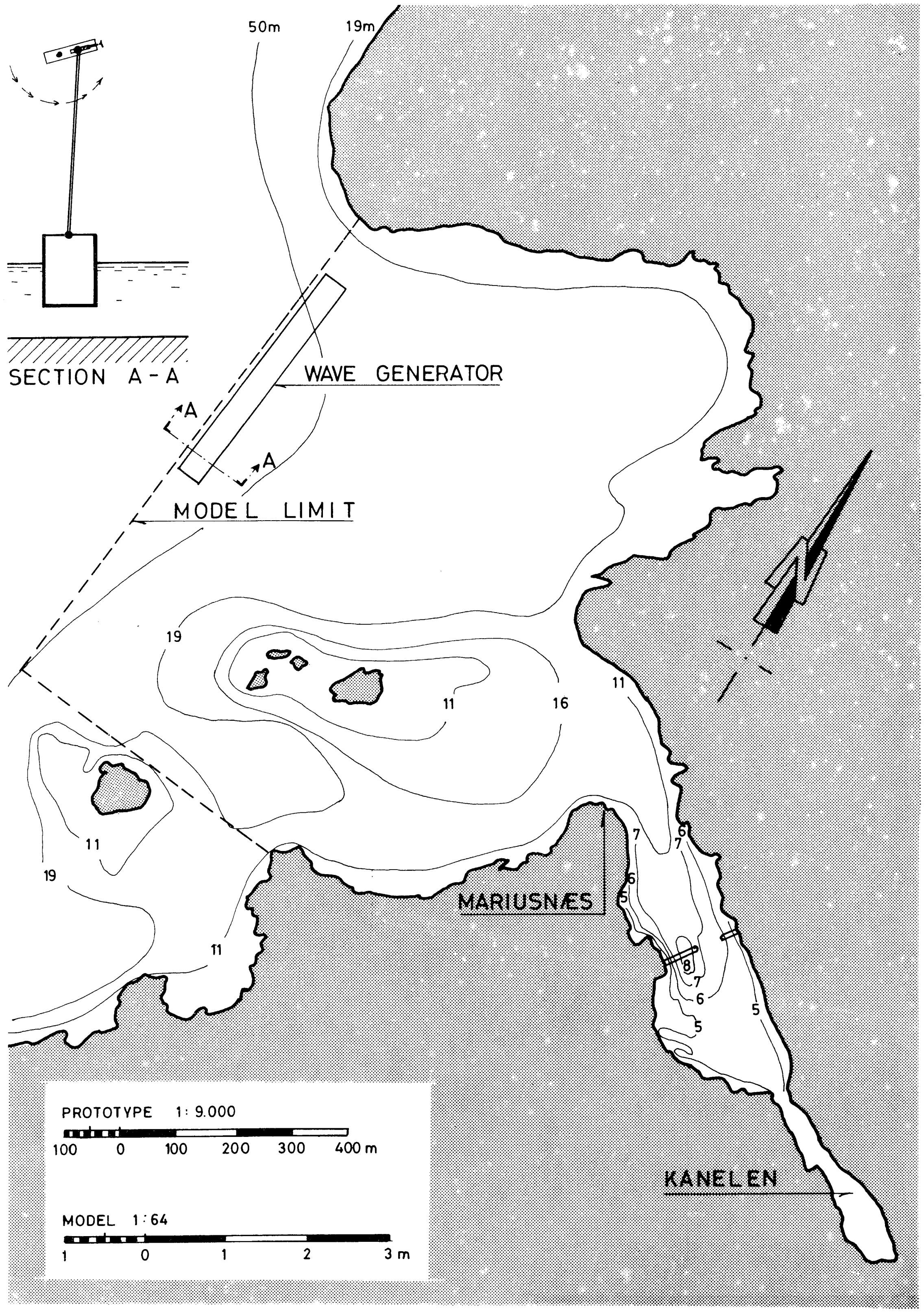
In 1958 the resonance problem was investigated in a distorted model in connection with the planned construction of a wharf for ocean freighters. In 1969 model tests were performed in order to establish recommendations for the layout of a pier capable of accommodating 50 shrimp cutters under seiche conditions.

The present paper deals with the general background of the seiche phenomenon and the 1969 model tests.



OUTLINE MAP OF THE
JAKOBSHAVN FJORD AND BAY

FIG. 1



AREA COVERED BY MODEL

FIG. 2

NATURAL CONDITIONS

The harbour bay is subject to considerable oscillations occurring at irregular intervals giving rise to large current velocities and water level changes.

Unfortunately no instrument recordings of the phenomenon are available, and the analysis of the problem has therefore had to be based on visual observations in the harbour of water level changes and wave periods. The characteristics of the phenomenon may be summarized as follows:

a) Wave heights in the bay: 50-180 cm
b) Wave period: Appr. 6 minutes
c) Duration of noticeable oscillations ½-1 hour (5 to 10 oscillations)
d) No correlation of the occurrence with actual water level

Observations of older date indicate that the wave height used to be as much as 4 metres, whereas recently wave heights appear to have been less than 180 cm. In the last years the violence of the oscillations seems to have decreased considerably owing to the narrowing of the entrance constructed as recommended from the 1958 model tests.

Various explanations with respect to the origin of the long period waves have been set forth. The phenomenon is locally termed "kaneling" which probably is derived from a Dutch word meaning "the breaking off of big (ice) pieces". This indicates that the true origin of the long period waves has been understood for a long time. It is now generally accepted that the Jakobshavn Glacier, the outer end of which is floating, acts like a wave generator producing the waves when brought out of equilibrium as a result of detachment of large icebergs [3] .

The Jakobshavn Glacier is located at the inner end of the Icefiord about 48 km from the entrance. The ice production is estimated at 16 km^3 of ice per year, corresponding to a progression of 12-25 m of the ice front per day. Icebergs in all sizes continuously flow out of the fjord and cover the surface in its entire lenght. At the entrance the icebergs run aground on what is believed to be a terminal moraine of the Jakobshavn Glacier.

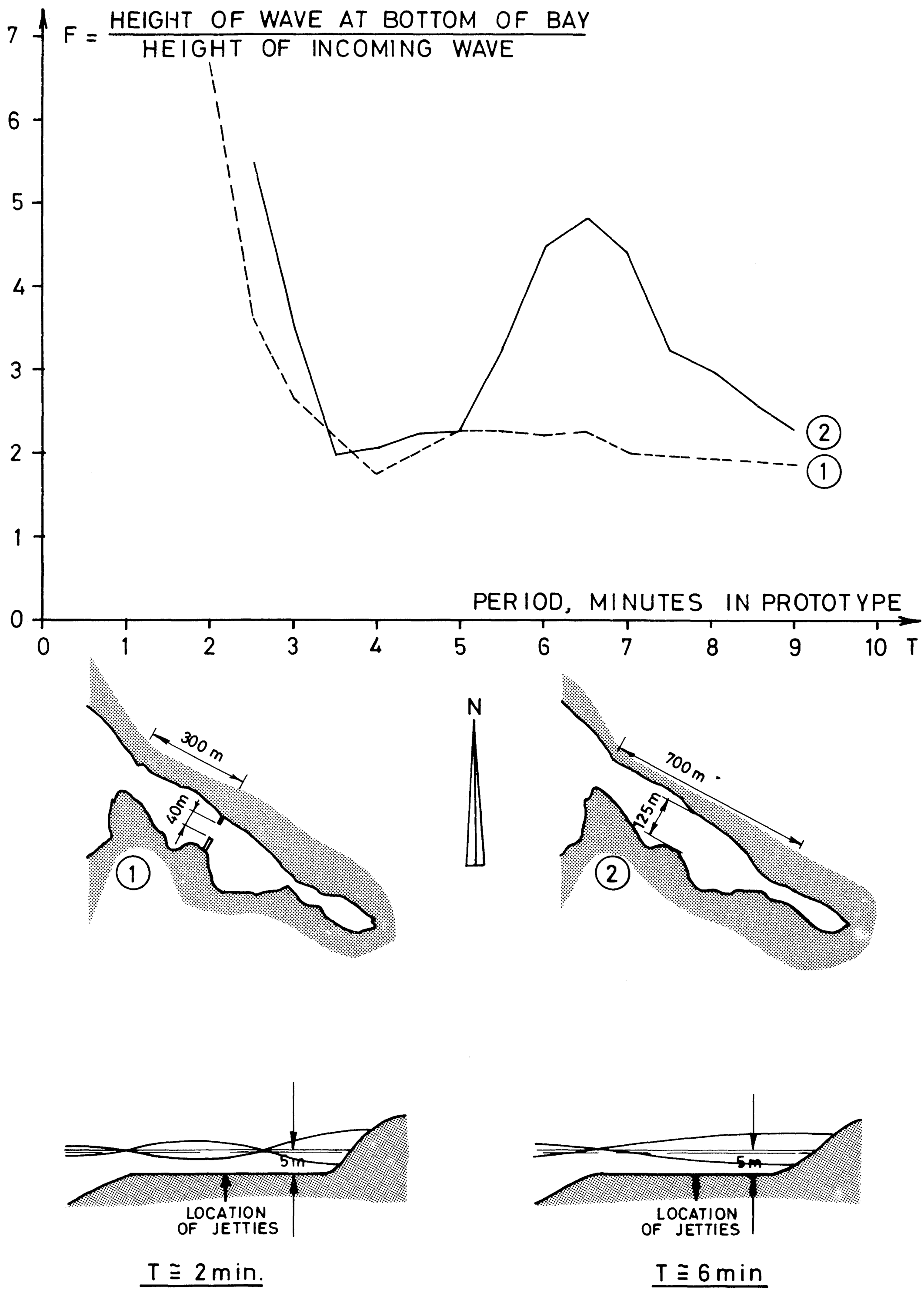
The average depth in the fjord is around 500 m and decreases to 100-200 m at the entrance. The icebergs here form a barrier which reflects some of the energy back into the fjord, while some of the energy is transmitted out into open water. The shape and density of the barrier varies from year to year, which to a certain extent may account for changes in the violence of the harbour bay oscillations. However, the bottom rise from 500 to 100 m depth alone causes 50% reflection of the incoming wave height. A possible and probable explanation for the long term changes in wave heights seems to be that the fjord between the glacier and the iceberg barrier in earlier times constituted a resonance system in which the energy could build up to considerable levels. In 1879 violent oscillations in Jakobshavn were observed [5] at a time when the glacier front was situated at a distance approximately one wave length from the barrier. Since 1879 the glacier has receded about 20 km [4] , and is now in a position more than 1½ wave lengths from the barrier.

It should be noted, that changes in the geometry of the glacier front may have caused changes along with those resulting from the recession of the front.

The height of the incoming waves at the harbour bay entrance is estimated to be 30-50 cm. Wave heights of this magnitude can only be accounted for by considering the effects of the iceberg barrier, and the shallow water wave propagation beyond the barrier.

The wave energy transmitted through the iceberg barrier is subject to diffraction, refraction and shoaling. Bottom friction can in this connection be neglected, while shoaling will amplify wave heights 2.6 times when a wave of the period considered propagates from a depth of 500 m to a depth of 10 m.

A deep water wave will radiate its diffracted energy in straight lines, but the wave considered is a shallow water wave and is thus subject to a considerable refraction. It is estimated that refraction causes about 80% of the diffracted wave energy to be trans-



WAVE HEIGHT AMPLIFICATION IN
BAY OF JAKOBSHAVN

FIG. 3

mitted towards the coast between the point of diffraction and the funnel-shaped entrance to the harbour bay. Moreover, it is noted that the wave energy is subject to a complete reflection along the coast. A wave front similar to the one shown on figure 4 is assumed to be formed.

The tidal range is 2.8 m at spring and 1.3 m at neap tide. An investigation of the dates of observed seichings in relation to predicted water levels has shown that the phenomenon is most likely to occur at spring tide conditions, but not necessarily at extreme water levels.

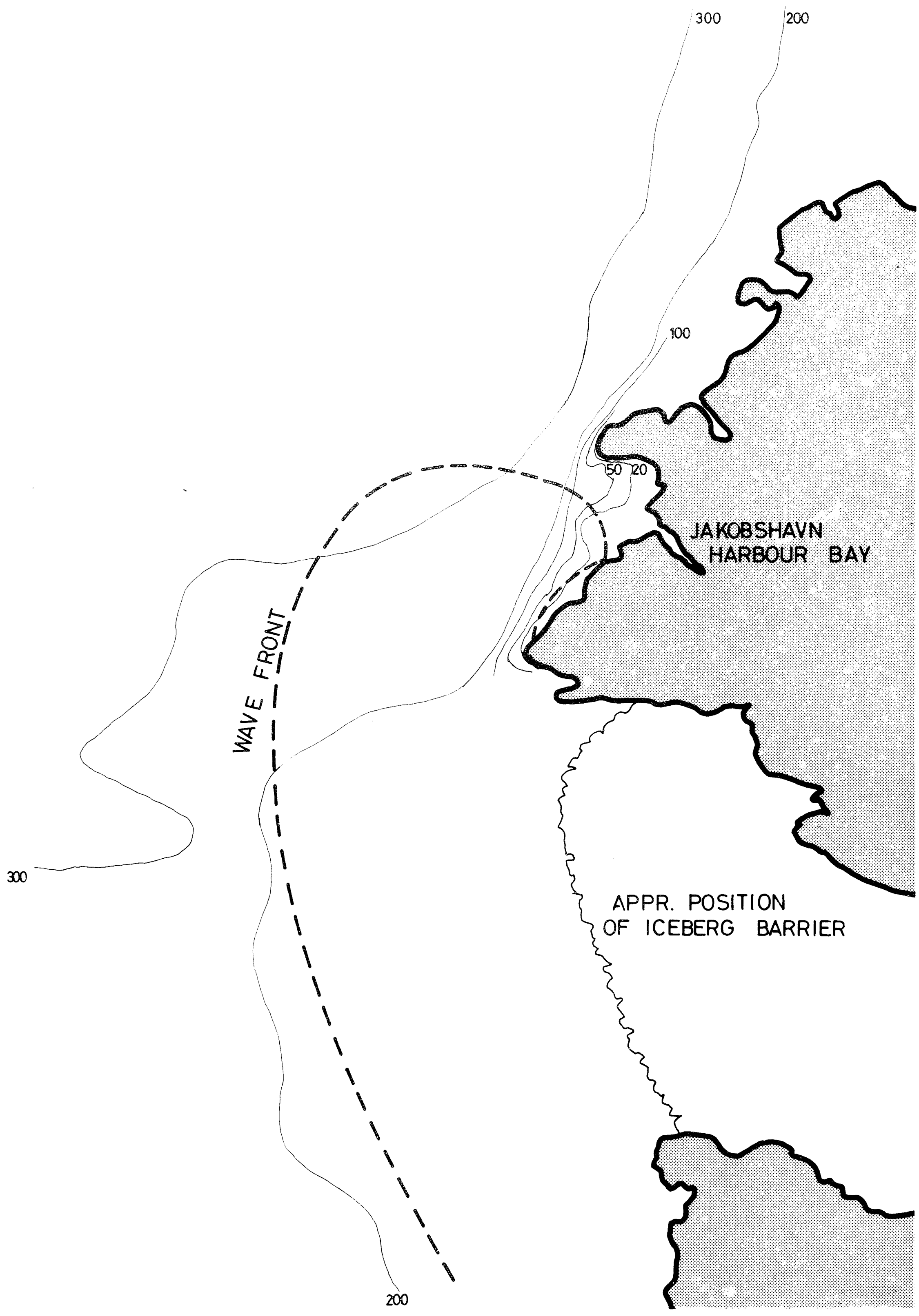
Judging from the geometry of the harbour bay excluding the innermost narrow part, a natural period of 5 minutes for the fundamental mode of oscillation is expected. Model tests, however, shows a maximum amplification for waves with a period of 6.5 minutes indicating that the narrow part of the bay has the effect of extending the "effective" length beyond the narrow entrance at the bottom of the bay.

MODEL TESTS

The object of the model study was to reach recommendations with respect to pier layouts yielding satisfactory current conditions during a seiching. A desired position for the land connection, and considerations of ice problems imposed certain restrictions on the general outline of the pier solutions.

In planning the model, emphasis was placed on the fact that the induced oscillating flow in the inner part of the bay was a far more important feature in the problem, than the actual changes in water level.

A plan of the area modelled to a scale of 1:140 in the vertical and horizontal direction is shown in figure 2. The model bottom consisted of concrete on sand. Two vertical side limitations had to be introduced in the model, constituting two reflecting sides. This is not considered any serious drawback, as the waves are so long that they give rise to an almost uniform change of water level, the distance between the wave generator and the bay entrance being only 1/7 of a wave length. The area outside the harbour bay was large



PROPAGATION OF WAVE FRONT
TOWARDS HARBOUR BAY

FIG. 4

enough to prevent coupling of oscillations of the two basins.

The wave generator was developed especially for use in these tests, and consists of a plunger driven harmonically in the vertical direction by an electric motor. Sinusoidal water level changes and currents with periods in the range from 1.3-11.8 minutes (prototype) could be reproduced. The generator could be set to any period in this interval.

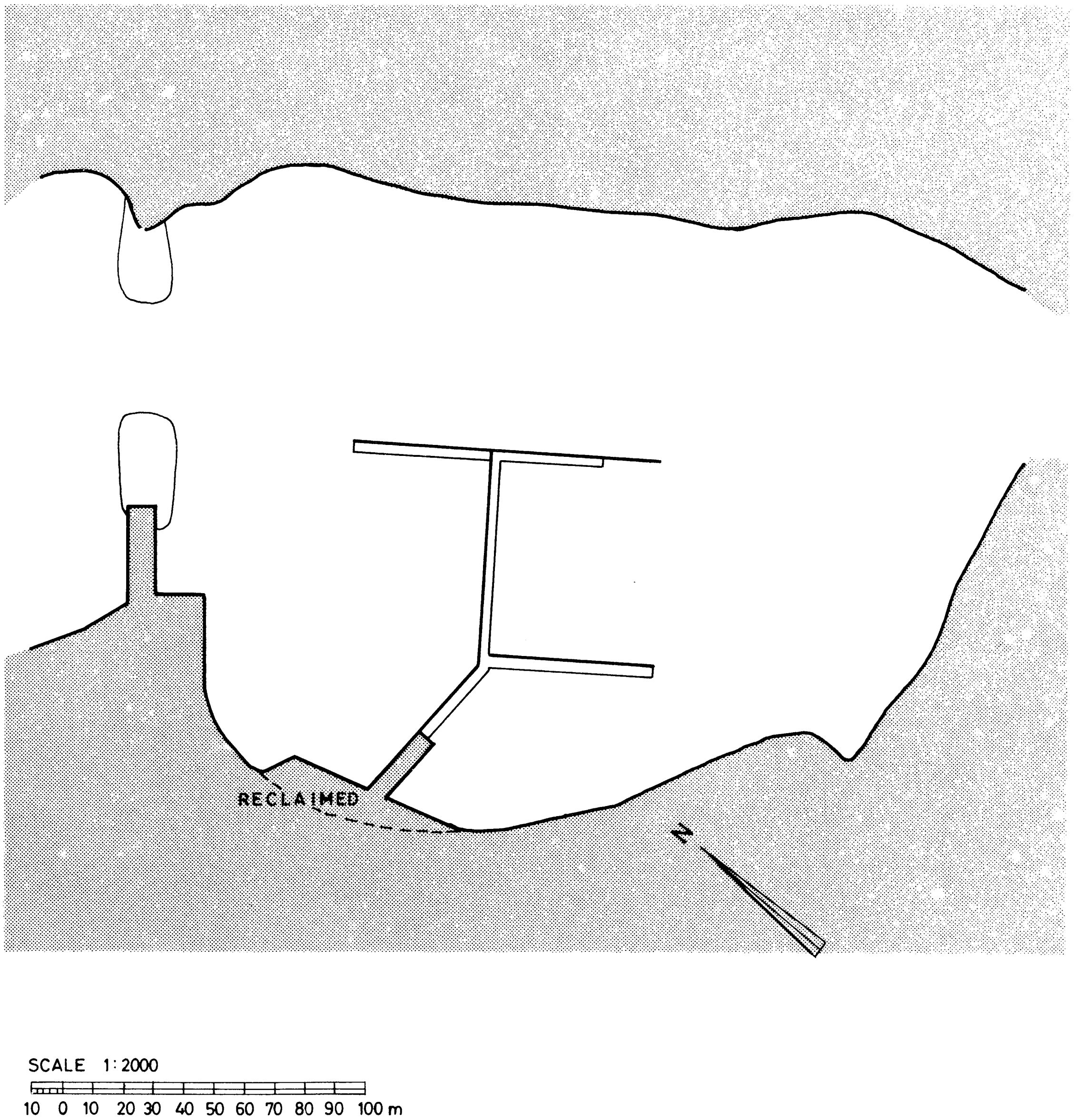
Current patterns in present conditions, and around a variety of piers, were studied using aluminium powder and revolving float fans on the water surface. Long exposure photographs were taken every 5 seconds during test runs by a Robot-camera placed 4 m above the model. The use of aluminium powder proved to be very successful for the purpose of revealing current patterns on photographs.

RESULTS

On the basis of the results from model tests performed in 1958 two jetties have been constructed leaving a 40 m wide opening to the inner part of the bay. The purpose was to create satisfactory current conditions during seiches for sea going vessels at a wharf situated just west of the southerly jetty.

The present tests showed that this had been obtained partly through a general wave height reduction of about 50% in the bay because of energy losses imposed by the jetties. However, introduction of the jetties in the oscillating flow had induced a complicated current pattern in the inner part of the bay used by the small crafts. Test runs with an empty bay revealed the existence of two large eddies revolving in opposite directions showing the same general pattern throughout the seiching period, see figure 6. During seiches with medium amplitudes velocities up to 1.2 m/s (prototype) were measured in the eddies. The innermost, narrow part of the bay (Kanelen) oscillates about 90 degrees out of phase and this, in combination with the excentrically placed opening between the jetties, is responsible for the formation of the observed current pattern.

A variety of piers were tested in order to determine the shape and size of a pier with weak currents along the wharves, and above all



RECOMMENDED PIER LAYOUT

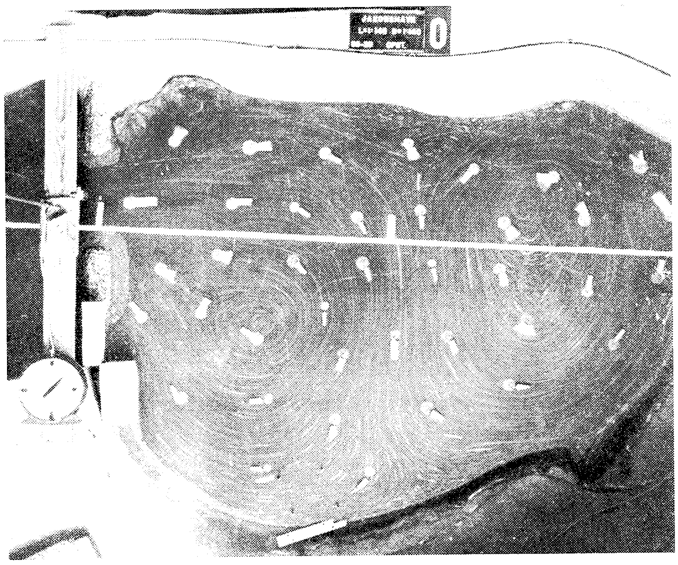
FIG. 5

with a minimum of current oscillations along the major part of its length. The water level changes as such are in this connection of secondary importance.

Figure 3 shows resonance curves measured with and without the influence of the jetties. The curve confirms the assumption that the bay is in a state of resonance at a period of about 6 minutes (peak value found at 6.5 minutes in the model tests), and the energy dissipating effect of the jetties at the two different modes of oscillation is clearly demonstrated.

An F-shaped pier (figure 5) was found to yield satisfactory current conditions along the greater part of its length. Current velocities of 100 cm/s (prototype) were measured at the ends of the pier, where also the flow tended to oscillate. Along 85% of the total pier length the current was uniform in direction in this layout. Tests were run with an incoming wave height equivalent to 25 cm in prototype. Runs with greater wave heights showed a small, non-linear increase in current velocities, probably owing to the fact that energy losses in the system rapidly become dominant.

The effect of introducing energy dissipating pile-walls at strategic points in the current was investigated in early tests. Such pile-walls did reduce velocities considerably along the piers in some of the layouts tested, but as a whole, and especially in the layouts which beforehand showed favourable current conditions, the effect was limited.



EMPTY BAY

PIER LAYOUT SIMILAR TO THE RECOMMENDED

EXAMPLES OF CURRENT PATTERNS

FIG. 6

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