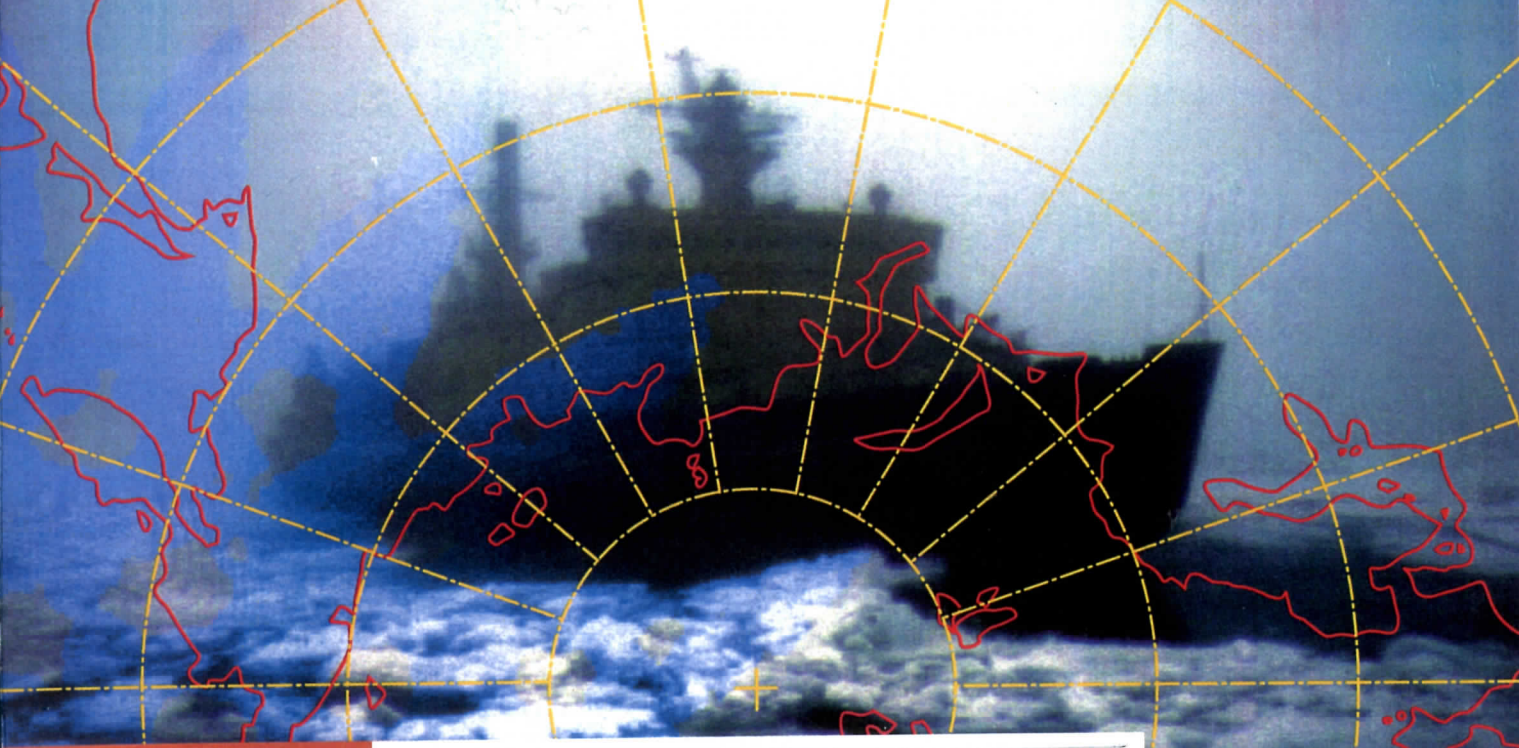




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The NSR Simulation Study Work Package 4:

Design of the NSR Service Ships.

Part I: Model Tests in Ice with M-224.

Part II: Design of 40 000 and 25 000 dwt Ice Breaking Bulk / Container Carrier.

By Ann-Cristin Forsén, Jari Kivelä and Erkki Ranki

INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship and Ocean Foundation, Japan

International Northern Sea Route Programme (INSROP)

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The Fridtjof Nansen Institute, Norway

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Box B: The Simulation Study of NSR Commercial Shipping

Work Package 4: The Service Ships

Supervisor: Kimmo Juurmaa, Kværner Masa-Yards Technology, Finland

Title: **Design of the NSR Service Ships.**
Part I: Model Tests in Ice with M-224.
Part II: Design of 40 000 and 25 000 dwt Ice Breaking Bulk / Container Carrier.

Authors: **Ann-Cristin Forsén, Jari Kivelä and Erkki Ranki**

Address: Kværner Masa-Yards Technology
Kaanaantie 3 A
00560 Helsinki, FINLAND

Date: 19 October 1998

Reviewed by: Alfred Tunik, American Bureau of Shipping, New York, USA

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FOREWORD - INSROP WORKING PAPER

INSROP is a five-year multidisciplinary and multilateral research programme, the main phase of which commenced in June 1993. The three principal cooperating partners are **Central Marine Research & Design Institute (CNIIMF)**, St. Petersburg, Russia; **Ship and Ocean Foundation (SOF)**, Tokyo, Japan; and **Fridtjof Nansen Institute (FNI)**, Lysaker, Norway. The INSROP Secretariat is shared between CNIIMF and FNI and is located at FNI.

INSROP is split into four main projects: 1) Natural Conditions and Ice Navigation; 2) Environmental Factors; 3) Trade and Commercial Shipping Aspects of the NSR; and 4) Political, Legal and Strategic Factors. The aim of INSROP is to build up a knowledge base adequate to provide a foundation for long-term planning and decision-making by state agencies as well as private companies etc., for purposes of promoting rational decisionmaking concerning the use of the Northern Sea Route for transit and regional development.

INSROP is a direct result of the normalization of the international situation and the Murmansk initiatives of the former Soviet Union in 1987, when the readiness of the USSR to open the NSR for international shipping was officially declared. The Murmansk Initiatives enabled the continuation, expansion and intensification of traditional collaboration between the states in the Arctic, including safety and efficiency of shipping. Russia, being the successor state to the USSR, supports the Murmansk Initiatives. The initiatives stimulated contact and cooperation between CNIIMF and FNI in 1988 and resulted in a pilot study of the NSR in 1991. In 1992 SOF entered INSROP as a third partner on an equal basis with CNIIMF and FNI.

The complete series of publications may be obtained from the Fridtjof Nansen Institute.

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- Norwegian Polar Research Institute
- SINTEF (Foundation for Scientific and Industrial Research - Civil and Environmental Engineering), Norway.

PROGRAMME COORDINATORS

- **Yuri Ivanov, CNIIMF**
Kavalergardskaya Str.6
St. Petersburg 193015, Russia
Tel: 7 812 271 5633
Fax: 7 812 274 3864
E-mail: cniimf@neva.spb.ru

- **Willy Østreng, FNI**
P.O. Box 326
N-1324 Lysaker, Norway
Tel: 47 67 11 19 00
Fax: 47 67 11 19 10
E-mail: sentralbord@fni.no

- **Hiroyasu Kawai, SOF**
Senpaku Shinko Building
15-16 Toranomon 1-chome
Minato-ku, Tokyo 105-0001, Japan
Tel: 81 3 3502 2371
Fax: 81 3 3502 2033
E-mail: sofkawa@blue.ocn.ne.jp

PART I

Model Tests in Ice with M-224

MARC REPORT A-261

July 1998

Ann-Cristin Forsén
Project Engineer

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1. SUMMARY

1.1 Background

Model tests with a double acting tanker (DAT) equipped with two Azipod propulsion units, were performed at the Kvaerner Masa-Yards Arctic research centre (MARC) in February - Mars 1998.

The tests are a part of the International Northern Sea Route Programme (INSROP) PHASE 2. The purpose of INSROP PHASE 2 is to analyze different aspects of the utilization of the Northern Sea Route.
INSROP PHASE 2 is organized as three integrated research programmes with international coordination by the Programme Secretariat.
The model tests are a part of a project of the programme B, Simulation of Ship Navigation Along the NSR. The project is WP4, The Service Ships - Design of Vessels for Selected Routes and Model Tests.

1.2 Objectives

Tests were carried out to find out the icebreaking capability of the vessel and the capability to penetrate ridges by running astern. Design basis for the ship indicates following icebreaking requirements:

- to be able to maintain a speed of 3 knots (1.5 m/s) in the maximum level ice of 8 months of an average year.
- maintain continuous movement in ice ridges with thickness which covers 70% of the ridges.
- maintain continuous movement in ice under compression in more than 50% of ice compression cases.

1.3 Program

The tests ahead were performed in one ice thickness (1.2 m) and the tests astern in two ice thicknesses (1.2 m and 1.8 m). The ridges built up from the thinner ice corresponds to 15 m in full scale and the ridge built up from the thicker ice corresponds to 20 m.

In general, the following test types were performed in each ice sheet:

- self propulsion tests in level ice, three power levels
- breaking out from own channel
- self propulsion tests in floe ice, two power levels
- self propulsion tests in ridge

The tested model M-224 is designed for ice breaking when going astern. The stern is equipped with two Azipod propulsion units, which could rotate 360° in the tests.
The main dimensions and the propeller of the vessel are given as full scale and model scale values in the table below. Drawings of the model are presented in APPENDIX E.

Table 1-1 Main dimensions of M-224

	MSC (1:30)	FSC
Lwl	6.52 m	195.7 m
Bcwl	0.92 m	27.5 m
Tcwl	0.42 m	12.5 m
Propeller	0.193 m	5.8 m

The tests were performed with the Azipods in a pulling mode (propeller comes first). Constant power was used, which enabled propeller shaft speed to vary with the propeller load. The estimated full scale bollard pull values are given in Table 1-2 Bollard pull of the vessel. The model scale bollard pull graphs are presented in APPENDIX F in Figure F-1.

Table 1-2 Bollard pull of the vessel

	BOLLARD PULL [FSC]
AHEAD	2910 kN
ASTERN	2580 kN

1.4 Results

Level ice tests

According to the tests the vessel can break 1.2 m thick ice with a speed of 3 m/s (6 kn), when going ahead.

Tests astern were made in two ice thicknesses, 1.2 m and 1.8 m. According to these tests the ice breaking capability astern is about 1.85 m thick ice with a speed of 1 m/s (2 kn).

Floe ice tests

At low speed the vessel tends to push ice in front of it running astern. With increasing speed this tendency decreases and the vessel is able to make good progress.

When going ahead there are no such problems. The vessel do not push ice in front of it and due to that, higher speeds were reached in the tests when going ahead.

Compressive ice

Although no compressive ice tests were performed prediction estimates for performance in compressive ice were made. the compressive force per unit length was calculated from the net thrust, the length of the parallel midship and the friction coefficient between ice and ship hull. According to the calculations the ship is able to move with a speed of 1 m/s (2 kn) in 1.2 m thick ice, when the compressive force is 59.6 kN/m when going ahead and 40.4 kN/m when going astern.

Breaking out from own channel

When running ahead there was no problems to break out from own channel. A distance of 2.3 - 3 ship lengths was needed when breaking out from own channel.

When going astern in the thinner ice (1.2 m), the required distance to break out from own channel was twice that when going ahead. In the thicker ice (1.8 m) the model was not able to break out of own channel. The model runs diagonally in the channel making it wider by breaking the edge of the channel with the stern. The stem is unable to break the opposite edge of the channel , this prevents the model from turning out from the channel.

Ridge

When going ahead the vessel was not able to move continuously. Three rammings were needed to penetrate a ridge which thickness and length corresponds to 15 m and 240 m in full scale. The ridge resistance ahead was 2.3 to 2.5 times the available net thrust.

Tests astern were made in two ridges with thicknesses corresponding to 15m and 20m and the length to 180m in full scale. According to the tests the vessel is capable to penetrate the ridge more or less continuously. By turning the Azipods to and fro the vessel will break up the ridge and can penetrate the ridge bit by bit. The required time to penetrate the 20 m thick ridge was about 2.5 times the time to penetrate the 15 m thick ridge.

1.5 Conclusions

According to the tests the vessel will not fulfil the requirement of level ice breaking capability set by the design criteria.
The vessel is able to break 1.75 m thick level ice with a speed of 1.25 m/s (2.5 kn) when going astern. The required speed is 1.5 m/s (3 kn). The requirements can be fulfilled if the bollard pull astern can be increased 10% or with some improvement of the aft body shape which can decrease the ice resistance with about 10 %.

In ridges the DAT concept is up to expectations. Ridges with thicknesses of 15 - 20 m in full scale can be penetrated without ramming, just by turning the Azipods. When going ahead in a 15 m thick ridge several rammings were needed to penetrate the ridge.

The capability to break out of own channel is better when running ahead. When going astern the stem makes it difficult to turn out of the channel by having problems with breaking the opposite edge of the channel.

2. INTRODUCTION

Model tests with a double acting tanker (DAT) equipped with two Azipod propulsion units, were performed at the Kvaerner Masa-Yards Arctic Research Centre (MARC) in February - Mars 1998.

The tests are a part of the International Northern Sea Route Programme (INSROP) PHASE 2. The purpose of INSROP PHASE 2 is to analyze different aspects of the utilization of the Northern Sea Route. INSROP PHASE 2 is organized as three integrated research programmes with international coordination by the Programme Secretariat:

A Integration of INSROP Results.
B Simulation of Ship Navigation Along the NSR.
C Continuation of Sub-Programmes from Phase 1.

Each of these three programmes are organized as Projects in cooperation with research institutions as Sub Contractors.

The programme B, Simulation of Ship Navigation Along the NSR, is organized as 9 Projects:

WP0 Coordination for the simulation study.
WP1 Routes and associated operational infrastructure
WP2 Natural Condition along the Selected route
WP4 The Service Ships
WP5 Collection of SA-15 Operation Data
WP6 Ship Transit Velocity Simulation Algorithm
WP7 Legal and Environmental Evaluation for Selected Routes
WP8 Simulations Based on Year-round and Seasonal Operation Scenario

The model tests are a part of project WP4, The Service Ships - Design of Vessels for Selected Routes and Model Tests. The design of the tested vessel is done on the basis of route selection done in WP1 and the natural conditions defined in WP2.

The main dimensions of the tested vessel are given as model scale and full scale values in Table 1-1 on page 1-1. Line drawings of the model are presented in APPENDIX E.

The tests were conducted with the model running ahead and astern, and the Azipod in tractor mode i.e. propeller comes first. The estimated full scale bollard pull value ahead is 2910 kN and astern 2580 kN. Before the start of each test the power was adjusted to give the chosen bollard pull for the test.

The ice / test conditions were:
- ice breaking capability ahead in level ice (1.2 m)
- ice breaking capability astern in level ice (1.2 m and 1.8 m)
- behaviour in floe ice ahead and astern in tested ice thicknesses
- capability to break out of own channel, ahead and astern in tested ice thicknesses
- ridge penetration capability ahead (15 m)

ridge penetration capability ahead (15 m and 20 m)

3. THE MODEL

3.1 Model characteristics

The tested model M-224 was built to scale 1:30.
The model was equipped with two azimuthing propulsion units with a total power of 28 MW in full scale.
The main particulars of the vessel are given in Table 3-1 The main dimensions of the vessel in model scale and in full scale.

The surface was treated in accordance with the MARC standard methods. The measured friction coefficient between the surface and the ice was 0.059.

Table 3-1 The main dimensions of the vessel in model scale and in full scale.

	MSC (1:30)	FSC
Lwl	6.52 m	195.7 m
Bcwl	0.92 m	27.5 m
Tcwl	0.42 m	12.5 m

Drawings of the model are presented in APPENDIX E.

3.2 Propulsion characteristics

The vessel is designed to have a propeller diameter of 5.8 m. Corresponding model scale value is 193 mm. The diameter of the propeller used in the tests was 196 mm. The used propellers were stock propellers with simplified flat sections. The tests were performed assuming that the bollard pull astern is 2580 kN and ahead 2910 kN, at full power of 28 MW.

Table 3-2 Parameters of the propeller used in the tests

	MSC
Diameter	196 mm
P/D	0.76
Ae/Ao	0.61
z	4

4. METHODS

4.1 Measurements

The following quantities were recorded as analogue signal on magnetic tape and digitally sampled on computer during the tests:

- towing carriage speed
- model position compared to the towing carriage
- propeller rpm
- shaft torque from the drive shaft
- Azipod angle

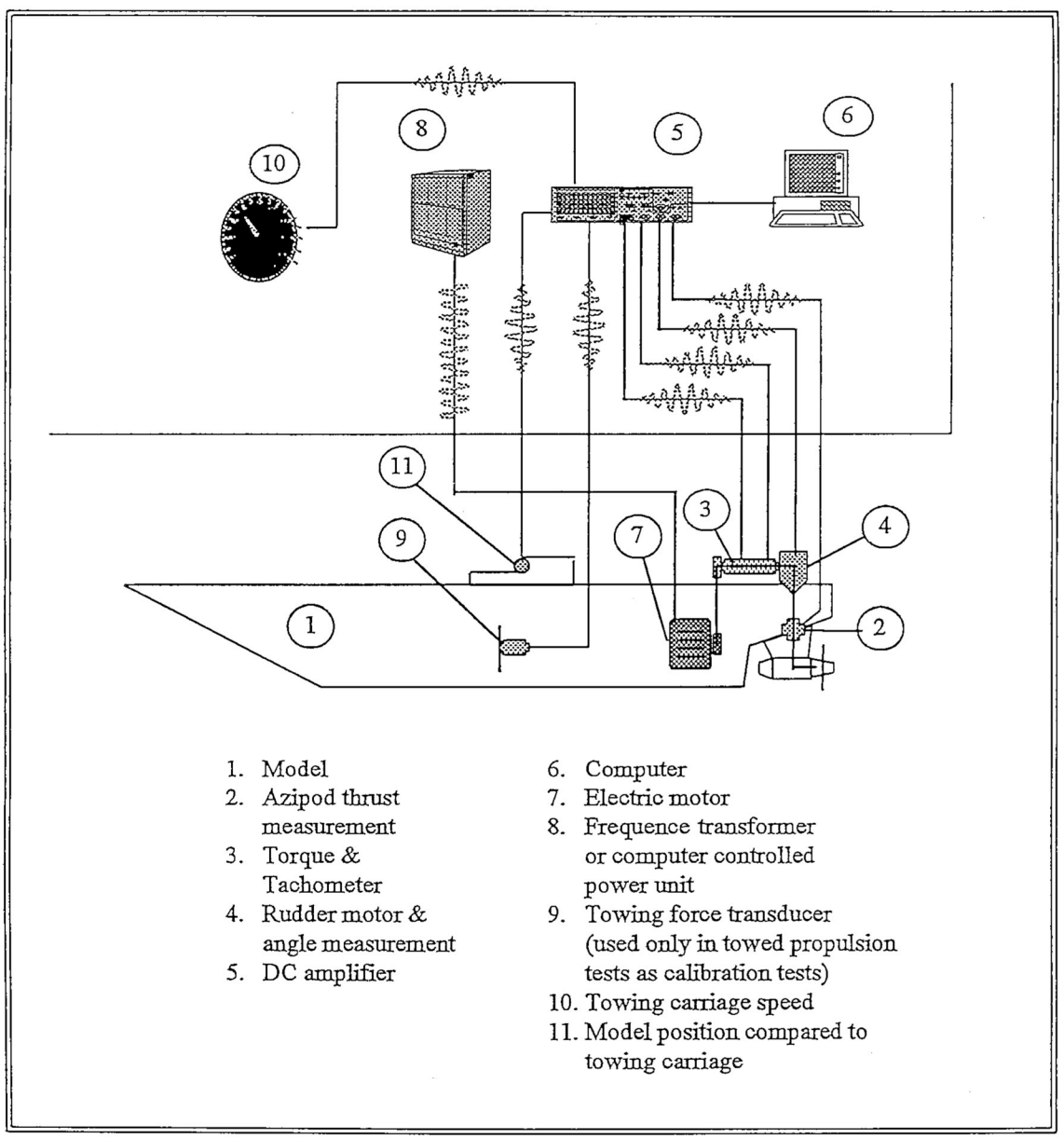


Figure 4-1 A schematic plan of the measuring arrangement, self propulsion tests.

In the beginning of the test series all the force transducers were calibrated.

The resistance, propulsion parameters and ice properties were measured according to the standards of MARC.

In the ridge tests the and ramming distance into the ridge over one ramming cycle was determined from the carriage speed and the model position signals. The average resistance was calculated from the propeller thrust and the mass forces. The mass forces were determined from the deceleration of the model according to the carriage speed and the model position signals

All tests were photographed and recorded on video. Photographs and video were taken from the towing carriage and from the side of the test basin. Underwater photographs and video shooting were also taken through the windows beside and under the basin. A series of selected photographs from the tests are shown in APPENDIX A.

4.2 Analysis

4.2.1 Calibration tests

The bollard pull graphs (model scale values) are presented in APPENDIX F CALIBRATION TESTS. In the chart also the linear regression values according to the tests are given. Net thrust curves that were used to analyse the tests are presented in APPENDIX F pages F-4 - F-5.

4.2.2 Ice resistance tests

The ice resistance is derived in accordance with the normal procedure of MARC. APPENDIX G WARC REPORT D66 II. A simplified description of the resistance analysis is presented here.

Bollard pull tests and ice-free water tests astern are run at the beginning of the test series. From the bollard pull tests the rpm which gives the desired thrust in bollard situation is determined. The tests in ice-free water are run as overload tests in order to determine the excessive thrust available at different speeds to overcome the ice resistance. The excessive thrust or net thrust is the total propeller thrust minus the ice-free water resistance at same speed.
The net thrust (= ice resistance in the test) can be calculated from the propeller rpm and model speed with a second order regression polynome. The coefficient for the polynome are derived from ice free water and bollard tests.

Ice resistance predictions are calculated by dividing the resistance into breaking and submersion components. The breaking component, which is considered to be independent of velocity, can be reduced from the tested value to the desired ice strength. The reduction to the desired thickness is made after the reduced breaking component and submergence component are added up. The resistance prediction to full scale is made by multiplying the obtained resistance by λ^3. If necessary, friction corrections are made after this procedure.

4.2.3 Compressive ice

Although no compressive ice tests were performed, prediction estimates for performance in compressive ice can be made. The compressive force per unit length can be calculated from the length of the parallel midship and the friction coefficient between ice and ship hull in following way:

$$Fc = \frac{Tn - Riw - Rice}{2 * L * \mu} \quad , \quad where \qquad (1)$$

Tn = Net thrust
Riw = Resistance in ice free water
Ri = Ice resistance
L = Length of parallel waterline
μ = friction coefficient between ice and ship hull

4.2.4 Breaking out from own channel

The tests were performed with a free running model. The Azipod units were turned 30° - 40° in the tests before the propellers were started.
The deviation of the new track from the original channel was measured

4.2.5 Ridges

Before the test runs the consolidated ridges were frozen to - 20°C*h in order to freeze the upper ice blocks together and to form a consolidated layer on the top of the ridge.

The ice resistance in ridges has been calculated for every ramming cycle separately. If the ship could proceed continuously after the ramming, the resistance is given from the steady movement period.

Resistance in ridges was calculated as follows:
The deceleration of the model (a) was calculated by differentialing the model speed signal against time. The model speed signal was generated from two signals: the towing carriage speed and the signal of the model position relative to the towing carriage.

The penetration length was calculated integrating the speed signal of the model during the penetration. The thickness of the ridge was calculated as the average of the measured ridge thickness.

The ridge resistance was calculated as follows:

$$R_{ridge} = m*a + T_{net} \ (V_m, rpm) \qquad (2)$$

where

m = The mass (displacement) of the model + the added mass. The added mass used in this case was 20% of the displacement

a = The deceleration derivated from the speed signal of the model

T_{net} (V_m, rpm) = The net thrust depending on the speed and propeller shaft revolutions

5. TESTS

The complete test programme is presented in APPENDIX B. In this chapter a short description of all tests is presented. The test results are presented in chapter 6 "Results". The results are presented in tables and graphs in Chapter 9 "Tables and charts".

The model was running in all tests with pulling Azipod units (the propeller comes first).

Bollard pull tests and tests in ice free water were performed ahead and astern. During these tests a force transducer and a counter weight were mounted to the model.

5.1 Calibration tests

5.1.1 Bollard pull and ice free water tests

In bollard pull and ice free water tests the characteristics of the model and the propulsion system were determined. Bollard pull tests are run to determine the right power level and propeller rpm for the model. Ice free propulsion tests are made to determine the net thrust of the propeller at a particular rpm and speed.

In bollard pull tests ahead the used rpm values are 300 rpm - 930 rpm.
Ice free propulsion tests ahead were run according to the following rpm - velocity matrix:

rpm	400; 550; 700; 910 rpm
velocity	0.1; 0.35; 0.55; 0.8 m/s

In bollard pull tests astern the used rpm values are 300 rpm - 900 rpm.
Ice free propulsion tests astern were run according to the following rpm - velocity matrix:

rpm	400; 550; 700; 900 rpm
velocity	0.1; 0.3; 0.5; 0.7 m/s

The results of these tests are presented in APPENDIX F CALIBRATION TESTS

5.1.2 Friction measurements

The surface was treated in accordance with the MARC standard methods. The measured friction coefficient between the surface of the model and the ice was $\mu = 0.059$

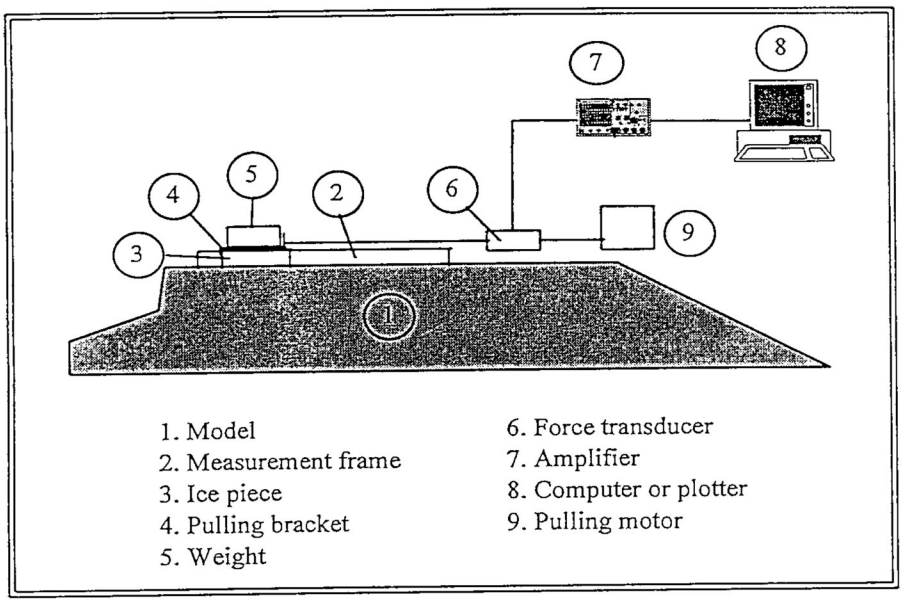


Figure 5-1 Friction measurement scheme

5.2 Level ice

The tests were performed as self propulsion tests, ahead in one ice thickness (1.2 m) and astern in two ice thicknesses (1.2 m and 1.8 m).

The tests were performed with three power levels in every level ice sheet.

The flexural strength corresponds to 600 kPa in full scale.

5.3 Floe ice

After the tests in level ice and the breaking out from own channel, the ice sheet was broken into pieces. the size of the ice floe varied from 1.5 x 1.5 m^2 to 4.5 x 4.5 m^2 (values in full scale). The concentration was in order 90%.

Tests were performed as self propulsion tests with two power levels.

5.4 Breaking out from own channel

After the tests in level ice a test to break out from own channel were performed. The Azipod units were turned into an angle of 35 - 50°, before the test started.

5.5 Ridge

After the tests in level ice and floe ice a ridge were built up and frozen to -20°C*h.
The thicknesses of the ridge in the test when going ahead, corresponds to 15 m. The thicknesses of the ridges when going astern corresponds to 15 m and 20 m.

6. RESULTS

6.1 Level ice

The results are presented in
- Tables 9-1 - 9-2
- Figures 9-1 -9-6
- time histories from the tests in APPENDIX D page D-2 - D-10

The full scale predictions are made for a newly-painted bottom coating and in a condition in which the ice is covered with a thin layer of snow (the snow has been noticed only in the friction coefficient). The friction coefficient factor $C\mu$ is based on the previous model tests with different friction coefficients. The $C\mu$ factor for the model is $C\mu = 1$, corresponding to the measured friction coefficient $\mu = 0.059$.

The ice breaking predictions are based on a power of 28 MW and a estimated bollard pull of 2910 kN ahead and 2580 kN astern.

Ahead
According to the tests the vessel can break 1.2 m thick ice with a speed of 3 m/s (6 kn), when going ahead. The speed dependence of the ice resistance was a bit higher than expected.

Astern
When going astern, the ice resistance was on an expected level, especially in the thinner ice. According to the tests the vessel can break 1.2 m thick ice with a speed of 3 m/s (6 kn) and 1.8 m thick ice with a speed of 1.1 m/s (2.2 kn). The icebreaking capability for the vessel is 1.85 m with a speed of 1 m/s (2 kn).
In the thicker ice, when there sometimes were bigger ice floes they turned against the Azipod bracket and caused a increase of the ice resistance.

6.2 Floe ice

The results are presented in
- Tables 9-3 - 9-4
- Figure 9-7 - 9-10
- time histories from the tests in APPENDIX D, page D-11 - D-16

At low speed the vessel tends to push ice in front of it running astern. The increasing quantity of ice in front of the vessel increases the resistance which decreases the speed. With increasing speed this tendency decreases and the vessel is able to make good progress.
This speed dependant pushing phenomenon causes a negative speed dependence of the ice resistance in floe ice over the rather small tested speed range.
The negative speed dependency is often found when testing vessels with a wide waterline at relatively low speeds.

When going ahead there are no such problems, the floe ice resistance increases with the speed. The vessel do not push ice in front of it and due to that, higher speeds were reached in the tests when going ahead.

6.3 Compressive ice

At the speed 1 m/s (2 kn) the ice resistance in 1.2 m thick level ice is 1105 kN ahead and 1270 kN astern.
When going ahead at this speed the thrust available is 2829 kN leaving 1724 kN to overcome the resistance from the compression of the ice field. This yields 59.6 kN/m for the maximum compressive force with the initial values used.
When going astern at this speed the thrust available is 2437 kN leaving 1167 kN to overcome the resistance from the compression of the ice field. This yields 40.4 kN/m for the maximum compressive force with the initial values used.

6.4 Breaking out from own channel

The results are presented in

- Figures 9-11 - 9-14

When running ahead there was no problems to break out from own channel. The used Azipod angles were 35° and 42°. A distance of 2.3 - 3 ship lengths was needed when breaking out from own channel.

When going astern in the thinner ice (1.2 m), the required distance to break out from own channel was twice that when going ahead and the used Azipod angle was 50°.
In the thicker ice (1.8 m) the model was not able to break out of own channel. The model runs diagonally in the channel making it wider by breaking the edge of the channel with the stern. The stem is unable to break the opposite edge of the channel , this prevents the model from turning out from the channel.

6.5 Ridges

The results are presented in

- Tables 9-5 - 9-6
- Figure 9-15 - 9-17
- time histories from the tests in APPENDIX D, page D-17 - D-22

When going ahead the vessel was not able to move continuously. Three rammings were needed to penetrate a ridge which thickness and length corresponds to 15 m and 240 m in full scale. The rammings started at a distance of 1.1-1.5 ship lengths from the edge of the ridge.
The ridge was profiled to be thinner in the beginning, and because of that the penetration length of the first ramming was about 60% of the ridge. The penetration length of the second ramming was about 25% of the ridge. The third ramming penetrated the rest of the ridge. The ridge resistance was 2.3 to 2.5 times the available net thrust.

Tests astern were made in two ridges with thicknesses corresponding to 15m and 20m and the length to 180m in full scale. According to the tests the vessel is capable to penetrate the ridge more or less continuously. By turning the Azipods to and fro the vessel will break up the ridge

and can penetrate the ridge bit by bit. The required time to penetrate the 20 m thick ridge was about 2.5 times the time to penetrate the 15 m thick ridge.

7. COMPARISON

7.1 Comparison to design criteria

Design criteria for the ship indicates following ice breaking requirements:

- to be able to maintain a speed of 3 knots (1.5 m/s) in the maximum level ice of 8 months of an average year.
- maintain continuous movement in ice ridges with thickness which covers 70% of the ridges.
- maintain continuous movement in ice under compression in more than 50% of ice compression cases.

The criteria that the vessel must achieve a speed of 1.5 m/s in the maximum level ice of 8 months of an average year (1.75 m) was not fulfilled. The ship can achieve a speed of 1.25 m/s (2.5 kn) in 1.75 m thick ice.

The criteria of maintain continuous movement in ridges was fulfilled. When running astern the vessel is able to penetrate 20 m thick ridges without ramming by turning the Azipod units to and fro, when the movement stopped.

Compressive ice tests were not run, but calculations based on the resistance in 1.2 m thick ice with a speed of 1 m/s (2 kn) gives 59.6 kN/m for the maximum compressive force when going ahead the corresponding value when going astern is 40.4 kN/m.

8. CONCLUSIONS

According to the tests the vessel will not fulfil the requirement of level ice breaking capability set by the design criteria.
The vessel is able to break 1.75 m thick level ice with a speed of 1.25 m/s (2.5 kn) when going astern. The required speed is 1.5 m/s (3 kn). The requirements can be fulfilled if the bollard pull astern can be increased 10% or with some improvement of the aft body shape which can decrease the ice resistance with about 10 %.
In 1.2 m thick ice the vessel can achieve a speed of 3 m/s (6 kn) when going ahead as well as when going astern.

In ridges the DAT concept is up to expectations, the benefit from Azipod is obvious. Ridges with thicknesses of 15 - 20 m in full scale can be penetrated without ramming, just by turning the Azipods. When going ahead in a 15 m thick ridge several rammings were needed to penetrate the ridge.

The capability to break out of own channel is better when running ahead. When going astern the stem makes it difficult to turn out of the channel by having problems with breaking the opposite edge of the channel.

9. TABLES AND CHARTS

9.1 Level ice tables

Table 9-1 Level ice resistance; ahead

TEST	v [m/s]	SB rpm	BB rpm	Hi [mm]	Sigmaf [kN]	Rice [N]	Rsigma [N]	Rs+v [N]	Rsigmared [N]	Ricered [N]	Riceredh [N]	Hi (f.sc.) [m]	Sigmaf (f.sc.) [kPa]	V (f.sc.) [m/s]	Rice (f.sc.) [kN]
1	0.546	864.2	876.9	37.71	21.27	86.56	10.10	76.46	9.50	85.96	94.46	1.2	600	3.0	2550.5
2	0.472	763.6	771.1	36.85	21.35	66.99	9.46	57.53	8.86	66.40	75.71	1.2	600	2.6	2044.1
3	0.305	615.8	622.7	36.36	21.42	47.41	9.48	37.93	8.85	46.79	54.50	1.2	600	1.7	1471.5

Table 9-2 Level ice resistance; astern

TEST	v [m/s]	SB rpm	BB rpm	Hi [mm]	Sigmaf [kN]	Rice [N]	Rsigma [N]	Rs+v [N]	Rsigmared [N]	Ricered [N]	Riceredh [N]	Hi (f.sc.) [m]	Sigmaf (f.sc.) [kPa]	V (f.sc.) [m/s]	Rice (f.sc.) [kN]
9	0.477	809.9	819.9	40.93	19.90	69.21	13.17	56.04	13.23	69.28	67.39	1.2	600	2.61	1819.57
10	0.316	695.8	700.3	41.54	19.98	57.09	13.62	43.47	13.63	57.10	54.57	1.2	600	1.73	1473.44
11	0.127	579.7	580.2	42.10	20.05	46.79	14.04	32.75	14.00	46.75	43.97	1.2	600	0.70	1187.16
16	0.183	767.8	761.3	53.27	21.88	80.87	21.13	59.74	19.32	79.06	91.19	1.6	600	1.00	2462.08
17	0.117	701.8	706.7	54.55	21.31	71.95	21.58	50.36	20.26	70.62	79.17	1.6	600	0.64	2137.60
18	0.264	810.3	817.4	56.10	20.75	86.26	21.99	64.27	21.20	85.47	93.25	1.6	600	1.45	2517.66

9.2 Floe ice tables

Table 9-3 Ice resistance in floe ice; ahead

TEST	v [m/s]	SB rpm	BB rpm	Hi [mm]	Rice [N]	Riceredh [N]	Hi (f.sc.) [m]	V (f.sc.) [m/s]	Rice (f.sc.) [kN]
6	0.57	566.6	577.9	37.28	20.46	21.96	1.2	3.12	592.86
7	0.44	479.3	493.7	36.75	15.48	16.84	1.2	2.41	454.80

Table 9-4 Ice resistance in floe ice; astern

TEST	v [m/s]	SB rpm	BB rpm	Hi [mm]	Rice [N]	Riceredh [N]	Hi (f.sc.) [m]	V (f.sc.) [m/s]	Rice (f.sc.) [kN]
13	0.535	640.6	646	41.5	31.07	29.95	1.2	2.93	808.66
14a	0.406	557.5	555.8	41.82	25.99	24.85	1.2	2.22	671.06
14b	0.263	533	537.6	41.82	31.53	30.16	1.2	1.44	814.21
20	0.453	617.3	611.2	53.64	32.08	35.89	1.8	2.48	968.90
21a	0.311	558.4	556.9	55.33	32.17	34.89	1.8	1.70	941.95
21b	0.233	547	551.1	55.33	35.47	38.46	1.8	1.28	1038.47

9.3 Ridge tables

Table 9-5 Ridge ahead; ramming data

Comments	Ram 1	Ram 2	Ram 3
Vo [m/s]	0.771	0.85	0.86
Average speed during ramming [m/s]	0.388	0.5	0.54
Penetration [m]	148.5	61.5	30 (through)
Hr average [m]	9.9	14.16	13.65
Resistance [kN]	6877.7	7445.0	7125.3

Table 9-6 Ridge resistance astern

TEST	v [m/s]	SB rpm	BB rpm	Hr average [mm]	Rridge [N]	Hr average (f.sc.) [m]	V (f.sc.) [m/s]	Rice (f.sc.) [kN]
15	0.015	785.8	780.3	488	97.26	14.64	0.082	2626.1
22	0.006	767	757.5	628	92.72	18.84	0.036	2503.4

9.4 Level ice charts

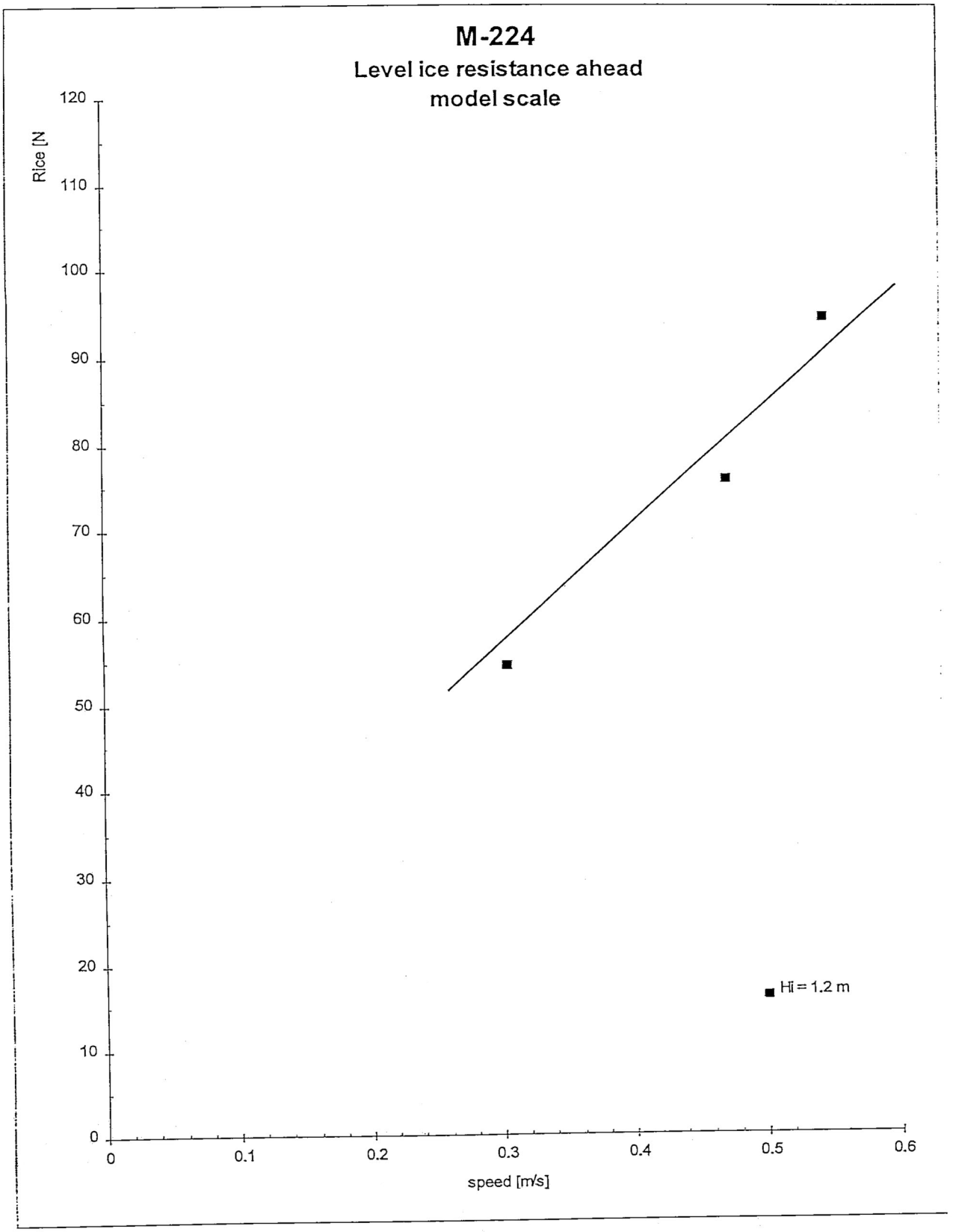


Figure 9-1 Level ice resistance, ahead model scale

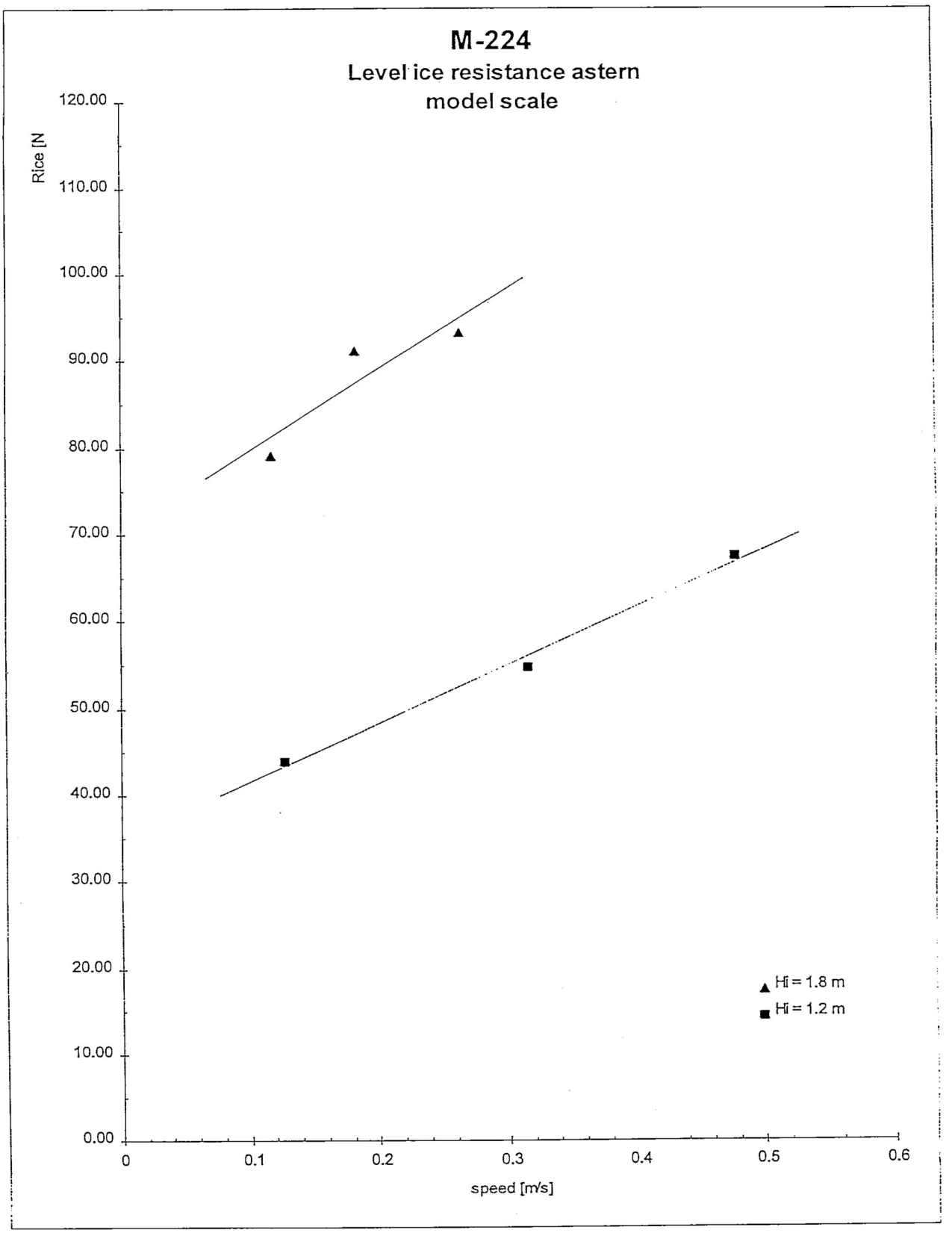


Figure 9-2 Level ice resistance; astern, model scale

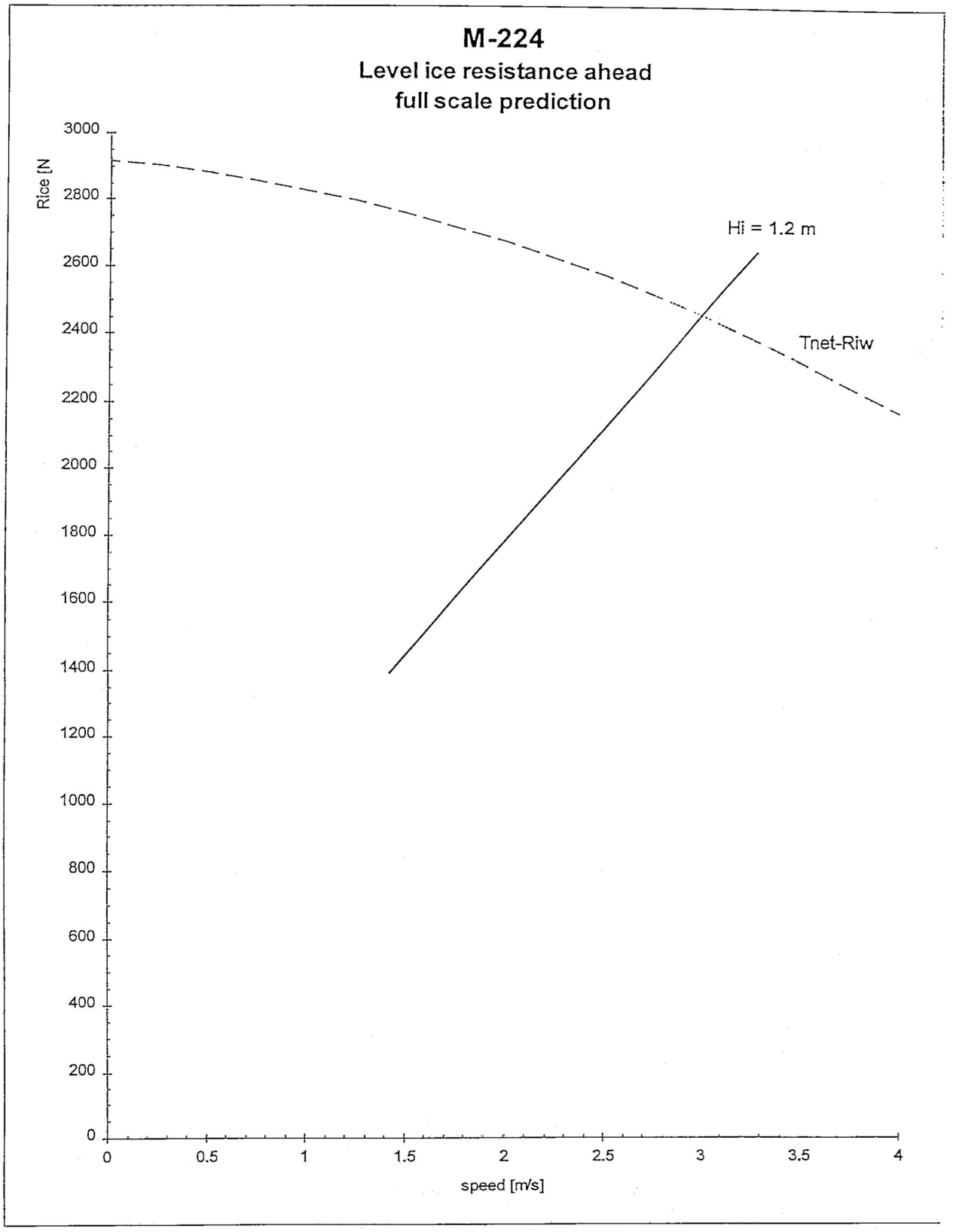


Figure 9-3 Level ice resistance; ahead full scale prediction

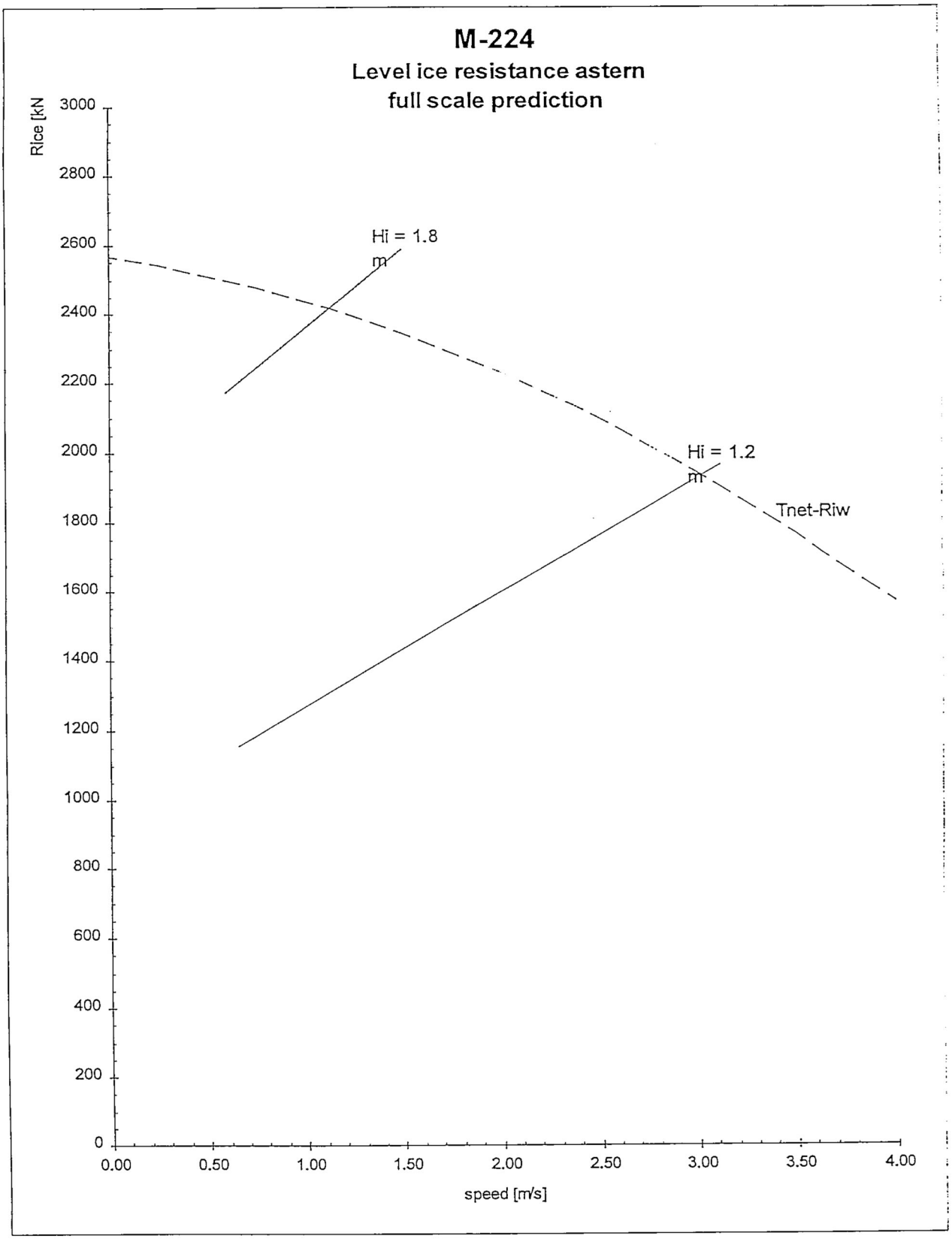


Figure 9-4 Level ice resistance; astern full scale prediction

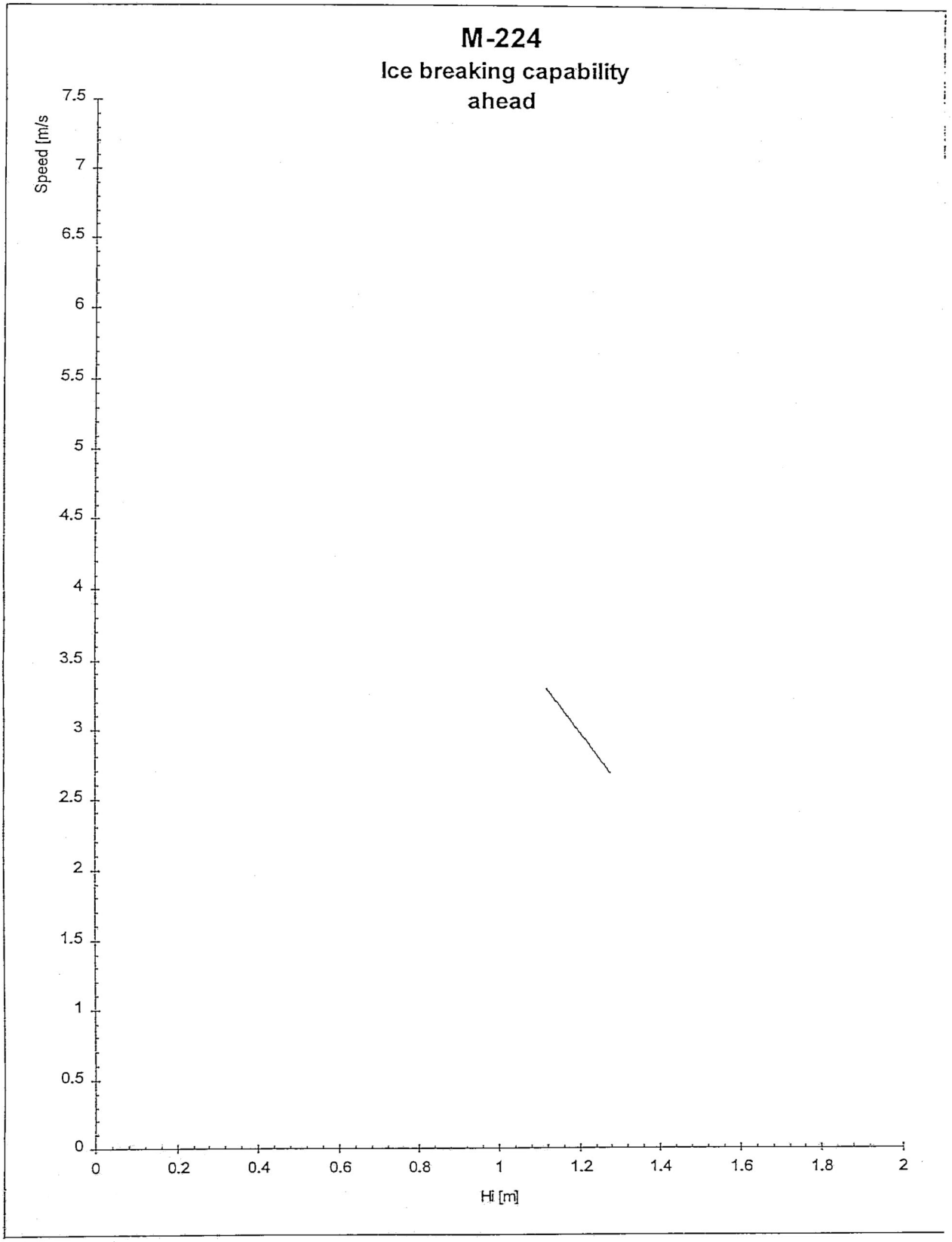


Figure 9-5 Ice breaking capability; ahead

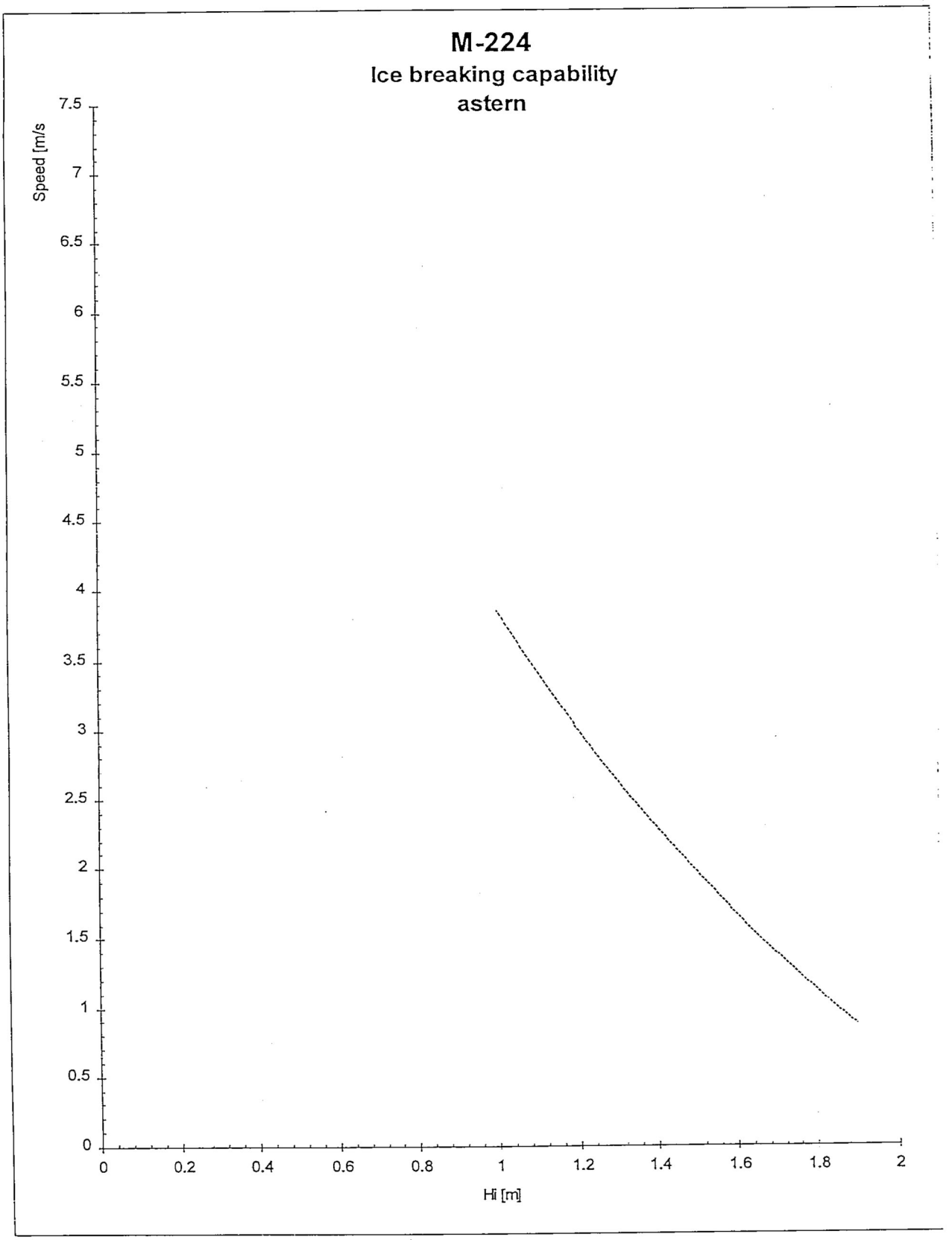


Figure 9-6 Ice breaking capability; astern

9.5 Floe ice charts

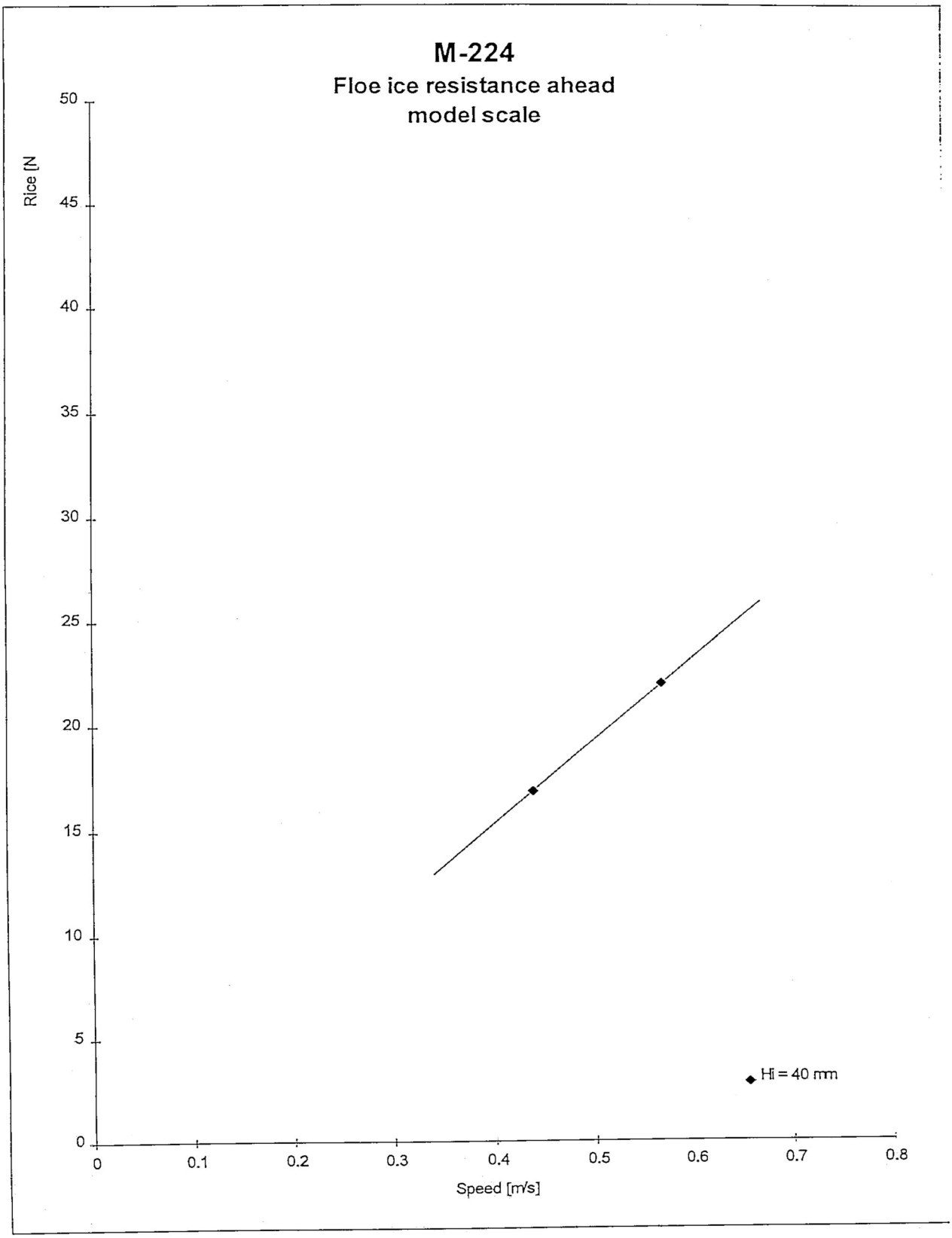


Figure 9-7 Floe ice resistance; ahead model scale

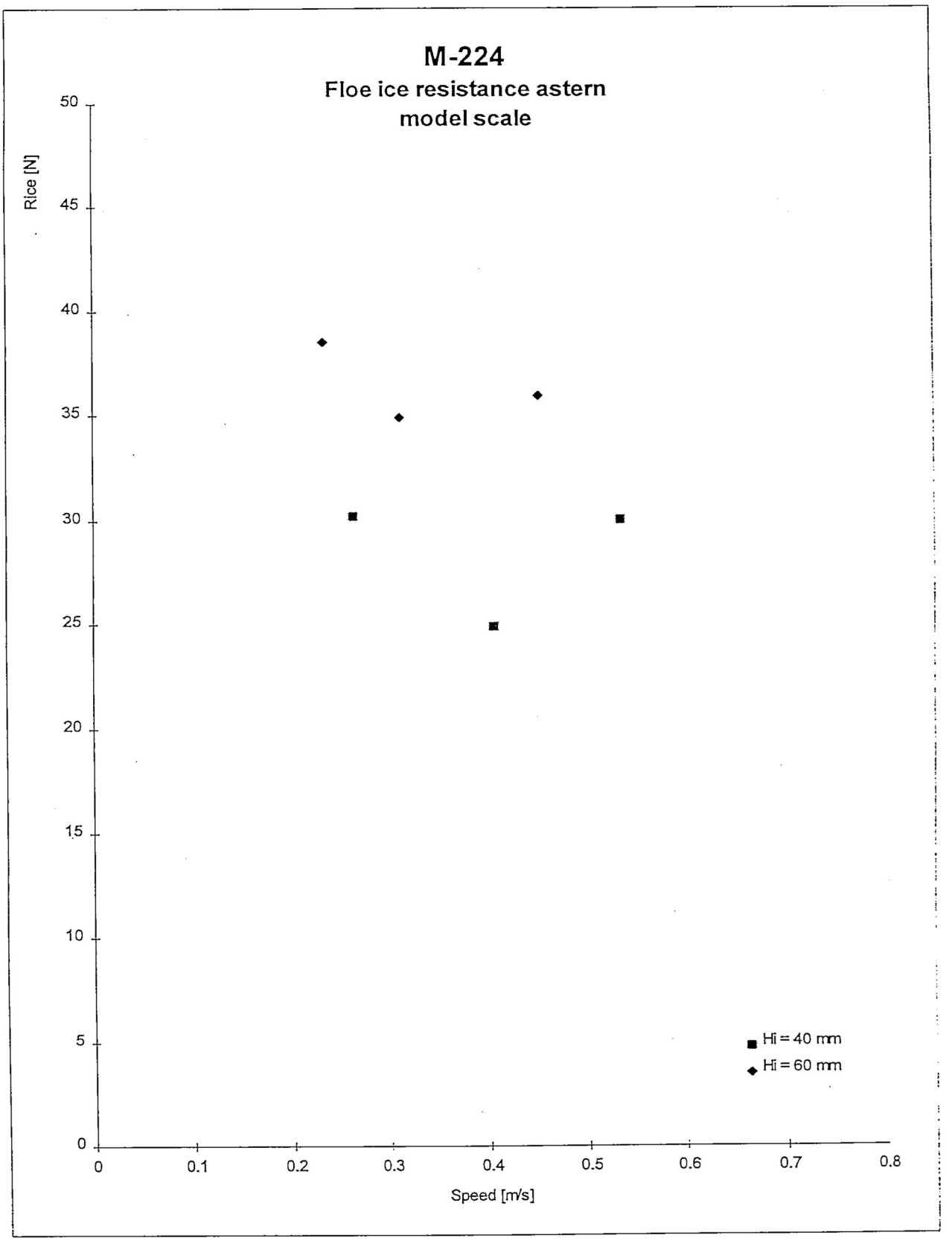


Figure 9-8 Floe ice resistance; astern model scale

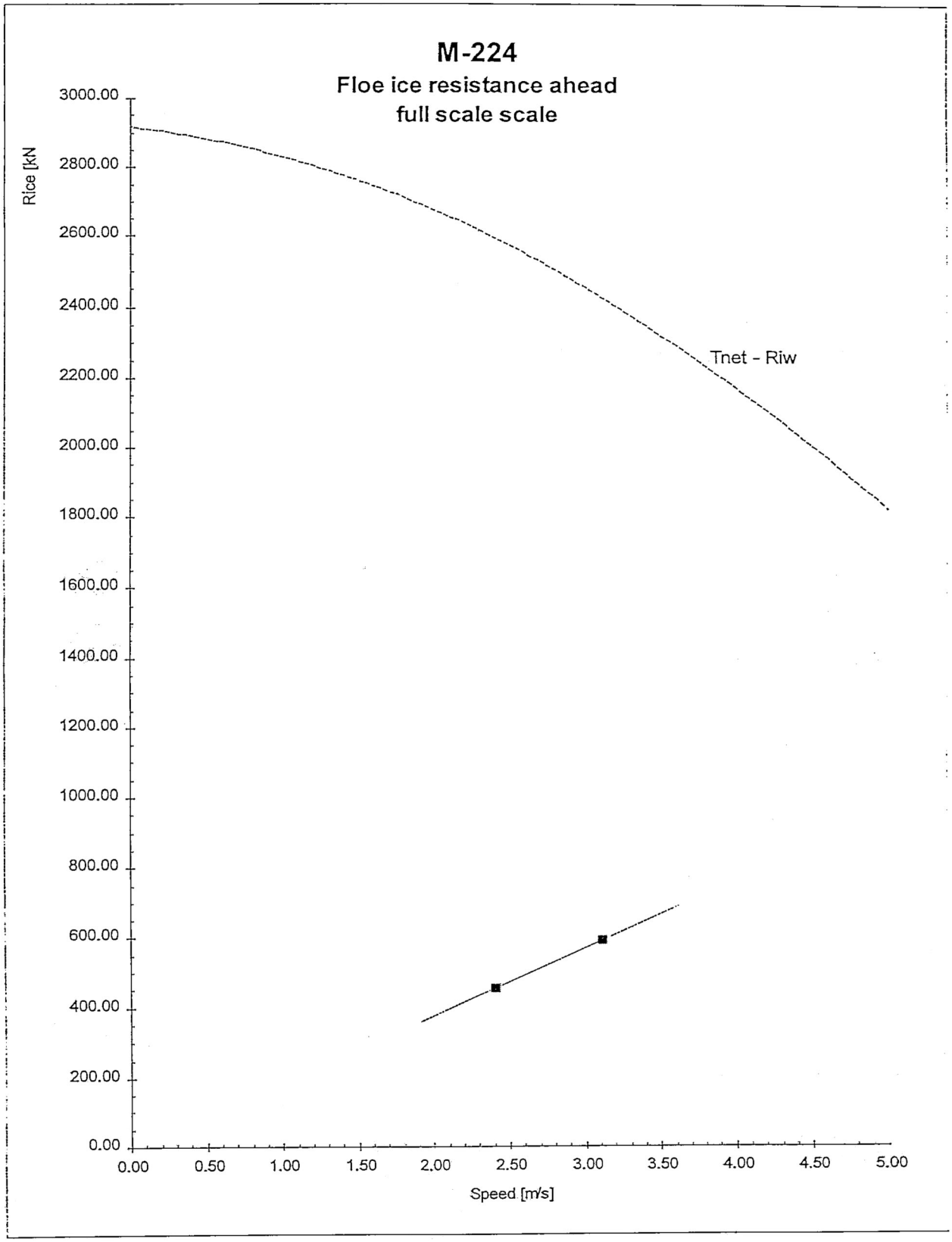


Figure 9-9 Ice resistance in floe ice ahead; full scale prediction

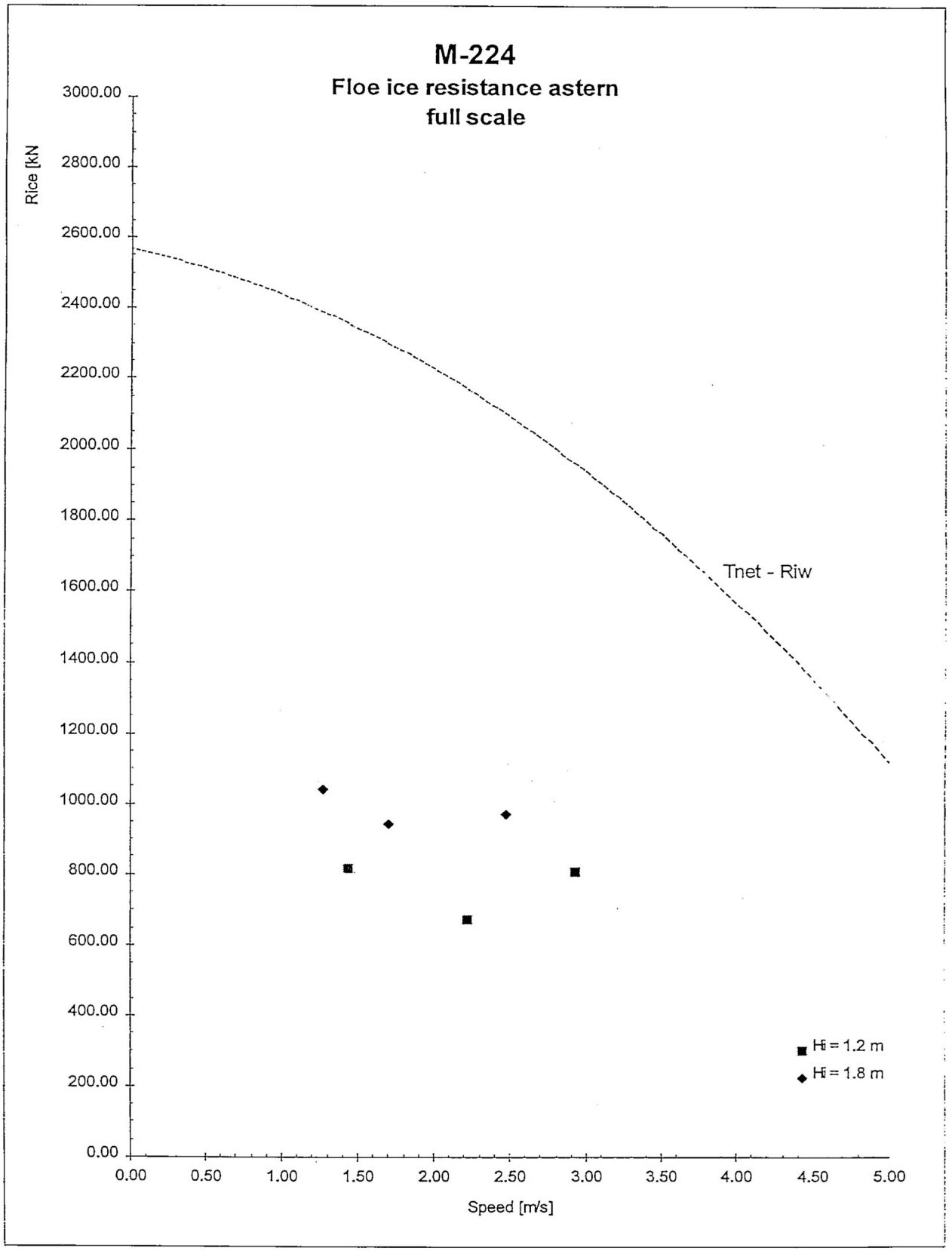


Figure 9-10 Ice resistance in floe ice astern; full scale prediction

9.6 Breaking out from own channel charts

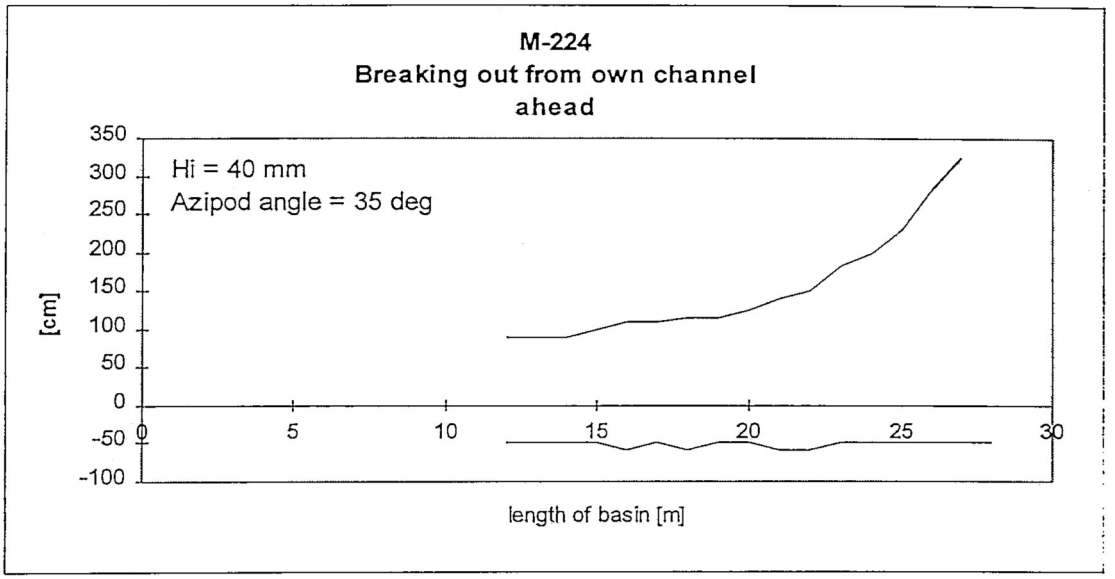


Figure 9-11 Breaking out from own channel; ahead

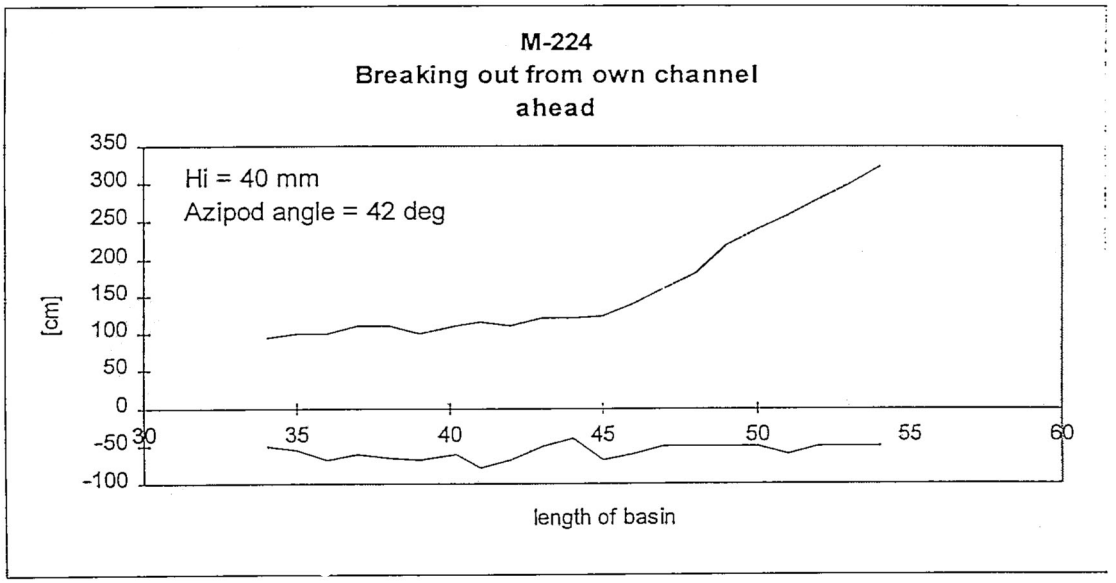


Figure 9-12 Breaking out from own channel; ahead

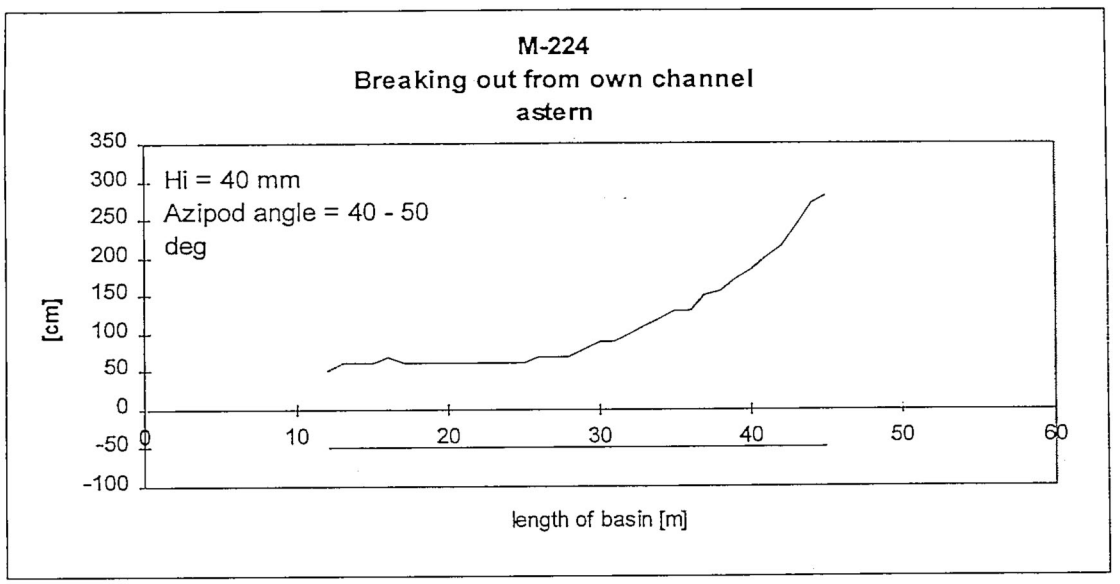


Figure 9-13 Breaking out from own channel; astern Hi = 40 mm

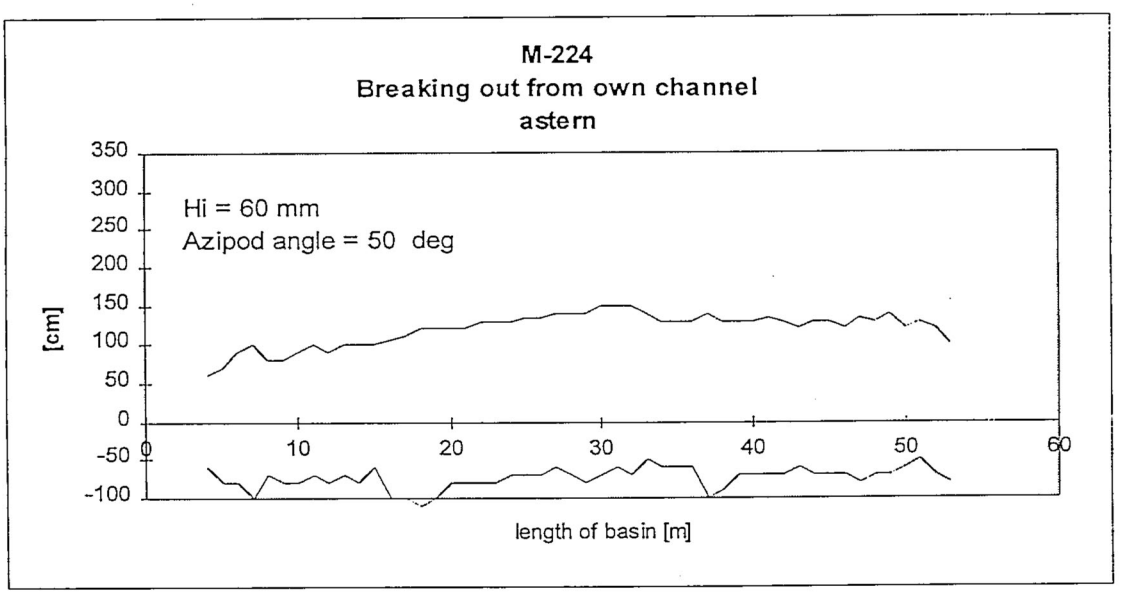


Figure 9-14 Breaking out from own channel; astern Hi = 60 mm

9.7 Ridge charts

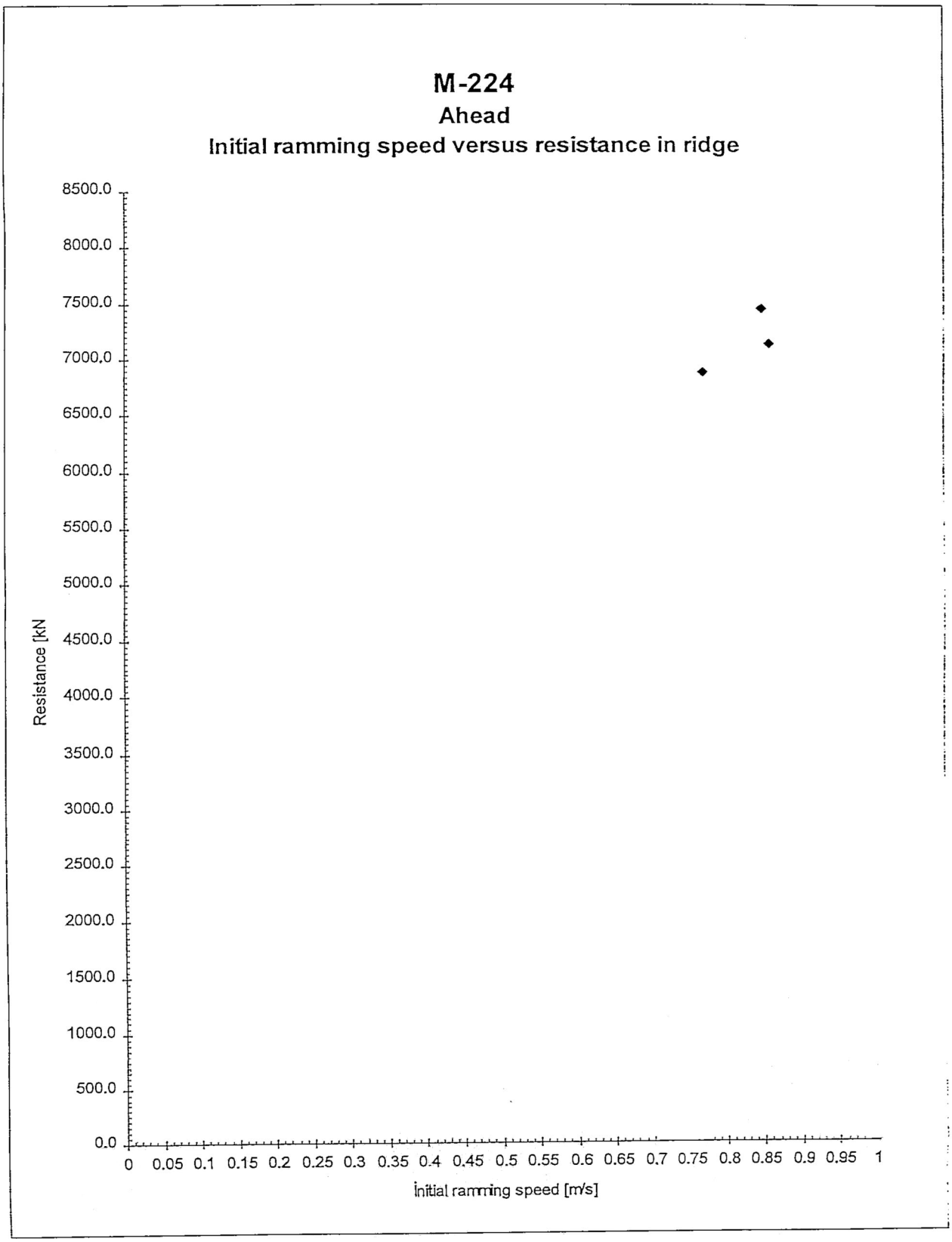


Figure 9-15 Initial ramming speed versus resistance in ridge; ahead

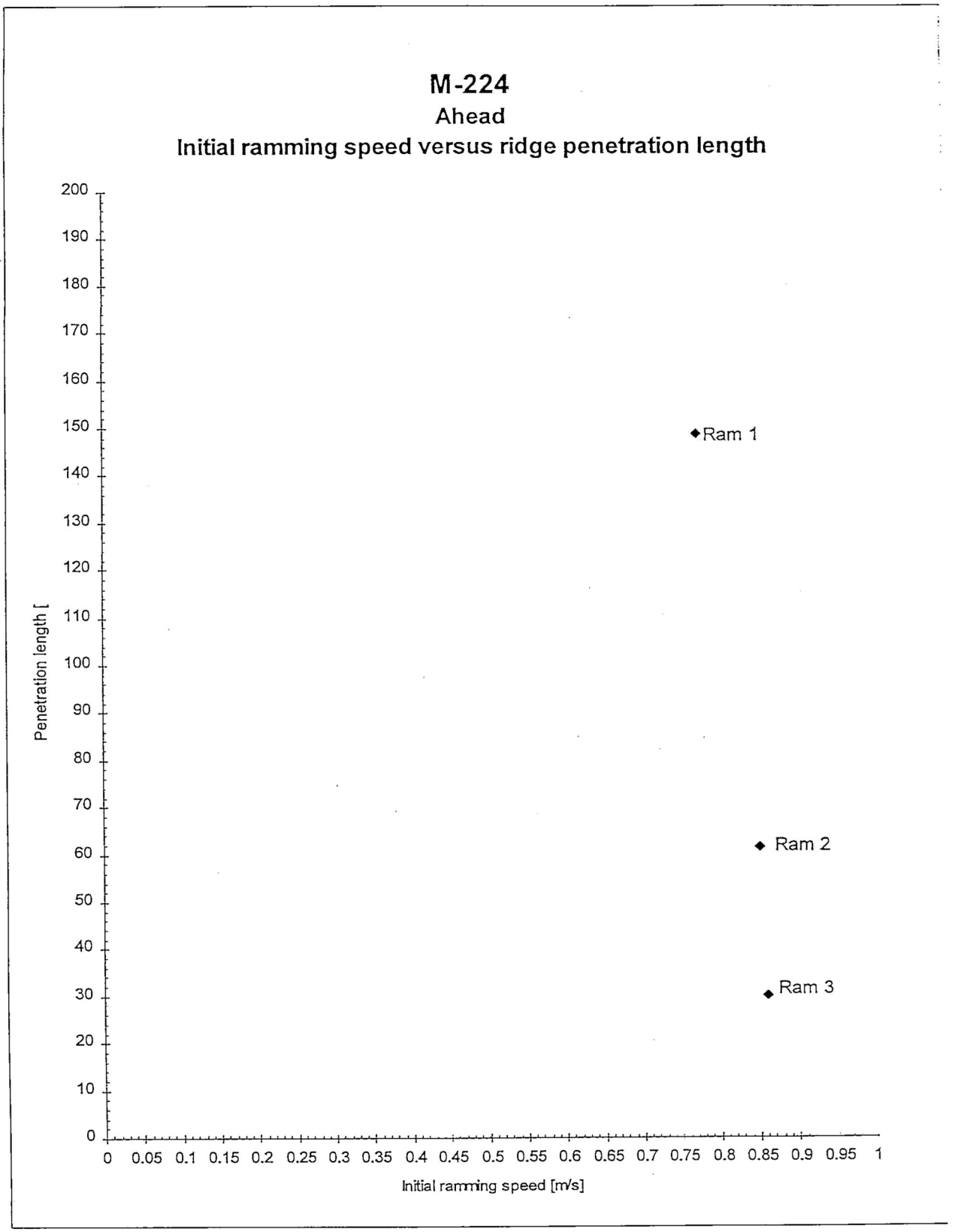


Figure 9-16 Initial ramming speed versus ridge penetration length; ahead

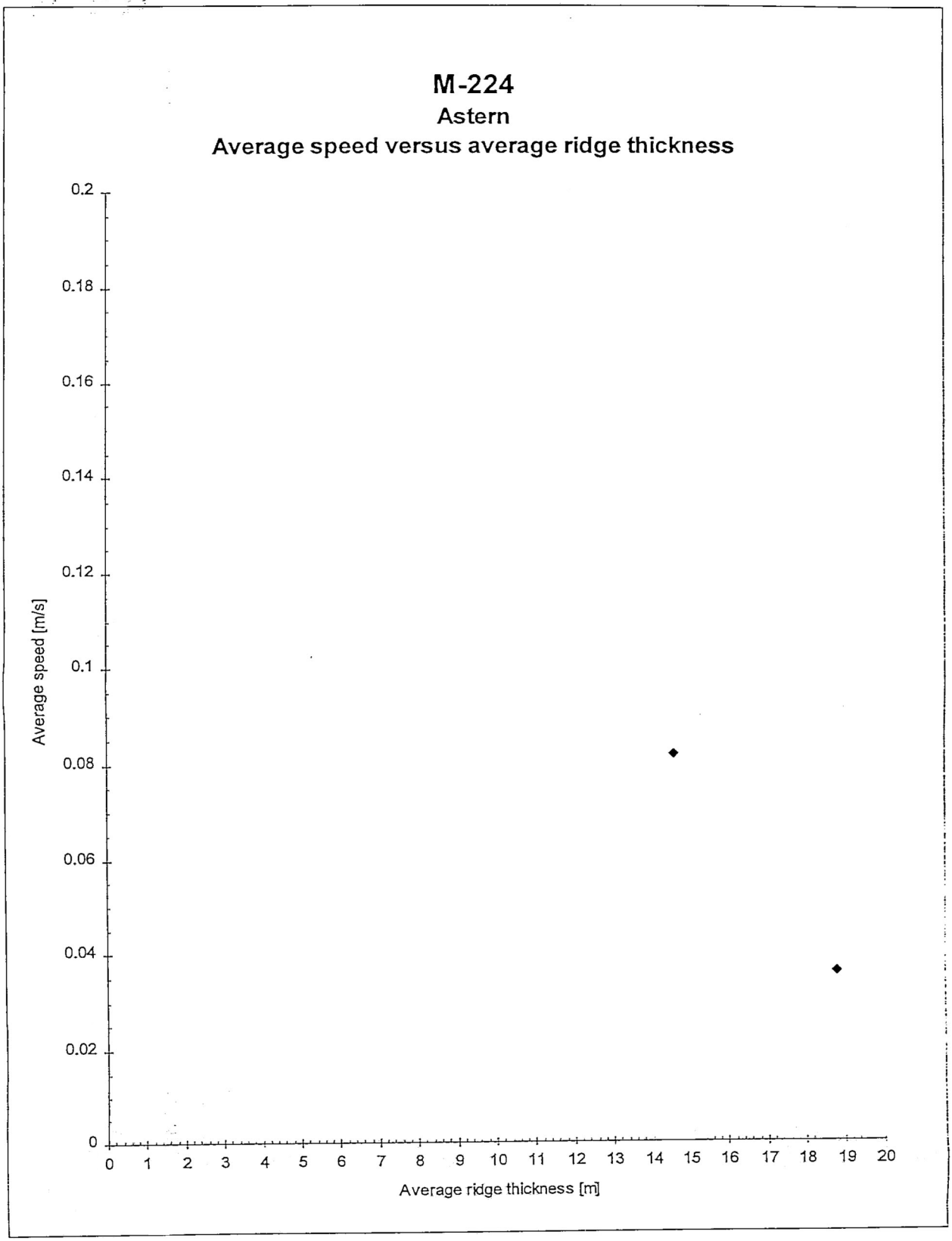


Figure 9-17 Average speed versus average ridge thickness; astern

Appendices

9.7.1.1.1.1.1.1.1 Test program

9.7.1.1.1.1.1.1.2 Ice data

9.7.1.1.1.1.1.1.3 Model drawings

9.7.1.1.1.1.1.1.4 Photographs

9.7.1.1.1.1.1.1.5 WARC report D-66

9.7.1.1.1.1.1.1.6 Calibration test data

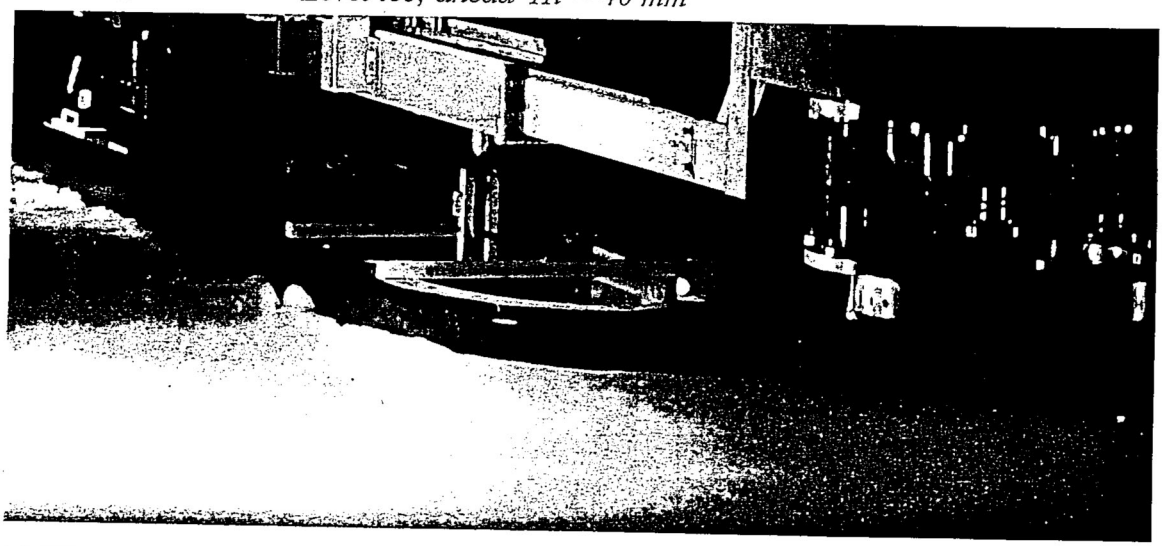
9.7.1.1.1.1.1.1.7 Time histories

Appendix A Photographs

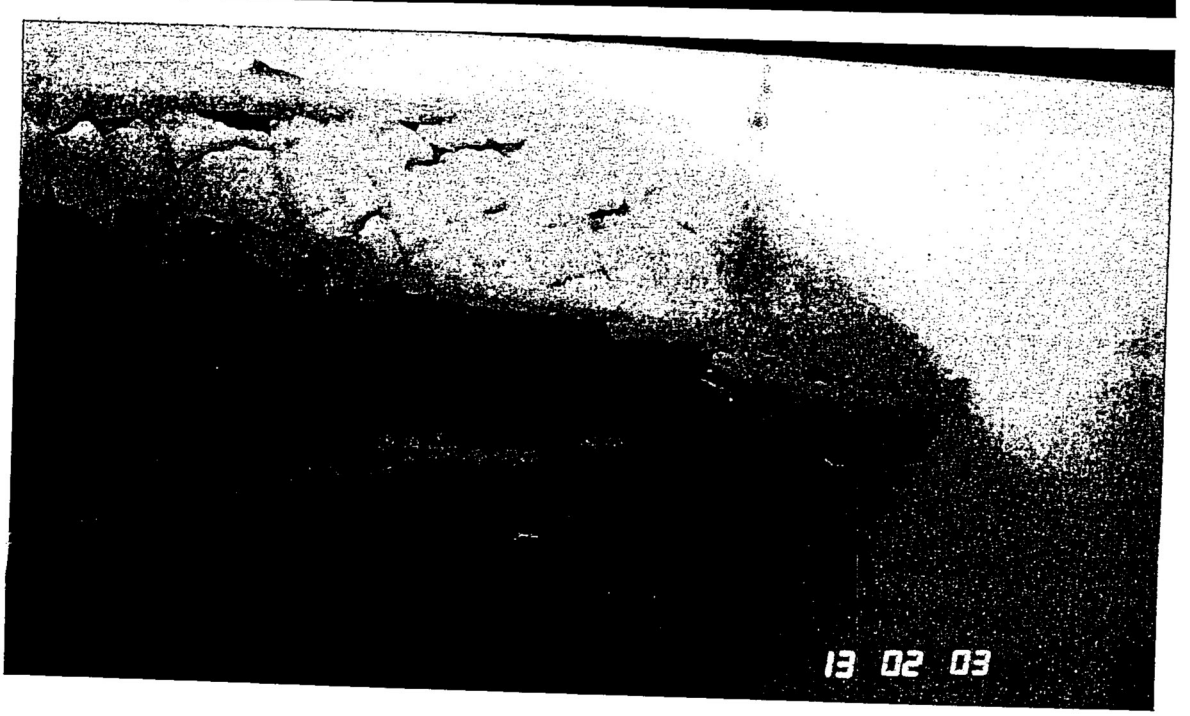
LIST OF CONTENT

TEST 1	*Level ice; ahead Hi = 40 mm*	A-2
TEST 2	*Level ice; ahead Hi = 40 mm*	A-3
TEST 3	*Level ice; ahead Hi = 40 mm*	A-4
TEST 9	*Level ice; astern Hi = 40 mm*	A-5
TEST 10	*Level ice; astern Hi = 40 mm*	A-6
TEST 11	*Level ice; astern Hi = 40 mm*	A-7
TEST 16	*Level ice; astern Hi = 60 mm*	A-8
TEST 17	*Level ice; astern Hi = 60 mm*	A-9
TEST 18	*Level ice; astern Hi = 60 mm*	A-10
TEST 4	*Breaking out of own channel; ahead Hi = 40 mm*	A-11
TEST 5	*Breaking out of own channel; ahead Hi = 40 mm*	A-12
TEST 12	*Breaking out of own channel; astern Hi = 40 mm*	A-13
TEST 19	*Breaking out of own channel; astern Hi = 60 mm*	A-14
TEST 6	*Floe ice; ahead Hi = 40 mm*	A-15
TEST 7	*Floe ice; ahead Hi = 40 mm*	A-16
TEST 13	*Floe ice; astern Hi = 40 mm*	A-17
TEST 14	*Floe ice; astern Hi = 40 mm*	A-18
TEST 20	*Floe ice; astern Hi = 60 mm*	A-19
TEST 21	*Floe ice; astern Hi = 60 mm*	A-20
TEST 8	*Ridge; ahead Hi = 15 m (f.sc.)*	A-21
TEST 15	*Ridge; astern Hi = 15 m (f.sc.)*	A-22
TEST 22	*Ridge; astern Hi = 20 m (f.sc.)*	A-23

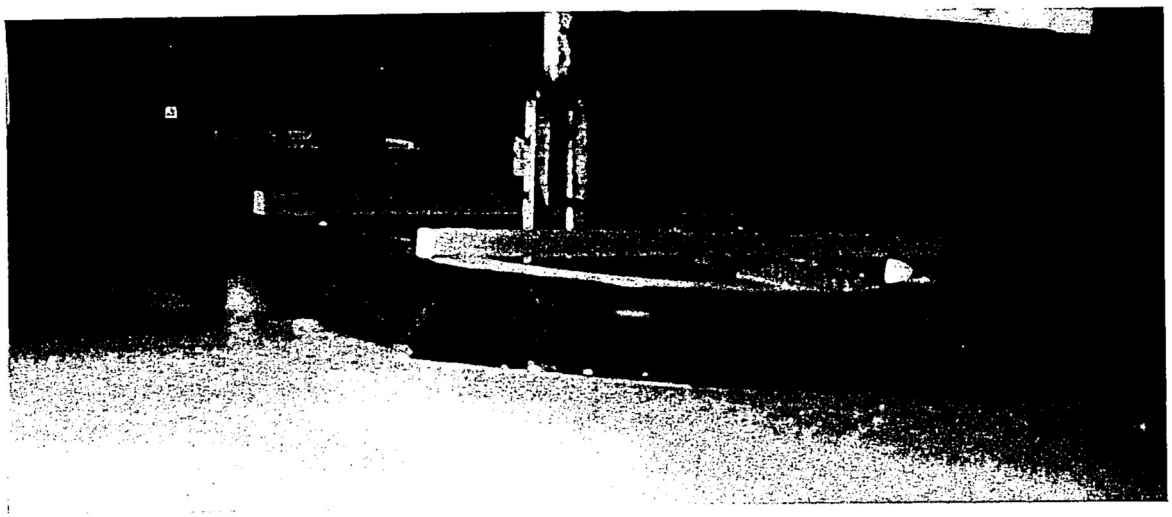
TEST 1 *Level ice; ahead Hi = 40 mm*



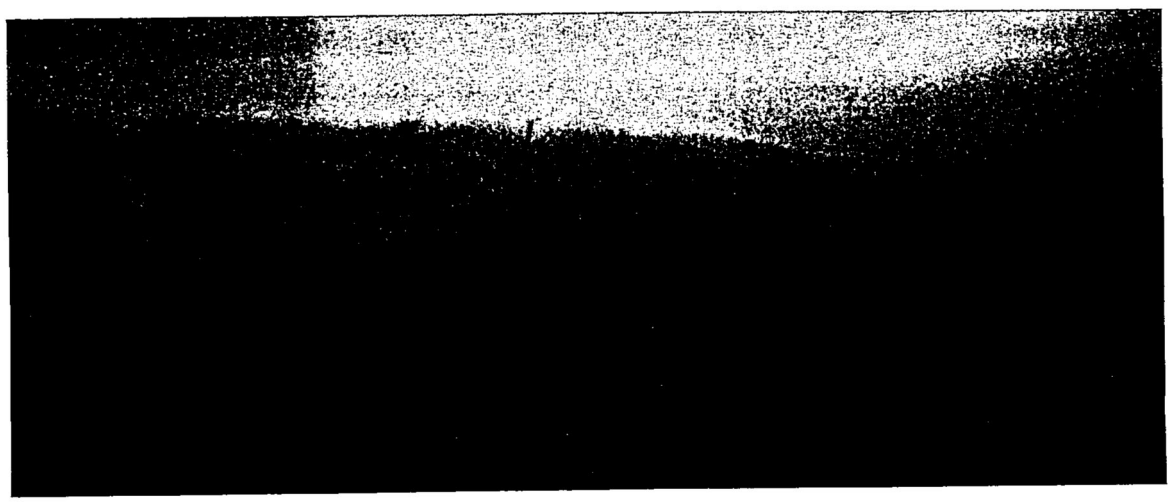




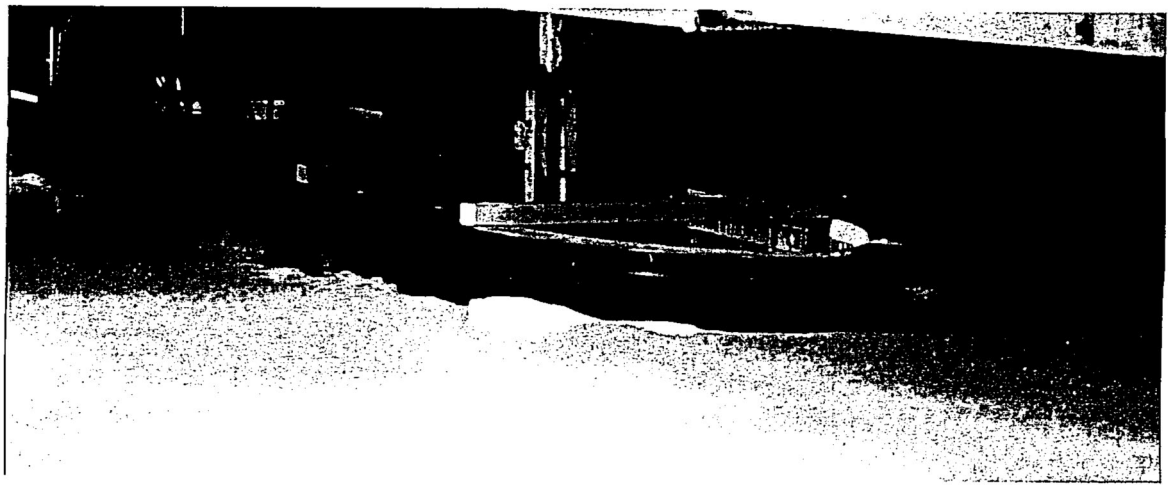
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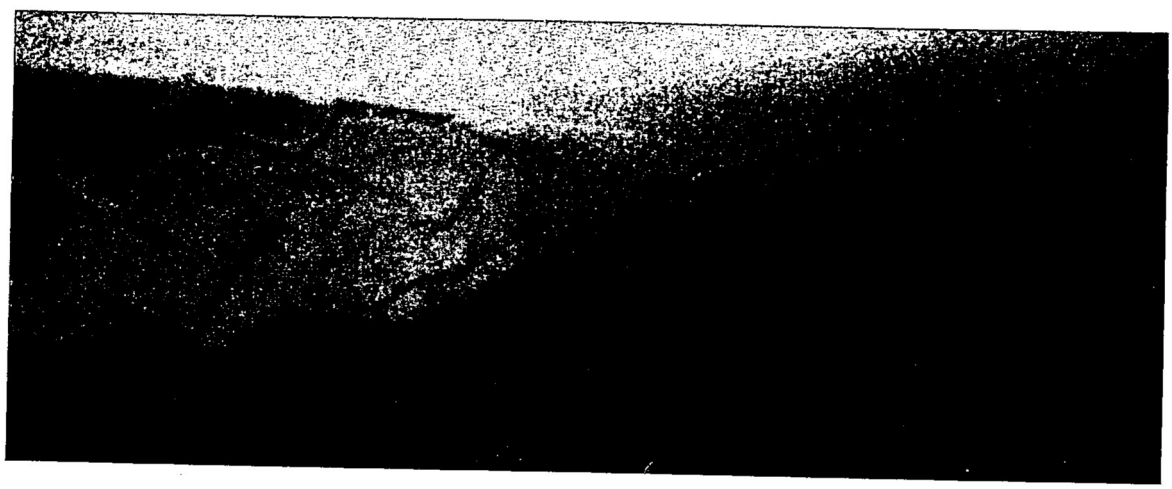






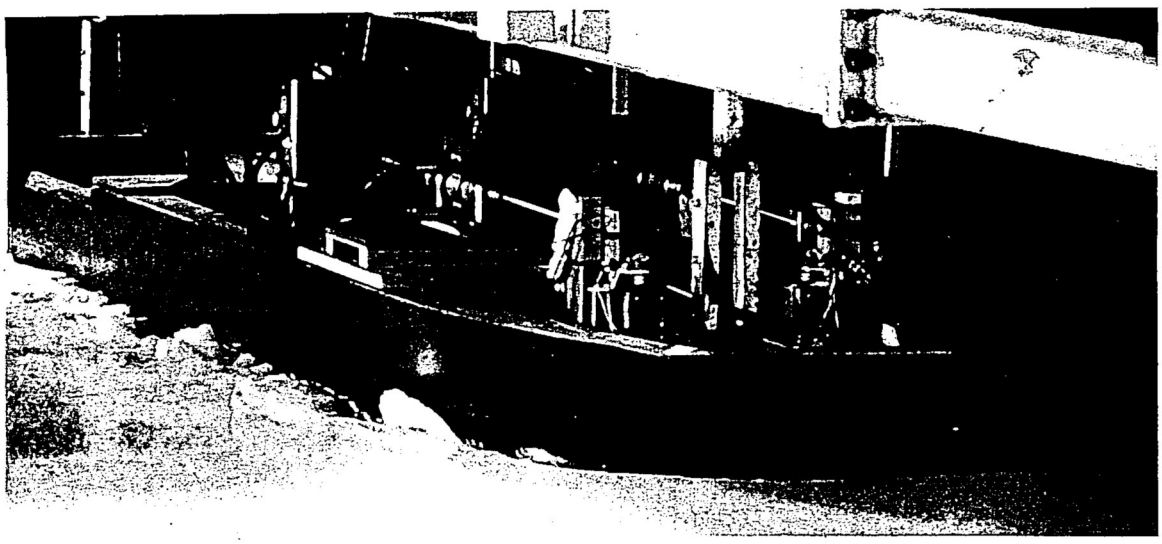
TEST 3 *Level ice; ahead Hi = 40 mm*







TEST 9 *Level ice; astern Hi = 40 mm*







TEST 10 *Level ice; astern Hi = 40 mm*







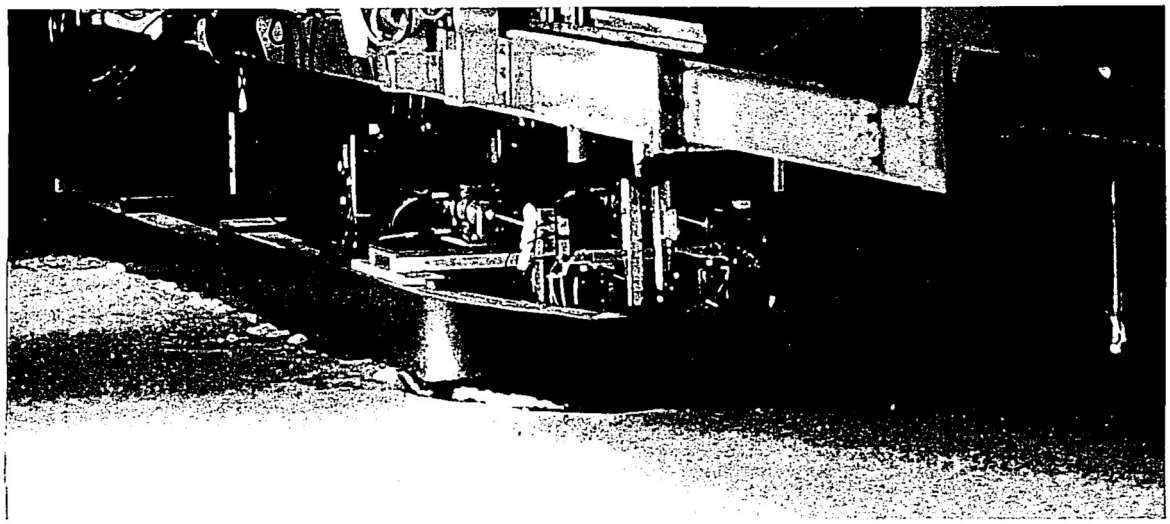
TEST 11 *Level ice; astern Hi = 40 mm*







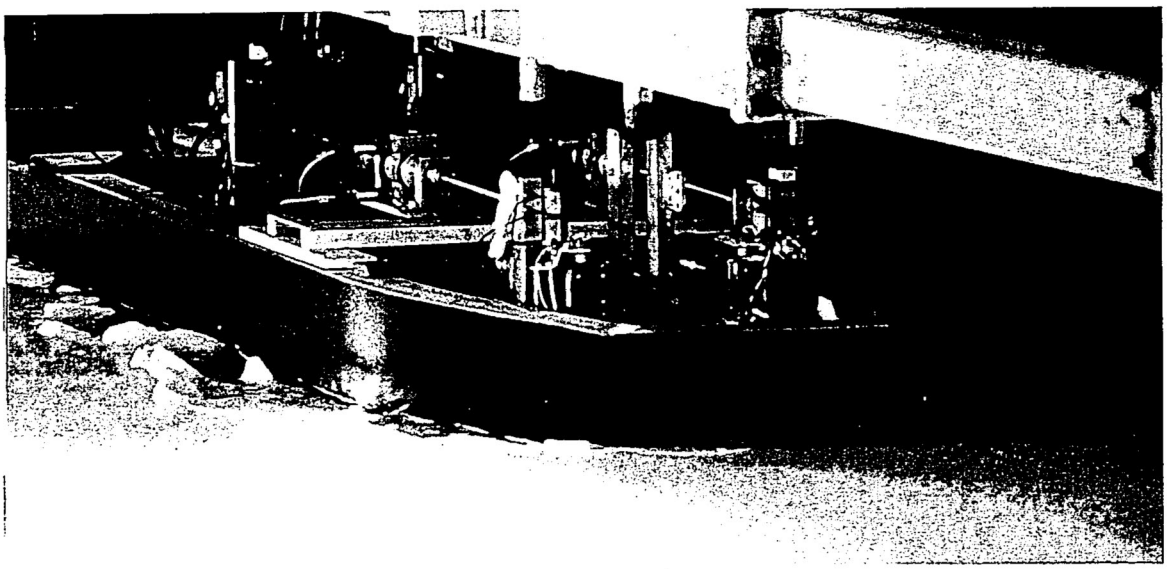
TEST 16 *Level ice; astern Hi = 60 mm*







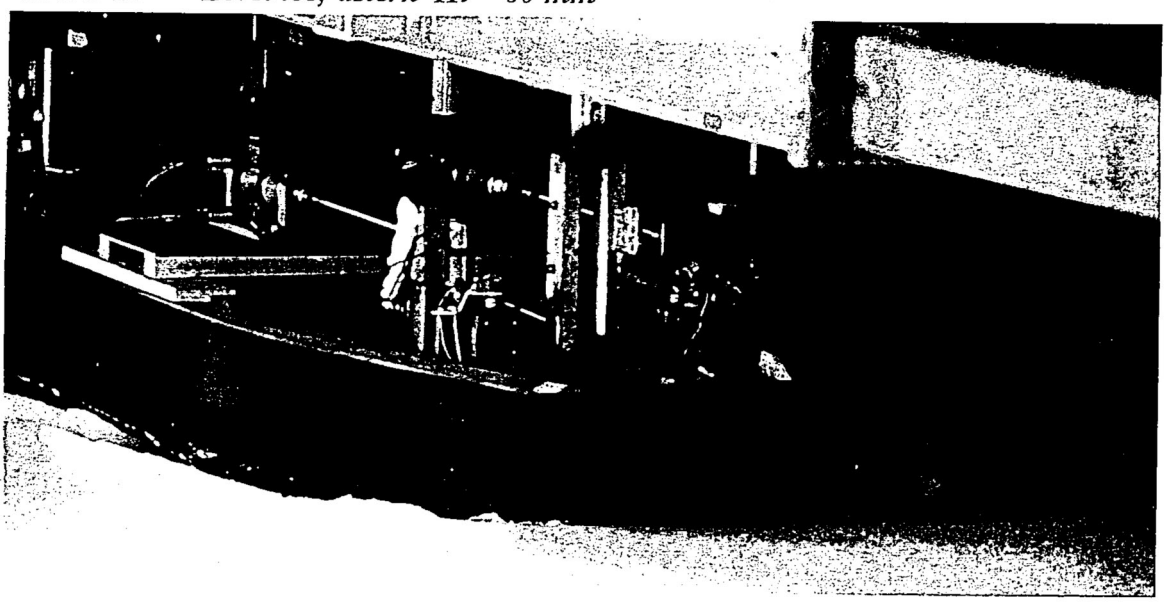
TEST 17 *Level ice; astern Hi = 60 mm*



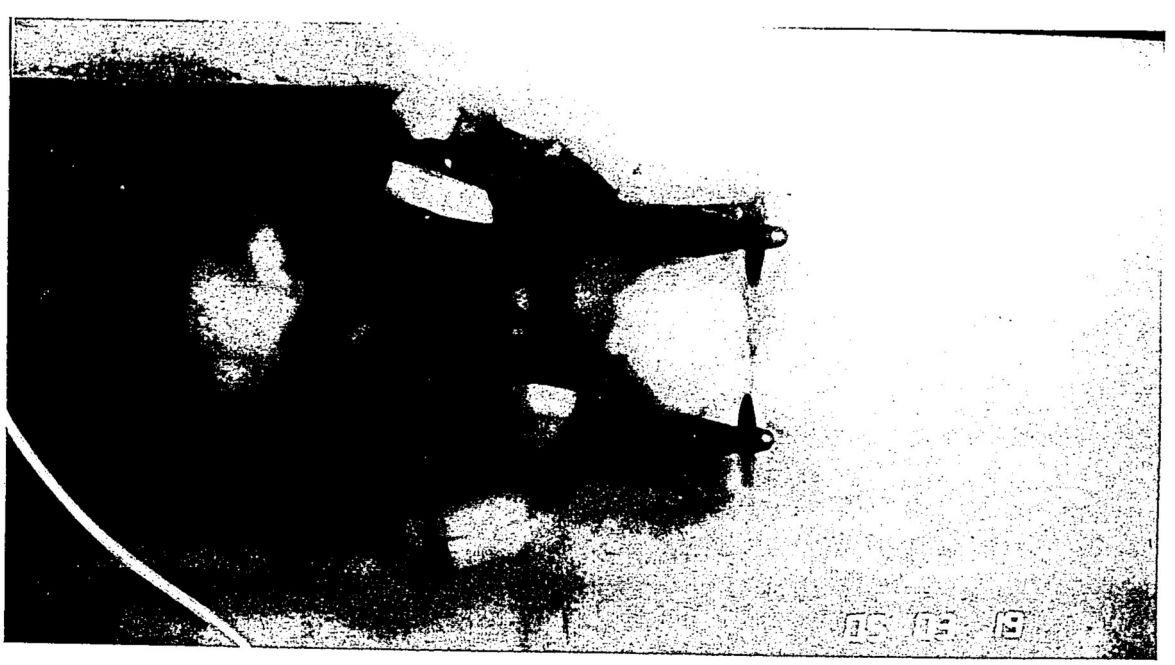




TEST 18 *Level ice; astern Hi = 60 mm*



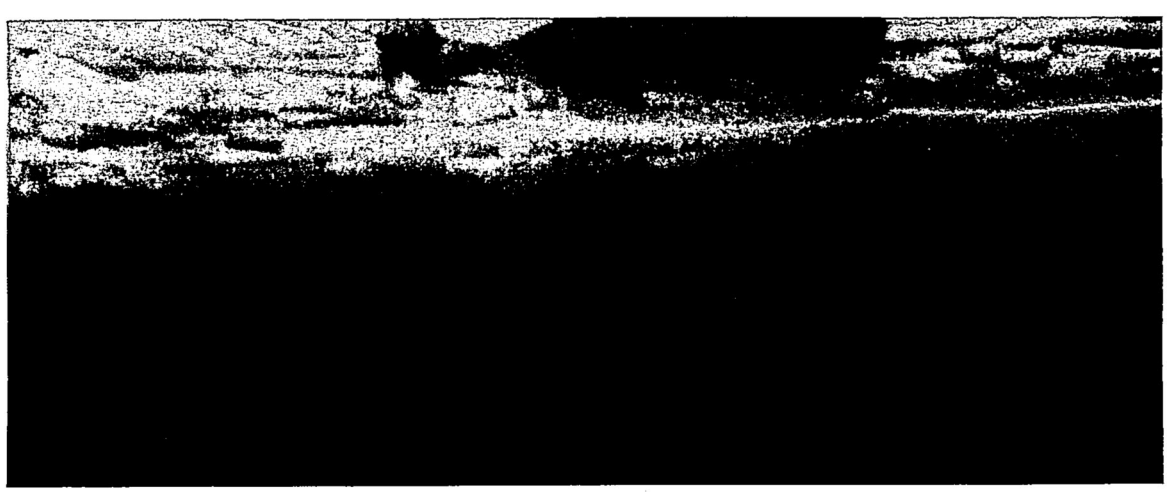




TEST 4 *Breaking out of own channel; ahead Hi = 40 mm*

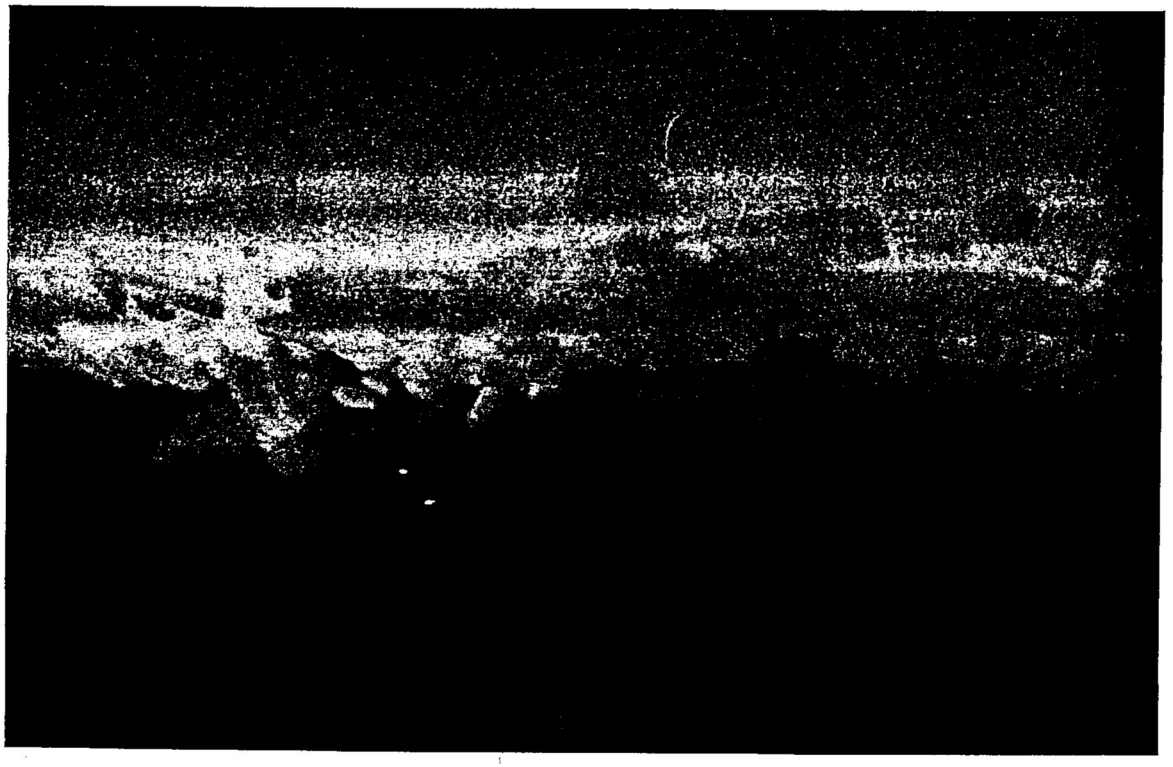






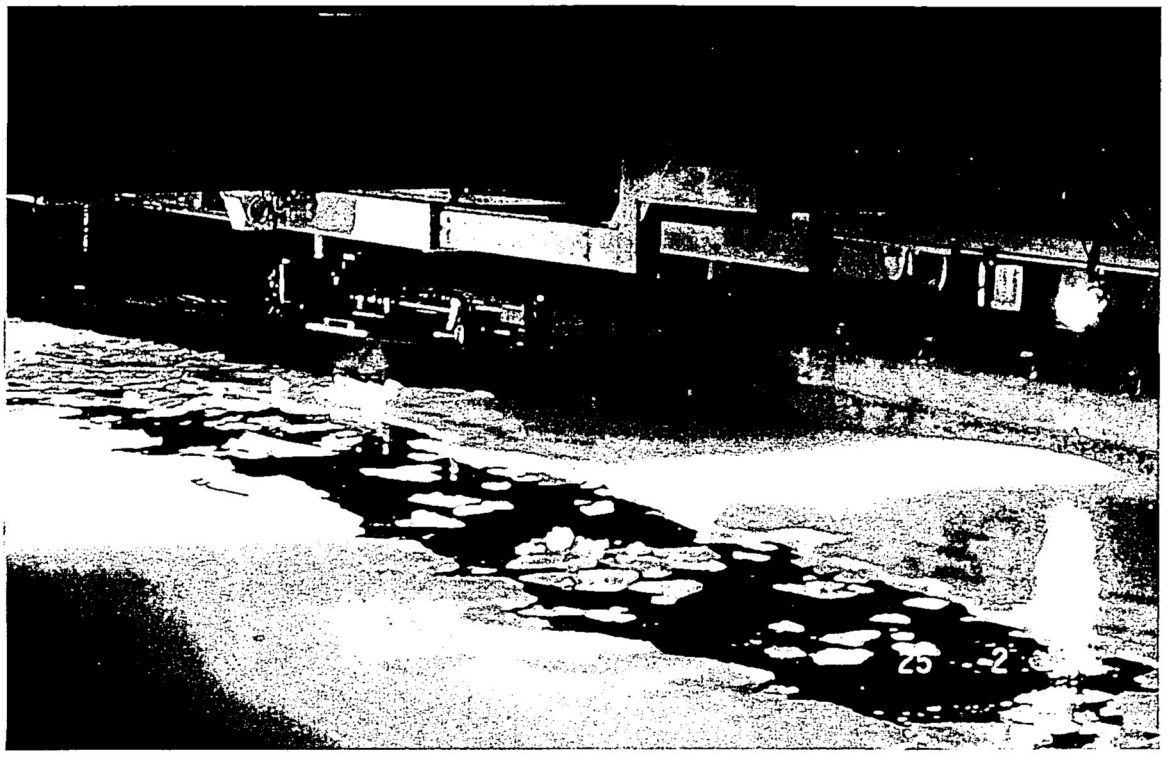
TEST 5 *Breaking out of own channel; ahead Hi = 40 mm*





TEST 12 *Breaking out of own channel; astern Hi = 40 mm*



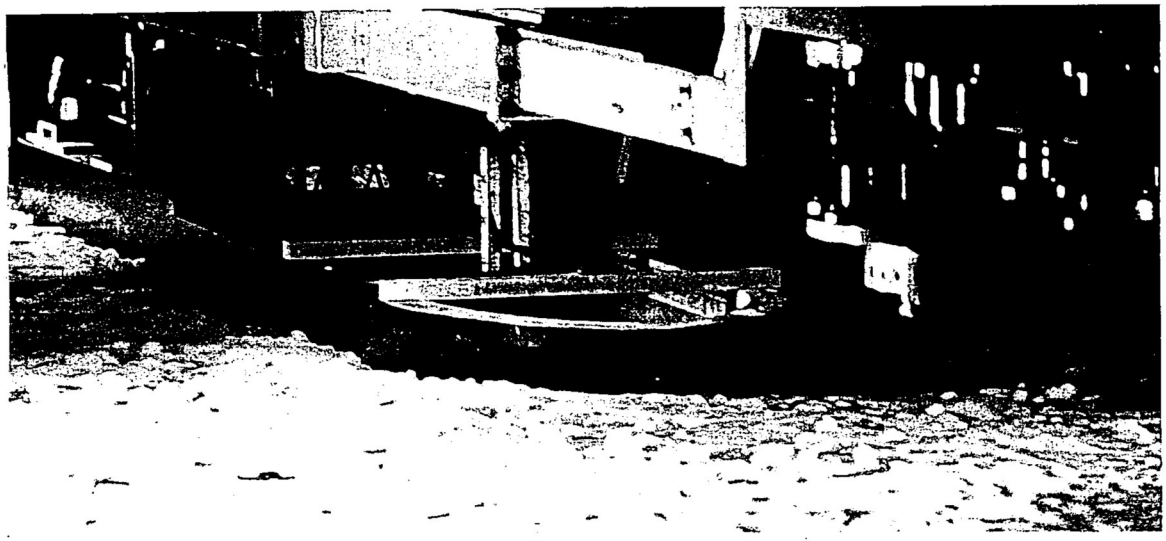


TEST 19 *Breaking out of own channel; astern Hi = 60 mm*

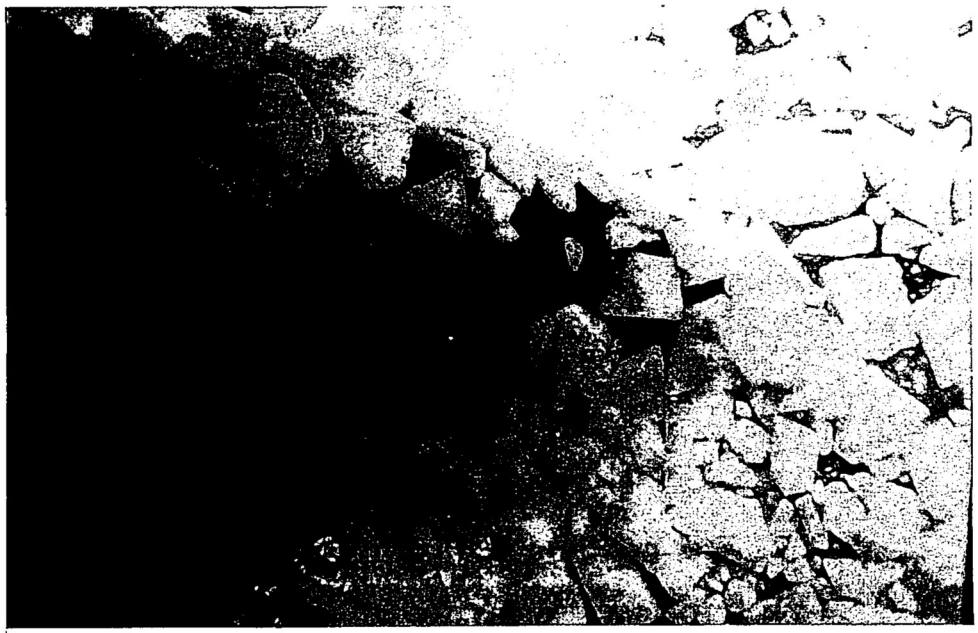




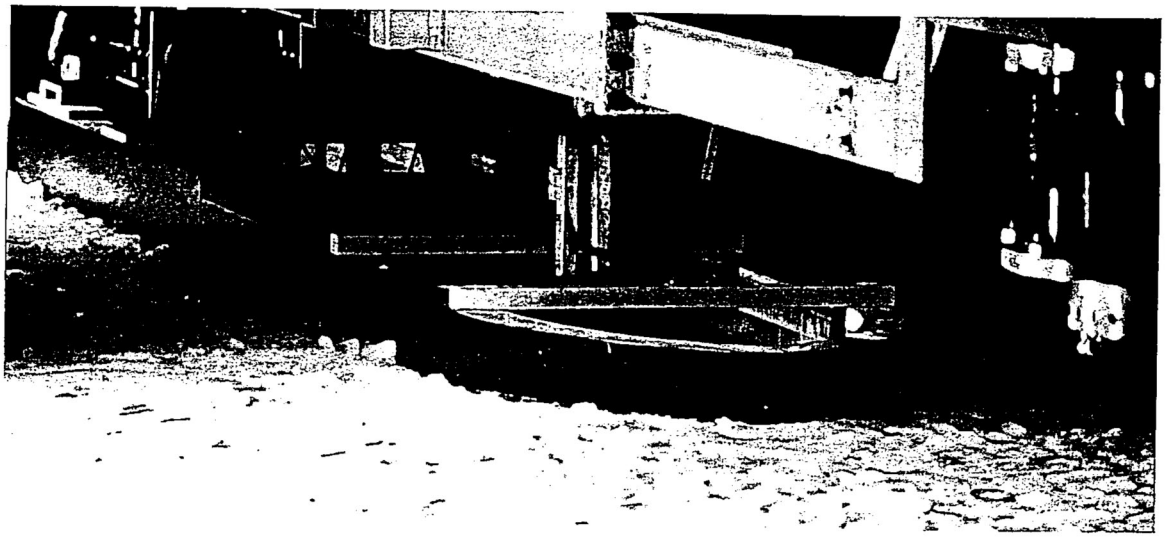
TEST 6 *Floe ice; ahead Hi = 40 mm*



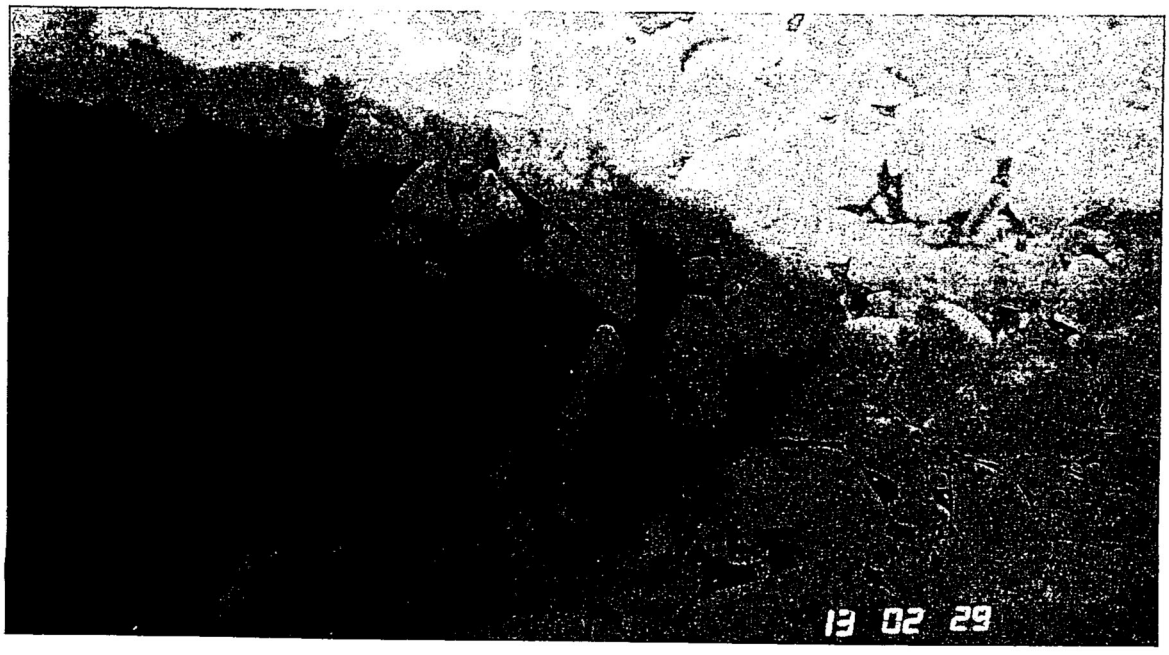




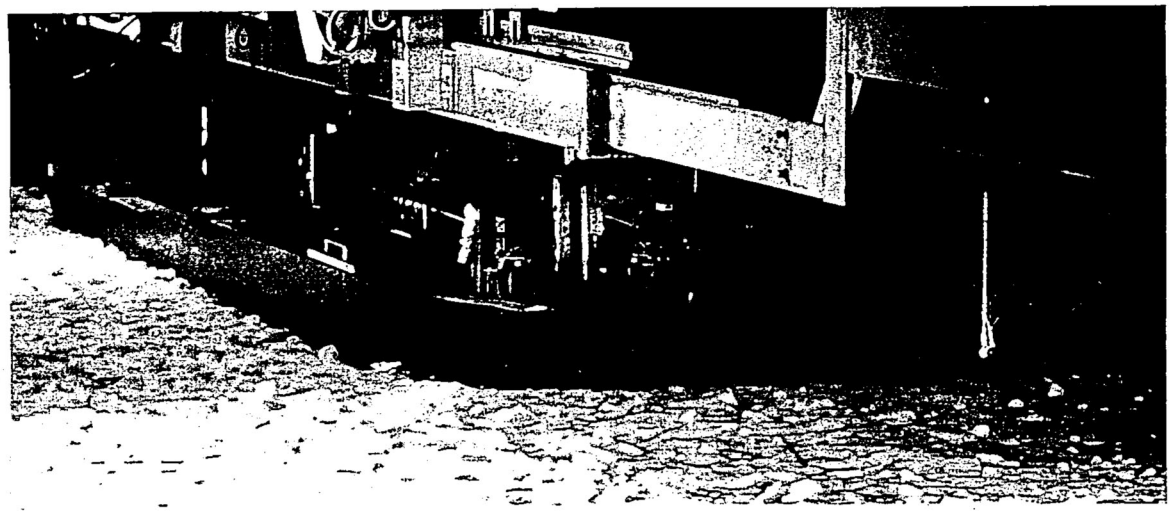
TEST 7 *Floe ice; ahead Hi = 40 mm*

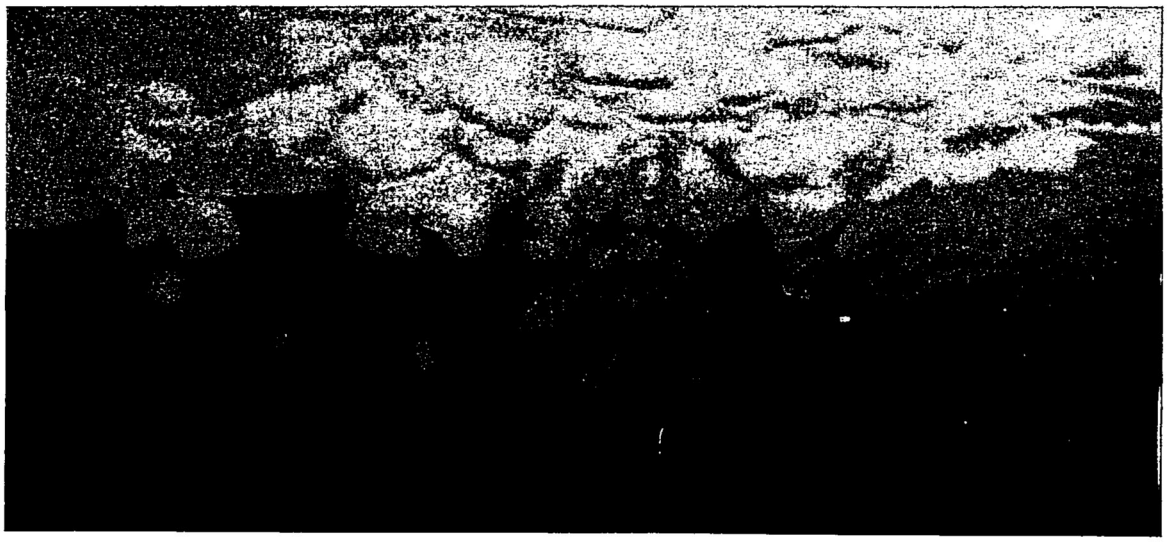






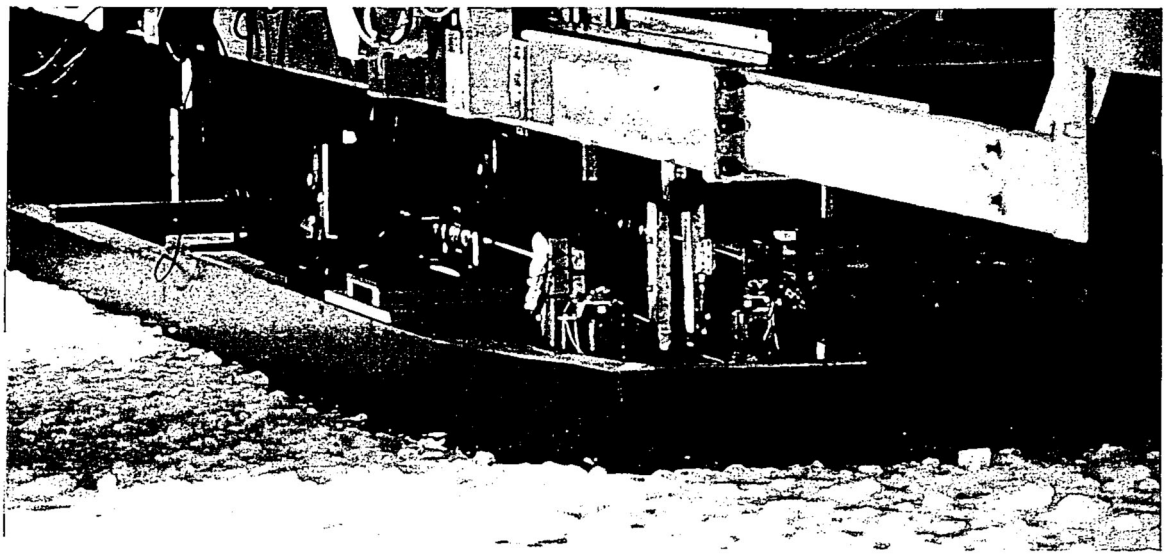
TEST 13 *Floe ice; astern Hi = 40 mm*







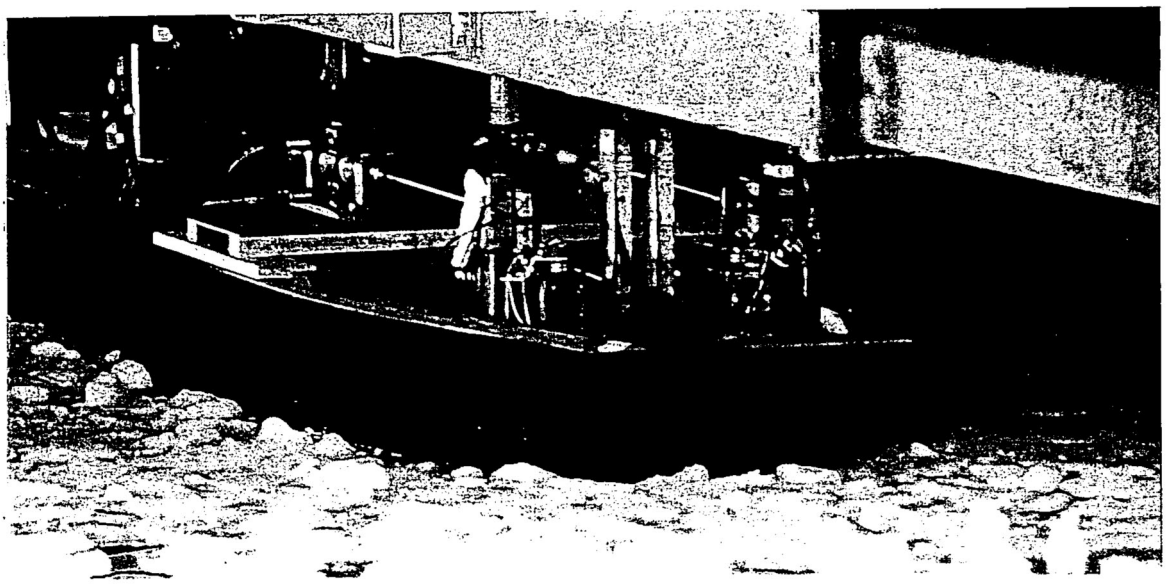
TEST 14 *Floe ice; astern Hi = 40 mm*



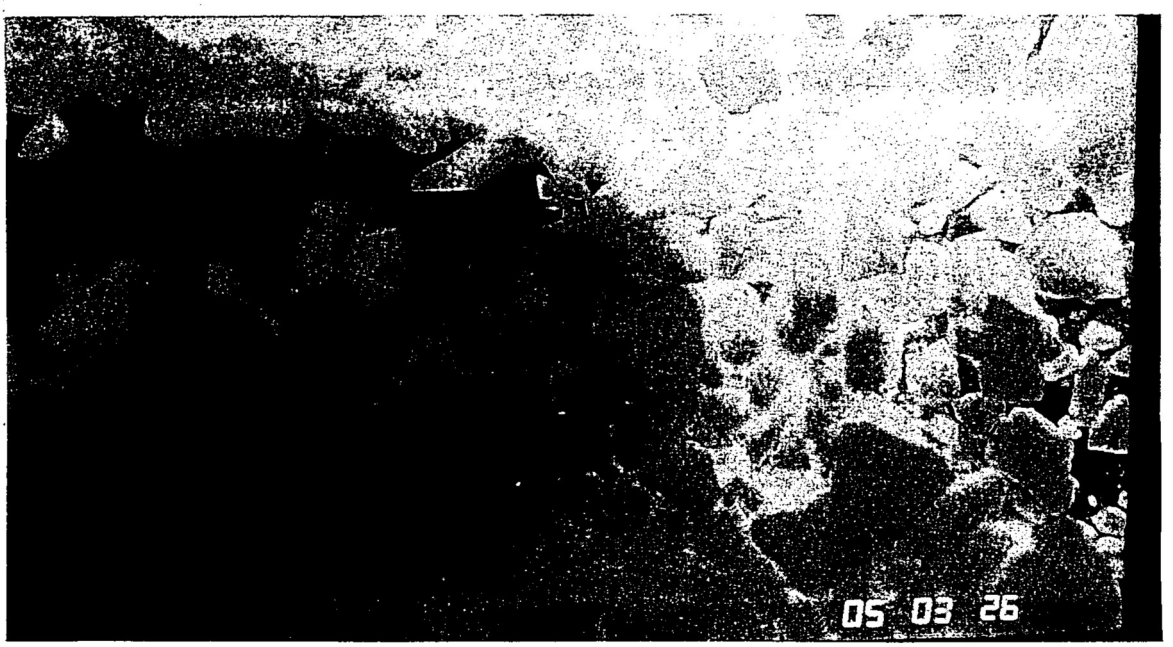




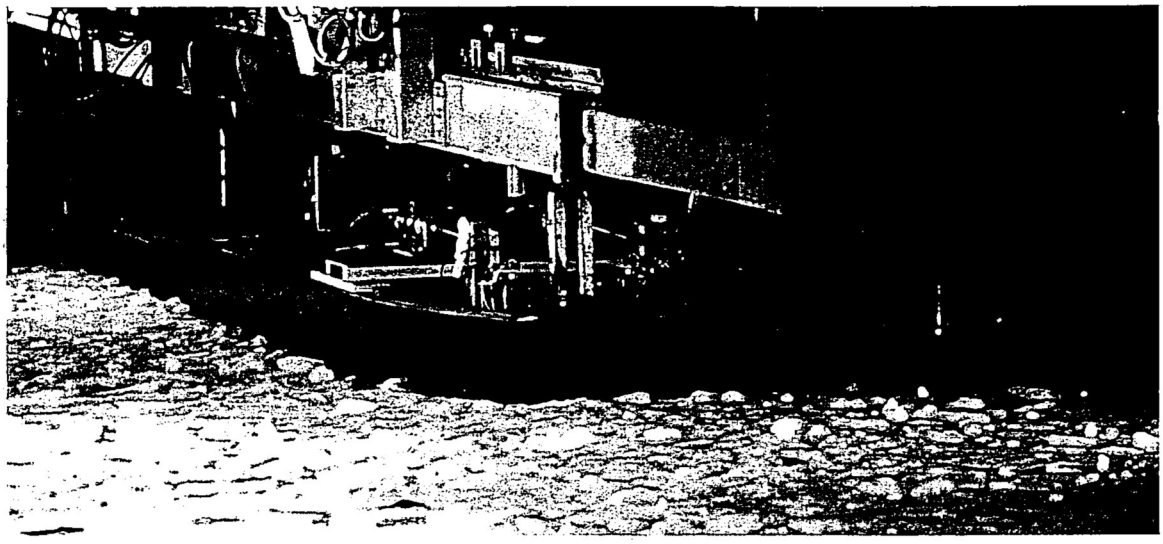
TEST 20 *Floe ice; astern Hi = 60 mm*



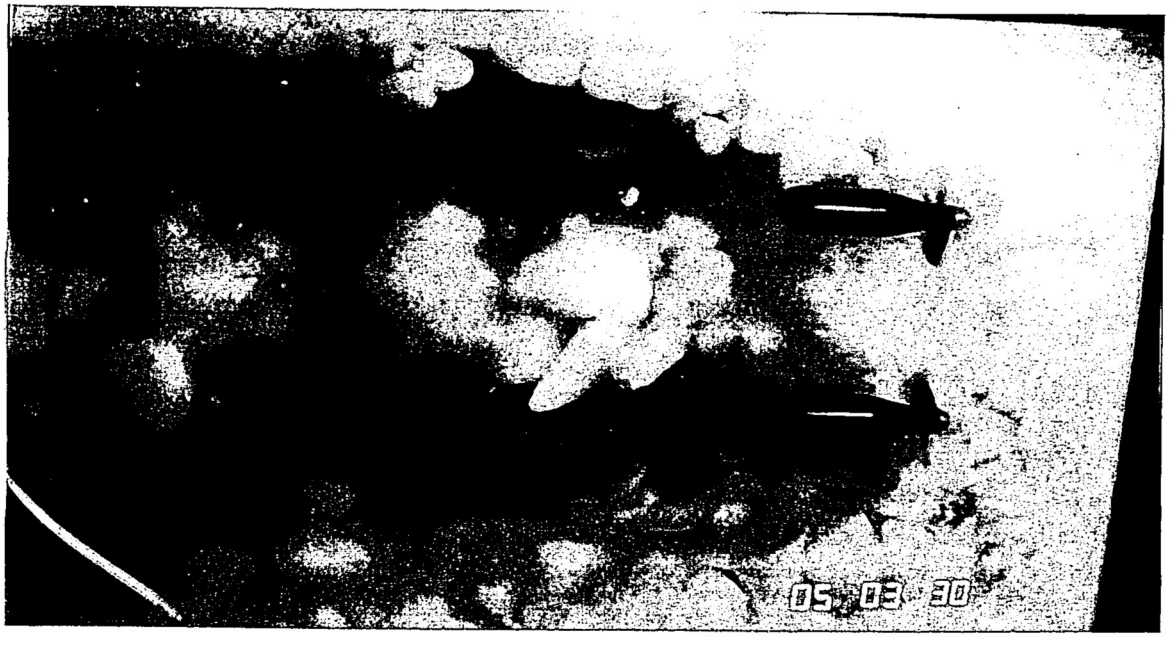




TEST 21 *Floe ice; astern Hi = 60 mm*







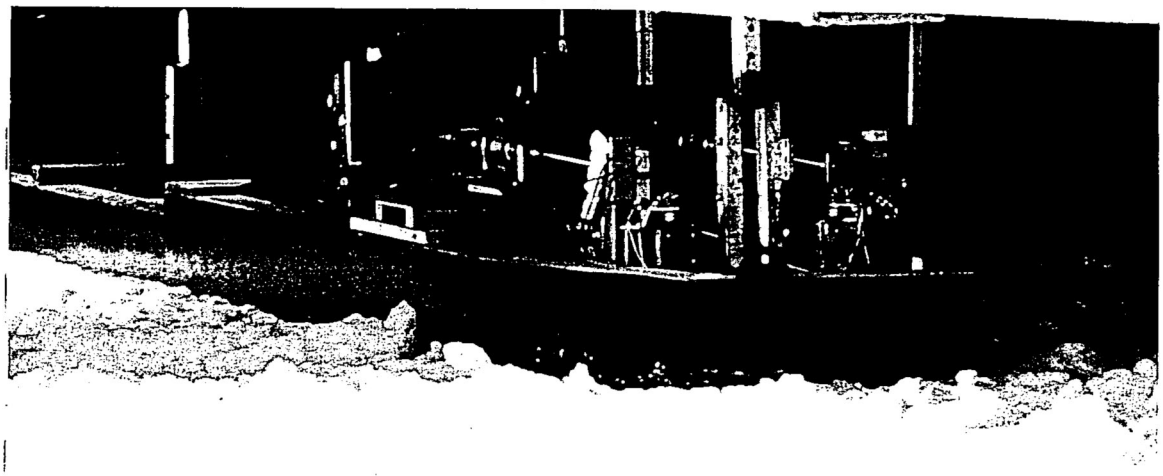
TEST 8 *Ridge; ahead Hi = 15 m (f.sc.)*

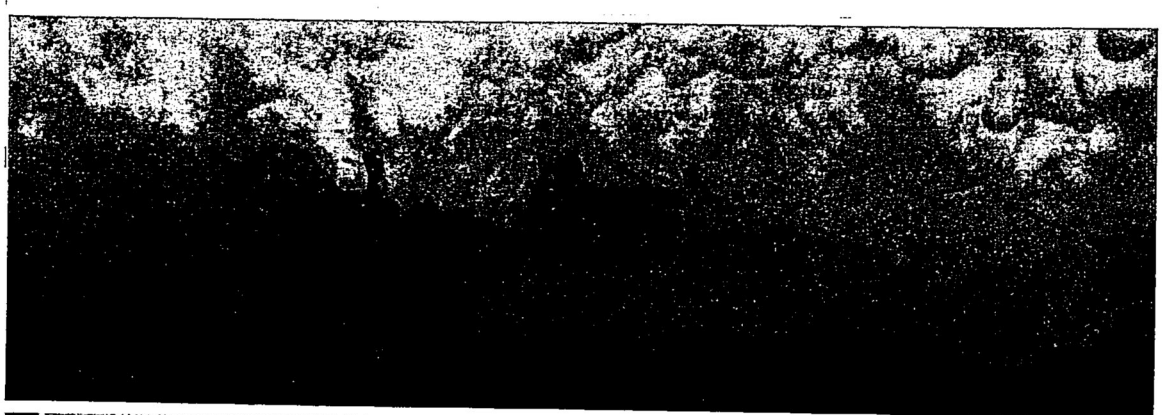


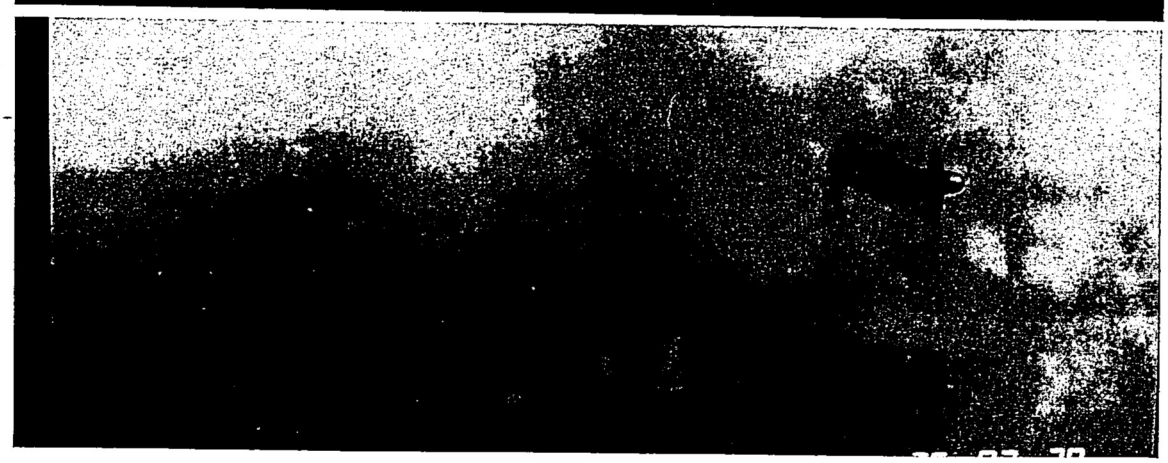




TEST 15 *Ridge; astern Hi = 15 m (f.sc.)*

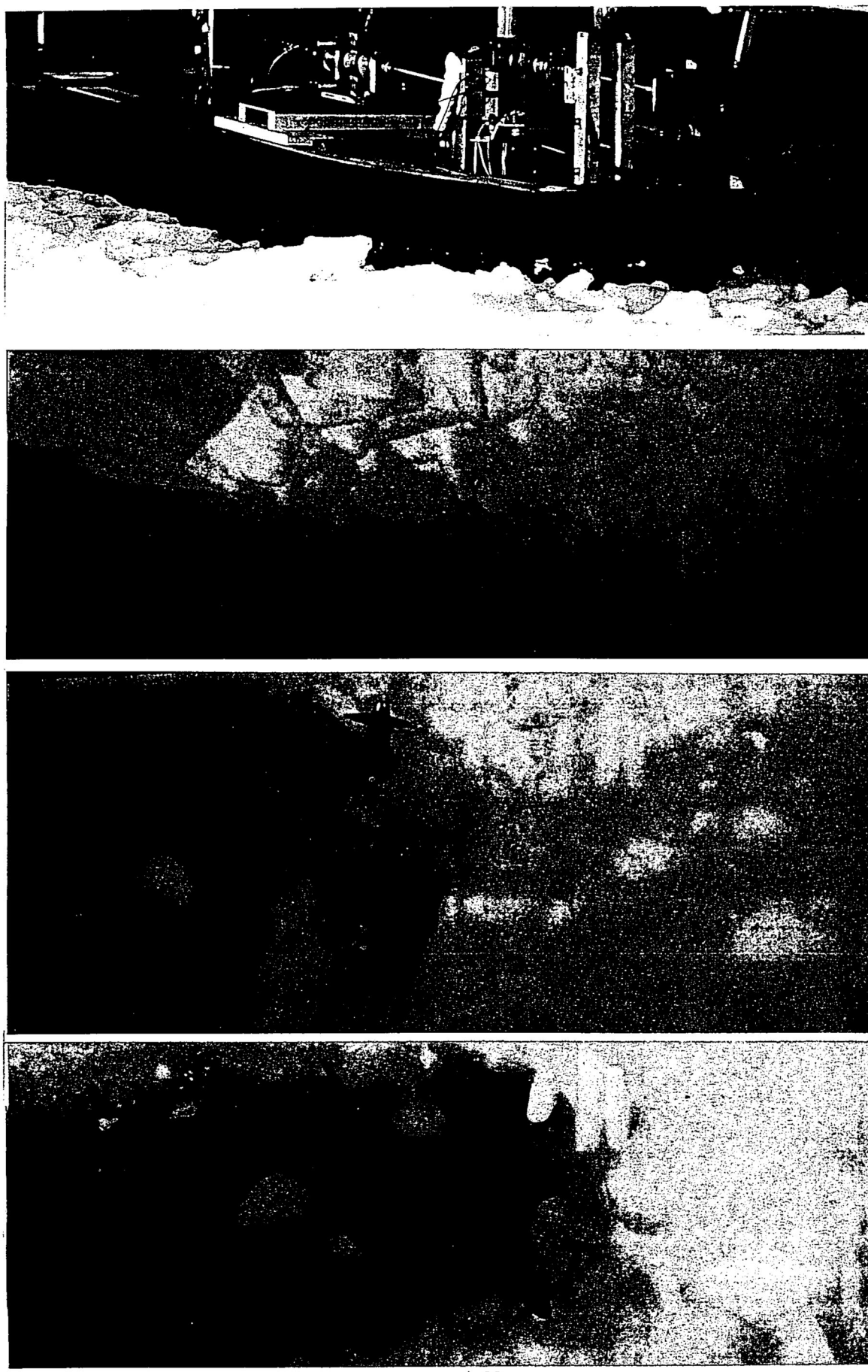








TEST 22 *Ridge; astern Hi = 20 m (f.sc.)*



Appendix B Test program

TEST	type of test	direction of movement	target ice thickness [m]	target flexural strength [kPa]
1	level ice	ahead	1.2	600
2	level ice	ahead	1.2	600
3	level ice	ahead	1.2	600
4	breaking out of own channel	ahead	1.2	-
5	breaking out of own channel	ahead	1.2	-
6	floe ice	ahead	1.2	-
7	floe ice	ahead	1.2	-
8	ridge	ahead	15.0	-
9	level ice	astern	1.2	600
10	level ice	astern	1.2	600
11	level ice	astern	1.2	600
12	breaking out of own channel	astern	1.2	-
13	floe ice	astern	1.2	-
14	floe ice	astern	1.2	-
15	ridge	astern	15.0	-
16	level ice	astern	1.8	600
17	level ice	astern	1.8	600
18	level ice	astern	1.8	600
19	breaking out of own channel	astern	1.8	-
20	floe ice	astern	1.8	-
21	floe ice	astern	1.8	-
22	ridge	astern	20.0	-

Appendix C Ice data

FGX -MODEL ICE

DATA SHEET: TEST DAY 13.2.1998, 1:30

LEVEL ICE:

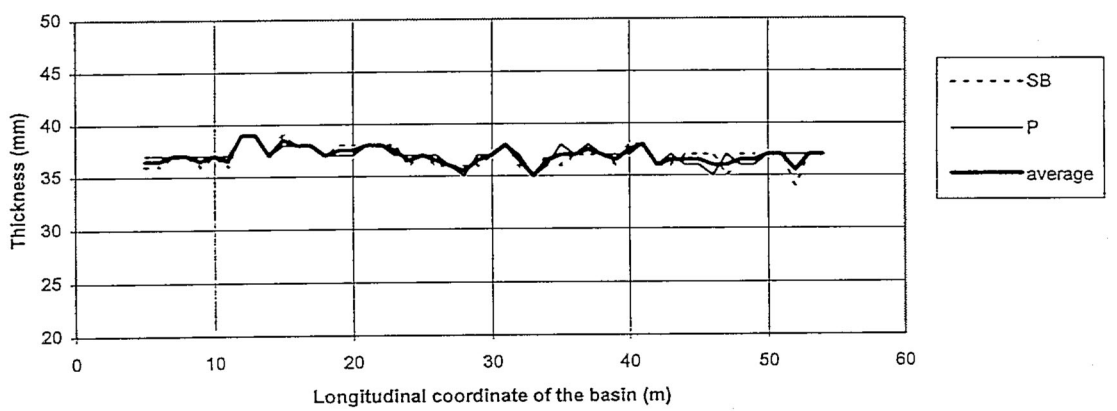
Target values for the ice sheet:

hice	=	40 mm
σf	=	20 kPa
E/σf	=	1500

Achieved values for the ice sheet:

									sigmaf (kPa)	E/sigmaf
Time	Frame(#), Bend. dir.	Beam position (m)	l(mm)	b(mm)	h(mm)	F(mm)*	F(N)	sigmaf (kPa)	frame av.	frame,h E/sigmaf
8:30	23	-1	240	104	37	29	1.96	19.84		39,35.5
	23	1	266	107	34	26	1.76	22.70	21.27	1675
	41	-1	245	107	36	27	1.83	19.36		
	41	1	240	105	35	31	2.10	23.48	21.42	

FGX -model ice 13.2.1998, ice thickness



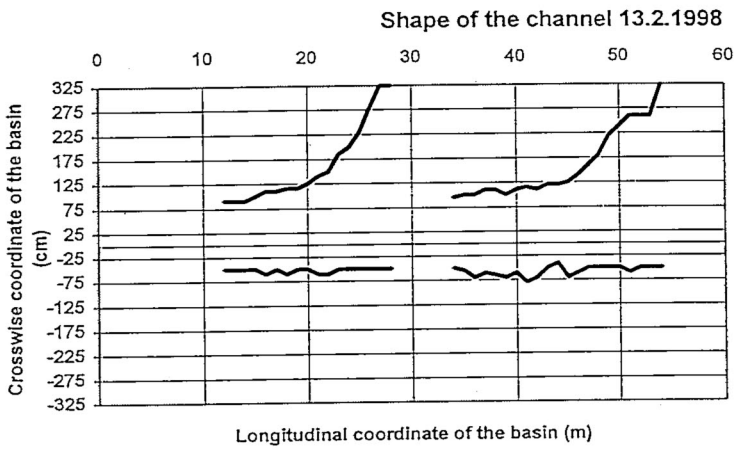
Level ice thickness (mm):

Frame #	SB	P	Average	Frame #	SB	P	Average
1				31	38	38	38
2				32	36	37	36.5
3				33	35	35	35
4				34	37	36	36.5
5	36	37	36.5	35	36	38	37
6	36	37	36.5	36	37	37	37
7	37	37	37	37	37	38	37.5
8	37	37	37	38	37	37	37
9	36	37	36.5	39	36	37	36.5
10	37	37	37	40	38	37	37.5
11	36	37	36.5	41	38	38	38
12	39	39	39	42	36	36	36
13	39	39	39	43	36	37	36.5
14	37	37	37	44	37	36	36.5
15	39	38	38.5	45	37	36	36.5
16	38	38	38	46	37	35	36
17	38	38	38	47	35	37	36
18	37	37	37	48	37	36	36.5
19	38	37	37.5	49	37	36	36.5
20	38	37	37.5	50	37	37	37
21	38	38	38	51	37	37	37
22	38	38	38	52	34	37	35.5
23	38	37	37.5	53	37	37	37
24	36	37	36.5	54	37	37	37
25	37	37	37	55			
26	36	37	36.5	56			
27	36	36	36	57			
28	36	35	35.5	58			
29	36	37	36.5	59			
30	37	37	37	60			

Statistic of the ice thickness:

	SB	P
Average	36.90	37.00
Stdev	1.04	0.86
Stdev/avg	3 %	2 %
Diff. from	-7.75 %	-7.50 %
the target		

Outbreaking from the channel:



Outbreaking in numbers:

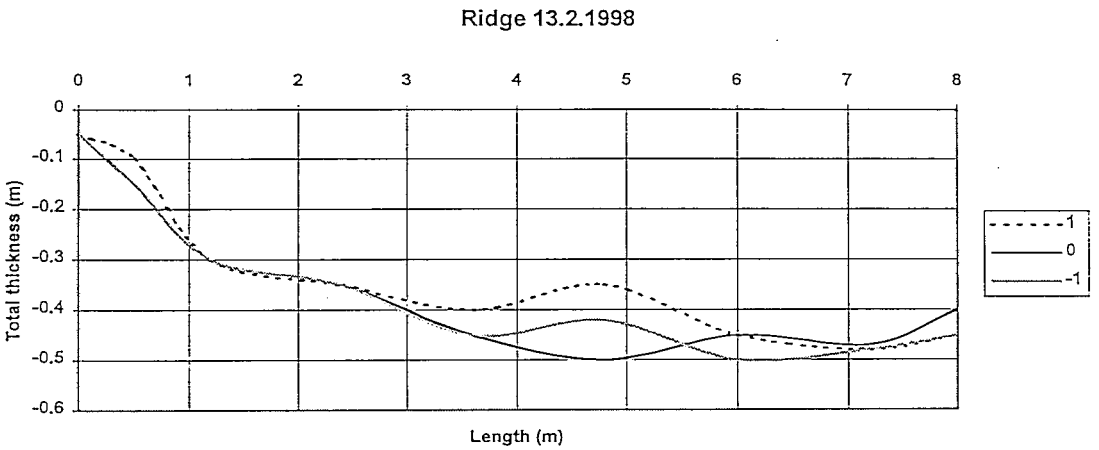
Frame #	SB	P	Width of the channel (m)	Frame #	SB	P	Width of the channel (m)
1				31			
2				32			
3				33			
4				34	-50	95	1.45
5				35	-55	100	1.55
6				36	-70	100	1.7
7				37	-60	110	1.7
8				38	-65	110	1.75
9				39	-70	100	1.7
10				40	-60	110	1.7
11				41	-80	115	1.95
12	-50	90	1.4	42	-70	110	1.80
13	-50	90	1.4	43	-50	120	1.70
14	-50	90	1.4	44	-40	120	1.60
15	-50	100	1.5	45	-70	125	1.95
16	-60	110	1.7	46	-60	140	2.00
17	-50	110	1.6	47	-50	160	2.10
18	-60	115	1.75	48	-50	180	2.30
19	-50	115	1.65	49	-50	220	2.70
20	-50	125	1.75	50	-50	240	2.90
21	-60	140	2	51	-60	260	3.20
22	-60	150	2.1	52	-50	260	3.10
23	-50	185	2.35	53	-50	260	3.10
24	-50	200	2.5	54	-50	325	3.75
25	-50	230	2.8	55			
26	-50	280	3.3	56			
27	-50	325	3.75	57			
28	-50	325	3.75	58			
29				59			
30				60			

FLOE ICE:

Size of the ice floes varied from 5 x 5 cm^2, 10 x 10 cm^2 to 15 x 15 cm^2; concentration was in order 90 %.

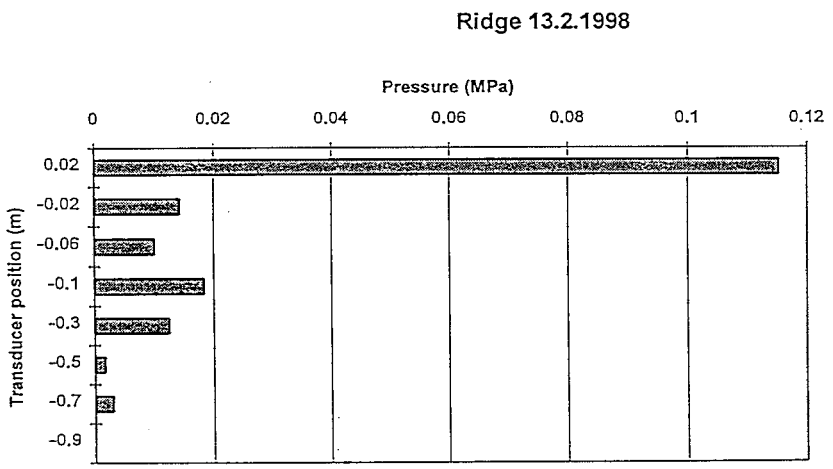
RIDGE:

Target thickness of the ridge was 0.5 m (maximum). Size of the keel blocks varied from 5 x 5 cm^2, 10 x 10 cm^2 to 15 x 15 cm^2 (built from the floe ice).



TOTAL LOAD AND VERTICAL PRESSURE DISTRIBUTION IN THE RIDGE

Total load against the indenter was 92.4 N.



FGX -MODEL ICE

DATA SHEET: TEST DAY 25.2.1998, 1:30

LEVEL ICE:

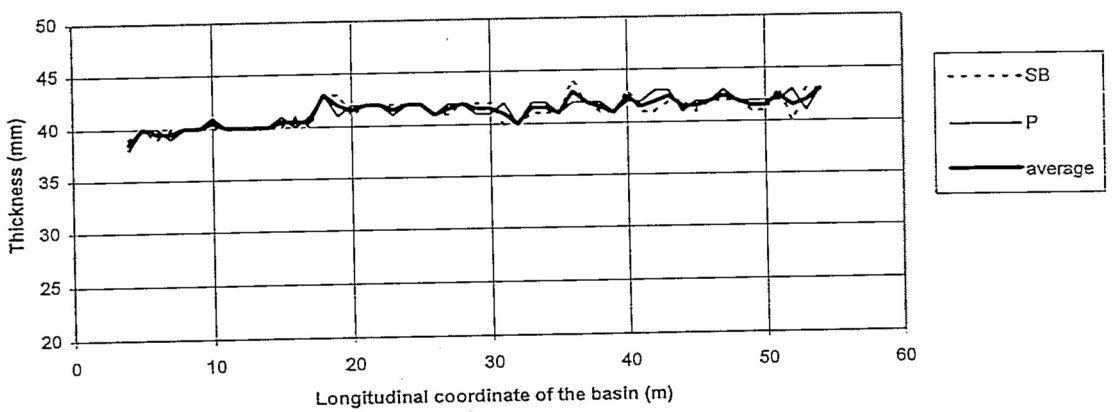
Target values for the ice sheet:

hice	=	40 mm
σf	=	20 kPa
E/σf	=	1500

Achieved values for the ice sheet:

									sigmaf (kPa)	E/sigmaf
Time	Frame(#), Bend. dir.	Beam position (m)	l(mm)	b(mm)	h(mm)	F(mm)*	F(N)	sigmaf (kPa)	frame av.	frame,h E/sigmaf
8:20	23	-1	245	103	40.5	32	2.20	19.17		
	23	1	245	100	39	31	2.13	20.63	19.90	
	42	-1	250	108	42	34	2.34	18.43		40,41
	42	1	235	105	40	37.5	2.58	21.67	20.05	1678

FGX -model ice 25.2.1998, ice thickness



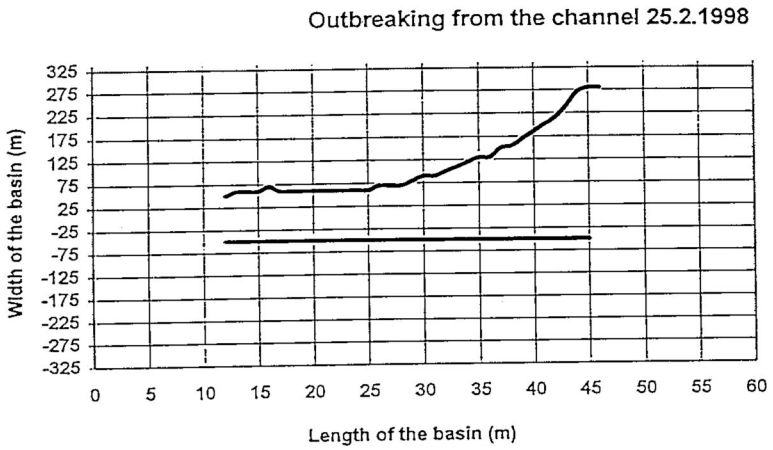
Level ice thickness (mm):

Frame #	SB	P	Average	Frame #	SB	P	Average
1				31	40	42	41
2				32	40	40	40
3				33	41	42	41.5
4	39	38	38.5	34	41	42	41.5
5	40	40	40	35	41	41	41
6	39	40	39.5	36	44	42	43
7	40	39	39.5	37	42	42	42
8	40	40	40	38	41	42	41.5
9	40	40	40	39	41	41	41
10	40	41	40.5	40	43	42	42.5
11	40	40	40	41	41	42	41.5
12	40	40	40	42	41	43	42
13	40	40	40	43	42	43	42.5
14	40	40	40	44	42	41	41.5
15	40	41	40.5	45	41	42	41.5
16	41	40	40.5	46	42	42	42
17	40	41	40.5	47	42	43	42.5
18	43	43	43	48	42	42	42
19	43	41	42	49	41	42	41.5
20	41	42	41.5	50	41	42	41.5
21	42	42	42	51	43	42	42.5
22	42	42	42	52	40	43	41.5
23	42	41	41.5	53	43	41	42
24	42	42	42	54	43	43	43
25	42	42	42	55			
26	41	41	41	56			
27	41	42	41.5	57			
28	42	42	42	58			
29	42	41	41.5	59			
30	42	41	41.5	60			

Statistic of the ice thickness:

Average	41.22	41.35
Stdev	1.15	1.11
Stdev/avg	3 %	3 %
Diff. from	3.05 %	3.38 %
the target		

Outbreaking from the channel:



Outbreaking in numbers:

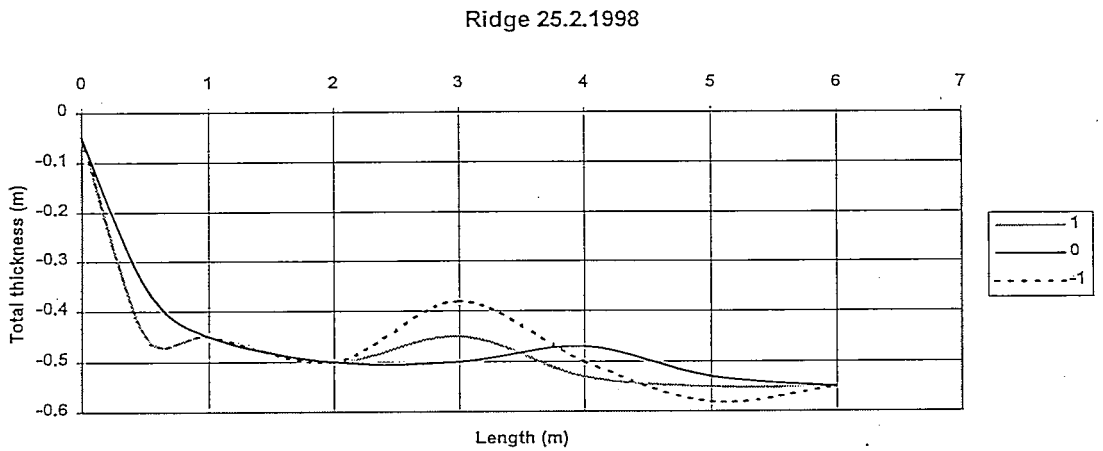
Frame #	SB	P	Width of the channel (m)	Frame #	SB	P	Width of the channel (m)
1				31			
2				32	-50	50	1
3				33			
4	-50	60	1.1	34			
5				35			
6				36	-50	50	1
7				37			
8	-60	50	1.1	38			
9				39			
10				40	-50	50	1
11				41			
12	-50	60	1.1	42			
13				43			
14				44	-50	60	1.1
15				45			
16	-50	60	1.1	46			
17				47			
18				48	-50	65	1.15
19				49			
20	-50	50	1	50			
21				51			
22				52	-50	55	1.05
23				53			
24	-50	50	1	54			
25				55			
26				56			
27				57			
28	-50	50	1	58			
29				59			
30				60			

FLOE ICE:

Size of the ice floes varied from 5 x 5 cm^2, 10 x 10 cm^2 to 15 x 15 cm^2; concentration was in order 90 %.

RIDGE:

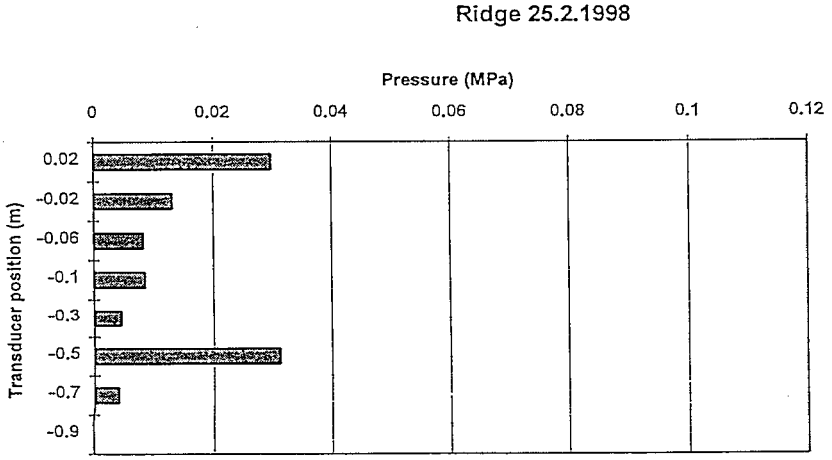
Target thickness of the ridge was 0.5 m (maximum). Size of the keel blocks varied from 5 x 5 cm^2, 10 x 10 cm^2 to 15 x 15 cm^2 (built from the floe ice).



Ridge in numbers:								
	0	0.5	1	2	3	4	5	6
1	-0.05	-0.45	-0.45	-0.5	-0.45	-0.53	-0.55	-0.55
0	-0.05	-0.35	-0.45	-0.5	-0.5	-0.47	-0.53	-0.55
-1	-0.05	-0.45	-0.45	-0.5	-0.38	-0.50	-0.58	-0.55

TOTAL LOAD AND VERTICAL PRESSURE DISTRIBUTION IN THE RIDGE

Total load against the indenter was 174.2 N



FGX -MODEL ICE

DATA SHEET: TEST DAY 5.3.1998, 1:30

LEVEL ICE:

Target values for the ice sheet:

hice	=	60 mm
σf	=	20 kPa
E/σf	=	1500

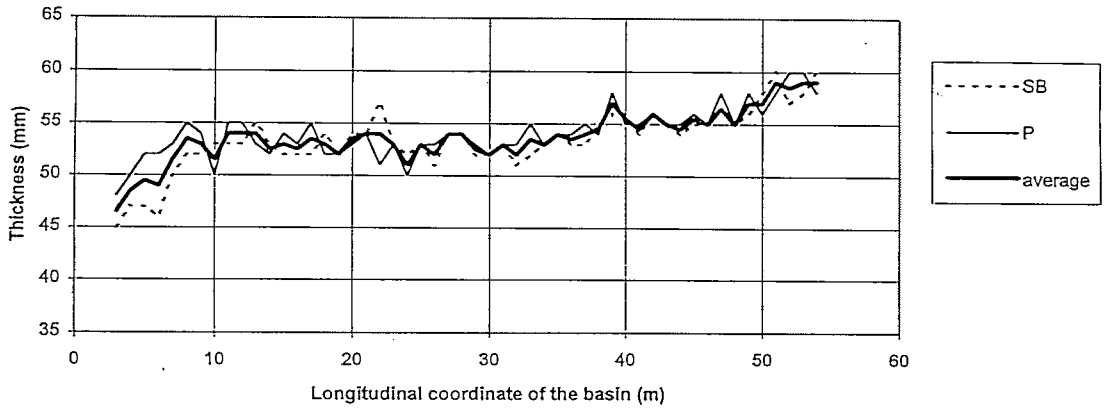
Achieved values for the ice sheet:

									sigmaf (kPa)	E/sigmaf
Time	Frame(#), Bend. dir.	Beam position (m)	l(mm)	b(mm)	h(mm)	F(mm)	F(N)	sigmaf (kPa)	frame av.	frame,h E/sigmaf
8:20	22	-1	255	110	55	47	3.13	14.37		
	22	1	250	105	53	42	2.79	14.21	14.29	
	42	-1	245	105	56	50	3.33	14.85		40,56
	42	1	255	115	56	52	3.46	14.67	14.76	838
10:00	22	-1	260	110	55	69	4.59	21.51		
	22	1	253	105	55	67	4.46	21.30	21.41	
	42	-1	231	105	58	73	4.86	19.05		40,58
	42	1	242	105	58	68	4.52	18.59	18.82	1267
10:55	24	-1	250	100	51	60	3.99	23.01		
	24	1	255	108	50	57.5	3.82	21.67	22.34	
	42	-1	260	105	52	75	4.99	27.41		
	42	1	253	107	52	65	4.32	22.68	25.04	

Proper test beams measured at 10:00.

Note the thinning of the ice during the test run. Thicknesses measured in connection of the beam tests are advised to use in analysis.

FGX -model ice 5.3.1998, ice thickness



Level ice thickness (mm):

Frame #	SB	P	Average	Frame #	SB	P	Average
1				31	53	53	53
2	40	40	40	32	51	53	52
3	45	48	46.5	33	52	55	53.5
4	47	50	48.5	34	53	53	53
5	47	52	49.5	35	54	54	54
6	46	52	49	36	53	54	53.5
7	50	53	51.5	37	53	55	54
8	52	55	53.5	38	55	54	54.5
9	52	54	53	39	56	58	57
10	53	50	51.5	40	56	55	55.5
11	53	55	54	41	54	55	54.5
12	53	55	54	42	56	56	56
13	55	53	54	43	55	55	55
14	53	52	52.5	44	54	55	54.5
15	52	54	53	45	55	56	55.5
16	52	53	52.5	46	55	55	55
17	52	55	53.5	47	55	58	56.5
18	54	52	53	48	55	55	55
19	52	52	52	49	56	58	57
20	54	53	53.5	50	58	56	57
21	54	54	54	51	60	58	59
22	57	51	54	52	57	60	58.5
23	53	53	53	53	58	60	59
24	52	50	51	54	60	58	59
25	53	53	53	55			
26	51	53	52	56			
27	54	54	54	57			
28	54	54	54	58			
29	52	53	52.5	59			
30	52	52	52	60			

Statistic of the ice thickness:

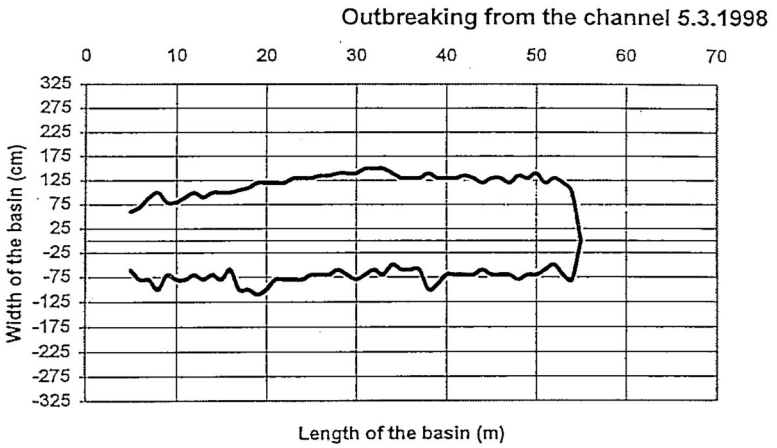
	SB	P
Average	53.59	54.24
Stdev	2.77	2.30
Stdev/avg	5 %	4 %
Diff. from	-10.68 %	-9.60 %
the target		

Note: Average includes values from frames 4 - 54 m

Channel after the first test run:

Frame #	SB (cm)	P (cm)	Width (m)	Frame #	SB (cm)	P (cm)	Width (m)
1				31			
2	-50	60	1.4	32			
3				33	-60	55	1.15
4				34			
5				35			
6	-50	50	1	36			
7				37	-70	45	1.15
8				38			
9				39			
10	-50	55	1.05	40			
11				41	-60	60	1.2
12				42			
13				43			
14	-50	60	1.1	44			
15				45	-60	55	1.15
16				46			
17	-60	50	1.1	47			
18				48			
19				49	-60	60	1.2
20				50			
21	-80	50	1.3	51			
22				52			
23				53	-50	55	1.05
24				54			
25	-60	55	1.15	55			
26				56			
27				57			
28				58			
29	-70	60	1.3	59			
30				60			

Outbreaking from the channel:



Outbreaking in numbers:

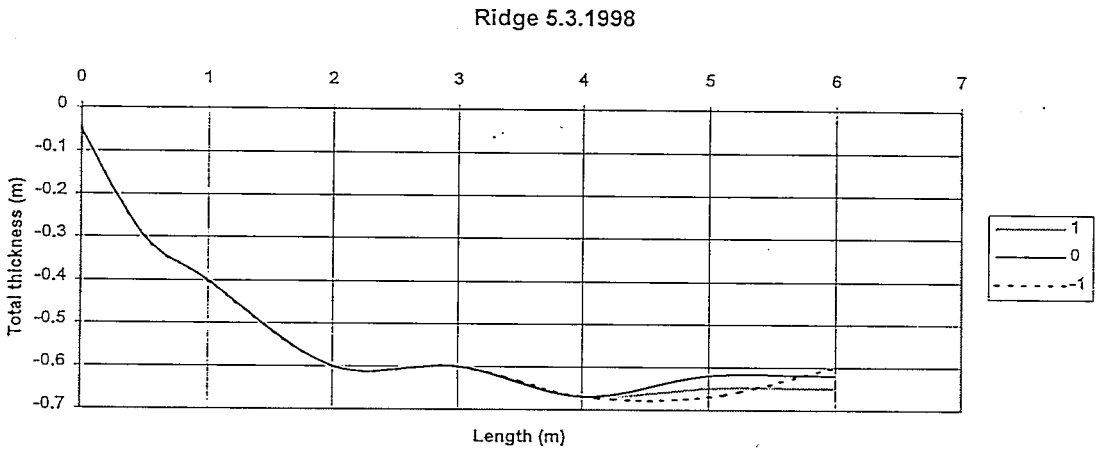
Frame #	SB	P	Frame #	SB	P
1			31	-60	150
2			32	-70	150
3			33	-50	140
4	-60	60	34	-60	130
5	-80	70	35	-60	130
6	-80	90	36	-60	130
7	-100	100	37	-100	140
8	-70	80	38	-90	130
9	-80	80	39	-70	130
10	-80	90	40	-70	130
11	-70	100	41	-70	135
12	-80	90	42	-70	130
13	-70	100	43	-60	120
14	-80	100	44	-70	130
15	-60	100	45	-70	130
16	-100	105	46	-70	120
17	-100	110	47	-80	135
18	-110	120	48	-70	130
19	-100	120	49	-70	140
20	-80	120	50	-60	120
21	-80	120	51	-50	130
22	-80	130	52	-70	120
23	-80	130	53	-80	100
24	-70	130	54		
25	-70	135	55		
26	-70	135	56		
27	-60	140	57		
28	-70	140	58		
29	-80	140	59		
30	-70	150	60		

FLOE ICE:

Size of the ice floes varied from 10 x 10 cm^2, 15 x 15 cm^2 to 20 x 20 cm^2; concentration was in order 90 %.

RIDGE:

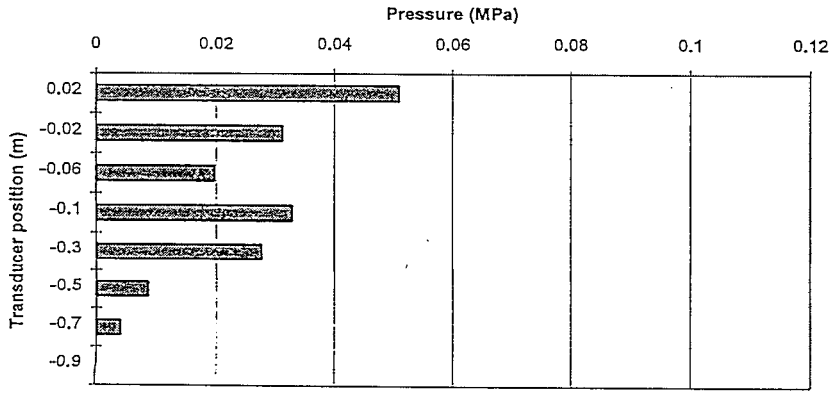
Target thickness of the ridge was 0.67 m (maximum). Size of the keel blocks varied from 10 x 10 cm^2, 15 x 15 cm^2 to 20 x 20 cm^2 (built from the floe ice).



Ridge in numbers:								
	0	0.5	1	2	3	4	5	6
1	-0.05	-0.3	-0.4	-0.6	-0.6	-0.67	-0.65	-0.65
0	-0.05	-0.3	-0.4	-0.6	-0.6	-0.67	-0.62	-0.62
-1	-0.05	-0.3	-0.4	-0.6	-0.6	-0.67	-0.67	-0.6

TOTAL LOAD AND VERTICAL PRESSURE DISTRIBUTION IN THE RIDGE

Total load against the indenter was 276.1 N

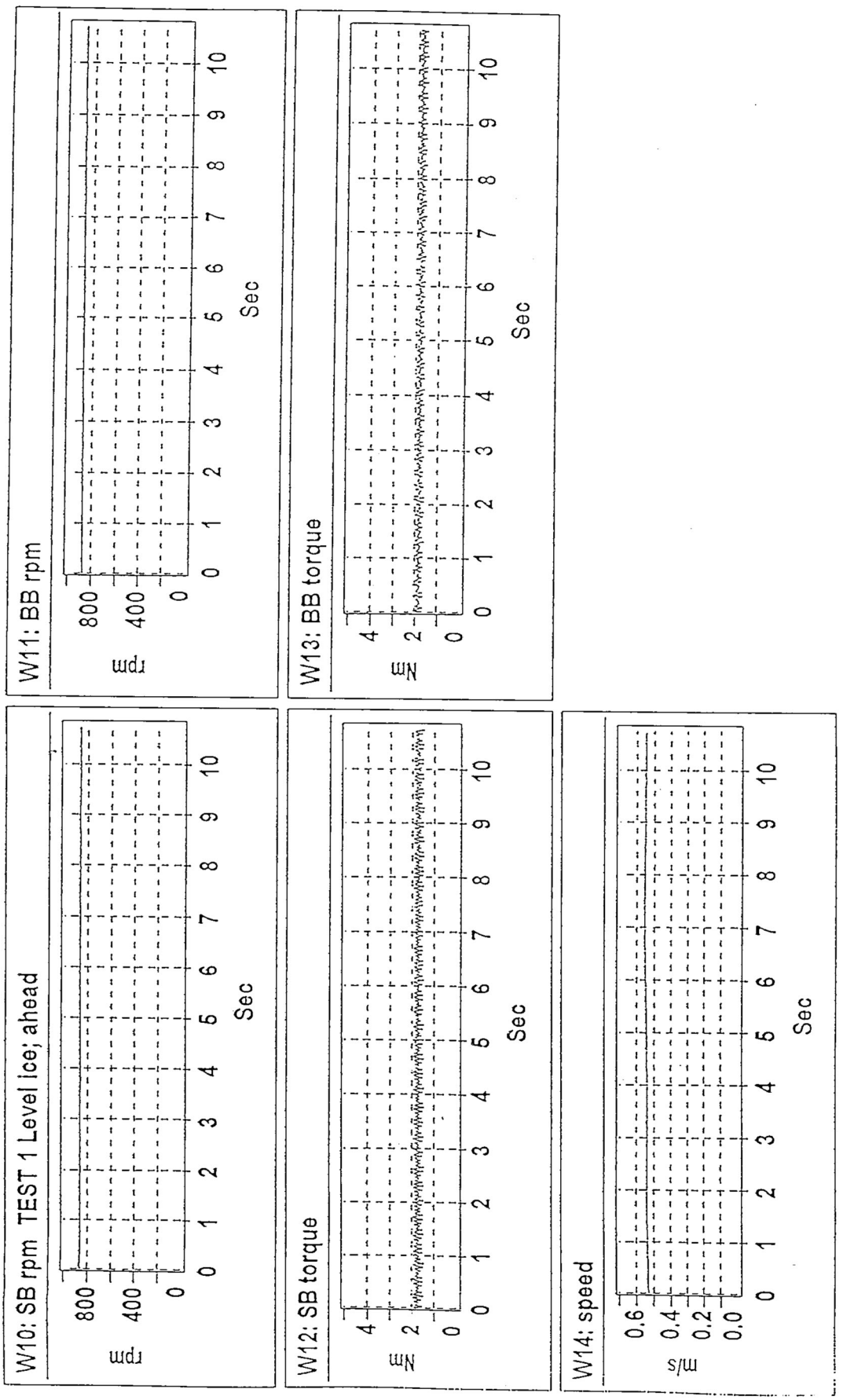


Appendix D Time histories

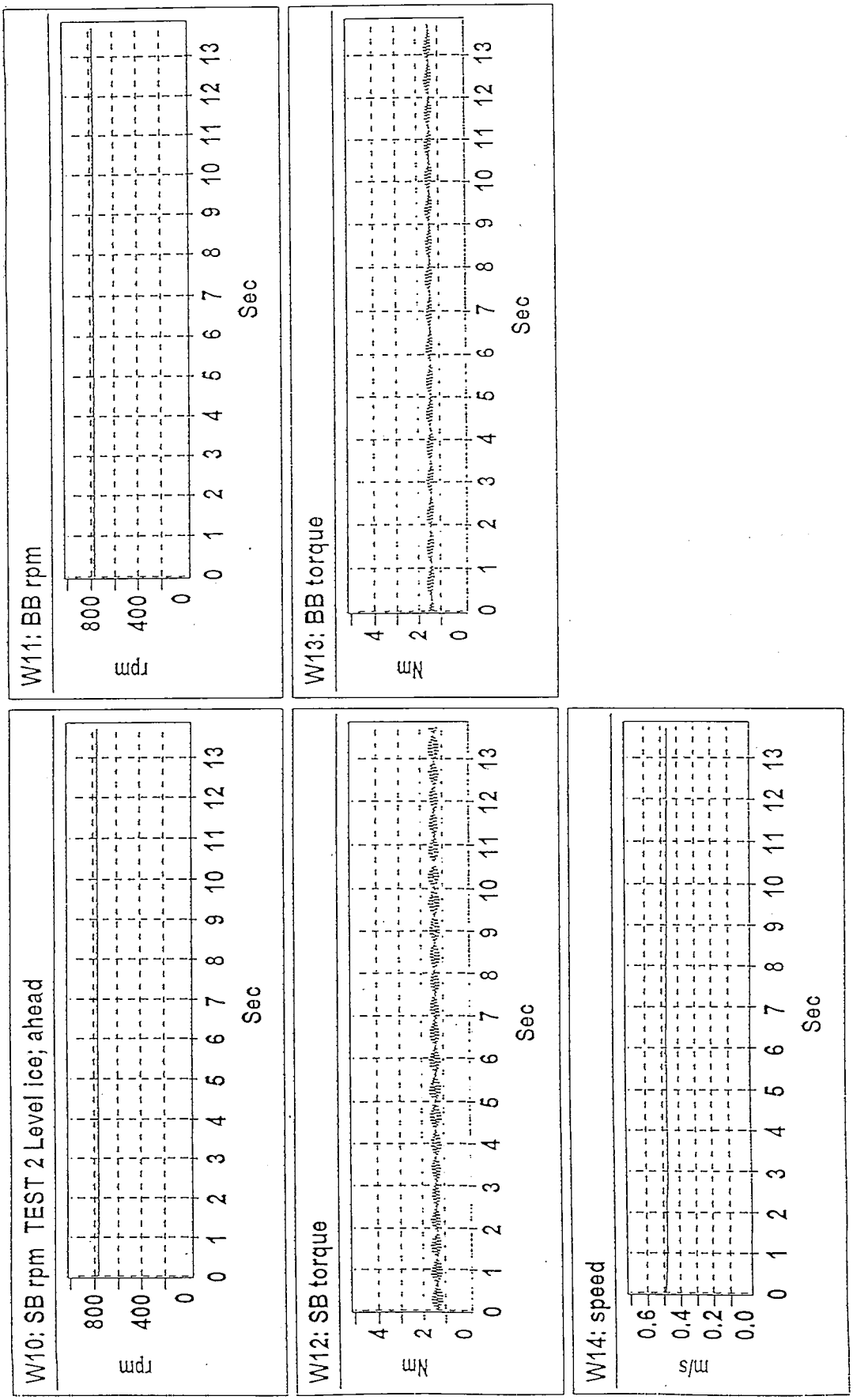
LIST OF CONTENT

TIME HISTORY 1 TEST 1 LEVEL ICE HI = 1.2M (F.SC.); AHEAD D-2
TIME HISTORY 2 TEST 2 LEVEL ICE HI = 1.2M (F.SC.); AHEAD D-3
TIME HISTORY 3 TEST 3 LEVEL ICE HI = 1.2M (F.SC.); AHEAD D-4
TIME HISTORY 4 TEST 9 LEVEL ICE HI = 1.2M (F.SC.); ASTERN D-5
TIME HISTORY 5 TEST 10 LEVEL ICE HI = 1.2M (F.SC.); ASTERN D-6
TIME HISTORY 6 TEST 11 LEVEL ICE HI = 1.2M (F.SC.); ASTERN D-7
TIME HISTORY 7 TEST 16 LEVEL ICE HI = 1.8 (F.SC.); ASTERN D-8
TIME HISTORY 8 TEST 17 LEVEL ICE HI = 1.8 (F.SC.); ASTERN D-9
TIME HISTORY 9 TEST 18 LEVEL ICE HI = 1.8 (F.SC.); ASTERN D-10
TIME HISTORY 10 TEST 6 FLOE ICE HI = 1.2 (F.SC.); AHEAD D-11
TIME HISTORY 11 TEST 7 FLOE ICE HI = 1.2 (F.SC.); AHEAD D-12
TIME HISTORY 12 TEST 13 FLOE ICE HI = 1.2 (F.SC.); ASTERN D-13
TIME HISTORY 13 TEST 14 FLOE ICE HI = 1.2 (F.SC.); ASTERN D-14
TIME HISTORY 14 TEST 20 FLOE ICE HI = 1.6 (F.SC.); ASTERN D-15
TIME HISTORY 15 TEST 21 FLOE ICE HI = 1.6 (F.SC.); ASTERN D-16
TIME HISTORY 16 TEST 8 RIDGE HR = 15 M (F.SC.); AHEAD D-17
TIME HISTORY 17 TEST 8 RIDGE HR = 15 M (F.SC.); AHEAD; SPEED VS LENGTH OF RIDGE D-18
TIME HISTORY 18 TEST 15 RIDGE HR = 15 M (F.SC.); ASTERN D-19
TIME HISTORY 19 TEST 15 RIDGE HR = 15 M (F.SC.); ASTERN; SPEED VS LENGTH OF RIDGE D-20
TIME HISTORY 20 TEST 22 RIDGE HR = 20 M (F.SC.); ASTERN D-21
TIME HISTORY 21 TEST 22 RIDGE HR = 20 M (F.SC.); ASTERN; SPEED VS LENGTH OF RIDGE D-22

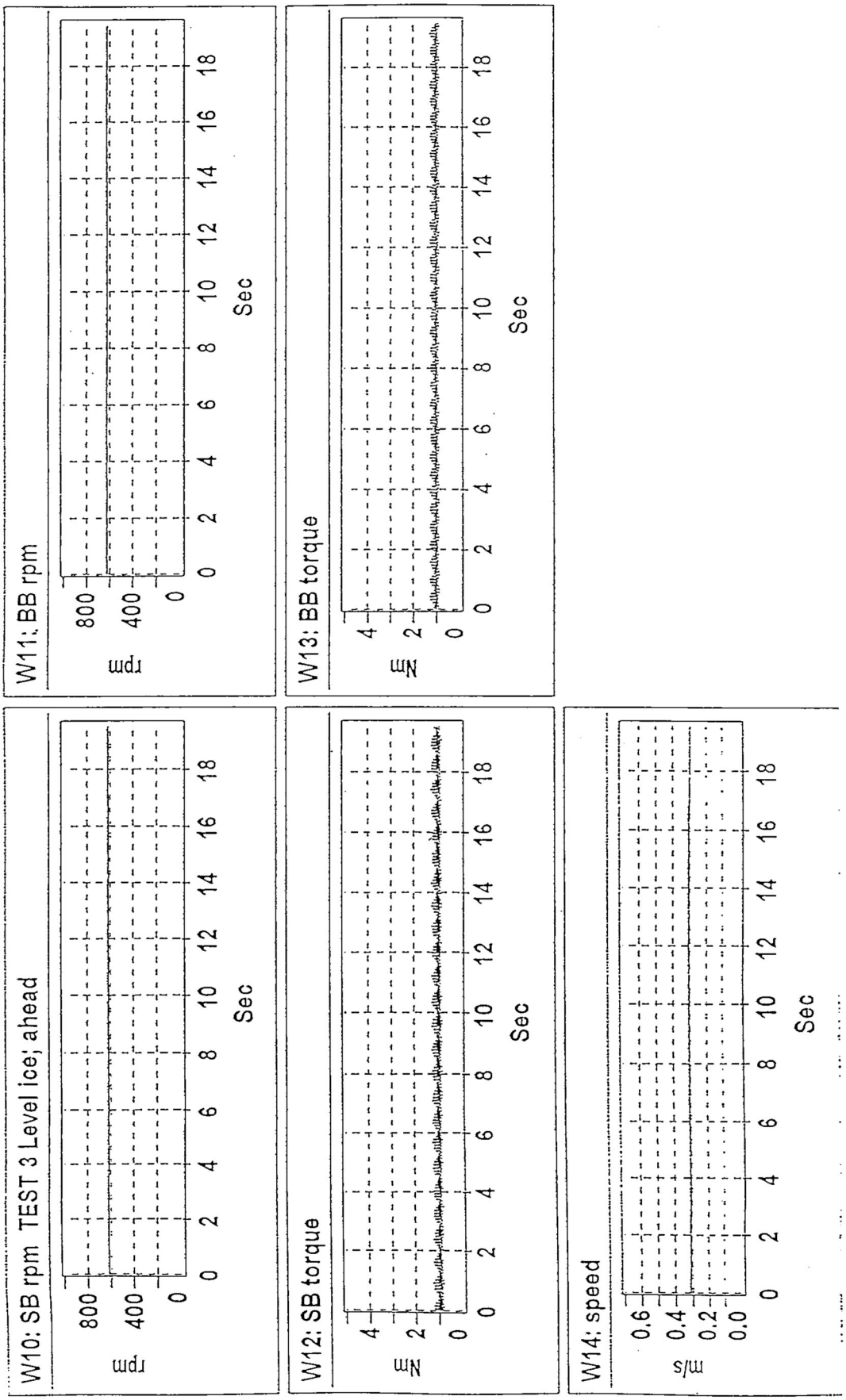
Time history 1 TEST 1 Level ice Hi = 1.2m (f.sc.); ahead



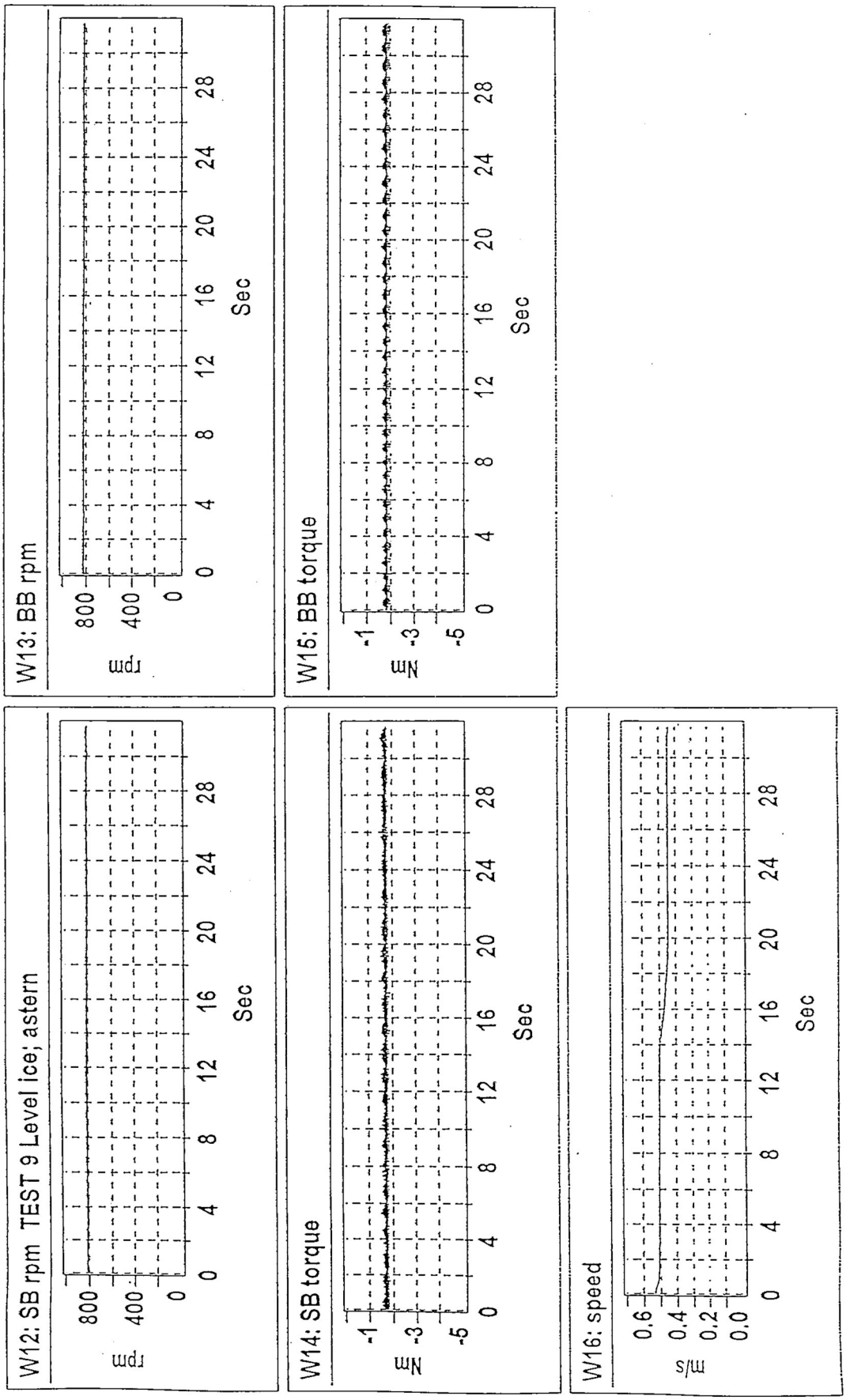
Time history 2 TEST 2 Level ice Hi = 1.2m (f.sc.); ahead



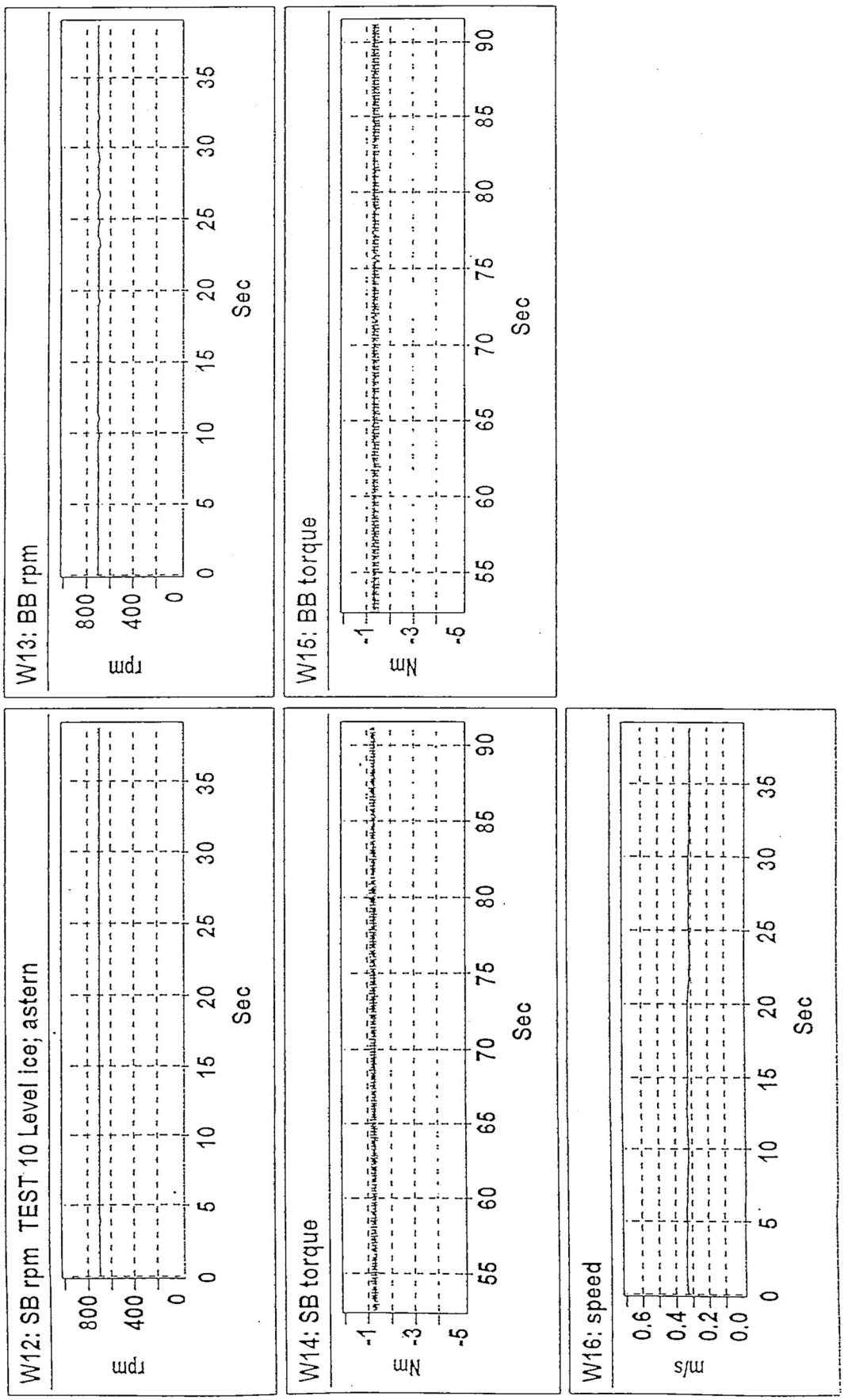
Time history 3 TEST 3 Level ice Hi = 1.2m (f.sc.); ahead



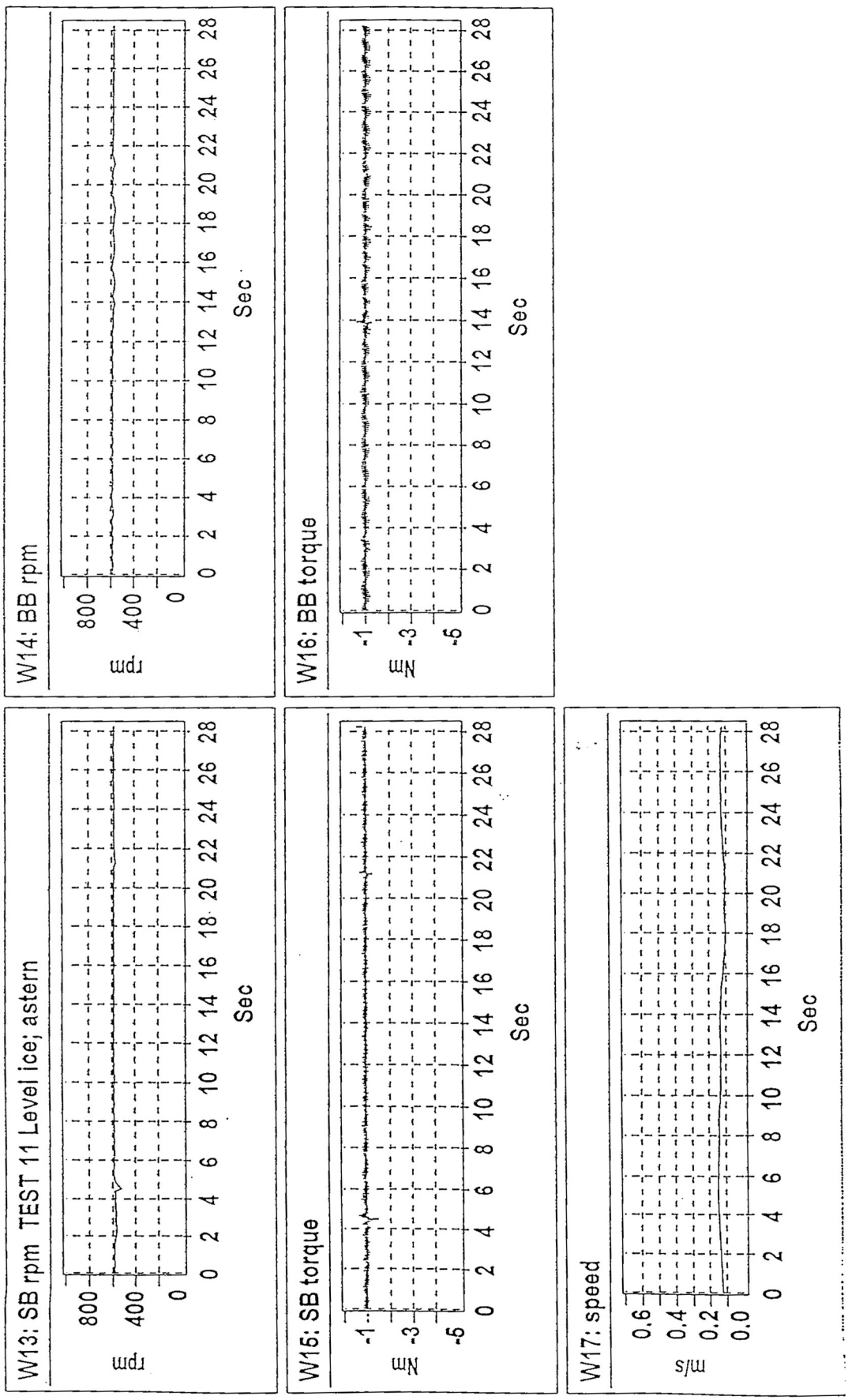
Time history 4 TEST 9 Level ice Hi = 1.2m (f.sc.); astern



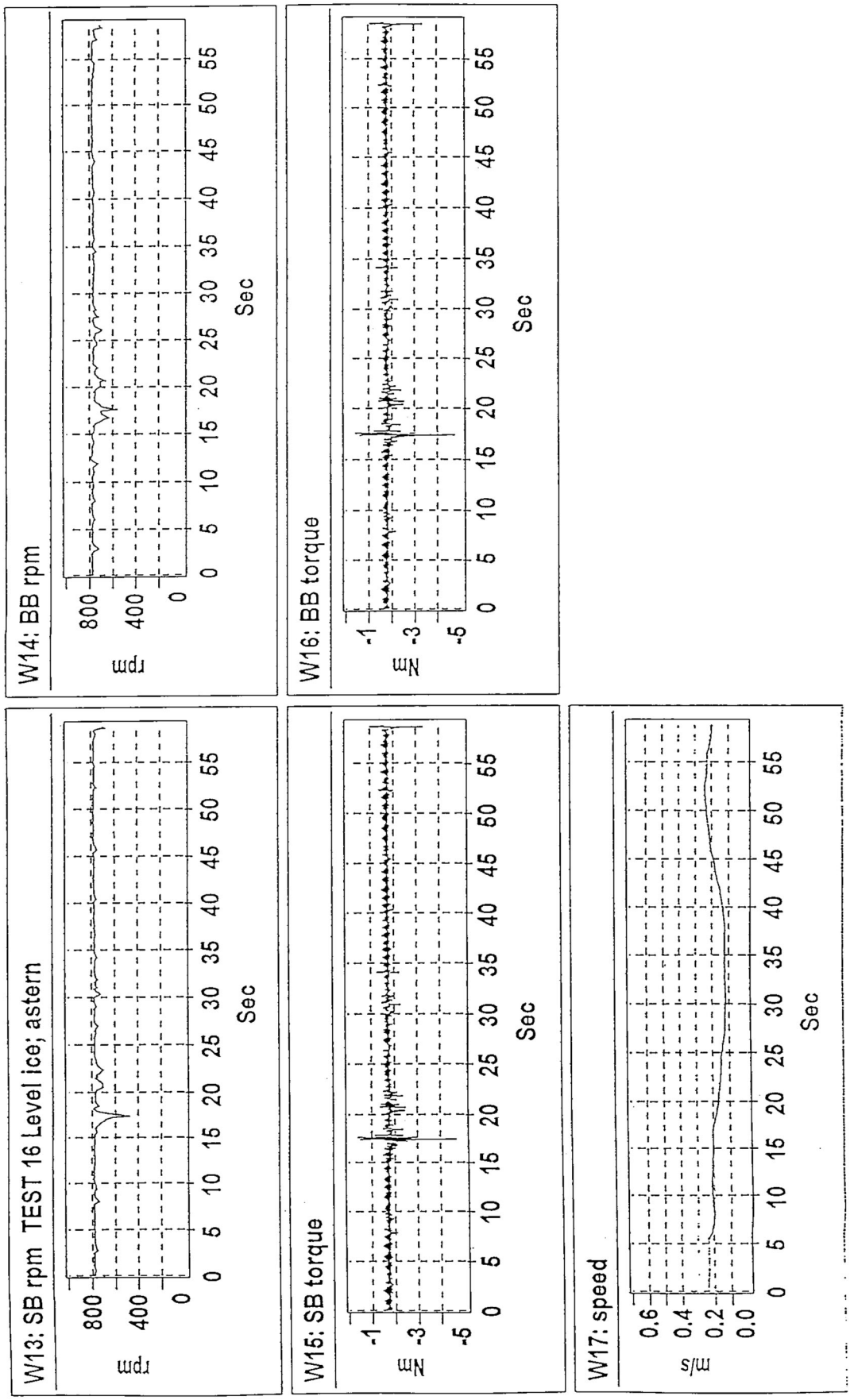
Time history 5 TEST 10 Level ice Hi = 1.2m (f.sc.); astern



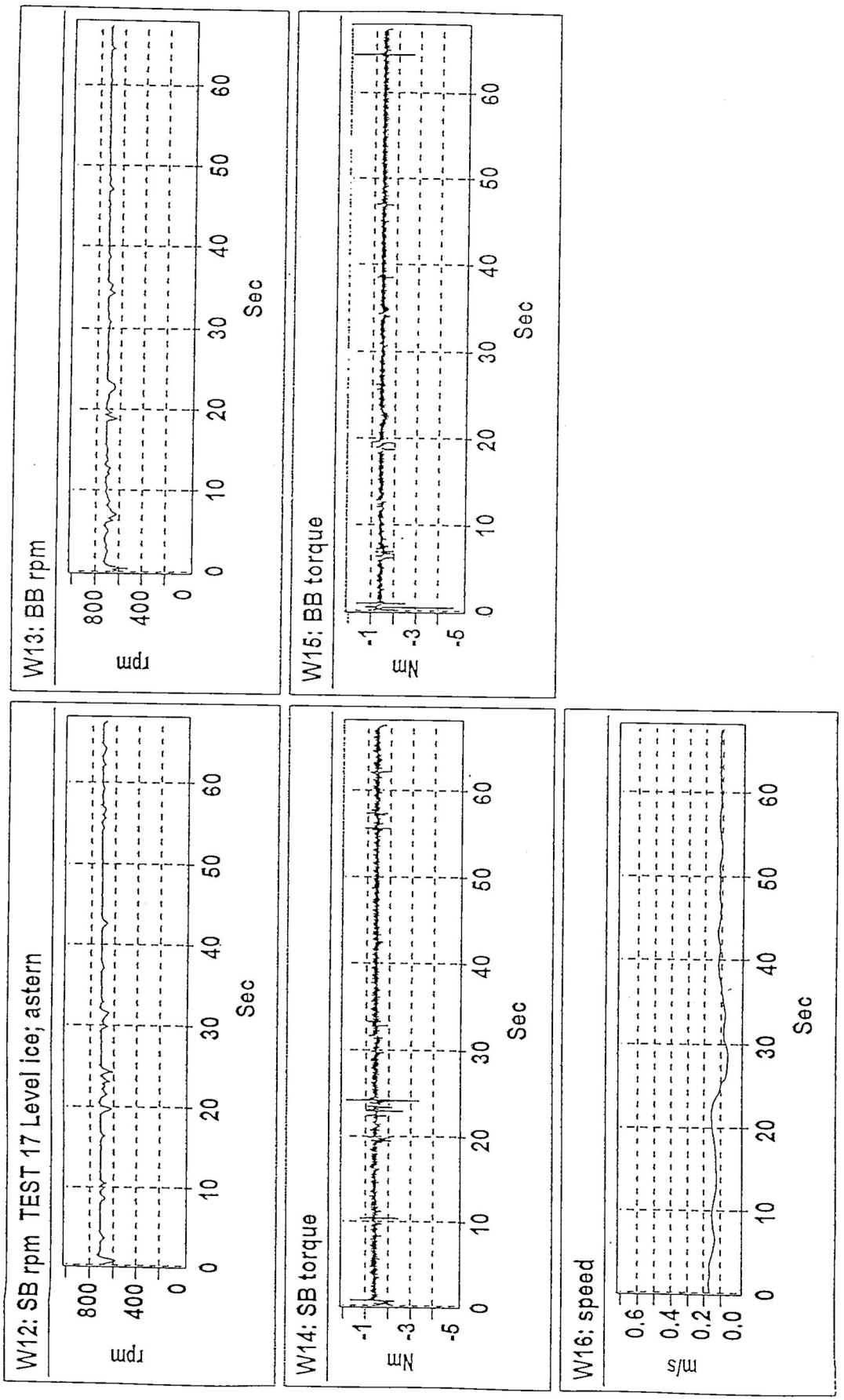
Time history 6 TEST 11 Level ice Hi = 1.2m (f.sc.); astern



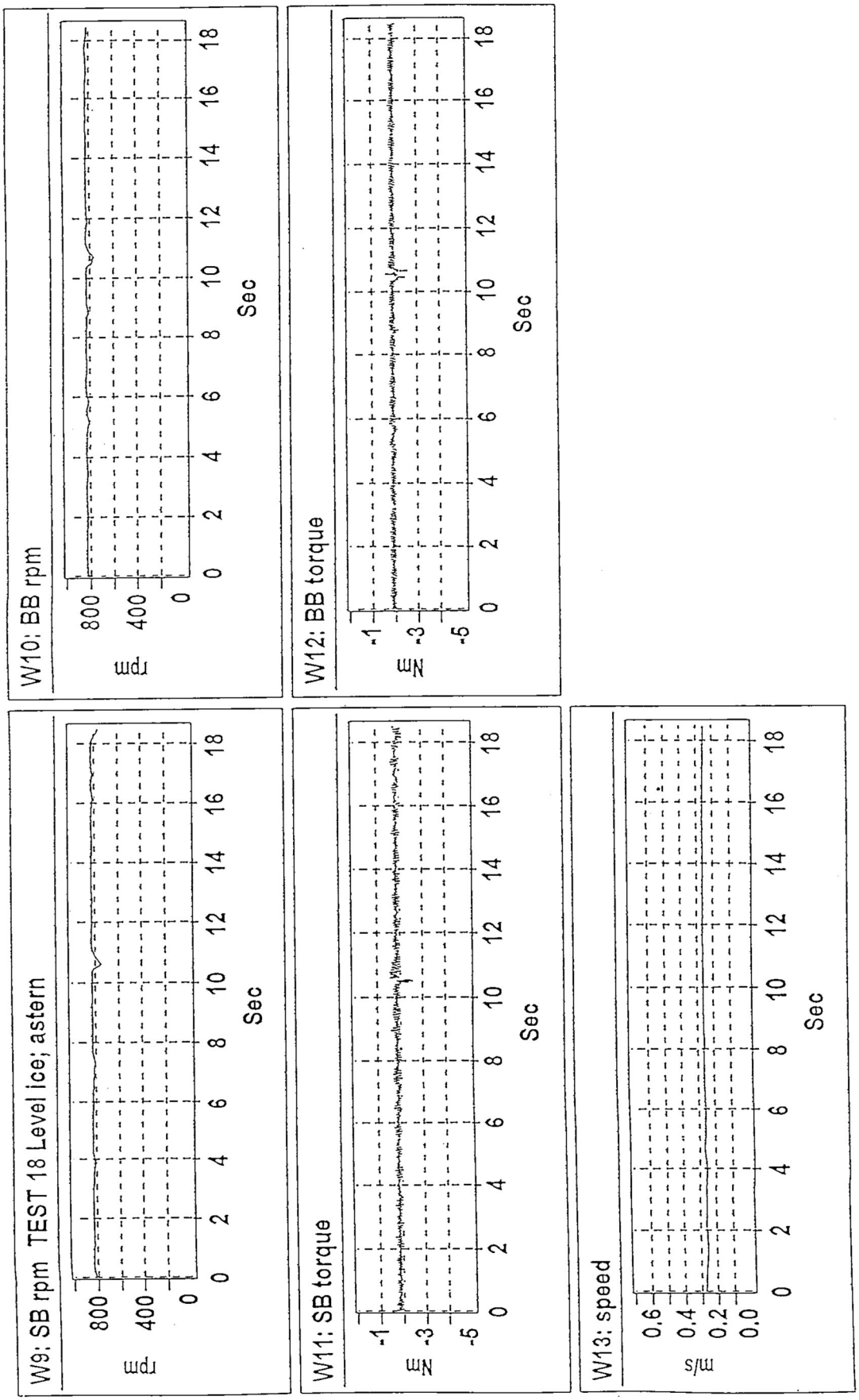
Time history 7 TEST 16 Level ice Hi = 1.8 (f.sc.); astern



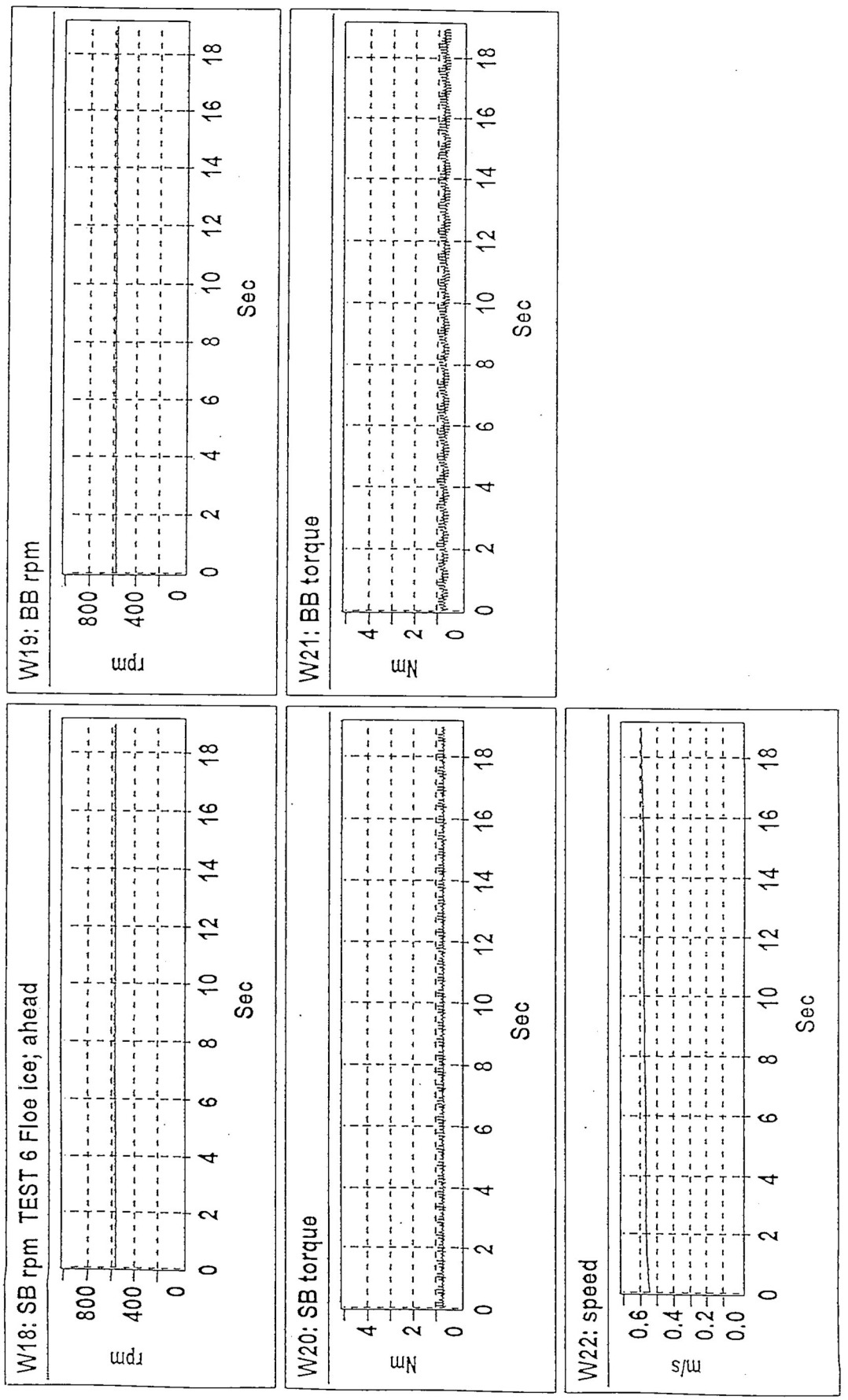
Time history 8 TEST 17 Level ice Hi = 1.8 (f.sc.); astern



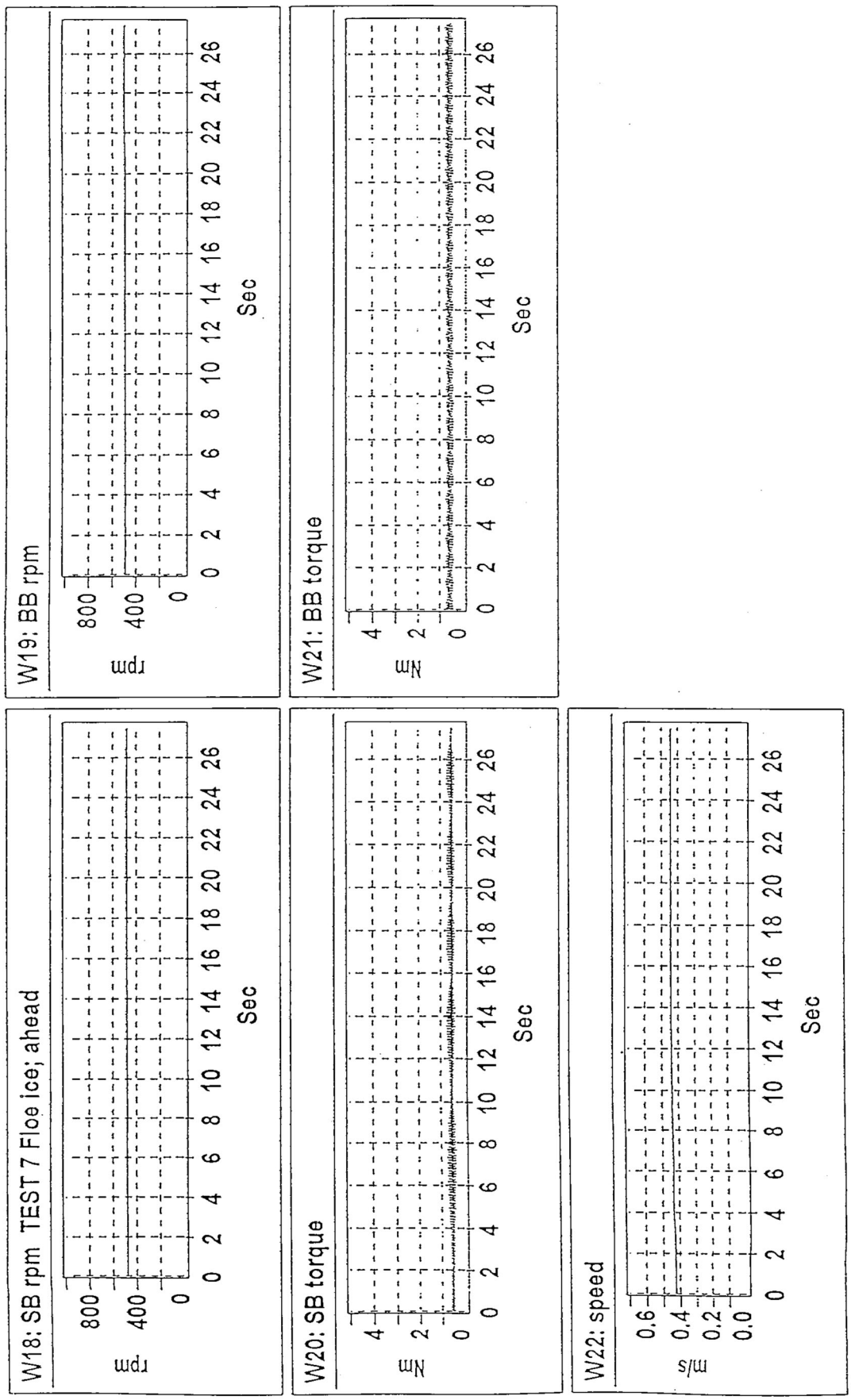
Time history 9 TEST 18 Level ice Hi = 1.8 (f.sc.); astern



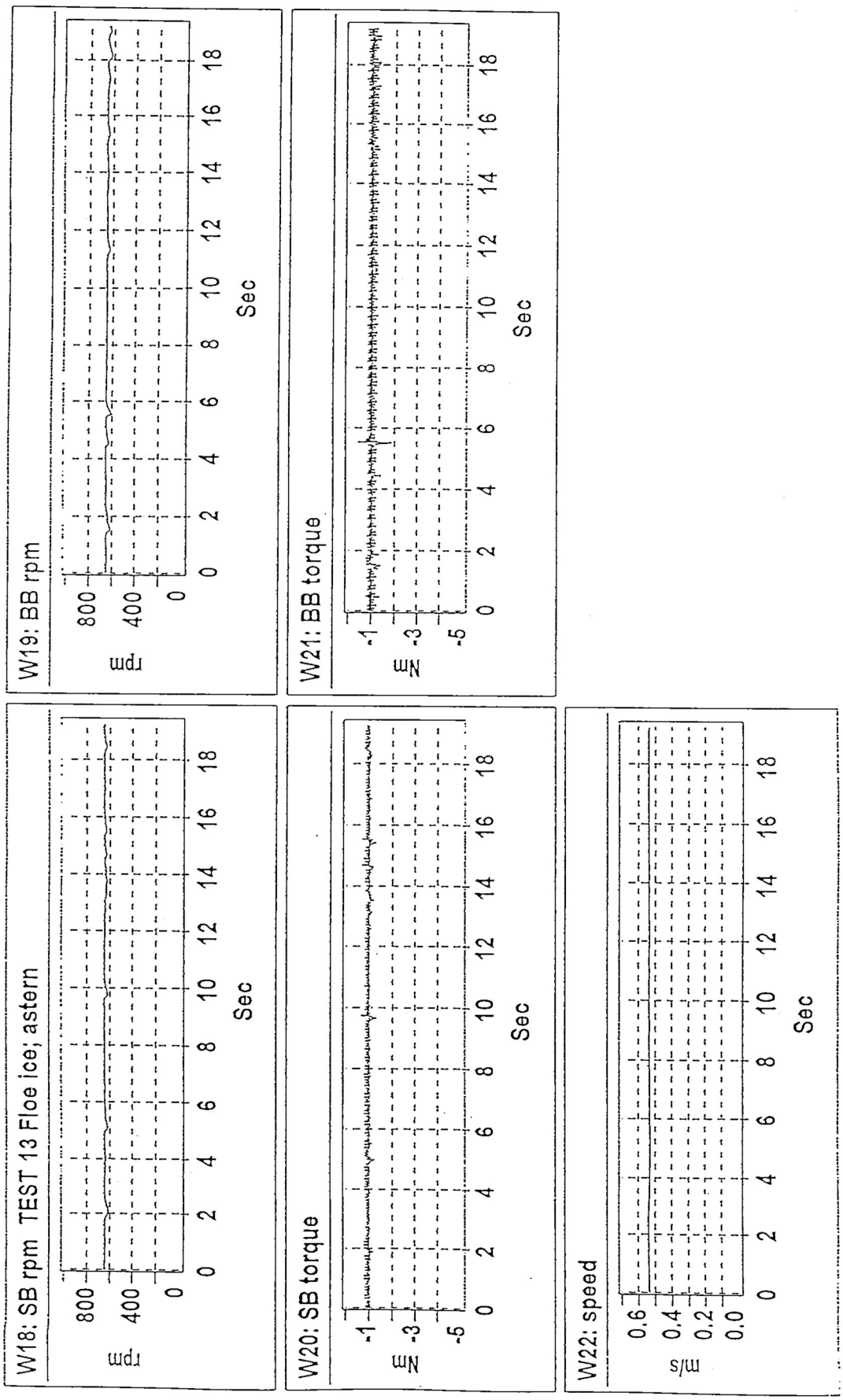
Time history 10 TEST 6 Floe ice Hi = 1.2 (f.sc.); ahead



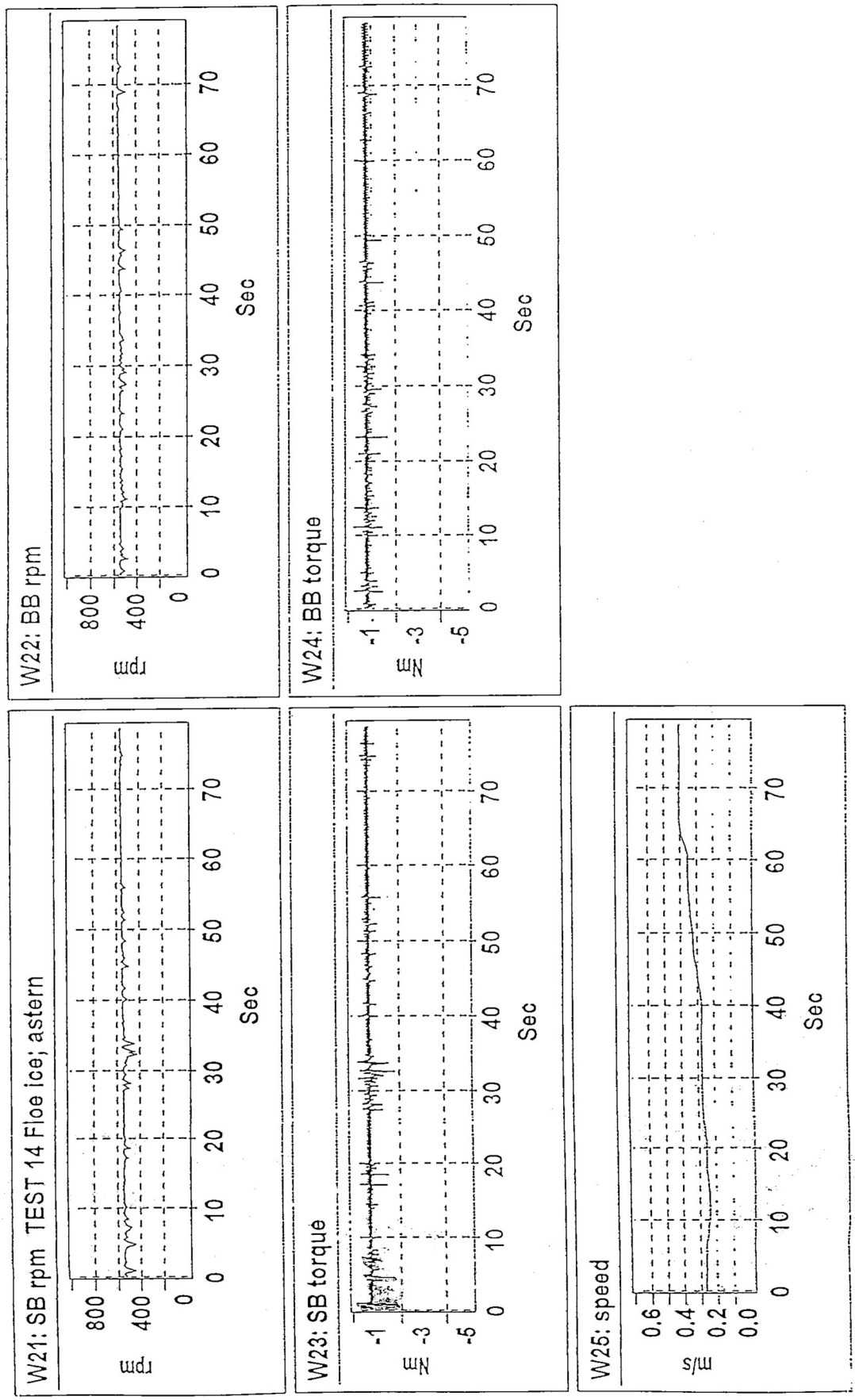
Time history 11 TEST 7 Floe ice Hi = 1.2 (f.sc.); ahead



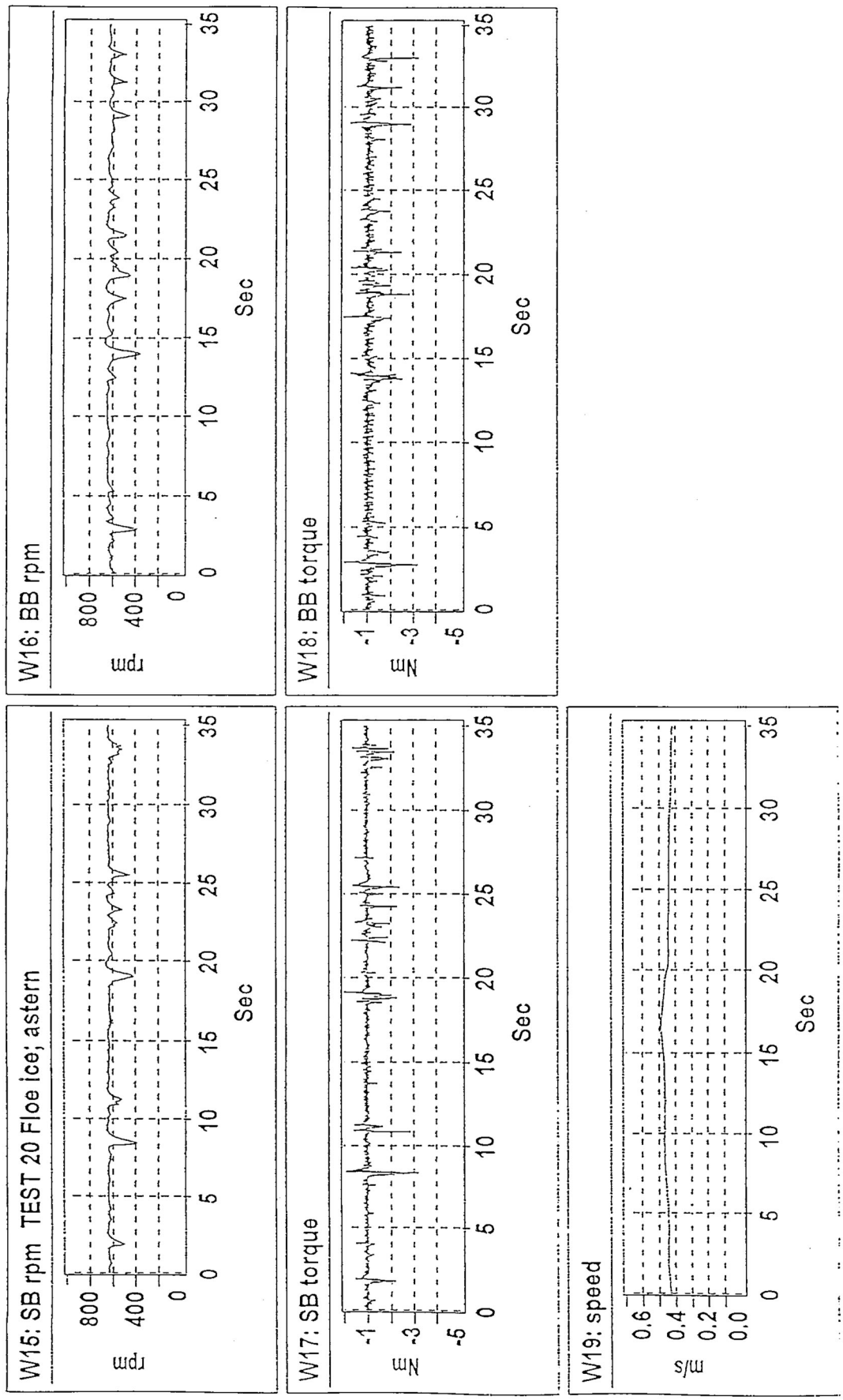
Time history 12 TEST 13 Floe ice Hi = 1.2 (f.sc.); astern



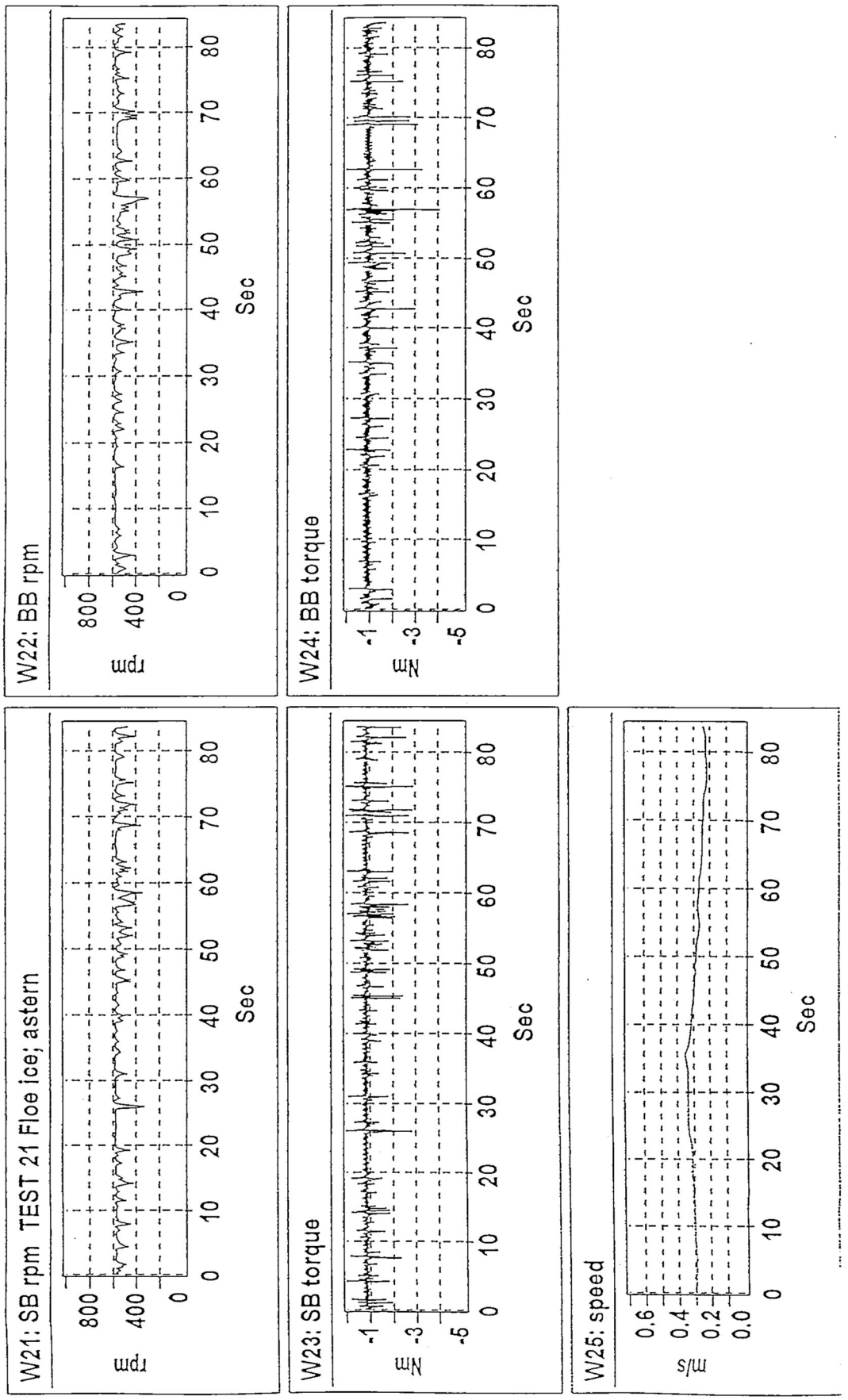
Time history 13 TEST 14 Floe ice Hi = 1.2 (f.sc.); astern



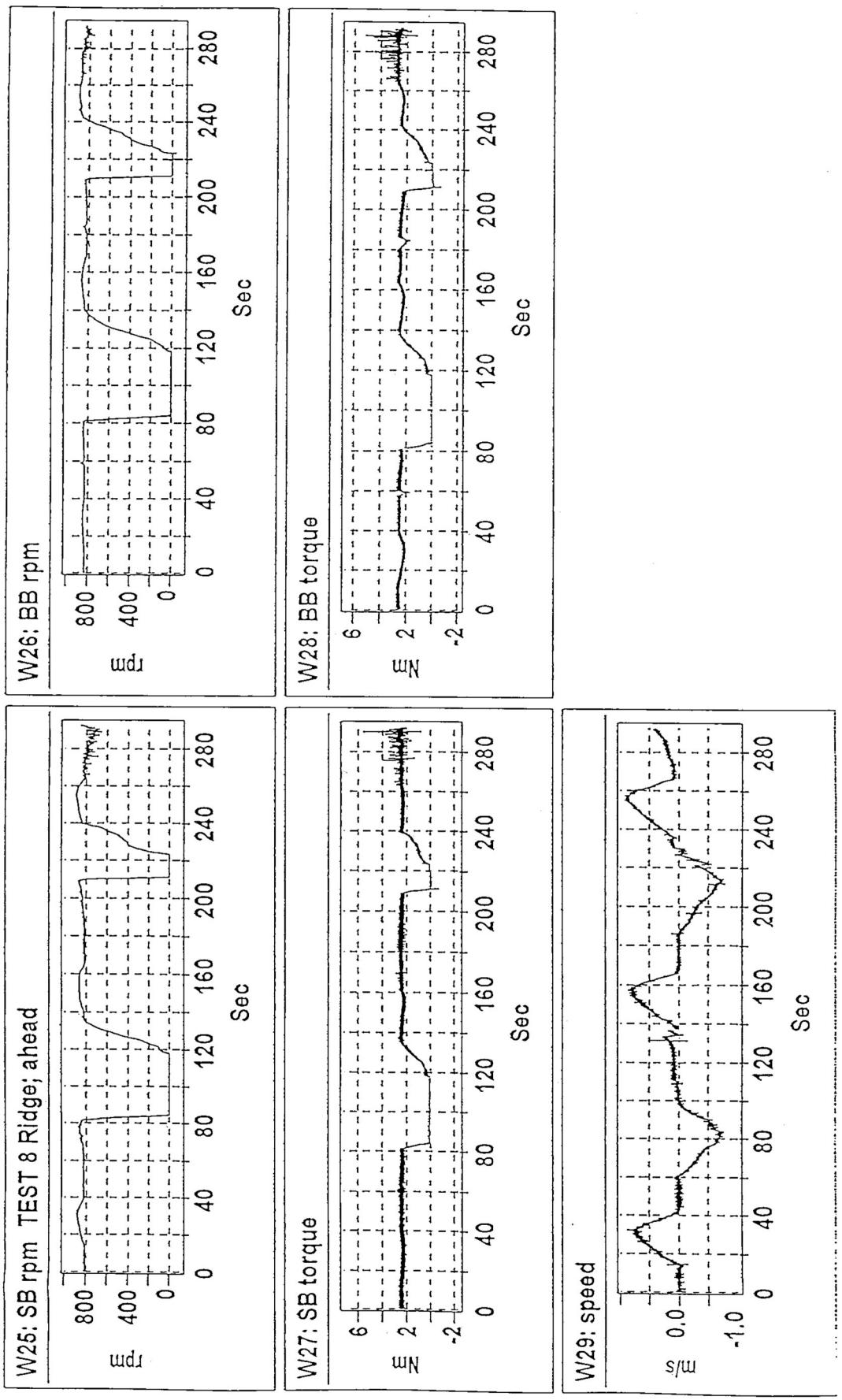
Time history 14 TEST 20 Floe ice Hi = 1.6 (f.sc.); astern



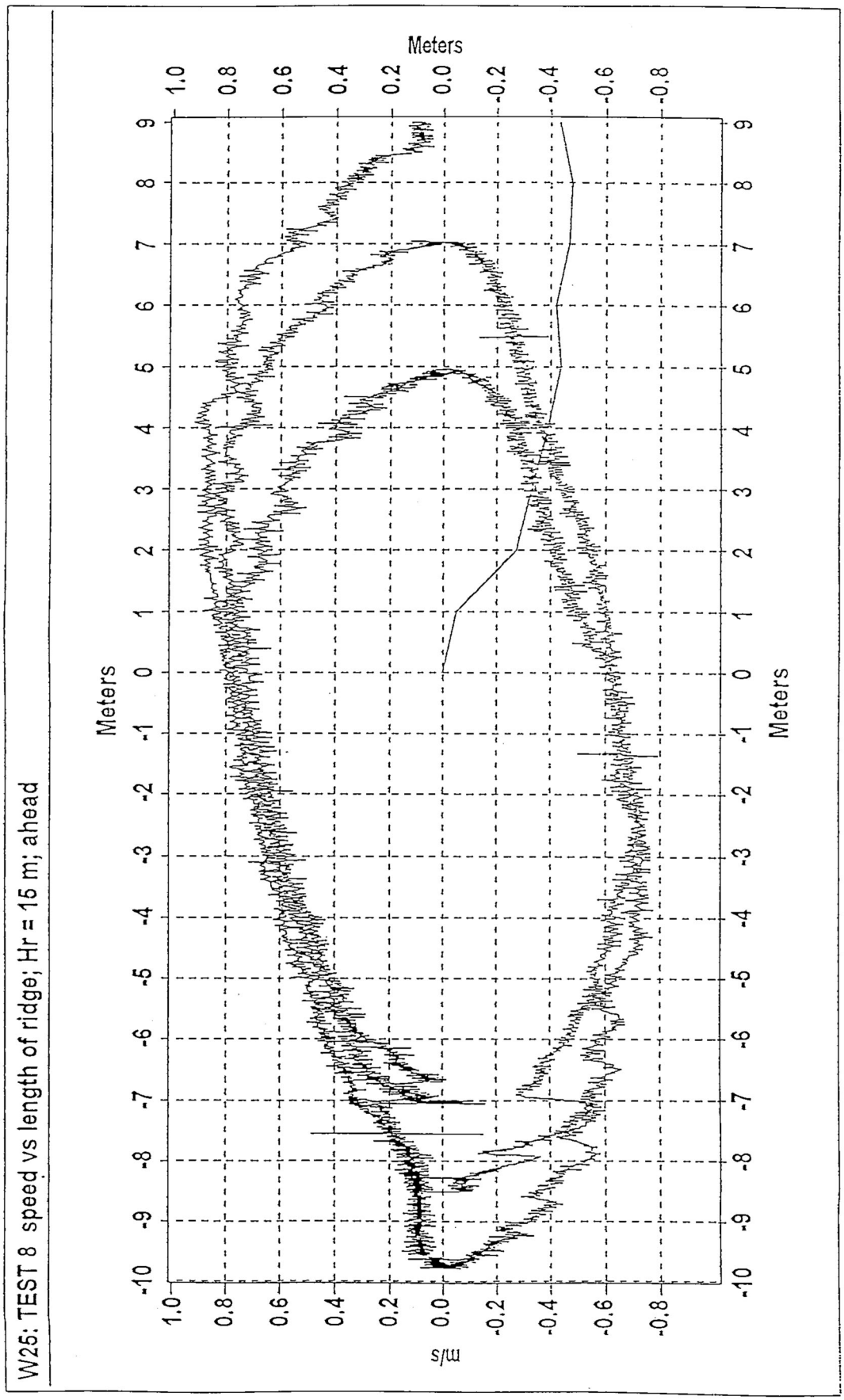
Time history 15 TEST 21 Floe ice Hi = 1.6 (f.sc.); astern



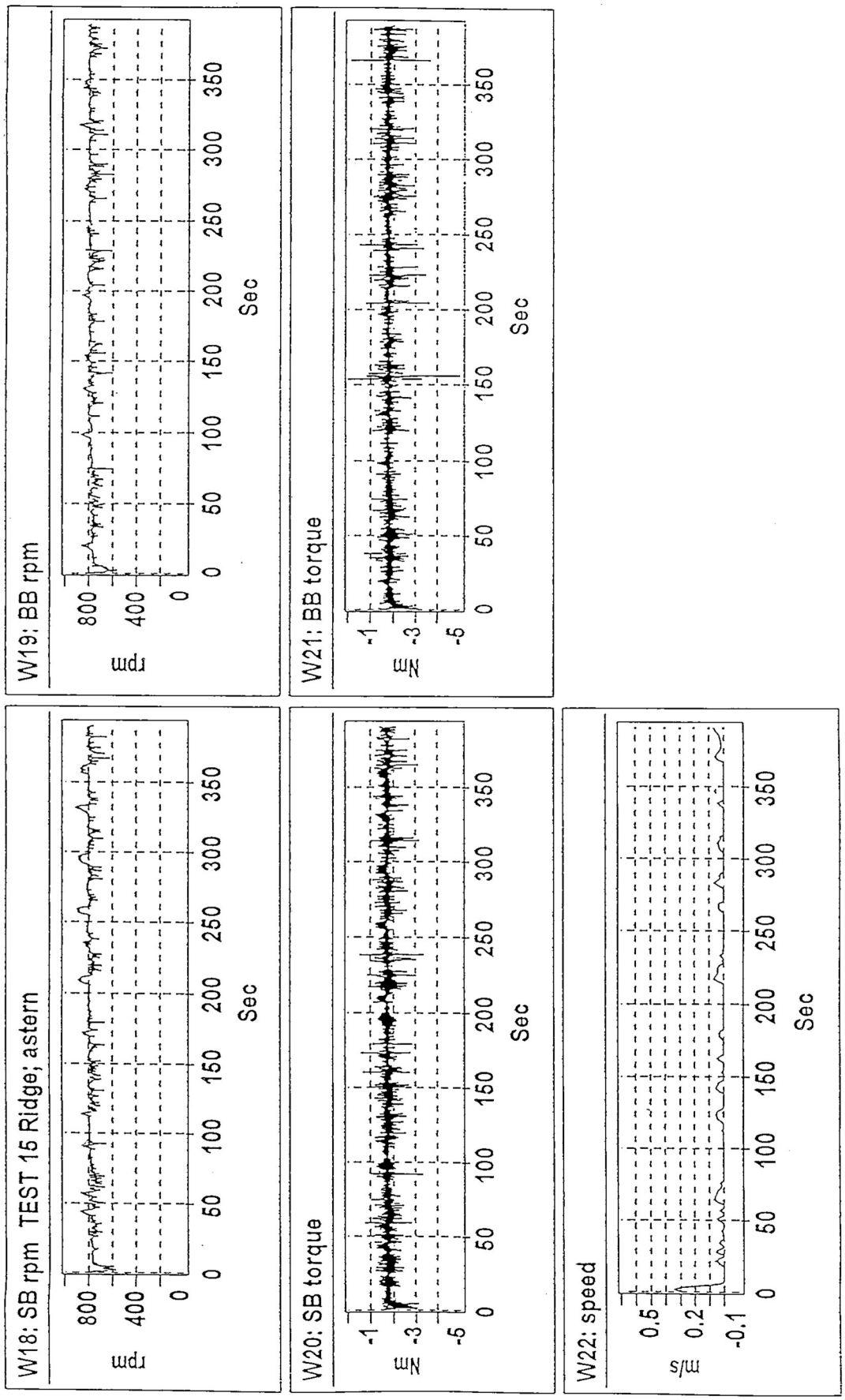
Time history 16 TEST 8 Ridge Hr = 15 m (f.sc.); ahead



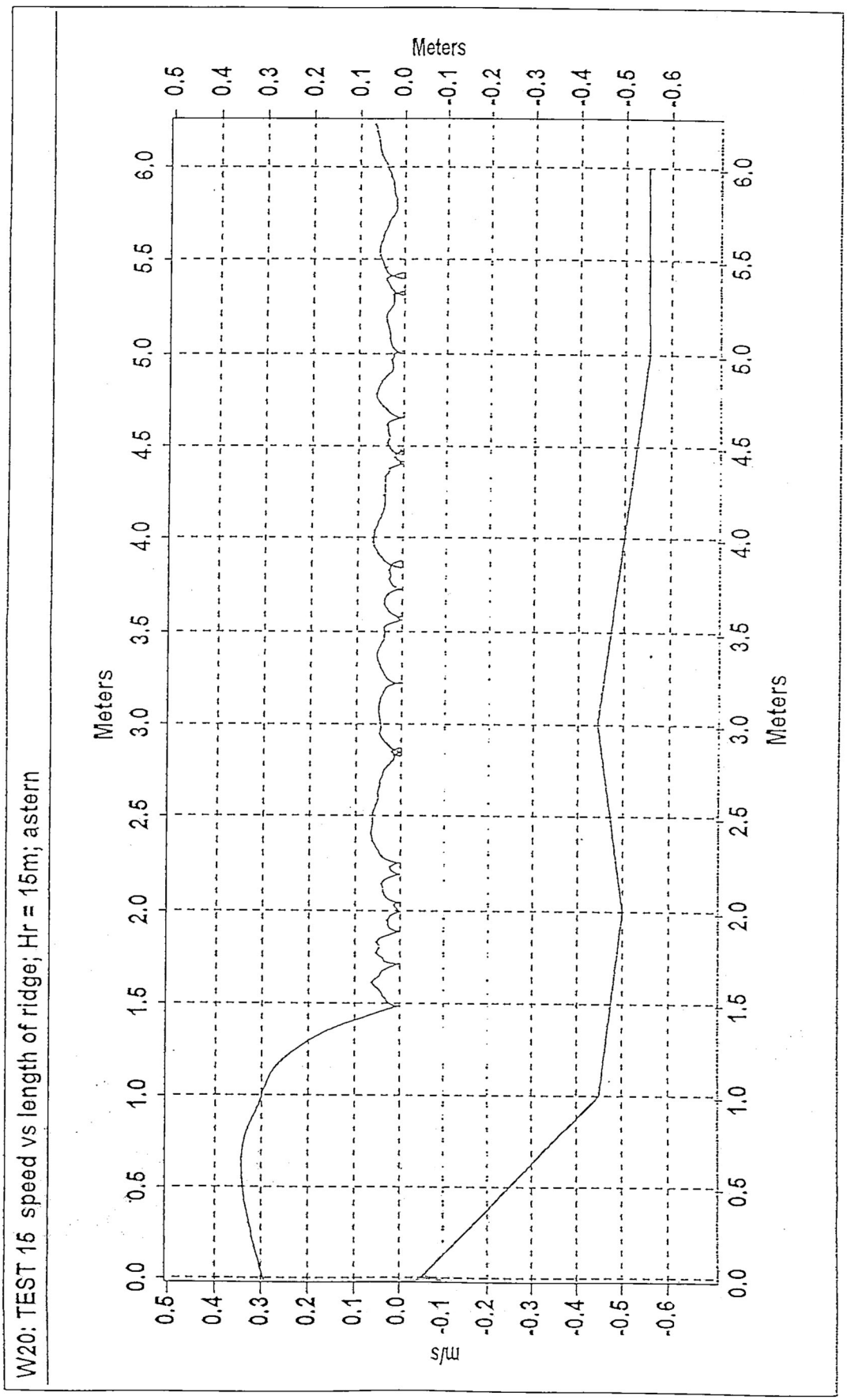
Time history 17 TEST 8 Ridge Hr = 15 m (f.sc.); ahead; speed vs length of ridge



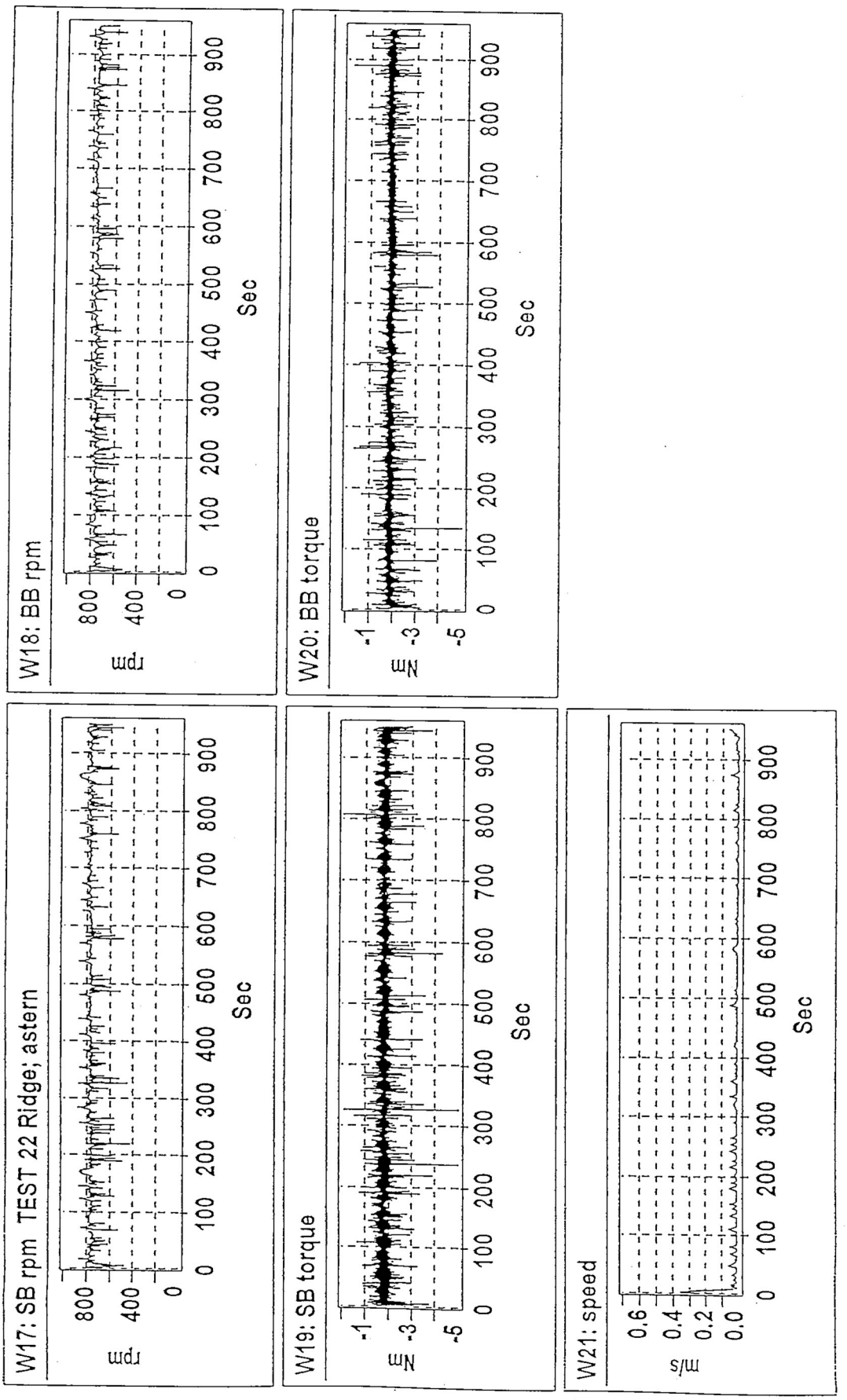
Time history 18 TEST 15 Ridge Hr = 15 m (f.sc.); astern



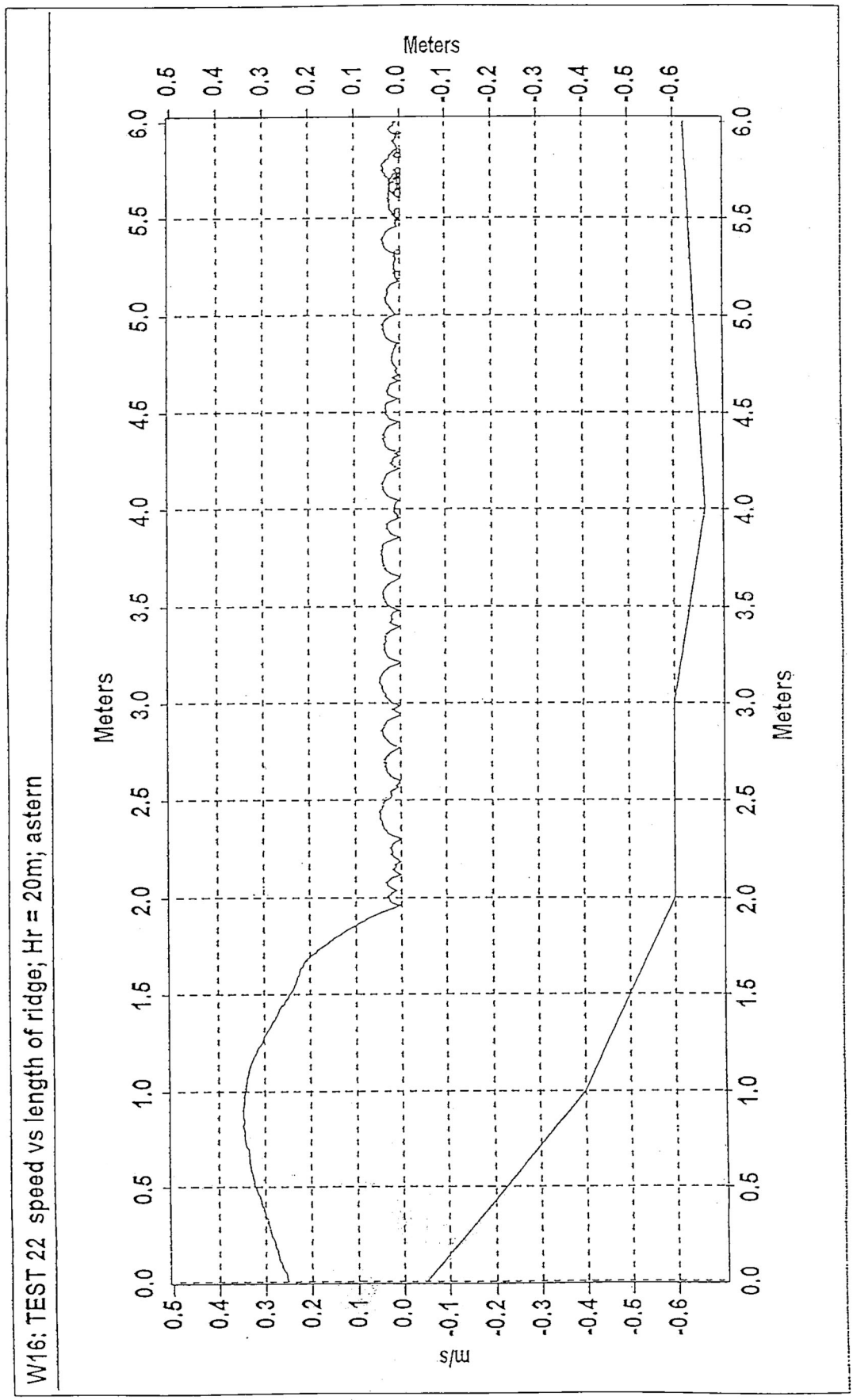
Time history 19 TEST 15 Ridge Hr = 15 m (f.sc.); astern; speed vs length of ridge



Time history 20 TEST 22 Ridge Hr = 20 m (f.sc.); astern

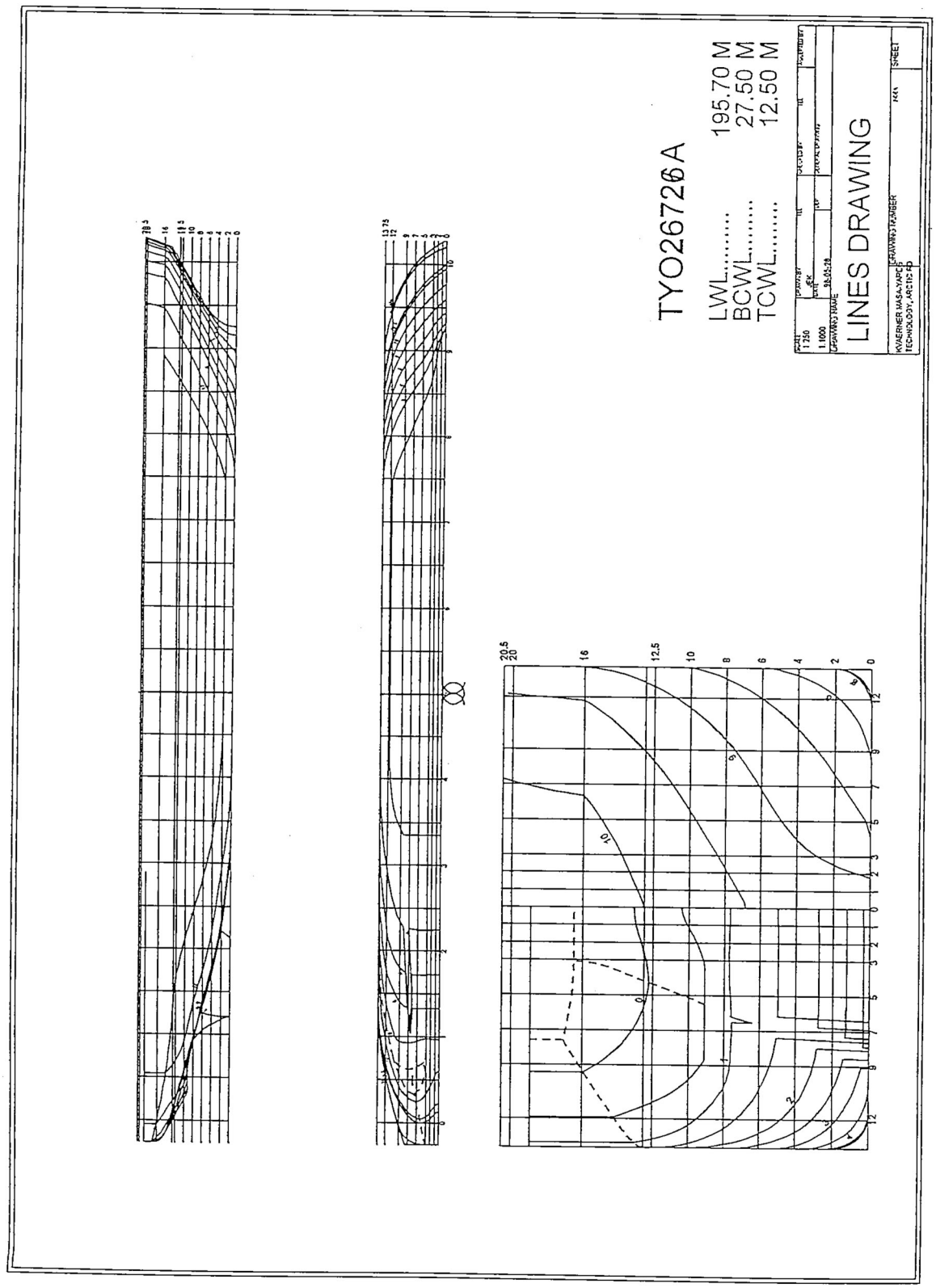


Time history 21 TEST 22 Ridge Hr = 20 m (f.sc.); astern; speed vs length of ridge;

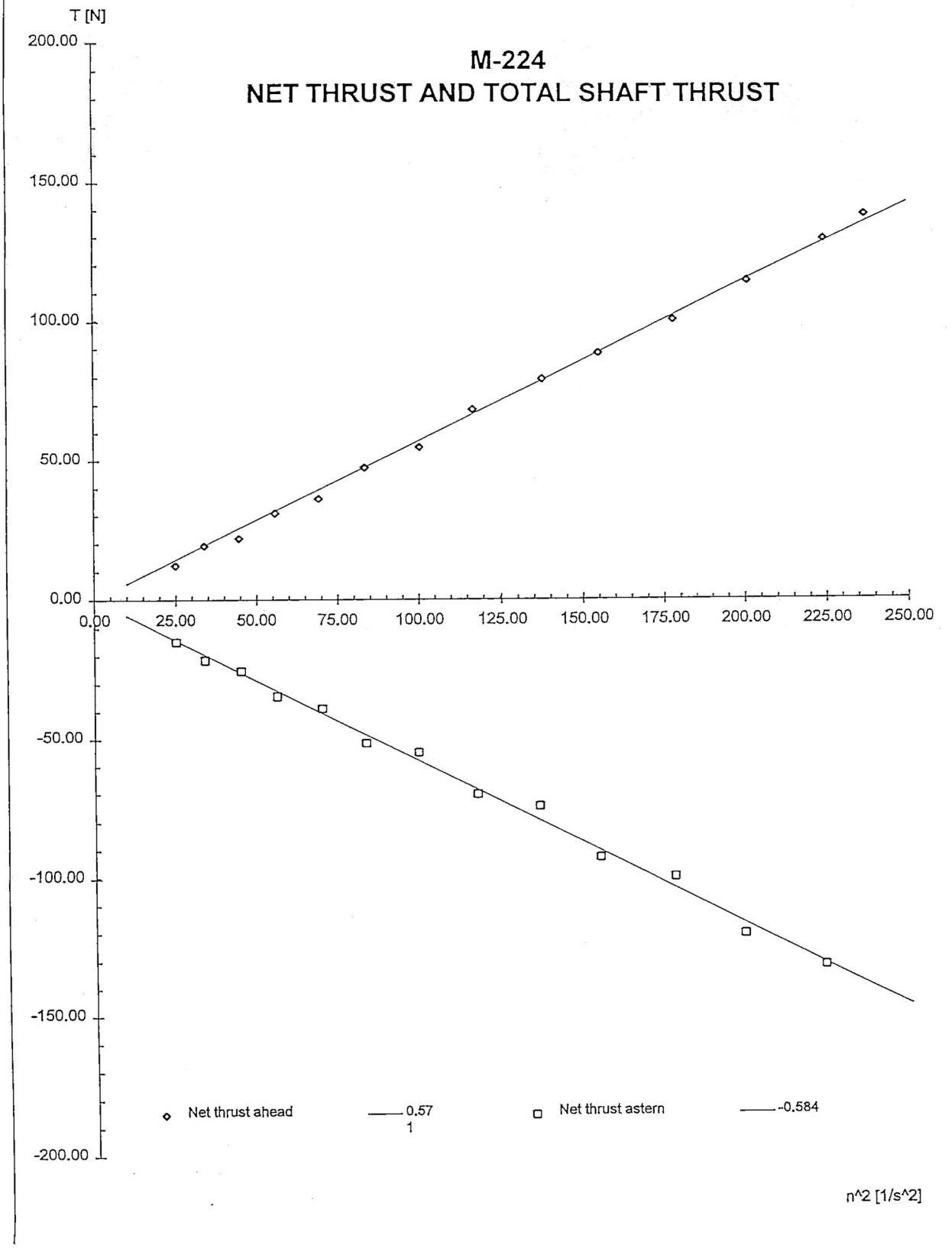


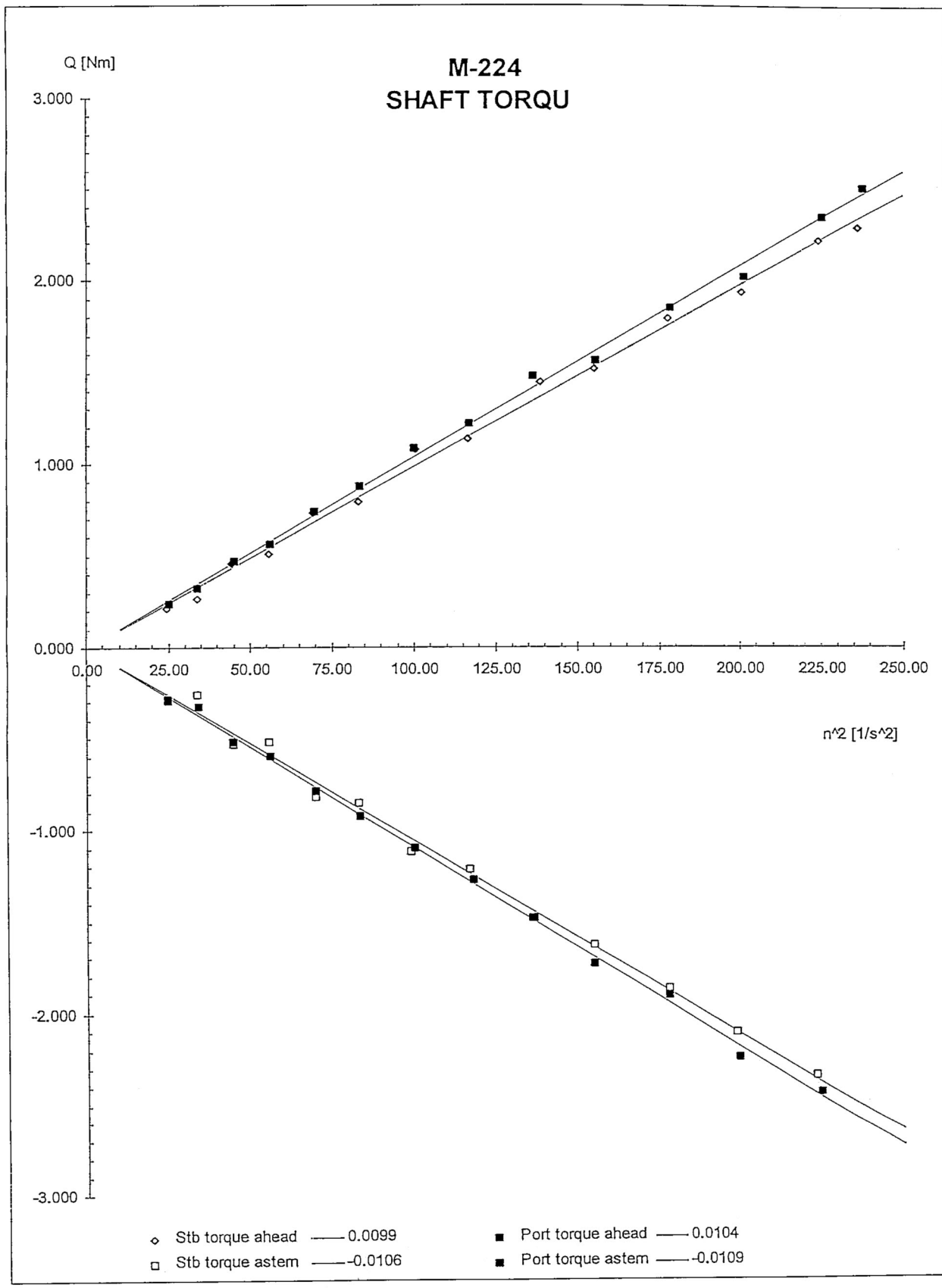
Appendix E Model drawings

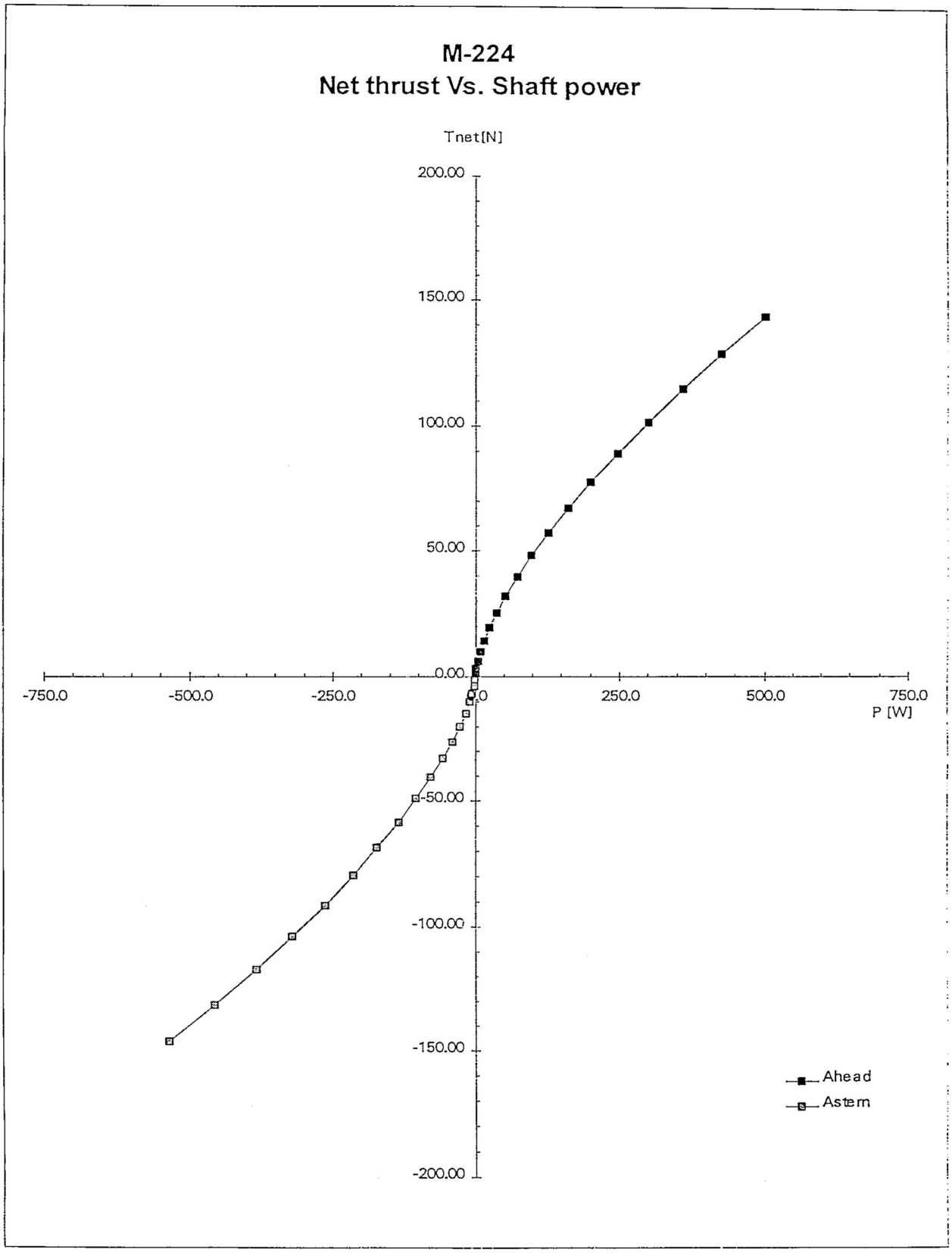
The body plan of M-224

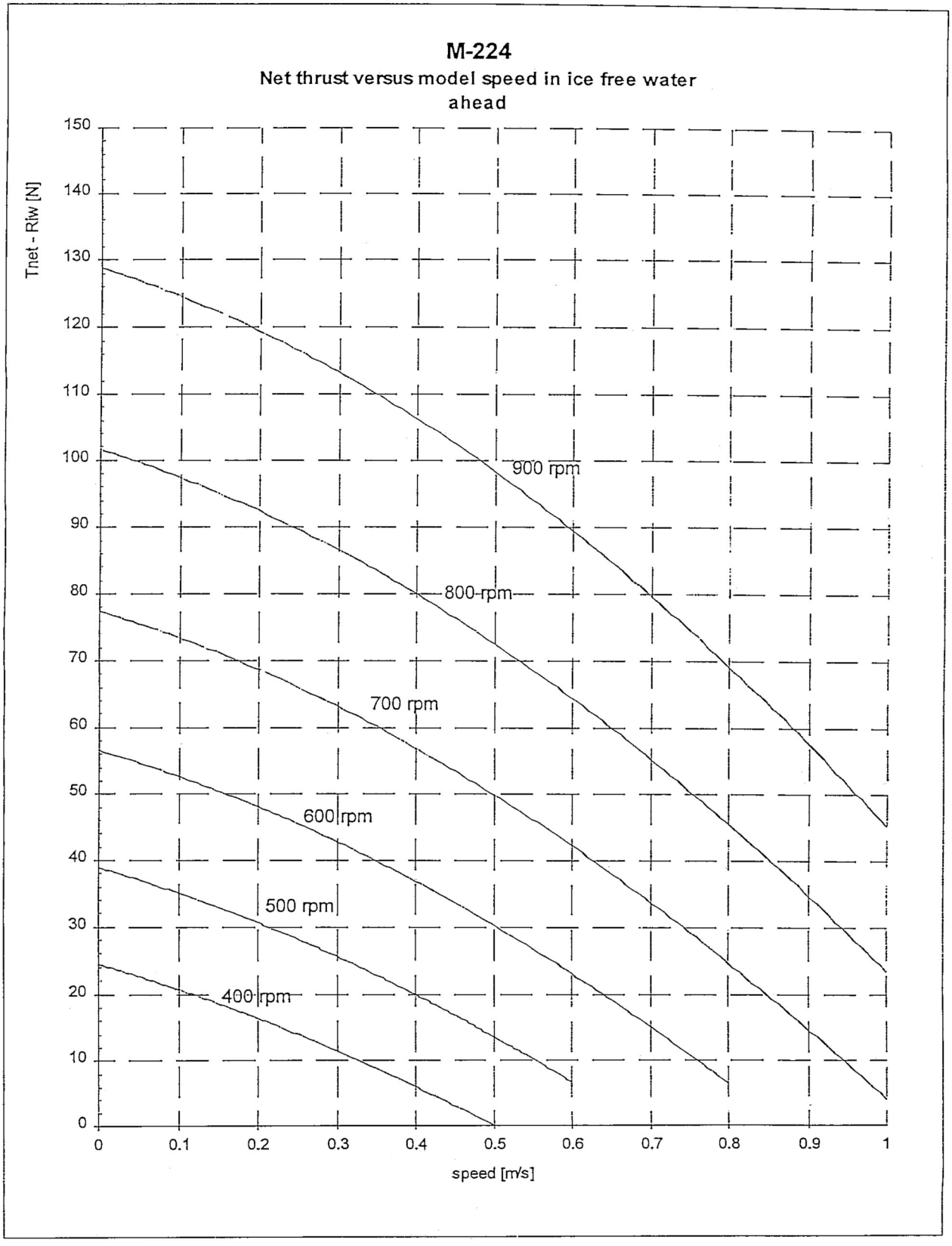


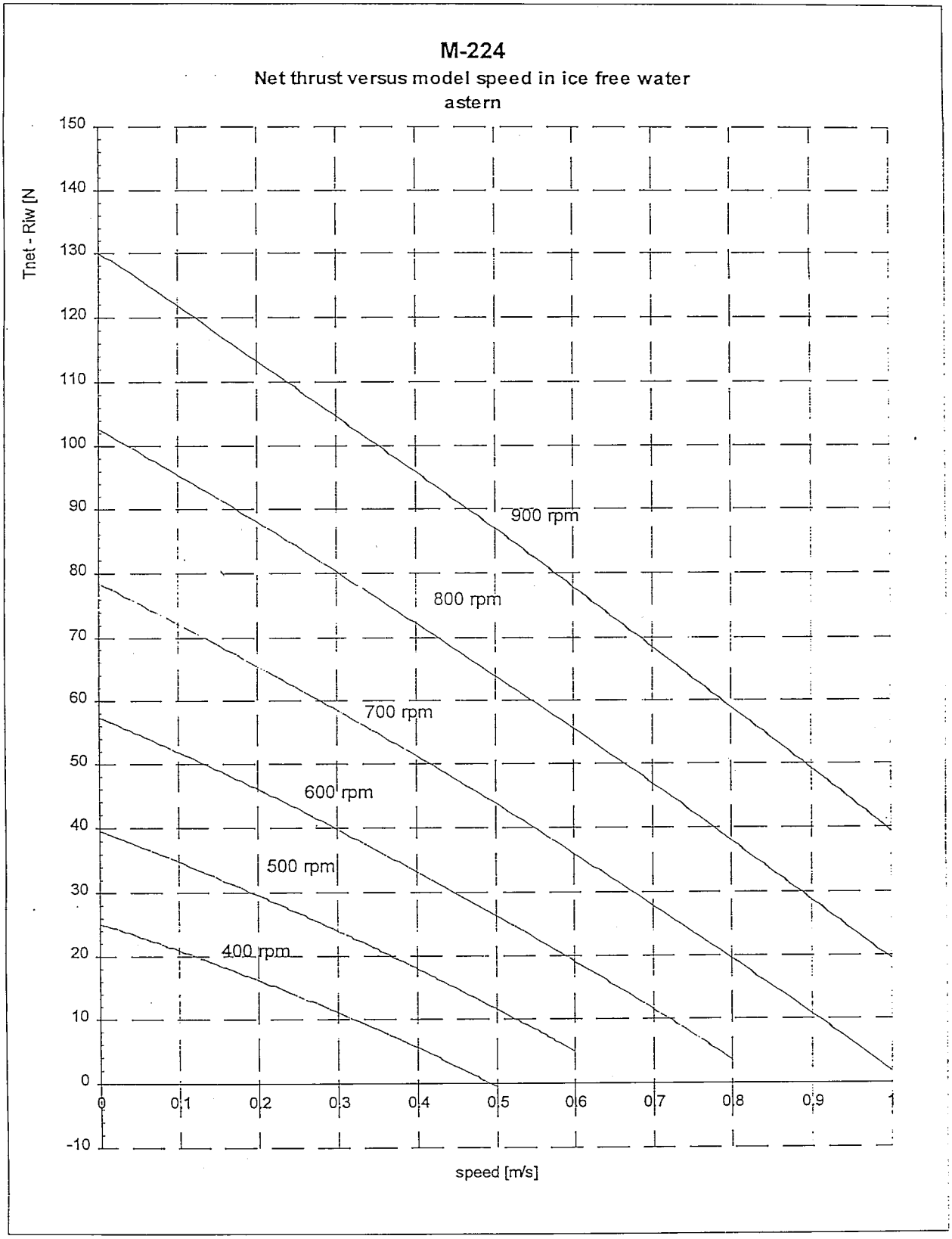
Appendix F Calibration tests


T [N]
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
M-224
NET THRUST AND TOTAL SHAFT THRUST
Net thrust ahead
0.57
1
Net thrust astern
-0.584
n^2 [1/s^2]


M-224
SHAFT TORQU
Q [Nm]
3.000
2.000
1.000
0.000
-1.000
-2.000
-3.000
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
n^2 [1/s^2]
Stb torque ahead —— 0.0099
Stb torque astern —— -0.0106
Port torque ahead —— 0.0104
Port torque astern —— -0.0109


M-224
Net thrust Vs. Shaft power
Tnet[N]
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-750.0
-500.0
-250.0
0.0
250.0
500.0
750.0
P [W]
Ahead
Astern


M-224
Net thrust versus model speed in ice free water
ahead
Tnet - Rtw [N]
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
900 rpm
800 rpm
700 rpm
600 rpm
500 rpm
400 rpm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
speed [m/s]


M-224
Net thrust versus model speed in ice free water
astern
Tnet - Riw [N
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
speed [m/s]
900 rpm
800 rpm
700 rpm
600 rpm
500 rpm
400 rpm

Appendix G WARC Report D-66

WARC REPORT D 66/II

STANDARD TESTING PROCEDURES
AND ANALYSIS OF MODEL TEST IN ICE
AT THE WÄRTSILÄ ARCTIC RESEARCH CENTRE

MARCH 1988

CONTENTS

1 NOMENCLATURE

2 KEYWORDS

3 SCALING METHODS

4 METHODS OF ANALYSIS
4.1 Towing Tests
4.2 Propulsion Tests
4.3 Propeller/Ice Interactions

5 ICE PROPERTIES AND ICE MEASUREMENTS

6 MEASUREMENTS AND EQUIPMENT

7 FRICTION

1 NOMENCLATURE

ITTC STANDARD SYMBOLS (18th International Towing Tank Conference 1987)
Symbols marked with * not included in ITTC Standard Symbols

Standard symbol	Name of concept	Definition or explanation	SI Unit
Concepts in general			
F	Force in general		N
t	Time		s
v, V	Linear velocity		m/s
λ	Scale ratio	Ship dimension divided by corresponding model dimension	
Hull geometry			
B_{cwl}	Breadth at construction waterline		m
L_{cwl}	Length at construction waterline		m
L_{pp}	Length between perpendiculars		m
T_{cwl}	Draught at construction waterline		m
T_A	Draught at aft perpendicular		m
T_F	Draught at forward perpendicular		m
∇, V	Displacement volume		m^3
* γ (mean)	Mean value of buttock angles at CWL	Definition of bow angles, see app. 1	
* γ (cwl)	Sloping of centreline buttock at CWL		
* α (cwl)	Half angle of CWL entrance		
* φ (cwl)	Sloping of side at forebody		
* β	Flare side angle		

	Standard symbol	Name of concept	Definition or explanation	SI Unit
		Propulsor Geometry		
*	A_E/A_0	Blade area ratio		
	A_D	Developed blade area	Developed area of a screw propeller outside the boss or hub	m^2
	A_E	Expanded blade area	Expanded blade area of a screw propeller outside the boss or hub	m^2
	A_0	Disc area		m^2
	A_P	Projected blade area	Projected blade area of a screw propeller outside the boss or hub	m^2
	d	Boss or hub diameter		m
	D	Propeller diameter		m
*	P/D	Pitch ratio		
	P	Propeller pitch in general		m
	R	Propeller radius		m
	Z	Number of propeller blades		
		Ship performance/propulsor performance		
*	n	Propeller RPM		1/min
	P_b	Brake power		W
	P_d	Delivered power at propeller		W
	P_s	Shaft power	Power measured on the shaft	W
*	T_n	Net thrust	$T_n = T * (1-t)$	N
	T	Thrust	At propeller	N
	T_d	Duct thrust		N

	Standard symbol	Name of concept	Definition or explanation	SI Unit
	T_p	Ducted propeller thrust		N
	T_t	Total thrust of a ducted propeller unit		N
	t	Thrust deduction factor		
	Q	Torque	Corresponding to delivered power P_d	Nm
	Resistance and propulsion			
*	CW	Counterweight		N
*	F_w	Towing force in ice-free water		
*	C_μ	Friction correction factor		
*	μ	Dynamic friction coefficient		
	H_i	Thickness of ice		mm, cm, -
	P_{di}	Delivered power at propeller in ice		W
	Q_{ia}	Average torque in ice		Nm
*	R_b	Breaking component of ice resistance		N
	R_i	Net ice resistance	$R_i = R_{it} - R_{iw}$	N
	R_{it}	Total resistance in ice	Ship towing resistance in ice	N
	R_{iw}	Hydrodynamic resistance in presence of ice	Total water resistance of ship in ice	N
*	R_s	Submersion component of ice resistance		N
*	R_v	Velocity component of ice resistance		N
	T_{ia}	Average total thrust in ice		N

	Standard symbol	Name of concept	Definition or explanation	SI Unit
	T_{ni}	Net thrust in ice		N
*	dTn	Decrease of thrust due to ice when moving from open water to ice	dTn = Tn - Tni	N
	n_{ia}	Average rate of propeller revolution in ice		1/min
	Ice mechanics			
		Deflection of ice sheet	Vertical movement of ice surface	mm
	σ_f	Flexural strength of the ice		kPa
	σ_c	Compression strength of the ice		kPa
	E_i	Modulus of elasticity of the ice derived from a sheet deflection test		MPa
	F	Force		N
	B	Breadth of cantilever beam		mm
	L	Length of cantilever beam		mm
	H	Thickness of cantilever beam		mm
	ν	Poisson's constant		
	g	Acceleration due to gravity	Specific gravity acceleration	m/s^2
	ρ	Mass density		kg/m^3

2 KEYWORDS

m.sc.	=	model scale
f.sc.	=	full scale
m	=	model
s	=	ship
i	=	in ice
ia	=	average in ice
w	=	in ice-free water
max	=	maximum value
mean	=	mean value
min	=	minimum value

3 SCALING METHODS

Length	L_S	=	$\lambda * L_m$
Beam	B_S	=	$\lambda * B_m$
Draught	T_S	=	$\lambda * T_m$
Displacement	∇_S	=	$\lambda^3 * \nabla_m$
Velocity	V_S	=	$\sqrt{\lambda} * V_m$
Time	t_S	=	$\sqrt{\lambda} * t_m$
Force	F_S	=	$\lambda^3 * F_m$
Thrust	T_S	=	$\lambda^3 T_m$
Power	P_S	=	$\lambda^{3.5} * P_m$
Torque	Q_S	=	$\lambda^4 * Q_m$
Revolutions	n_S	=	$1/\sqrt{\lambda} * n_m$
Coefficient of friction	μ_S	=	μ_m
Ice thickness	H_S	=	$\lambda * H_m$
Ice strength	σ_S	=	$\lambda * \sigma_m$
Modulus of elasticity	E_S	=	$\lambda * E_m$

4 METHODS OF ANALYSIS

4.1 Towing Tests = Ice Resistance Tests

The forces acting on the model in the towed resistance test are shown below.

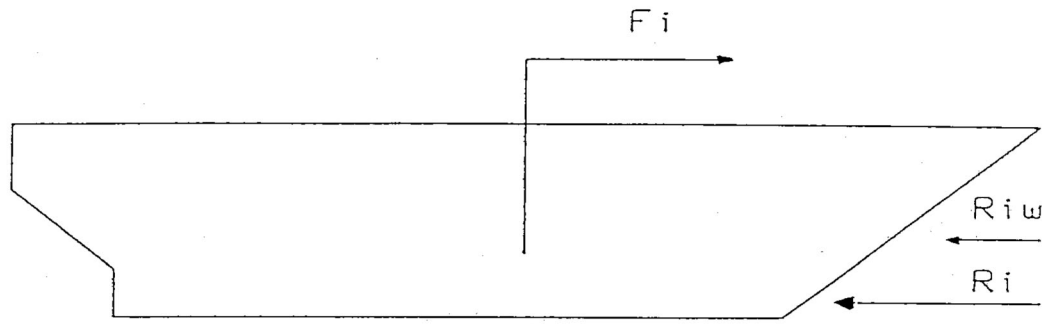


Fig. 1

The ice resistance is determined from the total resistance by subtracting the open-water resistance

(1) $R_i = F_i - R_{iw}$

The ice resistance has been divided into three components which are: breaking component R_b, submersion component R_s and velocity component R_v. In tests made at higher speed than creeping speed, the submersion and velocity components are usually combined into one submersion and velocity component R_{s+v}.

The submersion component of the ice resistance is determined from a test in presawn ice at creeping speed. In this case the ice strength = 0 (presawn ice and therefore $R_b = 0$). At creeping speed $R_v = 0$. From this we obtain:

(2) R_i (in presawn ice) $= R_s$

Presawn ice is an unnatural ice condition, where the ice has been sawn before the test to the same figure as the breaking pattern of the model.

The breaking component is determined from a level ice test at creeping speed, where

(3) R_i (in level ice, at creeping speed) = $R_b + R_s$

(4) R_b = R_i (in level ice, at creeping speed) - R_i (in presawn ice)

The breaking component is assumed to be constant regardless of speed. Thus we obtain (in level ice), at speeds greater than creeping speed, the following:

(5) $R_i = R_b + R_{s+v}$

If the thickness of the ice, in which the test was performed, deviates from the target thickness, the ice resistance can be reduced to the target thickness with the following formula:

(6) $$R_i \text{ (reduced)} = \left(\frac{H_i \text{ (target)}}{H_i \text{ (measured)}} \right)^x * R_i \text{ (measured)}$$

The exponent x is depending on the hull form of the ship, mainly the bow form. The exponent is based on previous model and full scale tests.

If the strength of the ice in which the test was performed deviates from the target strength, the ice resistance can be reduced to the target strength by correcting the breaking component of ice resistance according to the following formula:

(7) $$R_b \text{ (reduced)} = \left(\frac{\sigma_f \text{ (target)}}{\sigma_f \text{ (measured)}} \right) * R_b \text{ (measured)}$$

A full scale prediction based on the model tests is obtained by the following formula:

(8) $R_i(s) = \lambda^3 * C_\mu * R_i(m)$

where C_μ is the friction correction factor. The factor is based on previous model tests made with different friction coefficients.

4.2 Propulsion Tests

The forces acting on the model in towed propulsion tests are shown below. In self-propulsion tests there are of course no towing force or counterweight.

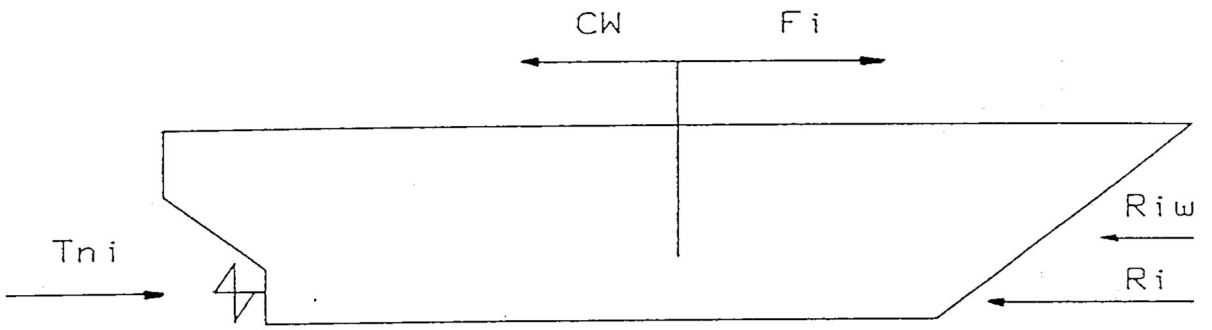


Fig. 2

4.2.1 Propulsion tests, constant shaft revolution

From the scheme presented in Fig. 2 we obtain:

(9) $F_i + T_{ni} = R_i + R_{iw} + CW$

where T_{ni} is the net propeller thrust in ice.

As the following is applicable to open water:

(10) $T_n = (1-t) * T$ in open water

then T_{ni} can be determined as follows:

(11) $T_{ni} = T_n - dT_n$

where dT_n is the decrease of net thrust due to ice.

Based on the equations presented above we obtain:

(12) $R_i + dT_n = T_n + F_i - R_{iw} - CW = F_i - F_w$

where F_w = towing force in ice-free water

$R_i + dT_n$ is usually the main result of towed propulsion tests, but if towed resistance tests have also been performed in the same conditions, dT_n can also be determined.

(13) $dT_n = (R_i + dT_n) - R_i$ (towing test)

Corresponding to the towed resistance tests, a full scale prediction for $R_i + dT_n$ based on the propulsion tests could be made using the following formula:

(14) $(R_i + dT_n)\,(s) = \lambda^3 * C_\mu * (R_i + dT_n)\,(m)$

4.2.2 Propulsion test, constant shaft output

The forces acting on the model are the same as in the tests with constant shaft revolution.

The difference to the tests with constant shaft revolution is that the power is constant, which means a decrease of the shaft speed during ice contacts.

The methods of analysis are the same as those presented in 4.2.1. The only difference is in formula (10) where the decrease of shaft revolution has to be noticed.

(10) $T_n = (1-t) * T$

T is calculated with the same shaft revolution as the average shaft speed in ice.

4.2.3 Self-propulsion tests

The methods of analysis are the same as those presented in 4.2.1 and 4.2.2. There is of course no towing force ($F_i = 0$) or counterweight ($CW = 0$).

4.3 Propeller/Ice Interactions

4.3.1 Ice torque

Constant shaft revolution

The effect on the propeller/ice interaction on the shaft torque is defined using the following formula:

(15) $Q_i = Q_{ia} - Q_w$

where Q_w = torque measured in propulsion tests in ice-free water

Constant shaft output

The ice torque is the dynamic shaft torque, open water torque and the inertia caused by retardation of the propeller and propeller shaft.

The ice torque can be derived from

(16) $Q_i = Q - Q_w - J*dn/dt$

J = the inertia of the propeller and the shaft behind the measuring point
n = propeller revolutions
t = time

where Q = total measured torque on the shaft

4.3.2 Propeller/ice interaction time

The propeller/ice interaction time is derived either from

- the shaft torque (constant shaft RPM)
  or
- the shaft revolution (constant shaft output)

Ice interaction occurs when

$$Q_{ia} \geq 1.10\text{-}1.15 * Q_w \text{ and } Q_{ia} \leq 0.85\text{-}0.90 * Q_w$$

or

$$n_{ia} \geq 1.05 * n_w \text{ and } n_{ia} \leq 0.95 * n_w$$

The ice interaction time is given as a percentage of the total measuring period.

$$(17) \quad \left(\frac{t_i}{t}\right) * 100$$

where t = time

4.3.3 Decrease of shaft revolution

The shaft revolution in ice is usually given as a percentage RPM of the shaft speed in ice-free water.

The results include an average value and a minimum value.

5 ICE PROPERTIES AND ICE MEASUREMENTS

Ice thickness

The ice thickness is measured after the tests at intervals of 1 m lengthwise on both sides of the broken channel.

Ridge thickness

The ridge thickness is measured before the tests lengthwise at intervals of 1 m.

Ice strength and modulus of elasticity

The flexural strength of the ice is determined by cantilever beam tests as follows:

A cantilever beam is when:

H_i = 10-25 mm	180 mm long and 70 mm wide
H_i = 25-50 mm	260 mm long and 100 mm wide
H_i = 50-100 mm	400 mm long and 140 mm wide

The cantilever beam is sawn in the ice and broken by submerging (pressing) its outer end. The force needed to break the beam is measured. In addition, the exact dimensions of the cantilever beam are measured from the broken beam. The flexural strength of the ice can be obtained by the following formula:

$$(18) \quad \sigma_f = \frac{6 * F * L}{B * H^2}$$

The modulus of elasticity is determined by an infinite plate bending test and can be obtained by

$$(19) \quad E_i = \frac{3}{16} * \frac{(1-\nu^2)}{\rho * g * H^3} * \left(\frac{F}{\delta_i}\right)^2$$

The flexural strength of the ice is measured daily by making a few cantilever beam tests before the ice tests and about eight cantilever beam tests on both sides of the channel. In connection with the propulsion tests, however, all the beam tests are made before the tests. The modulus of elasticity is measured daily just before the tests.

6 MEASUREMENTS AND EQUIPMENT

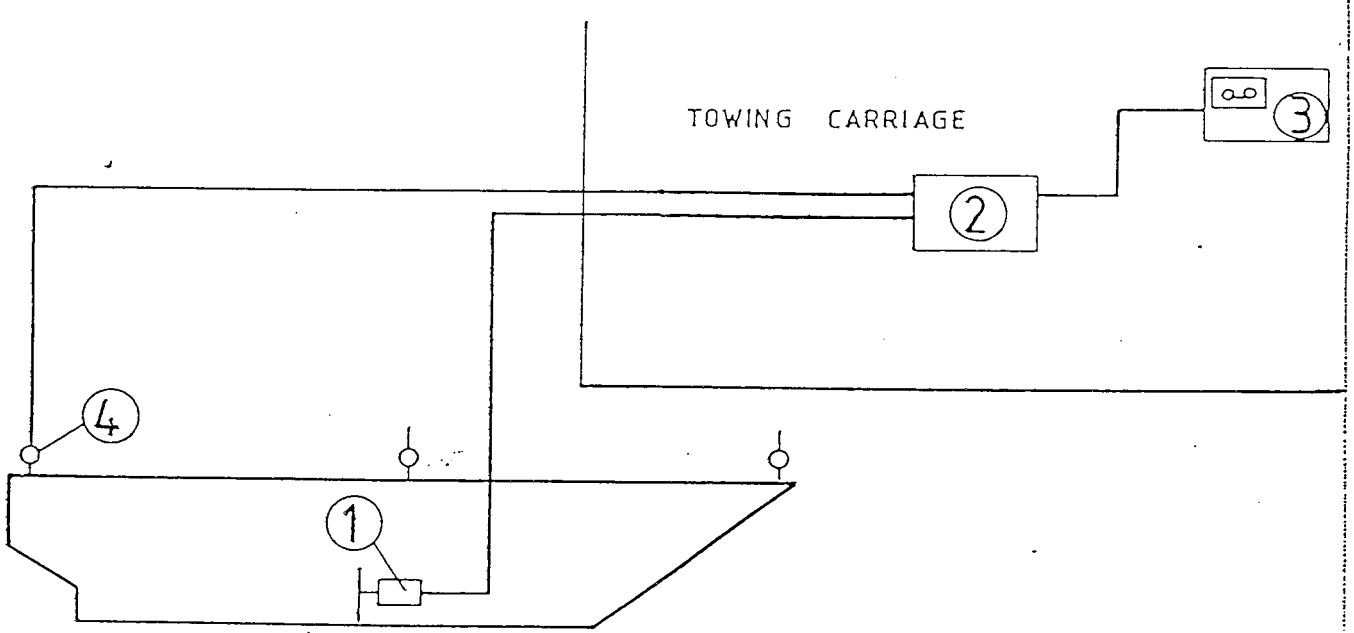
The standard measurements and equipment are presented in the following figures:

Figure 1 - Towed Resistance Tests
Figure 2 - Towed Propulsion Test

WARC	A SCHEMATIC PLAN OF THE MEASURING EQUIPMENT TOWING TEST	D 66
		FIG. 1

For determination of the ice resistance in the towing tests, the towing force is measured and recorded on magnetic tape.

The resistance tests are performed with the model free to heave, surge, pitch and roll but restrained in yaw and sway.

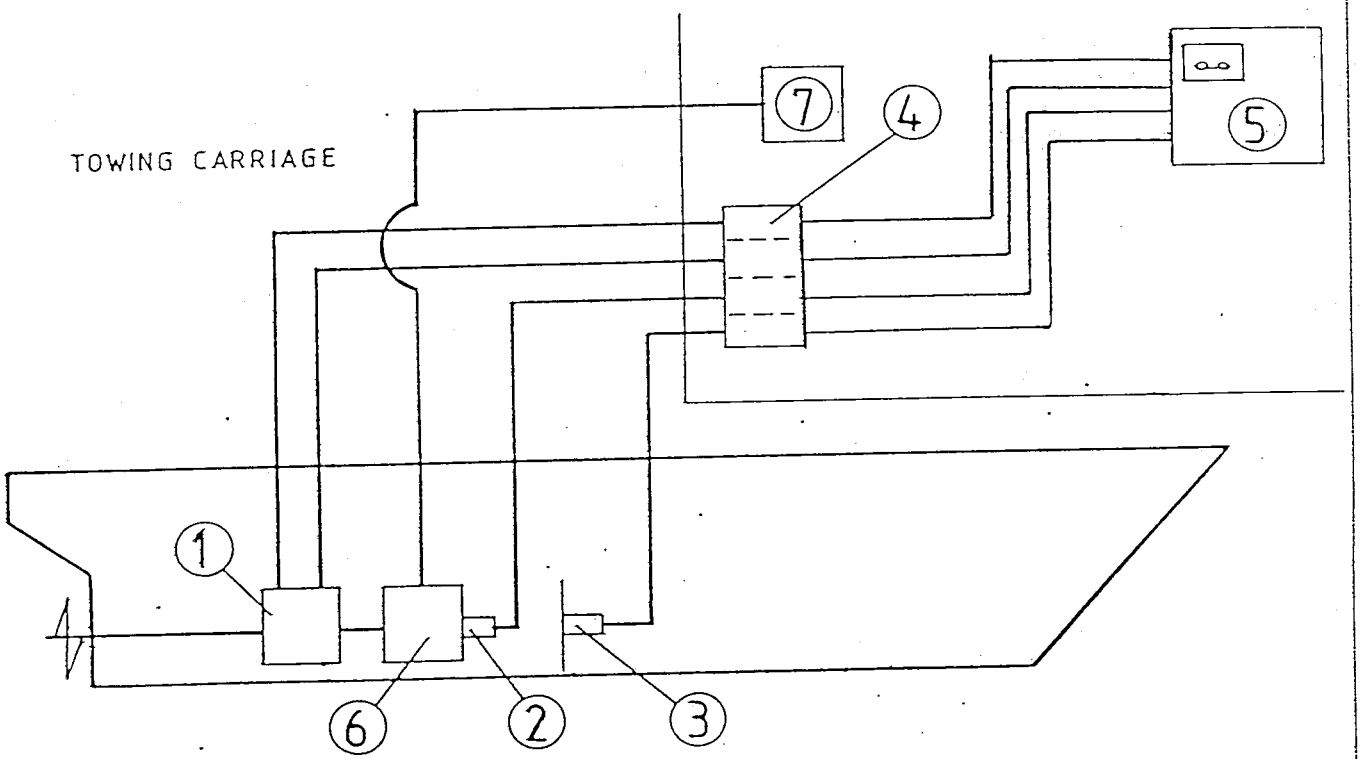


1. FORCE TRANSDUCER, HOTTINGER-BALDWIN, TYPE U-2
2. DC AMPLIFIER, ACCUDATA 218
3. MAGNETIC TAPE RECORDER, (KYOWA RTP-600)
4. POTENTIOMETER FOR MEASURING ROLL AND PITCH

   (NOT A STANDARD MEASUREMENT)

WARC	A SCHEMATIC PLAN OF THE MEASURING EQUIPMENT PROPULSION TEST	D 66
		FIG. 2

In addition to the towing force in the towed propulsion tests also the shaft torque, propeller thrust and propeller revolution are measured and recorded on magnetic tape.



1. MEASURING EQUIPMENT FOR THRUST AND TORQUE KEMPF & REMMERS
2. TACHOMETER, ELTOMATIC
3. FORCE TRANSDUCER, HOTTINGER-BALDWIN, TYPE U-2
4. DC AMPLIFIER, ACCUDATA 218
5. MAGNETIC TAPE RECORDER, (KYOWA RTP-600)
6. ELECTRIC MOTOR, (AC OR DC)
7. FREQUENCE TRANSFORMER (AC) OR COMPUTER CONTROLLED POWER UNIT (DC) FOR ELECTRIC MOTOR

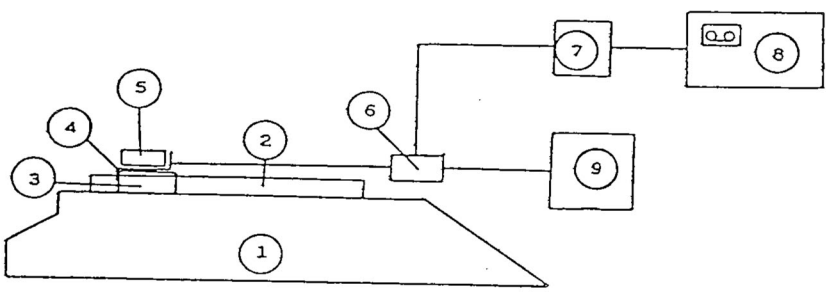
7 FRICTION

7.1 General

Based on several friction measurements performed in both full and model scales, the correct model/ice-friction coefficient (dynamic) that should be used in the ice model tests is μ = 0.04...0.06, when measured according to the friction measuring recommendations of the ITTC Ice Committee. In full scale this friction coefficient corresponds to the friction coefficient of a new ship with a new Inerta 160 coating in ice with a snow cover about 10 cm in thickness.

7.2 Friction Measurements

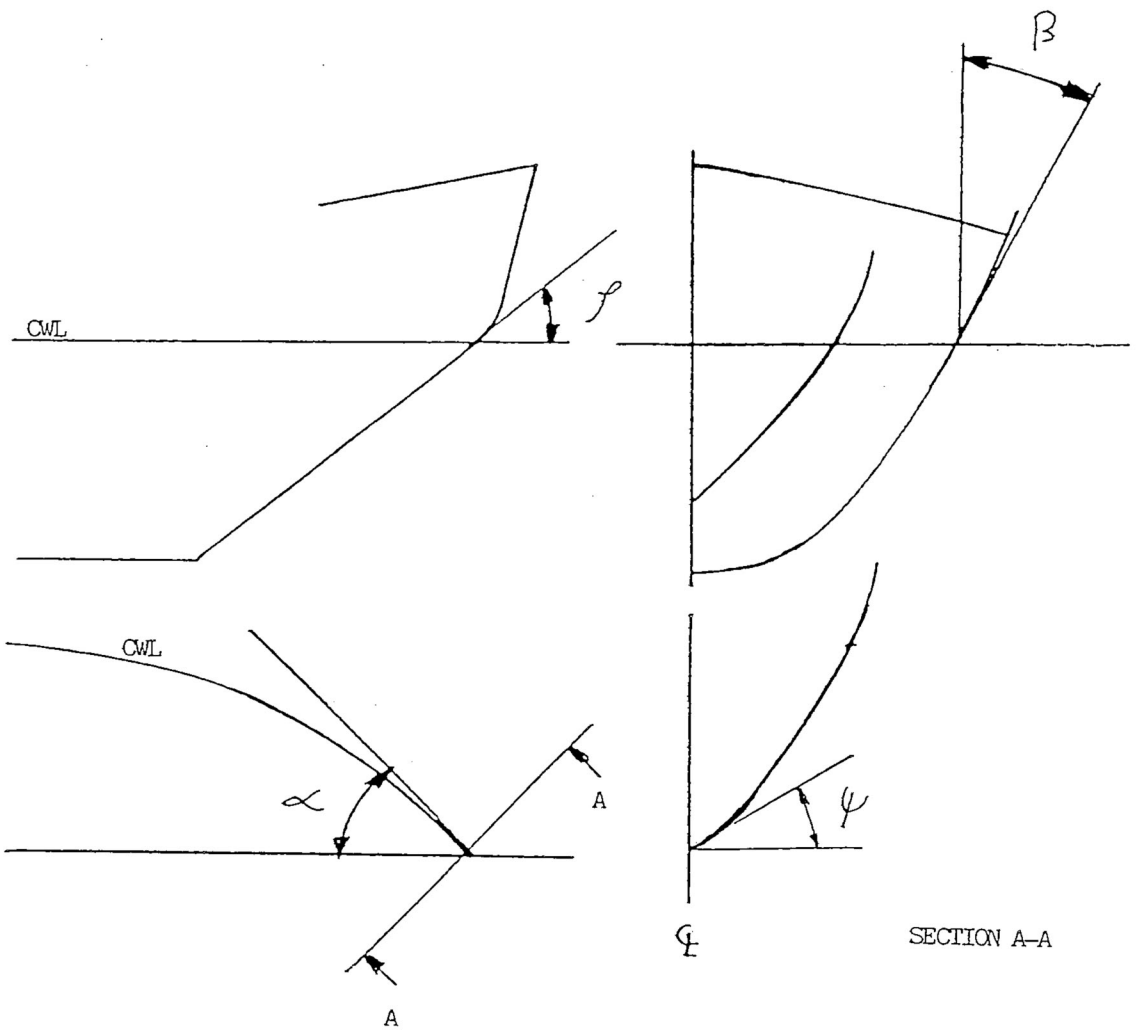
A schematic plan of the friction measuring arrangement in use at WARC is shown below. This friction measuring procedure is in accordance with the recommendations of the ITTC Ice Committee.



1 Model
2 Trough filled with water, water depth 3-5 mm
3 Ice piece (150 mm x 150 mm x ice thickness)
4 Ice piece holder
5 Weight (weights from 0 kg to 10 kg are used)
6 Force transducer
7 DC amplifier
8 Magnetic tape recorder
9 Linear motor for pulling the ice piece (pulling speeds of 50 mm/s and 75 mm/s are used)

7.3 Model Coating Procedure

The model is treated at WARC by adding a priming paint component to the lacquer layer applied last on the model surface. By varying the priming paint content in the mixture the friction coefficient of the model is controlled. Any friction coefficient between 0.02 and 0.2 to an accuracy of μ(target) $\pm$ 0.01 can be achieved by this method. This method has been in use at WARC since 1985.



$$\psi\,(\mathrm{CWL}) = \arctan\left(\frac{\tan\varphi\,(\mathrm{CWL})}{\sin\alpha\,(\mathrm{CWL})}\right)$$

PART II

Design of 40 000 and 25 000 dwt Ice Breaking Bulk / Container Carrier

Jari Kivelä
Erkki Ranki

40 000 dwt Ice Breaking Bulk / Container Carrier Design

1. Specification
2. General arrangement
3. Lines plan
4. Machinery arrangement
5. Midship Section
6. Main diagram
7. Hydrostatics
8. Capacities
9. Loading Conditions
10. Cost estimation

Kvaerner Masa-Yards
Technology

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1. GENERAL BASIC DESIGN

11. BASIC DESIGN

Brief Description

The purpose of this Arctic Conbulker is to carry timber and ore form Dikson to Japan and containers from Japan to various Russian ports on the Northern Sea Route during the trip back to Dikson.

The ship is designed to operate independently in a maximum ice thickness of 1.8 m and in ridged areas. Icebreaker assisted time will be four months in the Northern Sea Route.

The cargo area has 8 cargo holds where 5 of them can divided to upper and lower parts with hatch of a pivot design. Accommodation and engine room are located aft of cargo area. Each cargo hold is designed with lift off -type hatch.

The ship hull construction in way of cargo holds is double hull construction. None of tanks containing harmful substances are in side or bottom tanks toward sea.

Total cargo tank capacity is abt. 34500 cubic meters and the maximum dwt which the ship is able to carry at a draught of 12.5 m is about 40000 metric tons.

The ship is equipped with three cargo and two service cranes to have independence of loading and discharging. Lifting capacity of one cargo crane is about 40 tons.

Accommodation arrangement is designed for 24 persons. All the spaces like mess rooms, day rooms, galley, provision store etc. will be dimensioned for the maximum number of persons on board.

The ship's machinery is of diesel-electric type. Propulsion is provided by two (2) about 14 MW fully rotating Azipod-units.

Power is generated by diesel-generator sets feeding electricity to a common network. The number of engines is selected to give optimum engine loading in the main operating modes.

The total installed propulsion engine power is abt. 32 MW.

	Open water condition	Ice conditions
Engine power (kW)	15800	31600
Number of engines running	2	4

Ship Description

Ship's Purpose

The vessel is intended for year around operation in the Russian Arctic but also equipped for world wide operation. A proposed outbound voyage would involve loading ore and timber in the port of Dikson and discharging in the Japan. From Japan containers are carried to various places during the voyage in the Northern Sea Route

General Arrangement

The arrangement of the vessel is modern double hull arrangement divided into:

- forward part
- cargo area (midbody part)
- aft part (engine room and accommodation area)

In the forward part shall be located following spaces and equipment:

- Fore peak
- Store rooms
- Room for bow thruster
- Anchoring and mooring equipment

The cargo holds are protected with double bottom and double sides within the whole length of the cargo area.

- the cargo area shall be divided into 8 cargo holds and 6 of them are divided in upper and lower holds.
- upper holds are designed for timber and lower holds for ore
- when containers are laden, pivot type hatches in the middle of cargo holds will be kept open

Engine room and accommodation are located in the aft part, which is equipped and arranged as follows:

The accommodation deck house to be built compact in aft ship and all the spaces are to be practically equipped and to have a cozy atmosphere.

Working and living spaces to be separated from each other as far as practicable.

The spaces to be placed according to following guide-lines.

Bridge Deck:

- Wheelhouse will be arranged with completely enclosed bridge wings, and a steering post at the rear of the wheelhouse for running astern. The arrangement enables maximum clear view around to increase the safety of the ship.

4 th Poop Deck:
- Captain's & Chief engineers suites
- Captain's & Chief engineers offices
- Owner's cabin
- Pilot's cabin
- Pantry

3 rd Poop Deck
- 8 officer cabins
- Ships office

2 nd Poop Deck:
- 8 crew cabins
- Two repairman cabins
- Hospital

1 st Poop Deck:
- Galley
- Provision store
- Mess and day rooms for crew and officers

Main Deck:
- Sauna department
- Laundry & linen stores
- Sport room
- Hobby room

The General Arrangement shall be according to the drawing no. 1.26726.1110.212.001 dated 1998.06.25. When reference to the General Arrangement Plan is made in this specification it refers to the before mentioned drawing.

Machinery Arrangement

The main machinery consists of a Diesel Electric power plant.

The power plant consists of :

- four (4) medium-speed diesel engines, Wärtsilä 38, (12V38) or equal.
  each coupled to a generator for electric supply.

- one (1) medium speed diesel engine Wärtsilä 20, (6L20) or equal engine is coupled to a generator for electric supply.

In addition the machinery consists of:

- two (2) freely rotating propulsion units (Azipods) each including one cycloconverter driven propulsion motor
- one (1) steam boilers
- One emergency diesel generator set
- necessary fuel and lubrication oil treatment equipment

The Engine Room Arrangement to be according to the drawing no:1.26726.6000.212.001.

Special Features for Structural and Operational Safety and Economy:

- double hull (double bottom and double sides)
- reasonable size of cargo holds
- diesel electric Azipod propulsion
- safe and reliable technique

Reference

The quality of workmanship, structural features, fittings and equipment will be suitable for the proper functioning as a modern arctic cargo ship.

The vessel shall be built technically to the good European shipbuilding standard.

Main Dimensions

Length over all abt.	206.5 m
Length betw. perp.	186.0 m
Breadth mld	27.5 m
Depth mld	16.0 m
Draught design	12.5 m
Draught scantling	12.5 m
Deck height in forecastle	3.0 m
Deck height in accommodation	3.0 m
Maximum air draught	abt. 32 m

Capacities

Deadweight and Draught

Deadweight to be about 40000 metric tons at 12.5 m design draft (in sea water with specific gravity of 1025 kg/m^3)

In practice the distribution of deadweight has been assumed to be as follows:

- Cargo		36000 t
- Consumables		
- Fuel oil	3500 t	
- Lubricating oil	60 t	
- Fresh water	240 t	3800 t
- Misc. stores, & spares		200 t
Total deadweight		40000 t

Operating Range

The fuel oil capacity is for a range over 20000 nautical miles in open water based on an average service speed of 14.5 kn with 15 % sea margin.

Accommodation Spaces

Cabins:

- Single cabins with private toilet for all crew members as follows:

Type	No.	Berth each
Captain's class suite	2	1
Officer cabins	8	1
Crew cabins	8	1
Owner's cabins	1	1
Pilot cabins	1	1
Repairman cabins	2	2
Total	22 cabins	

Number of beds grand total 24 on board.

In addition to the cabins mentioned the accommodation includes:

- Public and Service Spaces
- Office Spaces
- Navigation and Control Space
- Catering Spaces
- Provision Spaces
- Sanitary Spaces
- Recreation Spaces
- Other Spaces ("Technical Spaces")
- Lift

In living and working spaces the free heights to be at least 2100 mm.

Cargo Capacities

Capacity of cargo holds (100 % full)		volume	ISO 20' containers:
Hold No. 1	á	3520 m3	84
Hold No. 2	á	4570 m3	108
Hold No. 3	á	4570 m3	108
Hold No. 4	á	4570 m3	108
Hold No. 5	á	4570 m3	108
Hold No. 6	á	4570 m3	108
Hold No. 7	á	4270 m3	108
Hold No. 8	á	3620 m3	93
Cargo Total		34560 m3	825
Containers on deck, max			846
Containers, grand total			1671

Capacity of tanks for ship's purposes:

Capacity of water ballast	15500 m3
Capacity of fuel oil	6000 m3
Capacity of fresh water	400 m3
Capacity of lubricating oil	70 m3

Tonnage

International and Suez tonnage measures will be executed in the shipyard by National Authorities.

Speed and Power, Propeller, Hull Form, Maneuverability, Model Tests:

Speed and Power

The mean speed of the vessel on trials with clean bottom when loaded to a mean transit draught of 12.5 m at even keel with an total propeller motor output of 9200 kW is designed to be 14.5 kn in calm weather (wind force not over 4 m/s) and smooth deep water on opposite runs.

The speed determination will be based on the Builder's trial trip results made on ballast condition. The results will be corrected according to the Builder's standard method considering ambient conditions, i.e. wind, wave, sea water temperature, water depth etc. and the ship's draughts which correspond to model test results.

The vessel is able to maintain continuous motion in 1.8 m thick level ice at a draught of 12.5 m in deep water with a propulsion power output of 28 MW.

Propeller

Two (2) four (4) bladed FP-propellers with diameter abt. 5.8 meter.

Hull Form

The hull form of the vessel is designed for good performance in ice. In independent mode both bow and aft ahead and in icebreaker assistance bow ahead.

Design Criteria

General Principles

Following main aspects shall be kept on mind during the whole design and construction period of the vessel.

1. Independent operation in specified area and ice conditions
2. Technically and economically acceptable and proven cargo handling systems and equipment.
3. Good systems and equipment for ship operation and handling.
4. Environmental safety
5. Specified Rules and Regulations

Environmental Conditions

Temperatures:

If not otherwise stated the ship's machinery systems to be dimensioned for the following ambient temperatures:

	Summer	Winter
Sea water temperature	32°C	-2°C
Air outside:	45°C	-50°C

Air Conditioning Temperatures / Relative Humidity:

Air Conditioning is to be dimensioned for the following conditions:

	Summer	Winter
Outside air temp./RH	35°C/70%	-50°C/ -
Inside air temp./RH	29°C/50%	20°C/25-35%

Ice Conditions

The design ice conditions for the Northern Sea Route concerning the independent mode may be summarized as follows:

- Ice Thickness 1.8 m
- Ice Bending Strength 550 kPa

2. CARGO AND BALLAST HANDLING

20. CARGO AND BALLAST HANDLING BASIC DESIGN

Cargo Handling Description

Cargoes

The vessel shall be constructed for the carriage of dry bulk cargoes, mainly the following cargoes:

-Ore
-Timber
-Containers

27. BALLAST PUMPS IN CARGO AREA

Ballast Pumps

Four (4) deep well type electrically driven ballast pumps shall be arranged.

28. DECK CRANES FOR CARGO

Cargo Cranes

Three electrohydraulic deck cranes with 40 tons capacity with outreach of abt. 28 m to be installed at between cargo holds at center line.

29. CARGO CONTROL AND MONITORING

General

Restrictions of cargo loading are required. Maximum ore weight / sq. m may not exceed more than 20 tons/sq. m. When ore is laden, pivot hatches should be kept closed, if other cargo will be laden to upper holds. When containers are laden, calculations for each load condition are required to achieve stability and trim. In some container loading cases use of water ballast should be accepted to achieve stability and trim.

3. HULL

31. GENERAL OF THE HULL

General

The hull and steel construction shall be designed and built generally according to Classification Society's requirements.

The ship is all-welded, as far as possible with automatic welding according to the Builder's normal practice. Continuous welding is used for the frames and stiffeners in tanks, cofferdams and void spaces and external structures exposed to condensation, and in wet spaces such as galleys, pantries, lavatories, WC's, etc., if these spaces are not lined. Elsewhere in dry spaces intermittent welding may be used.

Frame spacing is 800 mm along the whole length of the ship.

All lower cargo holds shall be designed to total cargo weight 20 t/m^2.

Every space in double bottom to be accessible through openings in floors and side girders, IMO rules to be observed regarding to the size of openings in way of cargo area.

Plate webs shall be arranged at every third frame in double side construction. Intermediate webs supporting the side longitudinals to be arranged between the plate webs in way of the ice belt.

Deckhouse

All accommodation decks are built without camber.

The deckhouse outer bulkheads will be vertical plane bulkheads. Inner bulkheads may be corrugated.

The deckhouse shall be properly supported by bulkheads in the hull at least below the front and rear bulkheads of the deckhouse. Special care to be taken in avoiding longitudinal vibration of the deckhouse due to propeller excitations.

6. MACHINERY

General Description

The main machinery is of diesel-electric AC-AC type and working according to the power plant principle, where all consumers get their power from a common network. The auxiliary net is also fed from the same network through transformers.

The machinery arrangement consists of four diesel engines driving electric generators. The generators' power is fed to the ship's network.

The propulsion is arranged by two electrical motors situated in two azimuthing propulsion devices called Azipods. The rotating speed of the electrical motors is controlled by cycloconverters. The propulsion motors rotate in both directions.

Main Diesel Engines

The main engines are of medium-speed type.

Number and Type	4 x Wärtsilä 12V38
Power Output	4 x 7920 kW at 600 rpm

The engine is four-stroke, medium speed, turbocharged and intercooled engine with direct fuel injection. The engines are designed for continuos operation on heavy fuel. It is however possible to operate the engine on diesel fuel without modification. Engine can be started and stopped on heavy fuel provided that the engine and fuel system are preheated to operating temperature. Fuel oil consumption at 100% power of MCR is 177 g/kWh

Mounting of Main Engines :

The engines are coupled through flexible couplings to generators as a generator set. The sets are resiliently mounted.

Harbor Engine

Harbor engine works as power plant to generate electricity for all ship purposes at harbor except loading or discharging with ship's own cranes.

When loading or discharging with ship's own cranes, one of the main engine generator set is used to supply all required electricity.

Harbor engine aggregate consists of diesel engine and 3-phase alternator, which is mounted on a common bed plate. This generating set is resiliently mounted to ship foundation.

The auxiliary engine is of medium-speed type.

Number and Type	one (1) Wärtsilä 6L20 or equal
Power Output	1 x 990 kW at 1000 rpm

62. POWER TRANSMISSION

The power source consists of 4 diesel-generators. The generators are coupled to a 6600 V main switchboard, from which two propeller motor cyclo-converters are fed via transformers.

The propeller motors are synchronous motors. Each motor is fed by a cyclo-converter.

Propeller motors

The two propeller motors are of single armature, single winding synchronous motors. The motors are equipped with sliprings for transformation of excitation.

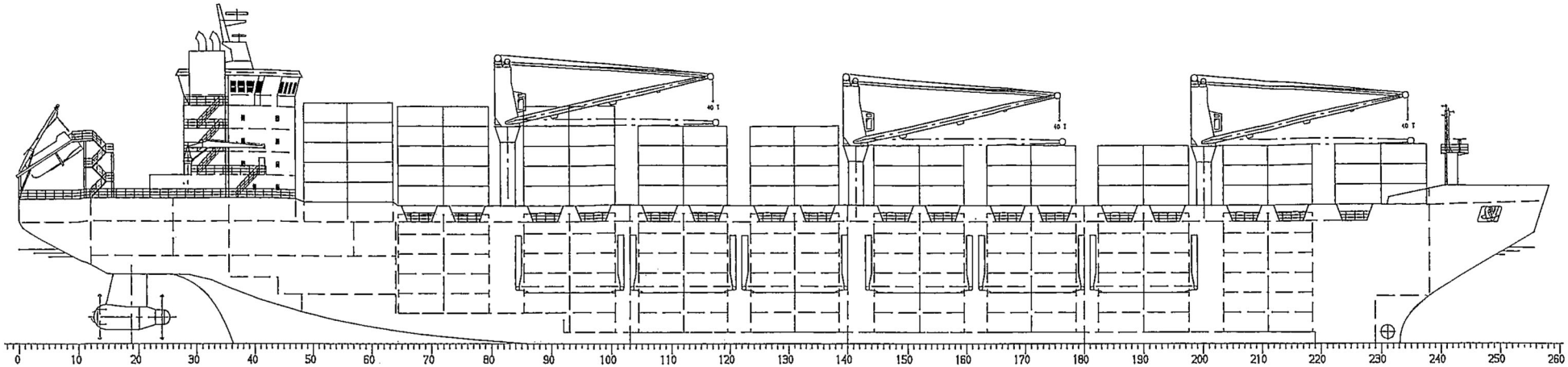
Power: 14.0 MW each
Voltage: 1000 V

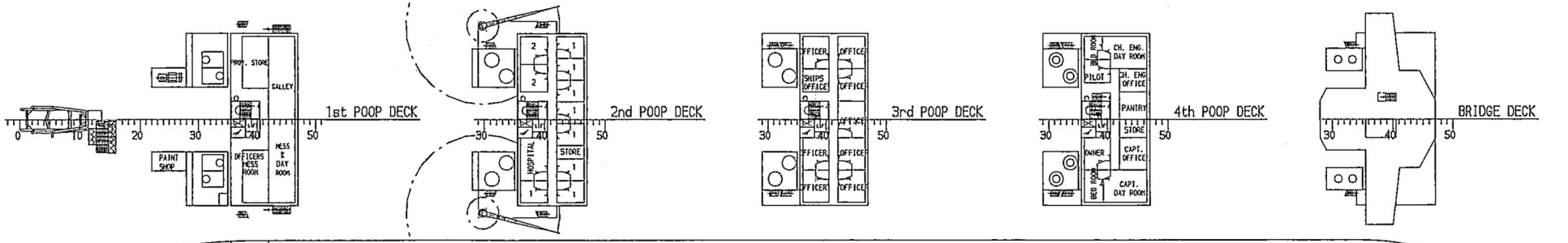
The motors are air-cooled.

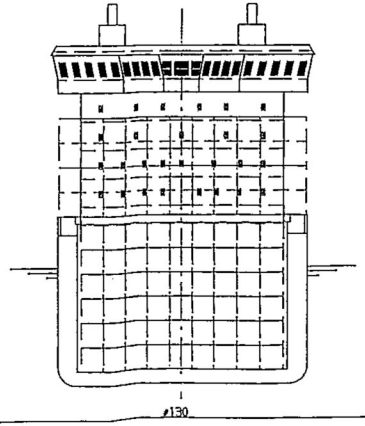
The motors are located in freely rotating rudder propeller units.

Power to the propulsion motors to be fed through sliprings.

Semantic main electric diagram is presented in picture 4.26726.9100.212.001.







40000 DWT Ice Breaking Bulk / Container Carrier

Length oa.	206.5 m
Length pp.	186.0 m
Breadth	27.5 m
Depth	16.0 m
Draught	12.5 m

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Piirretty ohjelmalla: Drawn with program

Korjattu Updated 07-JUL-98 12:45 / atc
Piirretty Drawn 07-JUL-98 12:55 / atc

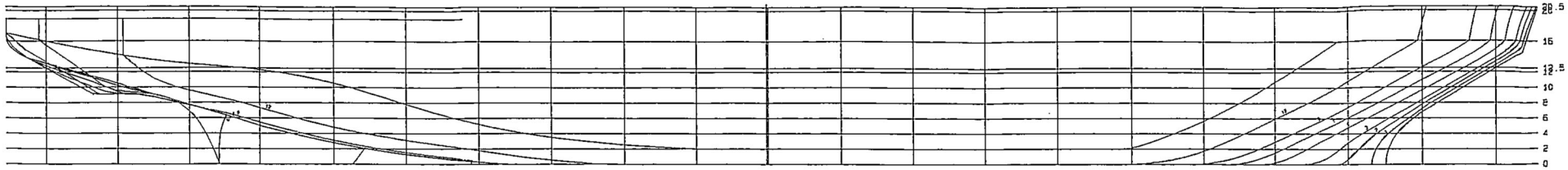
Suun. Design.	Osasto Dpt.	Tark. Chkd.		Hyv. App.	Alkuperäisen piir. App. to drw
Pvm Date	Puh. Tel.	Pvm Date	Puh. Tel.		

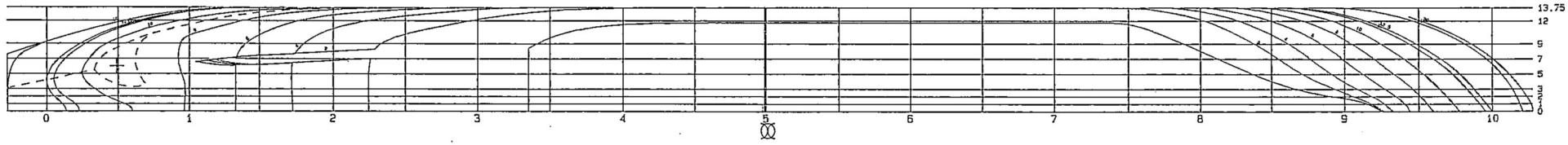
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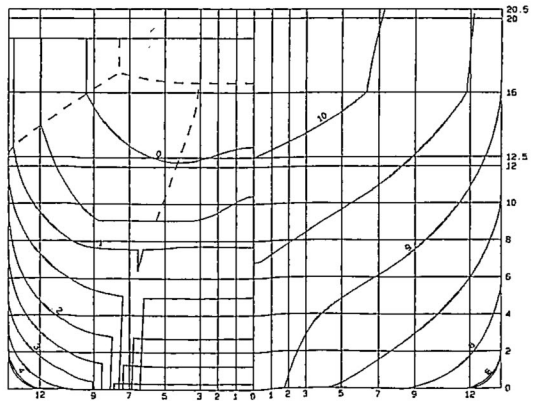
Kværner Masa-Yards
Helsinki New Shipyard

INSROP II
Ice Breaking Bulk / Container Carrie
General Arrangement

Korvaa Replaces	Suhde Scale	Piir.no Drw.No.	Korv. Ind.	Kenti Type
	1:~~100~~ 800	2.26726.1110.212.001		C







TY026726/A

LWL.....	195.70M
BCWL.....	27.50M
TCWL.....	12.50M

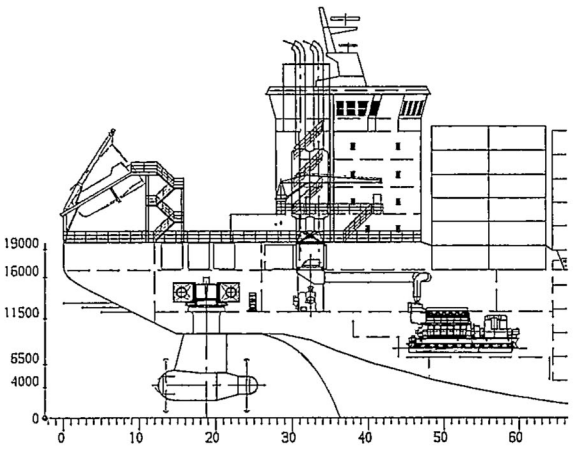
SCALE 1: ≥60 400 / 1: ≥60 800	DRAWN BY JEK	TEL	CHECKED BY	TEL / ACCEPTED
	DATE 98-07-06	DEP	GENERAL DRAWING	

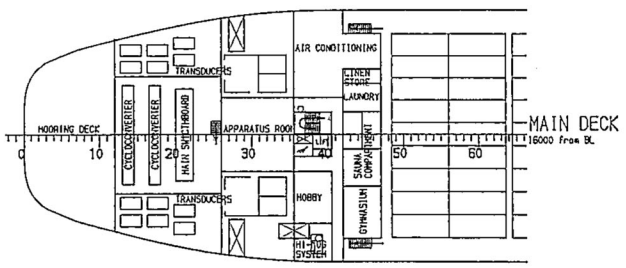
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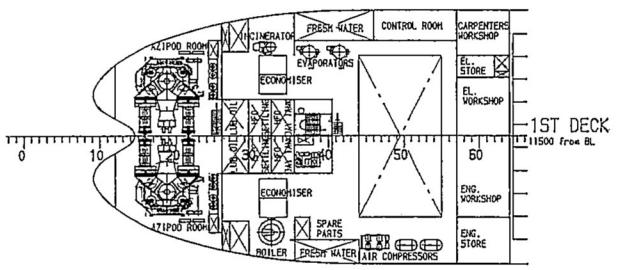
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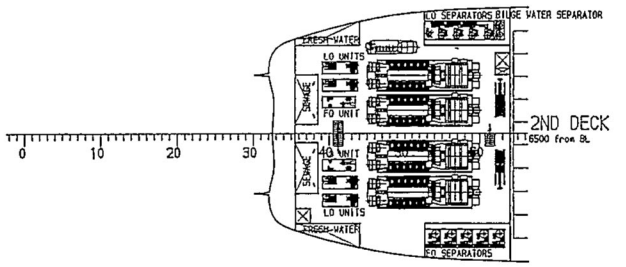
KVAERNER MASA-YARDS TECHNOLOGY, ARCTIC RD	DRAWING NUMBER	INDEX	SHEET 1

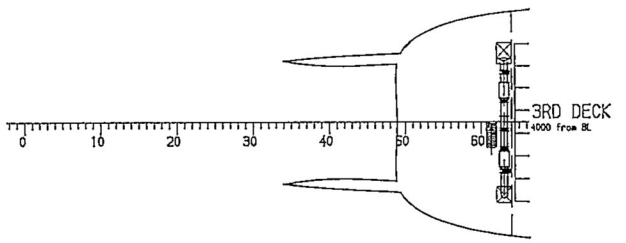
4











40000 DWT Ice Breaking Bulk / Container Carrier

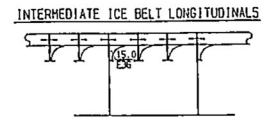
Length oa.	206.5 m
Length pp.	186.0 m
Breadth	27.5 m
Depth	15.0 m
Draught	12.5 m

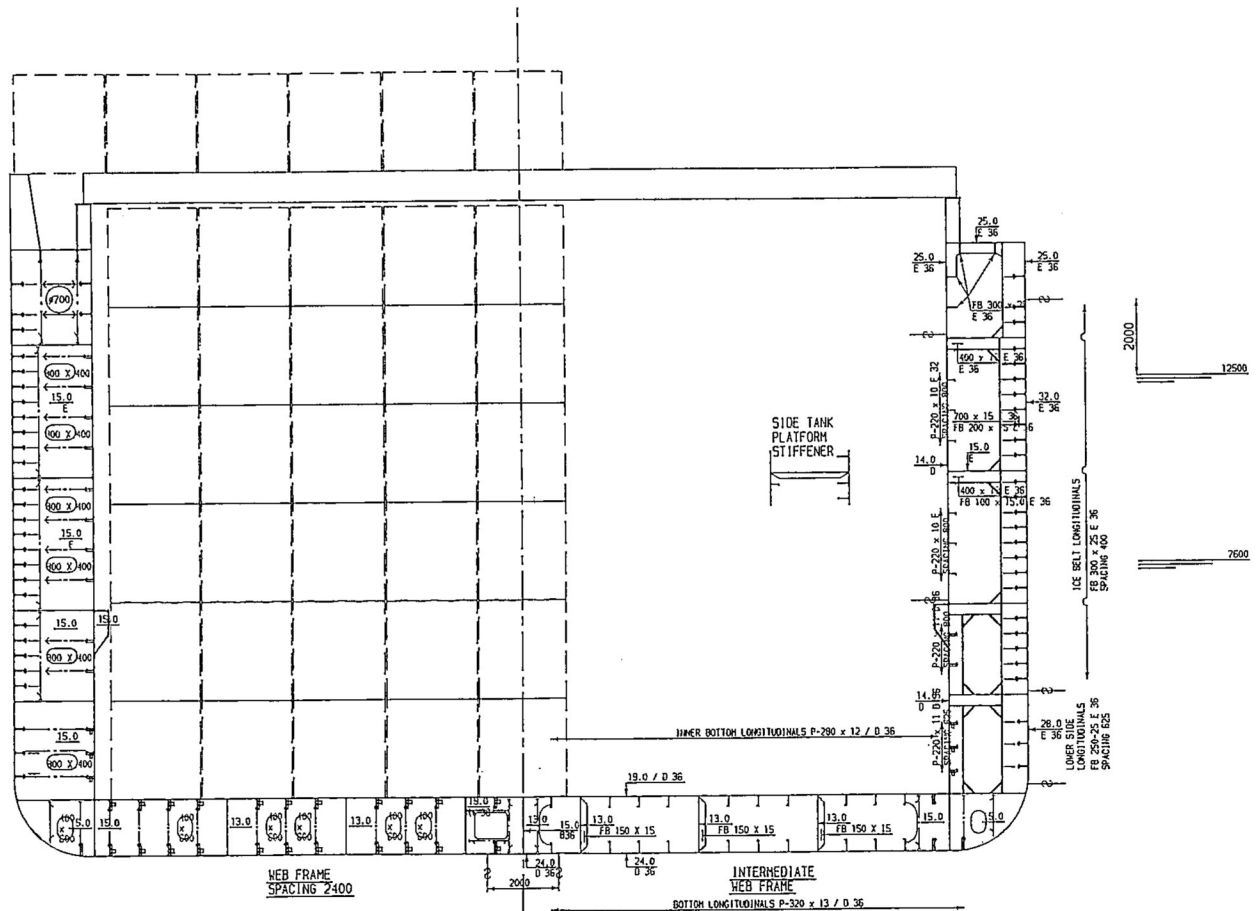
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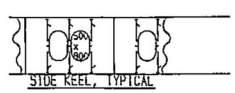
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Helsinki New Shipyard

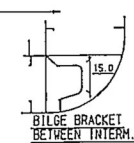
INSROP II
Ice Breaking Bulk / Container Carrier
Machinery Arrangement

2.26726.6000.212.001









NOTATIONS: P-...= BULB PROFILE
FB-..= FLAT PROFILE

40000 DWT Ice Breaking Bulk / Container Carrier

Length oa.	206.5 m
Length pp.	186.1 m
Breadth	27.5 m
Depth	16.0 m
Draught	12.5 m
Block coefficient	0.75

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Piirretty ohjelmalla: Drawn with program:

Korjattu Updated 03-JUL-98 08:20 + 07-JUL-98 15:32 +

Suun. Design. Pvm Date | Osasto Dept. Puh. Tel. | Tark. Insp. Pvm Date | Puh. Tel.

Hyv. Appr. | Liittyy p:r. App. to dwg

Kvaerner Masa-Yards
Helsinki New Shipyard

Nimitys Name
INSROP II
Ice Breaking Bulk / Container Carrie
Midship Section

Korvaa Replaces

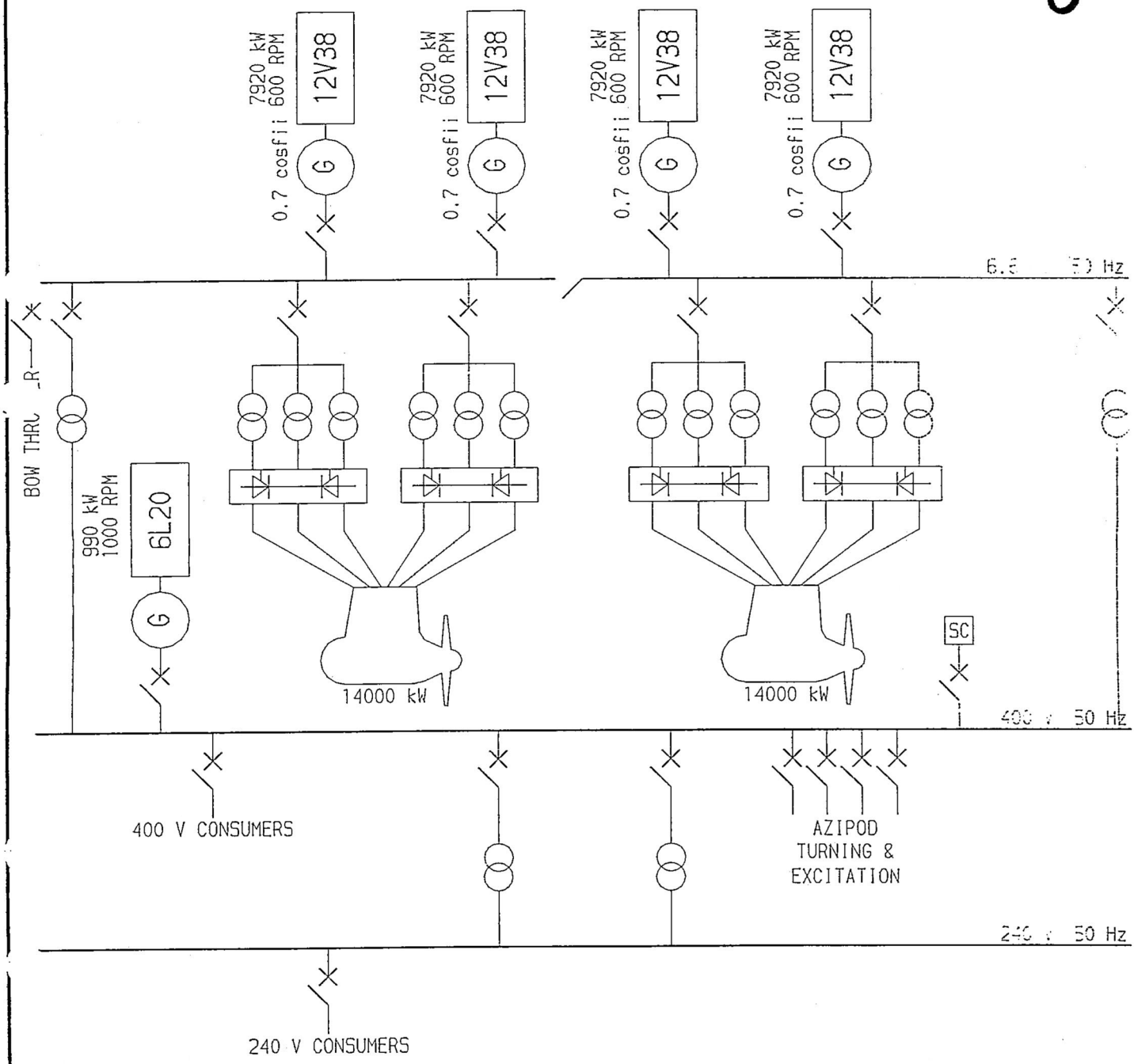
Suhde Scale 1:100 2:00

Piir.no Drw.No. 2.26726.3000.212.001

Vers. Ind. Lehti Page

Muutos	Osa no	Kenttä	Muutos ja/tai huomautus	Päiväys	Muutt.	Hyväks.

6



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Pvm Date	Puh. Tel.	Pvm Date	Puh. Tel.		

Nimitys Name

Kværner Masa-Yards
Helsinki New Shipyard

INSROP II
Ice Breaking Bulk / Container Carrier
Main Diagram

Korvaa Replaces	Suhde Scale	Piir.no Drw.No.
		A 26726 0100 212 001

Masa-Yards Helsinki
NAPA/D/HYD/971106
TYO26726/A
TYO26726

HYDROSTATICS

DATE 98-02-06
TIME 19:06
SIGN JEK
PAGE 1

MAIN CHARACTERISTICS OF THE VESSEL:

Length betw. perpendiculars	195.70	m
Breadth, moulded	27.50	m
Design draught	12.50	m
X-coord. of after perpendicular	5.36	m
X-coord. of reference point	103.21	m
X-coord. of midship section	103.21	m
X-coord. of building frame 0	0.00	m
Thickness of keelplate	0.010	m
Mean thickness of shell plating	0.010	m
Density of water	1.025	ton/m3

Calculations are based on HULL date 98-01-12 time 13.07

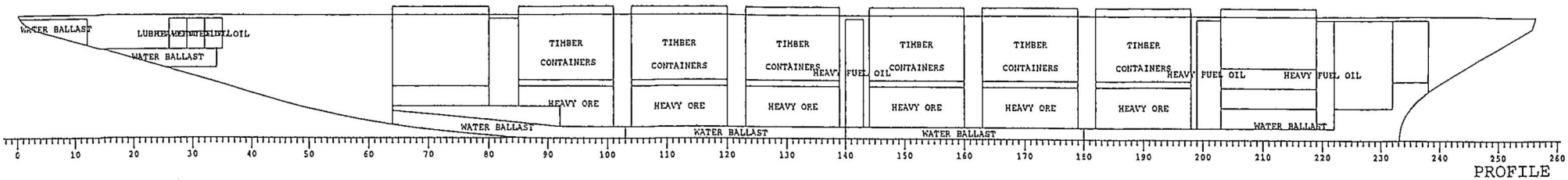
X-coord. of aft end of DWL	5.36	m
X-coord. of fore end of DWL	201.07	m

calc. sections 39

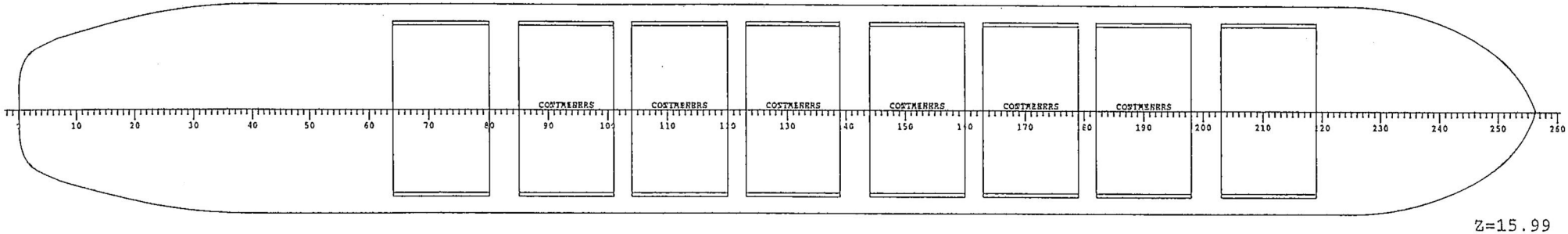
EXPLANATION OF SYMBOLS:

T	draught, moulded	m
DISP	total displacement	t
LCB	longitudinal centre of buoyancy	m
KMT	transv. metac. height	m
CB	block coefficient	
WLA	waterline area	m2
MCT	moment to change trim	tm/cm
TPC	change of displacement/change of draught	t/cm

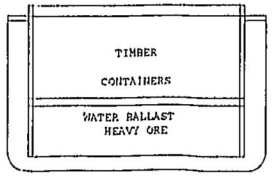
T m	DISP t	LCB m	KMT m	CB	WLA m2	MCT tm/cm	TPC t/cm
5.000	17311.5	111.531	15.987	0.6257	3827.4	331.0	39.2
5.500	19325.2	111.143	15.226	0.6351	3996.9	377.1	41.0
6.000	21391.1	110.739	14.580	0.6445	4060.1	393.9	41.6
6.500	23486.0	110.407	14.041	0.6533	4111.6	408.0	42.1
7.000	25606.4	110.141	13.601	0.6615	4159.8	421.9	42.6
7.500	27773.6	109.863	13.332	0.6697	4270.6	456.9	43.8
8.000	29992.3	109.562	13.106	0.6781	4352.6	483.2	44.6
8.500	32249.7	109.276	12.946	0.6863	4433.6	510.2	45.4
9.000	34555.0	108.979	12.851	0.6945	4533.7	545.3	46.5
9.500	36931.9	108.609	12.824	0.7033	4676.5	599.5	47.9
10.000	39357.5	108.231	12.756	0.7121	4740.8	623.6	48.6
10.500	41812.2	107.890	12.714	0.7205	4803.9	648.1	49.2
11.000	44291.5	107.551	12.690	0.7286	4858.9	670.0	49.8
11.500	46794.2	107.226	12.686	0.7363	4909.2	690.6	50.3
12.000	49323.7	106.926	12.702	0.7438	4970.4	716.6	50.9
12.500	51880.8	106.647	12.738	0.7511	5019.8	738.0	51.5
13.000	54465.5	106.391	12.792	0.7583	5069.9	760.1	52.0
13.500	57075.1	106.156	12.859	0.7652	5110.8	778.3	52.4
14.000	59706.2	105.945	12.942	0.7719	5170.1	806.0	53.0
14.500	62361.6	105.750	13.037	0.7784	5210.9	825.0	53.4
15.000	65037.8	105.572	13.142	0.7848	5245.6	841.2	53.8



PROFILE



Z=15.99



#130

NAME	PURP	VOLM m3	VNET m3	CGX m	CGY m	CGZ m	IY*RHO tm	IY/IMO tm
CAPACITY OF (RHO=0)								
HOLD1		3528.3	3528.3	168.80	0.00	10.67	0.0	0
HOLD2		4576.7	4576.7	152.00	0.00	9.27	0.0	0
HOLD3		4576.7	4576.7	136.80	0.00	9.27	0.0	0
HOLD4		4576.7	4576.7	121.60	0.00	9.27	0.0	0
HOLD5		4576.7	4576.7	104.80	0.00	9.27	0.0	0
HOLD6		4576.7	4576.7	89.60	0.00	9.27	0.0	0
HOLD7		4274.8	4274.8	74.67	0.00	9.73	0.0	0
HOLD8		3629.1	3629.1	57.60	0.00	10.83	0.0	0
STABHULL		68718.7	68718.7	105.34	0.00	8.79	0.0	0
SUBTOTAL		103034.5	103034.5	108.03	0.00	9.07		
CAPACITY OF CONTAINERS (RHO=0.627)								
HOLD1CO	CONTS	3203.1	3033.3	168.80	0.00	10.48	5350.4	3658
HOLD2CO	CONTS	3979.8	3768.8	152.00	0.00	9.27	5350.4	5067
HOLD3CO	CONTS	3979.8	3768.8	136.80	0.00	9.27	5350.4	5067
HOLD4CO	CONTS	3979.8	3768.8	121.60	0.00	9.27	5350.4	5067
HOLD5CO	CONTS	3979.8	3768.8	104.80	0.00	9.27	5350.4	5067
HOLD6CO	CONTS	3979.8	3768.8	89.60	0.00	9.27	5350.4	5067
HOLD7CO	CONTS	3717.2	3520.2	74.67	0.00	9.73	5350.4	4574
HOLD8CO	CONTS	3219.0	3048.4	57.60	0.00	10.73	5350.4	4845
SUBTOTAL	CONTS	30038.1	28446.1	113.54	0.00	9.61		
CAPACITY OF FRESH WATER (RHO=1)								
FW_SB	FW	195.1	191.2	31.76	-11.62	11.47	38.8	23
FW_BB	FW	217.3	212.9	32.66	11.73	11.09	45.1	23
SUBTOTAL	FW	412.4	404.1	32.24	0.68	11.27		
CAPACITY OF HEAVY FUEL OIL (RHO=0.94)								
HFO1	HFO	1845.5	1808.6	182.82	0.00	11.36	5752.6	4869
HFO2	HFO	576.1	564.6	176.39	0.00	9.86	2113.9	1443
HFO3	HFO	1021.7	1001.2	160.79	0.00	8.55	3049.9	2951
HFO4	HFO	772.8	757.3	113.20	0.00	8.50	2287.4	2242
HFO5	HFO	1760.9	1725.7	65.55	0.00	7.14	3812.3	2554
HFO_DAY	HFO	76.8	75.3	26.80	0.00	13.50	96.3	94
HFO_SETT	HFO	76.8	75.3	24.40	0.00	13.50	96.3	94
SUBTOTAL	HFO	6130.6	6008.0	132.14	0.00	9.23		

NAME	PURP	VOLM m3	VNET m3	CGX m	CGY m	CGZ m	IY*RHO tm	IY/IMO tm
CAPACITY OF LUBRICATING OIL (RHO=0.9)								
LUB	LO	76.8	75.3	22.00	0.00	13.50	92.2	90
CAPACITY OF HEAVY ORE (RHO=3.3)								
HOLD2L	ORE1	1530.9	1454.3	152.00	0.00	4.10	42827.9	40686
HOLD3L	ORE1	1530.9	1454.3	136.80	0.00	4.10	42827.8	40686
HOLD4L	ORE1	1530.9	1454.3	121.60	0.00	4.10	42827.8	40686
HOLD5L	ORE1	1530.9	1454.3	104.80	0.00	4.10	42827.9	40686
HOLD6L	ORE1	1530.9	1454.3	89.60	0.00	4.10	42827.8	40686
HOLD7L	ORE1	1228.9	1167.5	75.35	0.00	4.42	42827.8	29264
SUBTOTAL	ORE1	8883.3	8439.2	114.65	0.00	4.14		
CAPACITY OF TIMBER (RHO=0.8)								
HOLD2U	TIM	2810.3	2669.8	152.00	0.00	12.27	10382.5	9863
HOLD3U	TIM	2810.3	2669.8	136.80	0.00	12.27	10382.5	9863
HOLD4U	TIM	2810.3	2669.8	121.60	0.00	12.27	10382.5	9863
HOLD5U	TIM	2810.3	2669.8	104.80	0.00	12.27	10382.5	9863
HOLD6U	TIM	2810.3	2669.8	89.60	0.00	12.27	10382.5	9863
HOLD7U	TIM	2810.3	2669.8	74.40	0.00	12.27	10382.5	9863
SUBTOTAL	TIM	16862.1	16018.9	113.20	0.00	12.27		
CAPACITY OF WATER BALLAST (RHO=1.025)								
BW1	WB	4768.9	4673.6	165.87	0.00	6.43	32084.9	9544
BW2	WB	3280.9	3215.3	128.00	0.00	5.52	23588.3	6572
BW3	WB	3032.8	2972.1	97.21	0.00	5.52	21811.5	6075
BW4	WB	3367.8	3300.4	66.47	0.00	5.74	28117.1	6924
BW5	WB	806.7	790.6	19.90	0.00	10.38	15597.8	16909
BW6	WB	369.1	361.7	6.53	0.00	13.99	2787.6	1568
BW7	WB	234.0	229.3	40.91	0.00	2.07	2505.5	155
SUBTOTAL	WB	15860.2	15543.0	110.82	0.00	6.23		
TOTAL		181298.0	177969.1	110.60	0.00	8.98		

LOADING CONDITIONS

This paragraph contains various loading conditions.

Case	
LC1	heavy ore in lower holds, timber in upper holds and consumables as in departure condition
LC2	as LC1 but consumables are 20% of LC1
LC3	light ore in lower holds, timber in upper holds, empty containers on deck and consumables as in departure conditions
LC4	as LC3 but consumables are 20% of LC3. To keep the ship on even keel ballast water was required.
LC5	Containers in cargo holds and on deck. Heavy containers in holds and light on deck. Consumables are in departure condition.
BW1	Ballast water conditions with 20% consumables. Max aft trim was tried to obtain. The purpose was to sink the propeller as deep as possible.

LOADING CONDITION LC1

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
TIMBER, RHO= 0.800							
HOLD8	HOLD8	2903.3	248.5	57.60	0.00	4.79	0.0
HOLD4U	HOLD 4U	2135.9	1522.8	121.60	0.00	10.90	0.0
HOLD5U	HOLD 5U	2135.9	2135.9	104.80	0.00	12.27	0.0
HOLD6U	HOLD 6U	2135.9	2135.9	89.60	0.00	12.27	0.0
HOLD7U	HOLD 7U	2135.9	2135.9	74.40	0.00	12.27	0.0
Total of TIMBER		11446.7	8178.9	94.59	0.00	11.79	0.0
HEAVY ORE, RHO= 3.300							
HOLD2L	HOLD 2L	4799.3	4799.3	152.00	0.00	4.10	0.0
HOLD3L	HOLD 3L	4799.3	4799.3	136.80	0.00	4.10	0.0
HOLD4L	HOLD 4L	4799.3	4799.3	121.60	0.00	4.10	0.0
HOLD5L	HOLD 5L	4799.3	4799.3	104.80	0.00	4.10	0.0
HOLD6L	HOLD 6L	4799.3	4799.3	89.60	0.00	4.10	0.0
HOLD7L	HOLD 7L	3852.7	3852.7	75.35	0.00	4.42	0.0
Total of HEAVY ORE		27849.3	27849.3	114.65	0.00	4.14	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO2		520.1	151.6	176.37	0.00	5.17	954.3
HFO3		922.3	922.3	160.79	0.00	8.41	0.0
HFO4		697.7	697.7	113.20	0.00	8.36	0.0
HFO5		1589.7	1589.7	65.54	0.00	6.97	0.0
HFO_DAY		69.3	69.3	26.80	0.00	13.46	0.0
HFO_SETT		69.3	69.3	24.40	0.00	13.46	0.0
Total of HEAVY FUEL OIL		3868.5	3500.0	103.36	0.00	7.81	954.3
FRESH WATER , RHO= 1.000							
FW_SB		191.2	191.2	31.76	-11.62	11.47	0.0
FW_BB		212.9	212.9	32.66	11.73	11.09	0.0
Total of FRESH WATER		404.1	404.1	32.24	0.68	11.27	0.0
LUBRICATING OIL, RHO= 0.900							
LUB		67.7	67.7	22.00	0.00	13.50	0.0
Deadweight			40000.0	108.57	0.01	6.12	954.3
Lightweight			12000.0	100.00	0.00	8.60	
Displacement (rho=1.025)			52000.0	106.59	0.01	6.69	954.3

F L O A T I N G P O S I T I O N

Draught moulded	12.535	m	KM	12.74 m
Trim	0.005	m	KG	6.69 m
TA	12.532	m	GM0	6.05 m
TF	12.538	m	GMCORR	-0.02 m
Trimming moment	378	tonm	GM	6.04 m

			X	FRAME
SHEAR FORCE (MIN)	-6579.6	t	POSITION: 64.0 m	80
SHEAR FORCE (MAX)	5352.6	t	158.4 m	198
SAGGING MOMENT	-262037	tm	104.6 m	131
HOGGING MOMENT	592.0	tm	13.7 m	17

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.53	0.023	83.6	0.002
10.0	0.014	1.06	0.092	170.5	0.003
20.0	-0.037	2.03	0.366	363.3	0.007
30.0	-0.481	2.53	0.770	551.8	0.011
40.0	-1.074	2.80	1.238	741.2	0.014
45.0	-1.381	2.88	1.486	836.1	0.016

LOADING CONDITION LC2

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
TIMBER, RHO= 0.800							
HOLD8	HOLD8	2903.3	248.5	57.60	0.00	4.79	0.0
HOLD4U	HOLD 4U	2135.9	1522.8	121.60	0.00	10.90	0.0
HOLD5U	HOLD 5U	2135.9	2135.9	104.80	0.00	12.27	0.0
HOLD6U	HOLD 6U	2135.9	2135.9	89.60	0.00	12.27	0.0
HOLD7U	HOLD 7U	2135.9	2135.9	74.40	0.00	12.27	0.0
Total of TIMBER		11446.7	8178.9	94.59	0.00	11.79	0.0
HEAVY ORE, RHO= 3.300							
HOLD2L	HOLD 2L	4799.3	4799.3	152.00	0.00	4.10	0.0
HOLD3L	HOLD 3L	4799.3	4799.3	136.80	0.00	4.10	0.0
HOLD4L	HOLD 4L	4799.3	4799.3	121.60	0.00	4.10	0.0
HOLD5L	HOLD 5L	4799.3	4799.3	104.80	0.00	4.10	0.0
HOLD6L	HOLD 6L	4799.3	4799.3	89.60	0.00	4.10	0.0
HOLD7L	HOLD 7L	3852.7	3852.7	75.35	0.00	4.42	0.0
Total of HEAVY ORE		27849.3	27849.3	114.65	0.00	4.14	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1666.1	88.2	180.65	0.00	5.11	458.9
HFO5		1589.7	473.2	65.70	0.00	2.96	15017.6
HFO_DAY		69.3	69.3	26.80	0.00	13.46	0.0
HFO_SETT		69.3	69.3	24.40	0.00	13.46	0.0
Total of HEAVY FUEL OIL		3394.5	700.0	72.24	0.00	5.31	15476.5
FRESH WATER , RHO= 1.000							
FW_SB		191.2	38.2	32.18	-10.81	8.15	19.7
FW_BB		212.9	42.6	33.34	10.78	7.82	22.1
Total of FRESH WATER		404.1	80.8	32.79	0.57	7.98	41.8
LUBRICATING OIL, RHO= 0.900							
LUB		67.7	13.5	22.00	0.00	11.90	90.3
Deadweight			36822.5	109.17	0.00	5.88	15608.6
Lightweight			12000.0	100.00	0.00	8.60	
Displacement (rho=1.025)			48822.5	106.92	0.00	6.55	15608.6

F L O A T I N G P O S I T I O N

Draught moulded	11.909	m	KM	12.70 m
Trim	0.000	m	KG	6.55 m
TA	11.908	m	GM0	6.15 m
TF	11.909	m	GMCORR	-0.32 m
Trimming moment	31	tonm	GM	5.83 m

			X	FRAME
SHEAR FORCE (MIN)	-6991.5	t	POSITION: 68.0	m 85
SHEAR FORCE (MAX)	5736.1	t	158.4	m 198
SAGGING MOMENT	-255764	tm	104.6	m 131
HOGGING MOMENT	1329.5	tm	19.1	m 24

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.52	0.022	1103.0	0.023
10.0	0.014	1.05	0.091	1636.3	0.034
20.0	0.061	2.12	0.368	2352.4	0.048
30.0	-0.249	2.77	0.802	2843.9	0.058
40.0	-0.768	3.12	1.318	3276.9	0.067
45.0	-1.057	3.22	1.595	3487.8	0.071

LOADING CONDITION LC3

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
TIMBER, RHO= 0.800							
HOLD1	HOLD 1	2822.6	2822.6	168.80	0.00	10.67	0.0
HOLD8	HOLD8	2903.3	2903.3	57.60	0.00	10.83	0.0
HOLD2U	HOLD 2U	2135.9	2135.9	152.00	0.00	12.27	0.0
HOLD3U	HOLD 3U	2135.9	2135.9	136.80	0.00	12.27	0.0
HOLD4U	HOLD 4U	2135.9	2135.9	121.60	0.00	12.27	0.0
HOLD5U	HOLD 5U	2135.9	2135.9	104.80	0.00	12.27	0.0
HOLD6U	HOLD 6U	2135.9	2135.9	89.60	0.00	12.27	0.0
HOLD7U	HOLD 7U	2135.9	2135.9	74.40	0.00	12.27	0.0
Total of TIMBER		18541.0	18541.0	112.96	0.00	11.80	0.0
LIGHT ORE, RHO= 1.670							
HOLD2L	HOLD 2L	2428.7	2428.7	152.00	0.00	4.10	0.0
HOLD3L	HOLD 3L	2428.7	2428.7	136.80	0.00	4.10	0.0
HOLD4L	HOLD 4L	2428.7	2428.7	121.60	0.00	4.10	0.0
HOLD5L	HOLD 5L	2428.7	2428.7	104.80	0.00	4.10	0.0
HOLD6L	HOLD 6L	2428.7	2428.7	89.60	0.00	4.10	0.0
HOLD7L	HOLD 7L	1949.7	1949.7	75.35	0.00	4.42	0.0
Total of LIGHT ORE		14093.4	14093.4	114.65	0.00	4.14	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO2		520.1	151.6	176.37	0.00	5.17	954.3
HFO3		922.3	922.3	160.79	0.00	8.41	0.0
HFO4		697.7	697.7	113.20	0.00	8.36	0.0
HFO5		1589.7	1589.7	65.54	0.00	6.97	0.0
HFO_DAY		69.3	69.3	26.80	0.00	13.46	0.0
HFO_SETT		69.3	69.3	24.40	0.00	13.46	0.0
Total of HEAVY FUEL OIL		3868.5	3500.0	103.36	0.00	7.81	954.3
WATER BALLAST , RHO= 1.025							
BW5		794.1	756.0	19.95	0.00	10.31	17831.8
BW6		363.4	282.9	6.83	0.00	13.60	3558.1
Total of WATER BALLAST		1157.5	1039.0	16.37	0.00	11.21	21389.9
FRESH WATER , RHO= 1.000							
FW_SB		191.2	191.2	31.76	-11.62	11.47	0.0
FW_BB		212.9	212.9	32.66	11.73	11.09	0.0
Total of FRESH WATER		404.1	404.1	32.24	0.68	11.27	0.0
LUBRICATING OIL, RHO= 0.900							
LUB		67.7	67.7	22.00	0.00	13.50	0.0

Name	Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
CONTS1						
(CONTS1)	0.0	120.0	184.00	0.00	21.90	0.0
CONTS2						
(CONTS2)	0.0	132.0	168.80	0.00	21.90	0.0
CONTS3						
(CONTS3)	0.0	176.0	152.00	0.00	23.20	0.0
CONTS4						
(CONTS4)	0.0	176.0	136.80	0.00	23.20	0.0
CONTS5						
(CONTS5)	0.0	176.0	122.24	0.00	23.20	0.0
CONTS6						
(CONTS6)	0.0	220.0	104.80	0.00	24.50	0.0
CONTS7						
(CONTS7)	0.0	220.0	89.60	0.00	24.50	0.0
CONTS8						
(CONTS8)	0.0	260.0	74.40	0.00	25.80	0.0
CONTS9						
(CONTS9)	0.0	264.0	57.60	0.00	25.80	0.0
CONTS10						
(CONTS10)	0.0	300.0	44.80	0.00	25.80	0.0
Deadweight		39689.3	108.62	0.01	9.36	22344.3
Lightweight		12000.0	100.00	0.00	8.60	
Displacement (rho=1.025)		51689.3	106.62	0.01	9.18	22344.3

F L O A T I N G P O S I T I O N

Draught moulded	12.474	m	KM	12.74 m
Trim	-0.002	m	KG	9.18 m
TA	12.475	m	GM0	3.55 m
TF	12.474	m	GMCORR	-0.43 m
Trimming moment	-114	tonm	GM	3.12 m

			X	FRAME
SHEAR FORCE (MIN)	-2601.0	t	POSITION: 51.2	m 64
SHEAR FORCE (MAX)	2216.4	t	158.4	m 198
SAGGING MOMENT	-91812.7	tm	108.1	m 135
HOGGING MOMENT	12122.7	tm	35.2	m 44

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.29	0.013	851.9	0.016
10.0	0.014	0.61	0.052	1099.4	0.021
20.0	-0.025	1.16	0.210	1375.6	0.027
30.0	-0.458	1.29	0.430	1553.6	0.030
40.0	-1.044	1.21	0.650	1672.1	0.032
45.0	-1.349	1.13	0.752	1716.9	0.033

LOADING CONDITION LC4

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
TIMBER, RHO= 0.800							
HOLD1	HOLD 1	2822.6	2822.6	168.80	0.00	10.67	0.0
HOLD8	HOLD8	2903.3	2903.3	57.60	0.00	10.83	0.0
HOLD2U	HOLD 2U	2135.9	2135.9	152.00	0.00	12.27	0.0
HOLD3U	HOLD 3U	2135.9	2135.9	136.80	0.00	12.27	0.0
HOLD4U	HOLD 4U	2135.9	2135.9	121.60	0.00	12.27	0.0
HOLD5U	HOLD 5U	2135.9	2135.9	104.80	0.00	12.27	0.0
HOLD6U	HOLD 6U	2135.9	2135.9	89.60	0.00	12.27	0.0
HOLD7U	HOLD 7U	2135.9	2135.9	74.40	0.00	12.27	0.0
Total of TIMBER		18541.0	18541.0	112.96	0.00	11.80	0.0
LIGHT ORE, RHO= 1.670							
HOLD2L	HOLD 2L	2428.7	2428.7	152.00	0.00	4.10	0.0
HOLD3L	HOLD 3L	2428.7	2428.7	136.80	0.00	4.10	0.0
HOLD4L	HOLD 4L	2428.7	2428.7	121.60	0.00	4.10	0.0
HOLD5L	HOLD 5L	2428.7	2428.7	104.80	0.00	4.10	0.0
HOLD6L	HOLD 6L	2428.7	2428.7	89.60	0.00	4.10	0.0
HOLD7L	HOLD 7L	1949.7	1949.7	75.35	0.00	4.42	0.0
Total of LIGHT ORE		14093.4	14093.4	114.65	0.00	4.14	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1666.1	183.4	180.81	0.00	5.91	955.8
HFO5		1589.7	377.9	66.45	0.00	2.81	13739.1
HFO_DAY		69.3	69.3	26.80	0.00	13.46	0.0
HFO_SETT		69.3	69.3	24.40	0.00	13.46	0.0
Total of HEAVY FUEL OIL		3394.5	700.0	88.32	0.00	5.73	14694.9
WATER BALLAST , RHO= 1.025							
BW5		794.1	794.1	19.91	0.00	10.36	0.0
BW6		363.4	363.4	6.55	0.00	13.96	0.0
Total of WATER BALLAST		1157.5	1157.5	15.72	0.00	11.49	0.0
FRESH WATER , RHO= 1.000							
FW_SB		191.2	42.6	32.14	-10.85	8.27	21.6
FW_BB		212.9	38.2	33.41	10.74	7.71	20.2
Total of FRESH WATER		404.1	80.8	32.74	-0.63	8.00	41.8
LUBRICATING OIL, RHO= 0.900							
LUB		67.7	13.5	22.00	0.00	11.90	90.3
CONTS1							
(CONTS1)		0.0	120.0	184.00	0.00	21.90	0.0

Name	Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
CONTS2						
(CONTS2)	0.0	132.0	168.80	0.00	21.90	0.0
CONTS3						
(CONTS3)	0.0	176.0	152.00	0.00	23.20	0.0
CONTS4						
(CONTS4)	0.0	176.0	136.80	0.00	23.20	0.0
CONTS5						
(CONTS5)	0.0	176.0	122.24	0.00	23.20	0.0
CONTS6						
(CONTS6)	0.0	220.0	104.80	0.00	24.50	0.0
CONTS7						
(CONTS7)	0.0	220.0	89.60	0.00	24.50	0.0
CONTS8						
(CONTS8)	0.0	260.0	74.40	0.00	25.80	0.0
CONTS9						
(CONTS9)	0.0	264.0	57.60	0.00	25.80	0.0
CONTS10						
(CONTS10)	0.0	300.0	44.80	0.00	25.80	0.0
Deadweight		36630.3	109.22	-0.00	9.42	14827.0
Lightweight		12000.0	100.00	0.00	8.60	
Displacement (rho=1.025)		48630.3	106.94	-0.00	9.22	14827.0

F L O A T I N G P O S I T I O N

Draught moulded	11.871	m	KM	12.69 m
Trim	0.002	m	KG	9.22 m
TA	11.870	m	GM0	3.47 m
TF	11.871	m	GMCORR	-0.30 m
Trimming moment	111	tonm	GM	3.17 m

			X	FRAME
SHEAR FORCE (MIN)	-2624.7	t	POSITION: 68.0	m 85
SHEAR FORCE (MAX)	2530.3	t	158.4	m 198
SAGGING MOMENT	-81192.7	tm	119.8	m 150
HOGGING MOMENT	19118.7	tm	36.8	m 46

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.28	0.012	1182.1	0.024
10.0	0.014	0.58	0.050	1782.7	0.037
20.0	0.065	1.20	0.207	2426.5	0.050
30.0	-0.236	1.44	0.444	2909.5	0.060
40.0	-0.750	1.41	0.696	3412.3	0.070
45.0	-1.037	1.34	0.816	3636.5	0.075

LOADING CONDITION LC5

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
CONTAINERS, RHO= 0.627							
HOLD1CO	HOLD 1co	2020.0	2020.0	168.80	0.00	10.63	0.0
HOLD2CO	HOLD 2co	2599.4	2599.4	152.00	0.00	9.27	0.0
HOLD3CO	HOLD 3co	2599.4	2599.4	136.80	0.00	9.27	0.0
HOLD4CO	HOLD 4co	2599.4	2599.4	121.60	0.00	9.27	0.0
HOLD5CO	HOLD 5co	2599.4	2599.4	104.80	0.00	9.27	0.0
HOLD6CO	HOLD 6co	2599.4	2599.4	89.60	0.00	9.27	0.0
HOLD7CO	HOLD 7co	2427.9	2427.9	74.67	0.00	9.73	0.0
HOLD8CO	HOLD 8co	2068.9	2068.9	57.60	0.00	10.81	0.0
Total of CONTAINERS		19513.6	19513.6	113.44	0.00	9.63	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1666.1	273.6	181.18	0.00	6.52	1504.4
HFO2		520.1	520.1	176.39	0.00	9.75	0.0
HFO3		922.3	922.3	160.79	0.00	8.41	0.0
HFO4		697.7	697.7	113.20	0.00	8.36	0.0
HFO5		1589.7	947.7	65.22	0.00	4.02	3736.1
HFO_DAY		69.3	69.3	26.80	0.00	13.46	0.0
HFO_SETT		69.3	69.3	24.40	0.00	13.46	0.0
Total of HEAVY FUEL OIL		5534.6	3500.0	123.98	0.00	7.46	5240.5
FRESH WATER , RHO= 1.000							
FW_SB		191.2	191.2	31.76	-11.62	11.47	0.0
FW_BB		212.9	212.9	32.66	11.73	11.09	0.0
Total of FRESH WATER		404.1	404.1	32.24	0.68	11.27	0.0
LUBRICATING OIL, RHO= 0.900							
LUB		67.7	67.7	22.00	0.00	13.50	0.0
CONTS1							
(CONTS1)		0.0	540.0	184.00	0.00	21.90	0.0
CONTS2							
(CONTS2)		0.0	594.0	168.80	0.00	21.90	0.0
CONTS3							
(CONTS3)		0.0	594.0	152.00	0.00	21.90	0.0
CONTS4							
(CONTS4)		0.0	594.0	136.80	0.00	21.90	0.0

Name	Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
CONTS5						
(CONTS5)	0.0	594.0	122.24	0.00	21.90	0.0
CONTS6						
(CONTS6)	0.0	792.0	104.80	0.00	23.20	0.0
CONTS7						
(CONTS7)	0.0	792.0	89.60	0.00	23.20	0.0
CONTS8						
(CONTS8)	0.0	972.0	74.40	0.00	24.50	0.0
CONTS9						
(CONTS9)	0.0	990.0	57.60	0.00	24.50	0.0
CONTS10						
(CONTS10)	0.0	1152.0	44.80	0.00	24.50	0.0
Deadweight		31099.5	110.64	0.01	12.75	5240.5
Lightweight		12000.0	100.00	0.00	8.60	
Displacement (rho=1.025)		43099.5	107.67	0.01	11.59	5240.5

F L O A T I N G P O S I T I O N

Draught moulded	10.765	m	KM	12.70 m
Trim	0.001	m	KG	11.59 m
TA	10.764	m	GM0	1.10 m
TF	10.766	m	GMCORR	-0.12 m
Trimming moment	90	tonm	GM	0.98 m

			X	FRAME
SHEAR FORCE (MIN)	-929.6	t	POSITION: 54.6 m	68
SHEAR FORCE (MAX)	506.7	t	125.3 m	157
SAGGING MOMENT	-7684.3	tm	74.4 m	93
HOGGING MOMENT	7088.0	tm	36.8 m	46

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.09	0.004	459.0	0.011
10.0	0.015	0.19	0.016	929.3	0.022
20.0	0.112	0.44	0.070	1970.2	0.046
30.0	0.097	0.57	0.162	3512.4	0.081
40.0	-0.254	0.34	0.246	5011.2	0.116
45.0	-0.522	0.13	0.267	5480.7	0.127

LOADING CONDITION BW1

L O A D I N G C O M P O N E N T S

Name	Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
HEAVY FUEL OIL , RHO= 0.940						
HFO5	1589.7	561.3	65.24	0.00	3.09	15932.7
HFO_DAY	69.3	69.3	26.80	0.00	13.46	0.0
HFO_SETT	69.3	69.3	24.40	0.00	13.46	0.0
Total of HEAVY FUEL OIL	1728.4	700.0	57.39	0.00	5.14	15932.7
WATER BALLAST , RHO= 1.025						
BW1	4694.6	4694.6	165.83	0.00	6.25	0.0
BW2	3229.7	3229.7	128.00	0.00	5.32	0.0
BW3	2985.5	2985.5	97.21	0.00	5.32	0.0
BW4	3315.3	3315.3	66.46	0.00	5.55	0.0
BW5	794.1	794.1	19.91	0.00	10.36	0.0
BW6	363.4	363.4	6.55	0.00	13.96	0.0
BW7	230.3	230.3	41.17	0.00	1.98	0.0
Total of WATER BALLAST	15612.9	15612.9	110.81	0.00	6.05	0.0
FRESH WATER , RHO= 1.000						
FW_SB	191.2	38.2	32.18	-10.81	8.15	19.7
FW_BB	212.9	42.6	33.34	10.78	7.82	22.1
Total of FRESH WATER	404.1	80.8	32.79	0.57	7.98	41.8
LUBRICATING OIL, RHO= 0.900						
LUB	67.7	13.5	22.00	0.00	11.90	90.3
Deadweight		16407.3	108.08	0.00	6.03	16064.8
Lightweight		12000.0	100.00	0.00	8.60	
Displacement (rho=1.025)		28407.3	104.67	0.00	7.12	16064.8

F L O A T I N G P O S I T I O N

Draught moulded	7.658	m	KM	13.49 m
Trim	-3.026	m	KG	7.12 m
TA	9.171	m	GM0	6.37 m
TF	6.145	m	GMCORR	-0.57 m
Trimming moment	-146943	tonm	GM	5.81 m

			X	FRAME
SHEAR FORCE (MIN)	-1753.5	t	POSITION: 162.4	m 203
SHEAR FORCE (MAX)	2040.8	t	32.4	m 41
SAGGING MOMENT	-3.1	tm	1.5	m 2
HOGGING MOMENT	95563.0	tm	96.0	m 120

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.006	0.53	0.023	882.8	0.031
10.0	0.025	1.08	0.094	1383.2	0.049
20.0	0.165	2.27	0.384	2173.1	0.076
30.0	0.487	3.58	0.894	2691.7	0.095
40.0	0.483	4.47	1.608	3060.8	0.108
45.0	0.197	4.59	2.005	3220.5	0.113

ESTIMATION FOR THE CONSTRUCTION COSTS FOR 40000 DWT AND 25000 DWT ARCTIC BULK / CONTAINER CARRIERS

Construction costs can roughly be divided in two parts: material and labour. These costs have almost equal share concerning these ships.

Machinery costs are the main cost source of all material costs and the hull and superstructure take the second position as clear as machinery costs are taking the first place.

Building price estimation for 40000 dwt vessel will be 66 MUS$ and for 25000 dwt vessel 57 MUS$.

The small difference between vessels is because of high depth of smaller vessel. That requirement comes from restricted draught that will produce more length. The length will require more longitudinal strength and it can achieve by raising the depth.

25 000 dwt Ice Breaking Bulk / Container Carrier Design

1. Specification
2. General arrangement
3. Lines plan
4. Machinery arrangement
5. Midship Section
6. Main diagram
7. Hydrostatics
8. Capacities
9. Loading Conditions

Kvaerner Masa-Yards
Technology

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1. GENERAL BASIC DESIGN

11. BASIC DESIGN

Brief Description

The purpose of this Arctic Conbulker is to carry timber and ore form Dikson to Japan and containers from Japan to various Russian ports on the Northern Sea Route during the trip back to Dikson.

The ship is designed to operate independently in a maximum ice thickness of 1.8 m and in ridged areas. Icebreaker assisted time will be four months in the Northern Sea Route.

The cargo area has 8 cargo holds where 5 of them can divided to upper and lower parts with hatch of a pivot design. Accommodation and engine room are located aft of cargo area. Each cargo hold is designed with lift off -type hatch.

The ship hull construction in way of cargo holds is double hull construction. None of tanks containing harmful substances are in side or bottom tanks toward sea.

Total cargo tank capacity is abt. 32300 cubic meters and the maximum dwt which the ship is able to carry at a draught of 9.0 m is about 25000 metric tons.

The ship is equipped with three cargo and two service cranes to have independence of loading and discharging. Lifting capacity of one cargo crane is about 40 tons.

Accommodation arrangement is designed for 24 persons. All the spaces like mess rooms, day rooms, galley, provision store etc. will be dimensioned for the maximum number of persons on board.

The ship's machinery is of diesel-electric type. Propulsion is provided by two (2) about 12 MW fully rotating Azipod-units.

Power is generated by diesel-generator sets feeding electricity to a common network. The number of engines is selected to give optimum engine loading in the main operating modes.

The total installed propulsion engine power is abt. 29 MW.

	Open water condition	Ice conditions
Engine power (kW)	13200	29040
Number of engines running	2	4

Ship Description

Ship's Purpose

The vessel is intended for year around operation in the Russian Arctic but also equipped for world wide operation. A proposed outbound voyage would involve loading ore and timber in the port of Dikson and discharging in the Japan. From Japan containers are carried to various places during the voyage in the Northern Sea Route

General Arrangement

The arrangement of the vessel is modern double hull arrangement divided into:

- forward part
- cargo area (midbody part)
- aft part (engine room and accommodation area)

In the forward part shall be located following spaces and equipment:

- Fore peak
- Store rooms
- Room for bow thruster
- Anchoring and mooring equipment

The cargo holds are protected with double bottom and double sides within the whole length of the cargo area.

- the cargo area shall be divided into 8 cargo holds and 7 of them are divided in upper and lower holds.
- upper holds are designed for timber and lower holds for ore
- when containers are laden, pivot type hatches in the middle of cargo holds will be kept open

Engine room and accommodation are located in the aft part, which is equipped and arranged as follows:

The accommodation deck house to be built compact in aft ship and all the spaces are to be practically equipped and to have a cozy atmosphere.

Working and living spaces to be separated from each other as far as practicable.

The spaces to be placed according to following guide-lines.

Bridge Deck:

- Wheelhouse will be arranged with completely enclosed bridge wings, and a steering post at the rear of the wheelhouse for running astern. The arrangement enables maximum clear view around to increase the safety of the ship.

4 th Poop Deck:
- Captain's & Chief engineers suites
- Captain's & Chief engineers offices
- Owner's cabin
- Pilot's cabin
- Pantry

3 rd Poop Deck
- 8 officer cabins
- Ships office

2 nd Poop Deck:
- 8 crew cabins
- Two repairman cabins
- Hospital

1 st Poop Deck:
- Galley
- Provision store
- Mess and day rooms for crew and officers

Main Deck:
- Sauna department
- Laundry & linen stores
- Sport room
- Hobby room

The General Arrangement shall be according to the drawing no. 1.26726.1110.212.002 dated 1998.06.25. When reference to the General Arrangement Plan is made in this specification it refers to the before mentioned drawing.

Machinery Arrangement

The main machinery consists of a Diesel Electric power plant.

The power plant consists of :

- four (4) medium-speed diesel engines, Wärtsilä 38, 3 x (12V38), 1 x (8R38) or equal.
  each coupled to a generator for electric supply.

- one (1) medium speed diesel engine Wärtsilä 20, (6L20) or equal engine is coupled to a generator for electric supply.

In addition the machinery consists of:

- two (2) freely rotating propulsion units (Azipods) each including one cycloconverter driven propulsion motor
- one (1) steam boilers
- One emergency diesel generator set
- necessary fuel and lubrication oil treatment equipment

The Engine Room Arrangement to be according to the drawing no: 1.26726.6000.212.002.

Special Features for Structural and Operational Safety and Economy:

- double hull (double bottom and double sides)
- reasonable size of cargo holds
- diesel electric Azipod propulsion
- safe and reliable technique

Reference

The quality of workmanship, structural features, fittings and equipment will be suitable for the proper functioning as a modern arctic cargo ship.

The vessel shall be built technically to the good European shipbuilding standard.

Main Dimensions

Length over all abt.	199.9 m
Length betw. perp.	184.1 m
Breadth mld	25.1 m
Depth mld	15.0 m
Draught design	9.0 m
Draught scantling	9.0 m
Deck height in forecastle	3.0 m
Deck height in accommodation	3.0 m
Maximum air draught	abt. 35 m

Capacities

Deadweight and Draught

Deadweight to be about 25000 metric tons at 9.0 m design draft (in sea water with specific gravity of 1025 kg/m^3)

In practice the distribution of deadweight has been assumed to be as follows:

- Cargo		21500 t
- Consumables		
- Fuel oil	3000 t	
- Lubricating oil	60 t	
- Fresh water	240 t	3300 t
- Misc. stores, & spares		200 t
Total deadweight		25000 t

Operating Range

The fuel oil capacity is for a range over 20000 nautical miles in open water based on an average service speed of 14.5 kn with 15 % sea margin.

Accommodation Spaces

Cabins:

- Single cabins with private toilet for all crew members as follows:

Type	No.	Berth each
Captain's class suite	2	1
Officer cabins	8	1
Crew cabins	8	1
Owner's cabins	1	1
Pilot cabins	1	1
Repairman cabins	2	2
Total	22 cabins	

Number of beds grand total 24 on board.

In addition to the cabins mentioned the accommodation includes:

- Public and Service Spaces
- Office Spaces
- Navigation and Control Space
- Catering Spaces
- Provision Spaces
- Sanitary Spaces
- Recreation Spaces
- Other Spaces ("Technical Spaces")
- Lift

In living and working spaces the free heights to be at least 2100 mm.

Cargo Capacities

Capacity of cargo holds (100 % full)		volume	ISO 20' containers:
Hold No. 1	á	3310 m3	72
Hold No. 2	á	4140 m3	96
Hold No. 3	á	4140 m3	96
Hold No. 4	á	4140 m3	96
Hold No. 5	á	4140 m3	96
Hold No. 6	á	4140 m3	96
Hold No. 7	á	4140 m3	96
Hold No. 8	á	4140 m3	96
Cargo Total		32300 m3	744
Containers on deck, max			664
Containers, grand total			1408

Capacity of tanks for ship's purposes:

Capacity of water ballast	16800 m3
Capacity of fuel oil	4200 m3
Capacity of fresh water	400 m3
Capacity of lubricating oil	70 m3

Tonnage

International and Suez tonnage measures will be executed in the shipyard by National Authorities.

Speed and Power, Propeller, Hull Form, Maneuverability, Model Tests

Speed and Power

The mean speed of the vessel on trials with clean bottom when loaded to a mean transit draught of 9.0 m at even keel with an total propeller motor output of 8400 kW is designed to be 14.5 kn in calm weather (wind force not over 4 m/s) and smooth deep water on opposite runs.

The speed determination will be based on the Builder's trial trip results made on ballast condition. The results will be corrected according to the Builder's standard method considering ambient conditions, i.e. wind, wave, sea water temperature, water depth etc. and the ship's draughts which correspond to model test results.

The vessel is able to maintain continuous motion in 1.8 m thick level ice at a draught of 9 m in deep water with a propulsion power output of 24 MW.

Propeller

Two (2) four (4) bladed FP-propellers with diameter abt. 5.2 meter.

Hull Form

The hull form of the vessel is designed for good performance in ice. In independent mode both bow and aft ahead and in icebreaker assistance bow ahead.

Design Criteria

General Principles

Following main aspects shall be kept on mind during the whole design and construction period of the vessel.

1. Independent operation in specified area and ice conditions
2. Technically and economically acceptable and proven cargo handling systems and equipment.
3. Good systems and equipment for ship operation and handling.
4. Environmental safety
5. Specified Rules and Regulations

Environmental Conditions

Temperatures:

If not otherwise stated the ship's machinery systems to be dimensioned for the following ambient temperatures:

	Summer	Winter
Sea water temperature	32°C	-2°C
Air outside:	45°C	-50°C

Air Conditioning Temperatures / Relative Humidity:

Air Conditioning is to be dimensioned for the following conditions:

	Summer	Winter
Outside air temp./RH	35°C/70%	-50°C/ -
Inside air temp./RH	29°C/50%	20°C/25-35%

Ice Conditions

The design ice conditions for the Northern Sea Route concerning the independent mode may be summarized as follows:

- Ice Thickness 1.8 m
- Ice Bending Strength 550 kPa

2. CARGO AND BALLAST HANDLING

20. CARGO AND BALLAST HANDLING BASIC DESIGN

Cargo Handling Description

Cargoes

The vessel shall be constructed for the carriage of dry bulk cargoes. mainly the following cargoes:

-Ore
-Timber
-Containers

27. BALLAST PUMPS IN CARGO AREA

Ballast Pumps

Four (4) deep well type electrically driven ballast pumps shall be arranged.

28. DECK CRANES FOR CARGO

Cargo Cranes

Three electrohydraulic deck cranes with 40 tons capacity with outreach of abt. 28 m to be installed at between cargo holds at center line.

29. CARGO CONTROL AND MONITORING

General

Restrictions of cargo loading are required. Maximum ore weight / sq. m may not exceed more than 20 tons/sq. m. When ore is laden, pivot hatches should be kept closed, if other cargo will be laden to upper holds. When containers are laden, calculations for each load condition are required to achieve stability and trim. In some container loading cases use of water ballast should be accepted to achieve stability and trim.

3. HULL

31. GENERAL OF THE HULL

General

The hull and steel construction shall be designed and built generally according to Classification Society's requirements.

The ship is all-welded, as far as possible with automatic welding according to the Builder's normal practice. Continuous welding is used for the frames and stiffeners in tanks, cofferdams and void spaces and external structures exposed to condensation, and in wet spaces such as galleys, pantries, lavatories, WC's, etc., if these spaces are not lined. Elsewhere in dry spaces intermittent welding may be used.

Frame spacing is 800 mm along the whole length of the ship.

All lower cargo holds shall be designed to total cargo weight 20 t/m^2.

Every space in double bottom to be accessible through openings in floors and side girders, IMO rules to be observed regarding to the size of openings in way of cargo area.

Plate webs shall be arranged at every third frame in double side construction. Intermediate webs supporting the side longitudinals to be arranged between the plate webs in way of the ice belt.

Deckhouse

All accommodation decks are built without camber.

The deckhouse outer bulkheads will be vertical plane bulkheads. Inner bulkheads may be corrugated.

The deckhouse shall be properly supported by bulkheads in the hull at least below the front and rear bulkheads of the deckhouse. Special care to be taken in avoiding longitudinal vibration of the deckhouse due to propeller excitations.

6. MACHINERY

General Description

The main machinery is of diesel-electric AC-AC type and working according to the power plant principle, where all consumers get their power from a common network. The auxiliary net is also fed from the same network through transformers.

The machinery arrangement consists of four diesel engines driving electric generators. The generators' power is fed to the ship's network.

The propulsion is arranged by two electrical motors situated in two azimuthing propulsion devices called Azipods. The rotating speed of the electrical motors is controlled by cycloconverters. The propulsion motors rotate in both directions.

Main Diesel Engines

The main engines are of medium-speed type.

Number and Type	3 x Wärtsilä 12V38 1 x Wärtsilä 8R38
Power Output	3 x 7920 kW at 600 rpm 1 x 5280 kW at 600 rpm

The engine is four-stroke, medium speed, turbocharged and intercooled engine with direct fuel injection. The engines are designed for continuous operation on heavy fuel. It is however possible to operate the engine on diesel fuel without modification. Engine can be started and stopped on heavy fuel provided that the engine and fuel system are preheated to operating temperature. Fuel oil consumption at 100% power of MCR is 177 g/kWh

Mounting of Main Engines :

The engines are coupled through flexible couplings to generators as a generator set. The sets are resiliently mounted.

Harbor Engine

Harbor engine works as power plant to generate electricity for all ship purposes at harbor except loading or discharging with ship's own cranes.

When loading or discharging with ship's own cranes, one of the main engine generator set is used to supply all required electricity.

Harbor engine aggregate consists of diesel engine and 3-phase alternator, which is mounted on a common bed plate. This generating set is resiliently mounted to ship foundation.

The auxiliary engine is of medium-speed type.

Number and Type	one (1) Wärtsilä 6L20 or equal
Power Output	1 x 990 kW at 1000 rpm

62. POWER TRANSMISSION

The power source consists of 4 diesel-generators. The generators are coupled to a 6600 V main switchboard, from which two propeller motor cyclo-converters are fed via transformers.

The propeller motors are synchronous motors. Each motor is fed by a cyclo-converter.

Propeller motors

The two propeller motors are of single armature, single winding synchronous motors. The motors are equipped with sliprings for transformation of excitation.

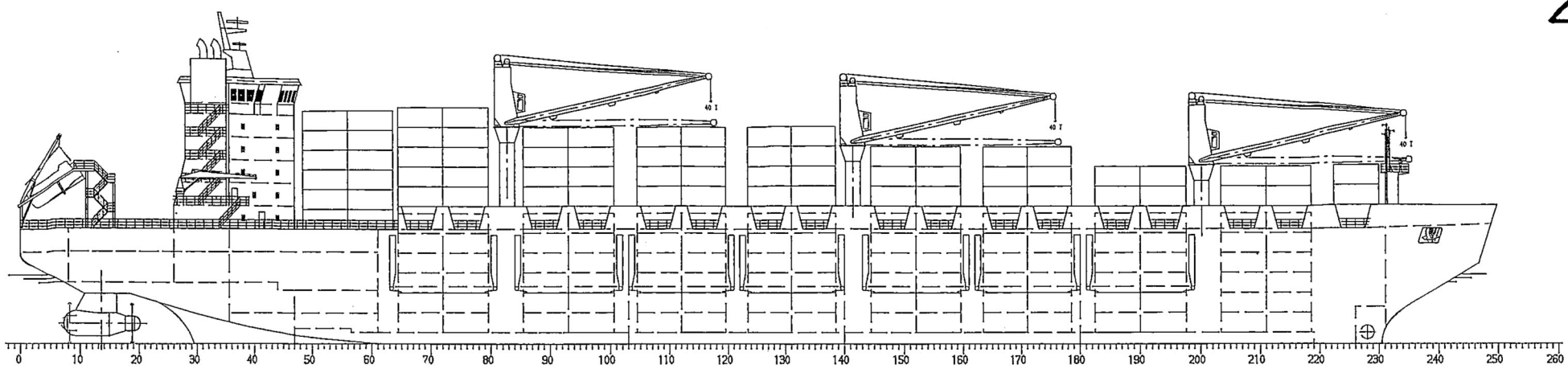
Power:	12.0 MW each
Voltage:	1000 V

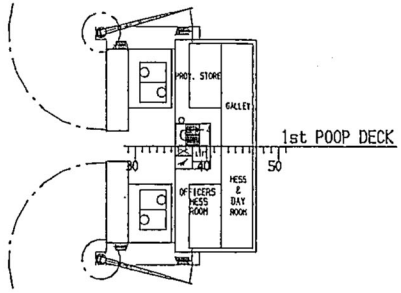
The motors are air-cooled.

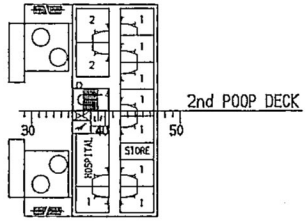
The motors are located in freely rotating rudder propeller units.

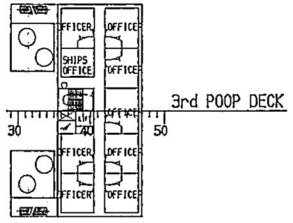
Power to the propulsion motors to be fed through sliprings.

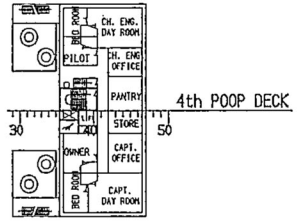
Semantic main electric diagram is presented in picture 4.26726.9100.212.002.

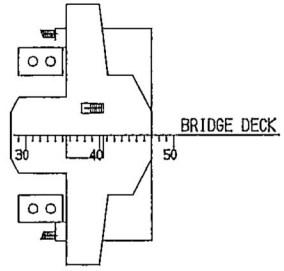


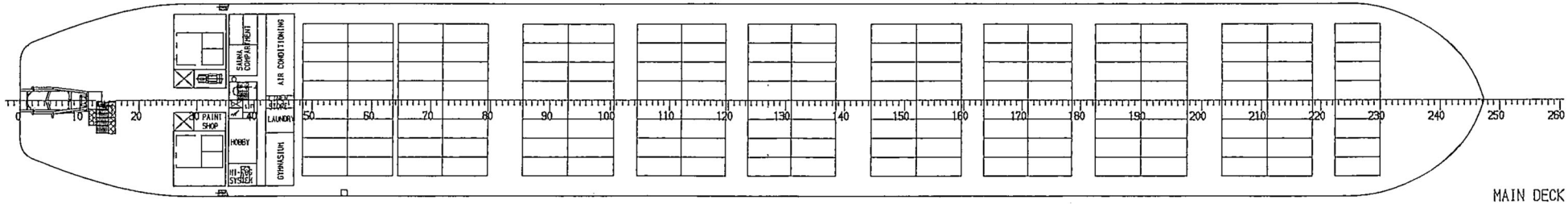


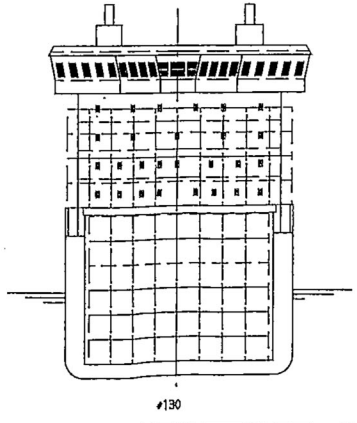












25000 DWT Ice Breaking Bulk / Container Carrier

Length oa.	199.9 m
Length pp.	184.1 m
Breadth	25.1 m
Depth	15.0 m
Draught	9.0 m

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Piirretty ohjelmalla: Drawn with program:

Korjattu Updated: 25-JUN-98 17.16 jk
Piirretyn Drawn: 07-JUL-98 13.22 jk

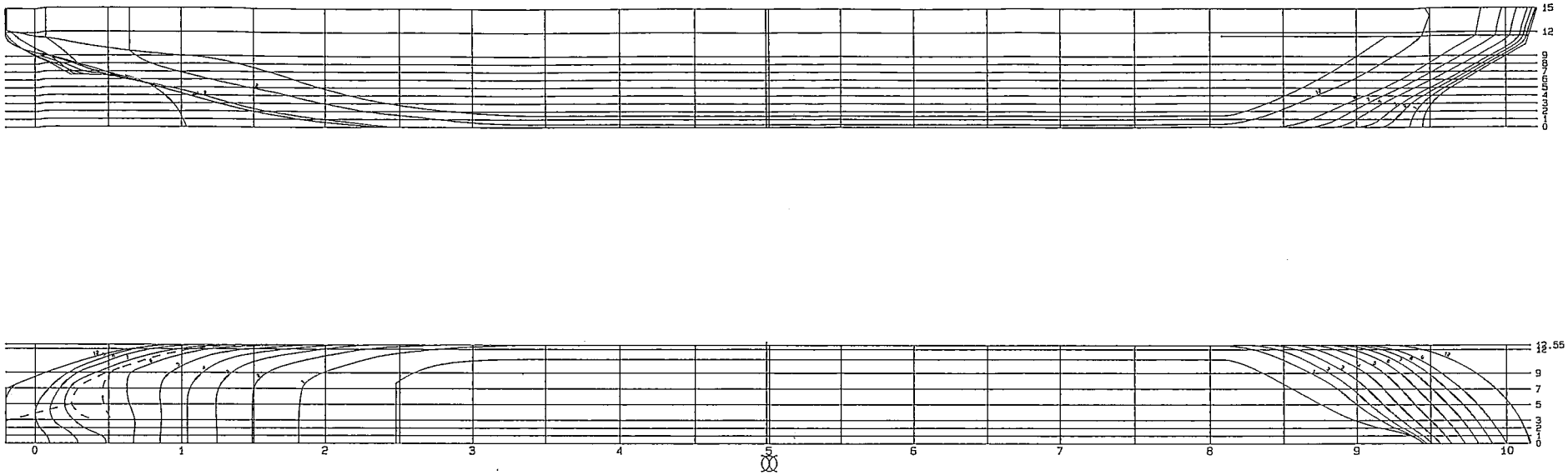
Suun. Design.	Osasto Dpt.	Tark. Insp.	Hyv. Appr.	Liittyy piir. App. to drw	Alk. koko Ist. koko
Pvm Date	Puh. Tel	Pvm Date	Puh. Tel.		

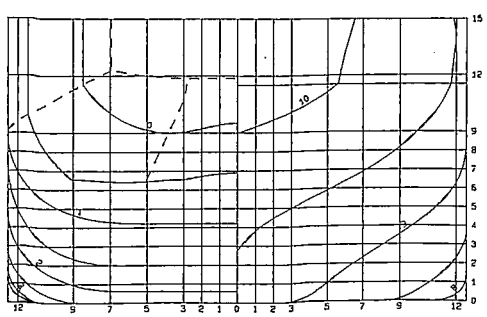
Kvaerner Masa-Yards
Helsinki New Shipyard

Yksityis Nimi

INSROP II
Ice Breaking Bulk / Container Carrier
General Arrangement

Korvaa Replaces	Suhde Scale	Piir.no Drw.No.	Vers.Ind.	Lehti Page
	1:400 800	2.26726.1110.212.002		0





TY026726/B

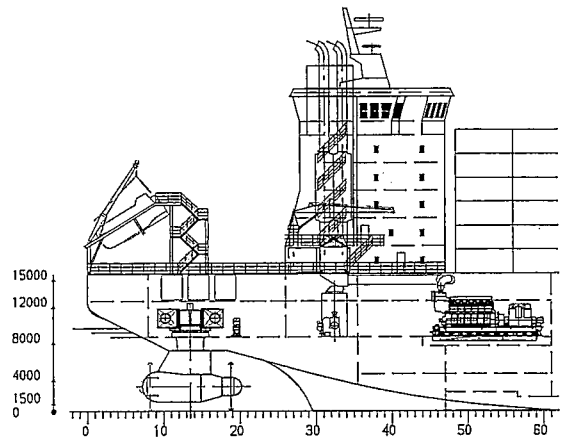
LWL.....	191.00M
BCWL.....	25.10M
TCWL.....	9.00 M

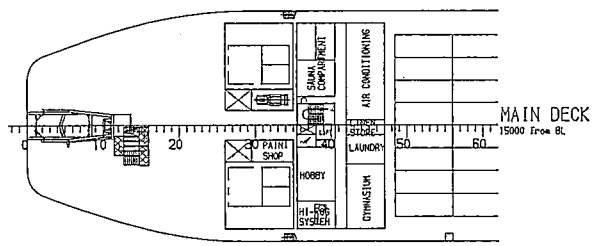
SCALE	DRAWN BY	TEL	CHECKED BY	TEL	ACCEPTED BY
1: 208.400 1: 484.800	NEK				
	DATE 98-07-05	DEP	GENERAL DRAWING		

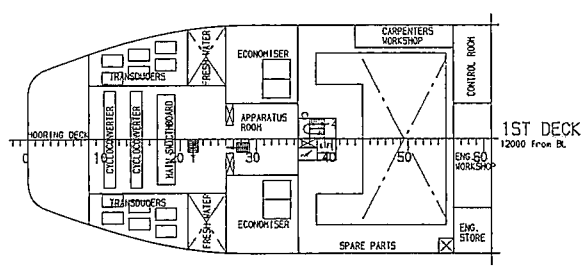
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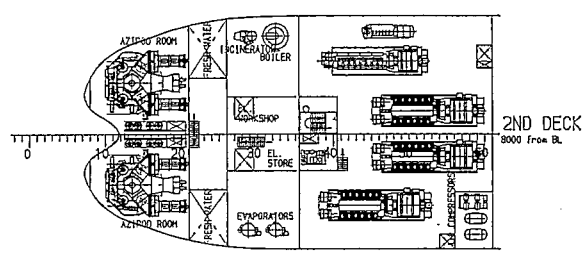
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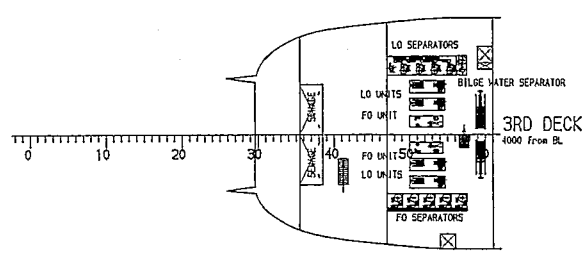
KVAERNER MASA-YARDS TECHNOLOGY. ARCTIC RD.	DRAWING NUMBER	INDEX	SHEET

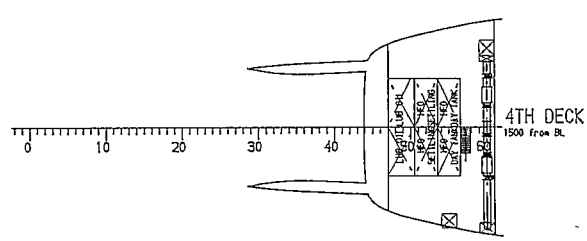












25000 DWT Ice Breaking Bulk / Container Carrier

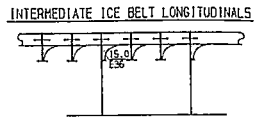
Length oa.	199.9 m
Length pp.	184.1 m
Breadth	25.1 m
Depth	15.0 m
Draught	9.0 m

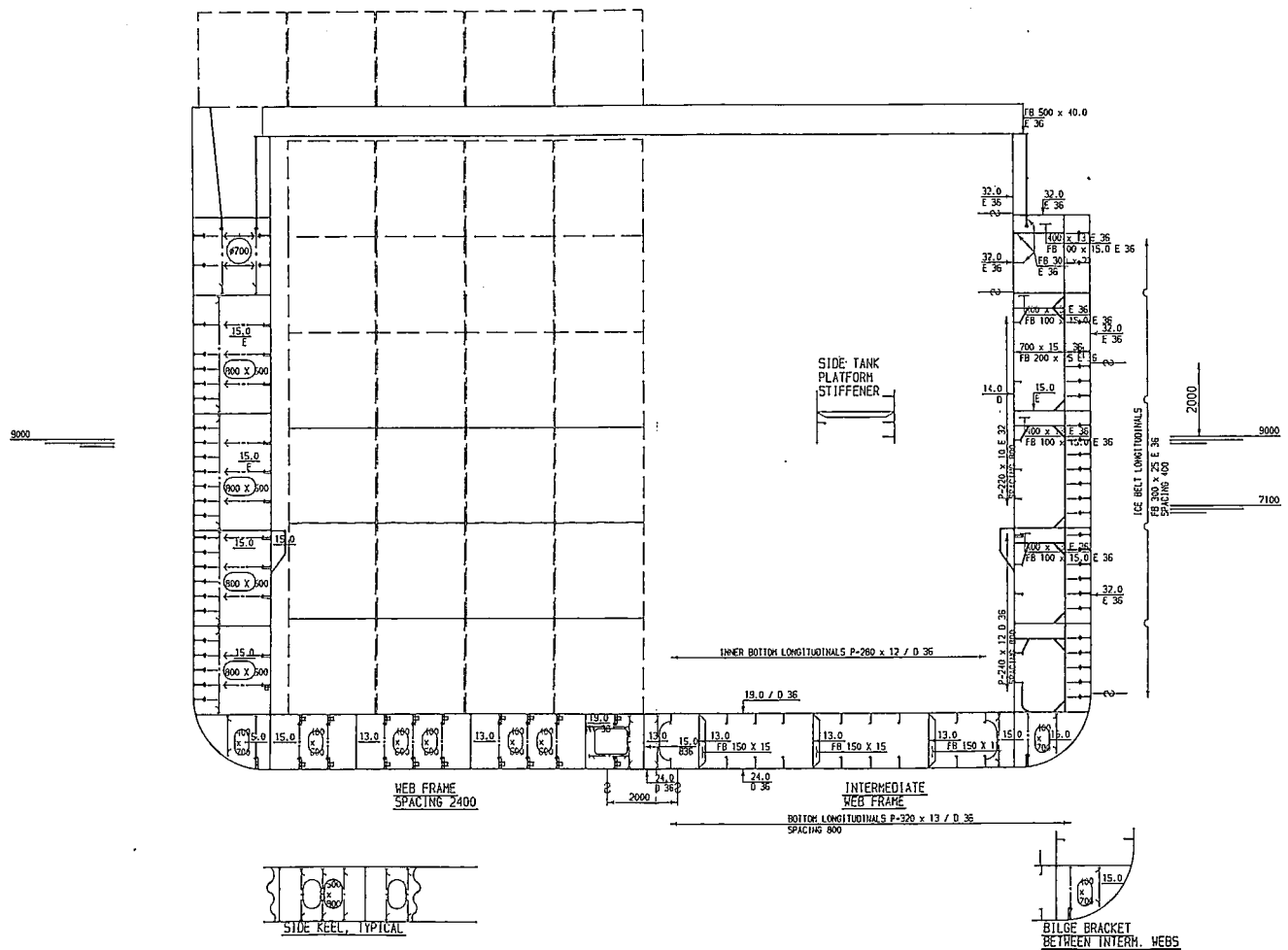
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Kværner Masa-Yards
Helsinki New Shipyard

INSROP II
Ice Breaking Bulk / Container Carrie
Machinery Arrangement

2.26726.6000.212.002





NOTATIONS: P-...= BULB PROFILE
FB-..= FLAT PROFILE

25000 DWT Ice Breaking Bulk / Container Carrier

Length oa.	199.9 m
Length pp.	184.1 m
Breadth	25.1 m
Depth	15.0 m
Draught	9.0 m
Block coefficient	0.81

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Piirretty ohjelmalla: Drawn with program:

Korjattu tiedosto: 03-JUL-98 08:2 jälveta
Piirretty: Drawn: 07-JUL-98 15:27 Jälveta

Suun. Design.	Omaista Ord.	Tark. Insp.		Hyv. Appr.	Liittyy piir. App. to drw
Pvm Date	Puh. Tel.	Pvm Date	Puh. Tel.		Kat.-numero Cat.-numb

Kværner Masa-Yards
Helsinki New Shipyard

Nimityn Name

INSROP II
Ice Breaking Bulk / Container Carrier
Midship Section

korvaa Replaces

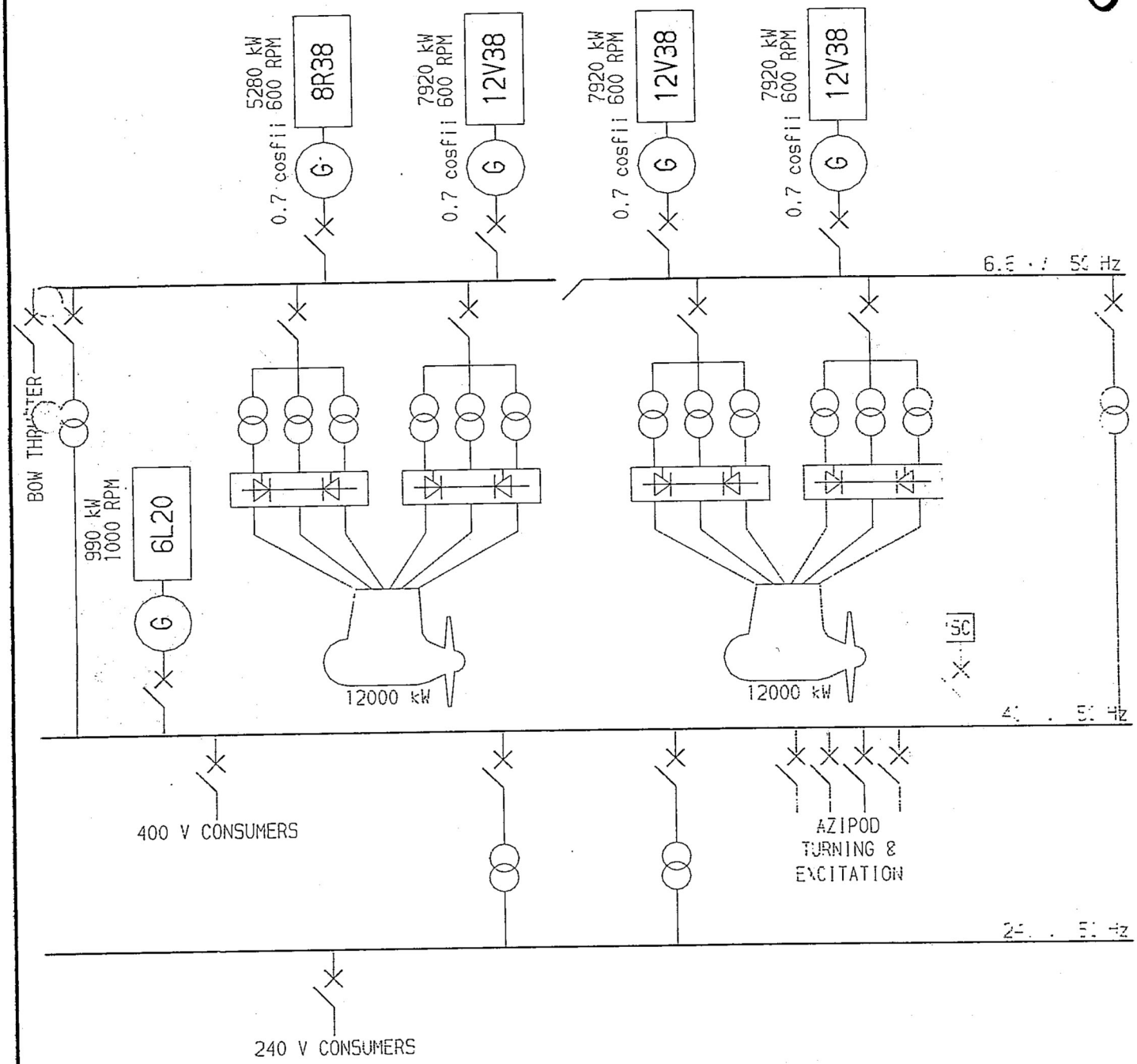
Suhde Scale 1:100 200

Piir.no Drw.No. 2.26726.3000.212.002

Vers. Ind. Levi Page ( )

Muutos	Osa no	Kenttä	Muutos ja/tai huomautus	Päiväys	Muutt.	Hyväks

6



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Piirretty ohjelmalla: Drawn with program:

Korjattu: Updated: 09-Jul-98 11:38

Piirretty: Drawn:

Suun. Design.	Osasto Dpt.	Tark. Insp.		Hyv. Appr.	Liittyy piir. App. to dr.	Tark. Assc. Ch. Insp.
Pvm Date	Puh. Tel.	Pvm Date	Puh. Tel.			

Kværner Masa-Yards
Helsinki New Shipyard

Nimitys Name

INSROP II
Ice Breaking Bulk / Container Carrier
Main Diagram

Korvaa Replaces	Suhde Scale	Piir.no Drw.No.	Vers. Ind. Verif. Appr.
		4.26726.9100.212.002	( )

Masa-Yards Helsinki
NAPA/D/HYD/971106
TYO26726/B
TYO26726

HYDROSTATICS

DATE 98-07-06
TIME 15:50
SIGN JEK
PAGE 1

MAIN CHARACTERISTICS OF THE VESSEL:

Length betw. perpendiculars	191.00	m
Breadth, moulded	25.10	m
Design draught	9.00	m
X-coord. of after perpendicular	3.86	m
X-coord. of reference point	99.36	m
X-coord. of midship section	99.36	m
X-coord. of building frame 0	0.00	m
Thickness of keelplate	0.010	m
Mean thickness of shell plating	0.010	m
Density of water	1.025	ton/m3

Calculations are based on HULL date 98-06-22 time 14.58

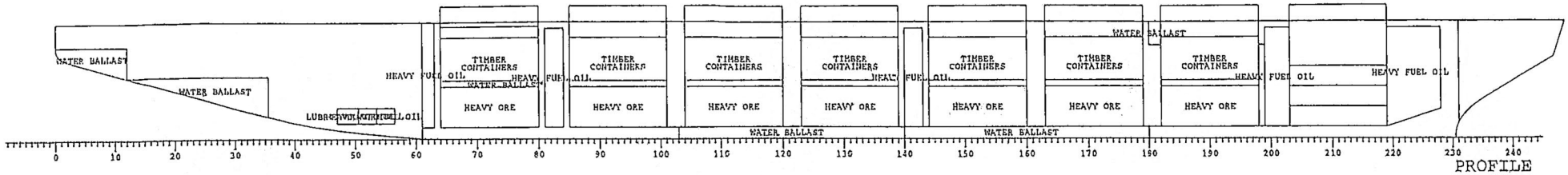
X-coord. of aft end of DWL	3.86	m
X-coord. of fore end of DWL	194.86	m

calc. sections 27

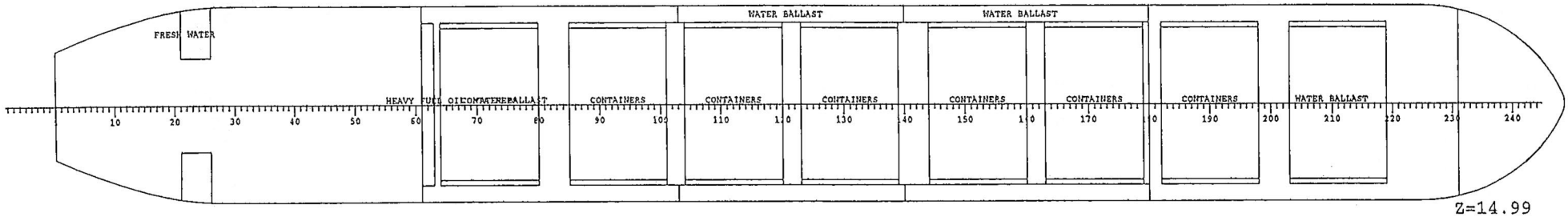
EXPLANATION OF SYMBOLS:

T	draught, moulded	m
DISP	total displacement	t
LCB	longitudinal centre of buoyancy	m
KMT	transv. metac. height	m
CB	block coefficient	
WLA	waterline area	m2
MCT	moment to change trim	tm/cm
TPC	change of displacement/change of draught	t/cm

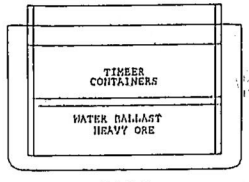
T m	DISP t	LCB m	KMT m	CB	WLA m2	MCT tm/cm	TPC t/cm
2.500	8521.6	107.337	22.890	0.6903	3630.3	343.3	37.2
3.000	10406.6	106.759	19.687	0.7029	3687.9	359.3	37.8
3.500	12330.3	106.271	17.498	0.7142	3776.1	385.8	38.7
4.000	14291.6	105.850	15.906	0.7246	3836.3	404.0	39.3
4.500	16294.6	105.468	14.734	0.7346	3896.7	422.9	39.9
5.000	18341.5	105.106	13.846	0.7444	3956.0	442.1	40.5
5.500	20419.0	104.815	13.286	0.7535	4094.5	489.3	42.0
6.000	22541.9	104.513	12.774	0.7626	4160.9	512.8	42.6
6.500	24713.0	104.178	12.383	0.7718	4248.6	547.1	43.5
7.000	26923.8	103.744	12.131	0.7809	4360.8	591.8	44.7
7.500	29171.4	103.320	11.846	0.7898	4410.1	611.8	45.2
8.000	31442.8	102.940	11.627	0.7981	4466.5	635.5	45.8
8.500	33739.4	102.596	11.461	0.8061	4509.5	653.7	46.2
9.000	36060.2	102.284	11.343	0.8138	4552.8	672.5	46.7
9.500	38400.7	102.012	11.266	0.8210	4597.9	692.6	47.1
10.000	40762.2	101.767	11.223	0.8280	4643.7	713.4	47.6
10.500	43144.4	101.548	11.211	0.8347	4679.1	729.5	48.0
11.000	45550.6	101.366	11.218	0.8412	4699.9	739.2	48.2
11.500	47972.1	101.205	11.249	0.8475	4720.4	749.0	48.4
12.000	50404.0	101.064	11.282	0.8533	4739.3	758.7	48.6
12.500	52842.4	100.940	11.334	0.8589	4747.4	762.9	48.7



PROFILE



Z=14.99



#130

NAME	PURP	VOLM m3	VNET m3	CGX m	CGY m	CGZ m	IY*RHO tm	IY/IMO tm
CAPACITY OF (RHO=0)								
HOLD1		3310.4	3310.4	168.80	0.00	10.51	0.0	0
HOLD2		4140.0	4140.0	152.00	0.00	9.27	0.0	0
HOLD3		4140.0	4140.0	136.80	0.00	9.27	0.0	0
HOLD4		4140.0	4140.0	121.60	0.00	9.27	0.0	0
HOLD5		4140.0	4140.0	104.80	0.00	9.27	0.0	0
HOLD6		4140.0	4140.0	89.60	0.00	9.27	0.0	0
HOLD7		4140.0	4140.0	74.40	0.00	9.27	0.0	0
HOLD8		4140.0	4140.0	57.60	0.00	9.27	0.0	0
STABHULL		63561.7	63561.7	100.54	0.00	8.03	0.0	0
SUBTOTAL		95852.4	95852.4	104.33	0.00	8.49		
CAPACITY OF CONTAINERS (RHO=0.627)								
HOLD1CO	CONTS	2916.2	2697.5	168.80	0.00	10.84	4959.1	2987
HOLD2CO	CONTS	3881.3	3590.2	152.00	0.00	9.27	4959.1	4587
HOLD3CO	CONTS	3881.3	3590.2	136.80	0.00	9.27	4959.1	4587
HOLD4CO	CONTS	3881.3	3590.2	121.60	0.00	9.27	4959.1	4587
HOLD5CO	CONTS	3881.3	3590.2	104.80	0.00	9.27	4959.1	4587
HOLD6CO	CONTS	3881.3	3590.2	89.60	0.00	9.27	4959.1	4587
HOLD7CO	CONTS	3881.3	3590.2	74.40	0.00	9.27	4959.1	4587
HOLD8CO	CONTS	3881.3	3590.2	57.60	0.00	9.27	4959.1	4587
SUBTOTAL	CONTS	30085.1	27828.8	111.42	0.00	9.43		
CAPACITY OF FRESH WATER (RHO=1)								
FW	FW	452.9	443.8	18.85	0.00	10.47	4420.0	1512
CAPACITY OF HEAVY FUEL OIL (RHO=0.94)								
HFO1	HFO	1595.0	1563.1	179.33	0.00	9.40	4888.2	3380
HFO2	HFO	843.6	826.7	160.80	0.00	7.86	2255.7	2204
HFO3	HFO	634.0	621.3	113.20	0.00	7.85	1691.8	1658
HFO4	HFO	634.0	621.3	66.00	0.00	7.85	1691.8	1658
HFO5	HFO	443.5	434.7	49.60	0.00	8.33	1127.9	1084
HFO_DAY	HFO	69.1	67.7	44.00	0.00	3.00	561.4	550
HFO_SETT	HFO	69.1	67.7	41.60	0.00	3.00	561.4	550
SUBTOTAL	HFO	4288.3	4202.6	131.33	0.00	8.32		
CAPACITY OF LUBRICATING OIL (RHO=0.9)								
LUB	LO	80.6	79.0	39.00	0.00	3.00	627.1	615

NAME	PURP	VOLM m3	VNET m3	CGX m	CGY m	CGZ m	IY*RHO tm	IY/IMO tm
CAPACITY OF HEAVY ORE (RHO=3.3)								
HOLD2L	ORE1	1384.4	1315.2	152.00	0.00	4.10	31676.2	30092
HOLD3L	ORE1	1384.4	1315.2	136.80	0.00	4.10	31676.1	30092
HOLD4L	ORE1	1384.4	1315.2	121.60	0.00	4.10	31676.2	30092
HOLD5L	ORE1	1384.4	1315.2	104.80	0.00	4.10	31676.2	30092
HOLD6L	ORE1	1384.4	1315.2	89.60	0.00	4.10	31676.2	30092
HOLD7L	ORE1	1384.4	1315.2	74.40	0.00	4.10	31676.2	30092
HOLD8L	ORE1	1384.4	1315.2	57.60	0.00	4.10	31676.2	30092
SUBTOTAL	ORE1	9691.1	9206.6	105.26	0.00	4.10		
CAPACITY OF TIMBER (RHO=0.8)								
HOLD2U	TIM	1464.3	1391.1	152.00	0.00	10.25	7679.1	7295
HOLD3U	TIM	1464.3	1391.1	136.80	0.00	10.25	7679.1	7295
HOLD4U	TIM	1464.3	1391.1	121.60	0.00	10.25	7679.1	7295
HOLD5U	TIM	1464.3	1391.1	104.80	0.00	10.25	7679.1	7295
HOLD6U	TIM	1464.3	1391.1	89.60	0.00	10.25	7679.1	7295
HOLD7U	TIM	1464.3	1391.1	74.40	0.00	10.25	7679.1	7295
HOLD8U	TIM	1464.3	1391.1	57.60	0.00	10.25	7679.1	7295
SUBTOTAL	TIM	10250.2	9737.7	105.26	0.00	10.25		
CAPACITY OF WATER BALLAST (RHO=1.025)								
BW1	WB	4780.5	4684.8	164.75	0.00	6.47	29301.5	9344
BW2	WB	3029.8	2969.2	128.00	0.00	5.35	18625.9	5342
BW3	WB	2802.6	2746.5	97.20	0.00	5.35	17228.9	4941
BW4	WB	4866.7	4769.4	64.48	0.00	6.41	27300.0	10613
BW5	WB	497.4	487.5	6.23	0.00	10.19	3426.9	2240
BW6	WB	1175.5	1152.0	21.33	0.00	6.40	16462.9	7522
BW7	WB	87.8	86.0	31.69	0.00	1.24	1333.4	62
SUBTOTAL	WB	17240.2	16895.4	103.97	0.00	6.15		
TOTAL		167940.9	164246.3	106.10	0.00	8.27		

LOADING CONDITIONS

This paragraph contains various loading conditions.

Case	
LC1	heavy ore in lower holds, timber in upper holds and consumables as in departure condition
LC2	as LC1 but consumables are 20% of LC1
LC3	light ore in lower holds, timber in upper holds and consumables as in departure conditions
LC4	as LC3 but consumables are 20% of LC3.
LC5	Containers in cargo holds and on deck. Heavy containers in holds and light on deck. Consumables are in departure condition.
BW1	Ballast water conditions with 20% consumables. Max aft trim was tried to obtain. The purpose was to sink the propeller as deep as possible.

LOADING CONDITION LC1

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
HEAVY ORE, RHO= 3.300							
HOLD3L	HOLD 3L	4340.2	3600.0	136.80	0.00	3.66	0.0
HOLD4L	HOLD 4L	4340.2	3600.0	121.60	0.00	3.66	0.0
HOLD5L	HOLD 5L	4340.2	3600.0	104.80	0.00	3.66	0.0
HOLD6L	HOLD 6L	4340.2	3600.0	89.60	0.00	3.66	0.0
HOLD7L	HOLD 7L	4340.2	3600.0	74.40	0.00	3.66	0.0
Total of HEAVY ORE		21701.2	18000.0	105.44	0.00	3.66	0.0
TIMBER, RHO= 0.800							
HOLD4U	HOLD 4U	1112.9	804.7	121.60	0.00	9.49	0.0
HOLD5U	HOLD 5U	1112.9	1112.9	104.80	0.00	10.25	0.0
HOLD6U	HOLD 6U	1112.9	1112.9	89.60	0.00	10.25	0.0
HOLD7U	HOLD 7U	1112.9	456.1	74.40	0.00	8.63	0.0
Total of TIMBER		4451.5	3486.5	99.85	0.00	9.86	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1439.9	568.5	178.82	0.00	6.28	4673.4
HFO2		761.6	761.6	160.80	0.00	7.73	0.0
HFO3		572.3	572.3	113.20	0.00	7.72	0.0
HFO4		572.3	572.3	66.00	0.00	7.72	0.0
HFO5		400.4	400.4	49.60	0.00	8.20	0.0
HFO_DAY		62.4	62.4	44.00	0.00	2.98	0.0
HFO_SETT		62.4	62.4	41.60	0.00	2.98	0.0
Total of HEAVY FUEL OIL		3871.4	3000.0	117.30	0.00	7.32	4673.4
LUBRICATING OIL, RHO= 0.900							
LUB		69.7	69.7	39.00	0.00	2.98	0.0
FRESH WATER , RHO= 1.000							
FW		443.8	443.8	18.85	0.00	10.47	0.0
Deadweight			25000.0	104.36	0.00	5.08	4673.4
Lightweight			10700.0	97.60	0.00	8.00	
Displacement (rho=1.025)			35700.0	102.33	0.00	5.96	4673.4

F L O A T I N G P O S I T I O N

Draught moulded	8.923	m	KM	11.36 m
Trim	0.003	m	KG	5.96 m
TA	8.921	m	GM0	5.40 m
TF	8.924	m	GMCORR	-0.13 m
Trimming moment	192	tonm	GM	5.27 m

			X	FRAME
SHEAR FORCE (MIN)	-5056.2	t	POSITION: 64.8	m 81
SHEAR FORCE (MAX)	5008.6	t	143.2	m 179
SAGGING MOMENT	-198967	tm	103.7	m 130
HOGGING MOMENT	522.6	tm	24.5	m 31

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.46	0.020	405.3	0.011
10.0	0.016	0.93	0.081	792.9	0.022
20.0	0.122	1.93	0.328	1455.5	0.041
30.0	0.372	3.02	0.762	1984.5	0.056
40.0	0.295	3.70	1.356	2396.2	0.067
45.0	0.086	3.83	1.686	2519.1	0.071

LOADING CONDITION LC2

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
HEAVY ORE, RHO= 3.300							
HOLD3L	HOLD 3L	4340.2	3600.0	136.80	0.00	3.66	0.0
HOLD4L	HOLD 4L	4340.2	3600.0	121.60	0.00	3.66	0.0
HOLD5L	HOLD 5L	4340.2	3600.0	104.80	0.00	3.66	0.0
HOLD6L	HOLD 6L	4340.2	3600.0	89.60	0.00	3.66	0.0
HOLD7L	HOLD 7L	4340.2	3600.0	74.40	0.00	3.66	0.0
Total of HEAVY ORE		21701.2	18000.0	105.44	0.00	3.66	0.0
TIMBER, RHO= 0.800							
HOLD4U	HOLD 4U	1112.9	804.7	121.60	0.00	9.49	0.0
HOLD5U	HOLD 5U	1112.9	1112.9	104.80	0.00	10.25	0.0
HOLD6U	HOLD 6U	1112.9	1112.9	89.60	0.00	10.25	0.0
HOLD7U	HOLD 7U	1112.9	456.1	74.40	0.00	8.63	0.0
Total of TIMBER		4451.5	3486.6	99.85	0.00	9.86	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1439.9	437.8	178.62	0.00	5.73	4174.1
HFO5		400.4	37.4	49.60	0.00	2.23	1052.1
HFO_DAY		62.4	62.4	44.00	0.00	2.98	0.0
HFO_SETT		62.4	62.4	41.60	0.00	2.98	0.0
Total of HEAVY FUEL OIL		1965.1	600.0	142.32	0.00	4.94	5226.2
LUBRICATING OIL, RHO= 0.900							
LUB		69.7	13.4	39.00	-0.00	2.19	614.5
FRESH WATER , RHO= 1.000							
FW		443.8	88.7	18.96	0.00	6.69	3784.3
Deadweight			22188.7	105.17	0.00	4.68	9625.0
Lightweight			10700.0	97.60	0.00	8.00	
Displacement (rho=1.025)			32888.7	102.71	0.00	5.76	9625.0

F L O A T I N G P O S I T I O N

Draught moulded	8.317	m	KM	11.52 m
Trim	-0.004	m	KG	5.76 m
TA	8.319	m	GM0	5.76 m
TF	8.315	m	GMCORR	-0.29 m
Trimming moment	-289	tonm	GM	5.47 m

			X	FRAME
SHEAR FORCE (MIN)	-5416.4	t	POSITION: 68.0	m 85
SHEAR FORCE (MAX)	5187.2	t	143.2	m 179
SAGGING MOMENT	-201858	tm	103.7	m 130
HOGGING MOMENT	1204.8	tm	20.8	m 26

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.48	0.021	813.9	0.025
10.0	0.016	0.97	0.084	1515.2	0.046
20.0	0.122	2.02	0.343	2314.3	0.070
30.0	0.429	3.23	0.801	2738.0	0.083
40.0	0.434	4.04	1.445	3057.9	0.093
45.0	0.213	4.19	1.805	3177.0	0.097

LOADING CONDITION LC3

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
LIGHT ORE, RHO= 1.670							
HOLD2L	HOLD 2L	2196.4	2196.4	152.00	0.00	4.10	0.0
HOLD3L	HOLD 3L	2196.4	2196.4	136.80	0.00	4.10	0.0
HOLD4L	HOLD 4L	2196.4	2196.4	121.60	0.00	4.10	0.0
HOLD5L	HOLD 5L	2196.4	2196.4	104.80	0.00	4.10	0.0
HOLD6L	HOLD 6L	2196.4	2196.4	89.60	0.00	4.10	0.0
HOLD7L	HOLD 7L	2196.4	2196.4	74.40	0.00	4.10	0.0
HOLD8L	HOLD 8L	2196.4	2196.4	57.60	0.00	4.10	0.0
Total of LIGHT ORE		15375.0	15375.0	105.26	0.00	4.10	0.0
TIMBER, RHO= 0.800							
HOLD3U	HOLD 3U	1112.9	994.3	136.80	0.00	9.96	0.0
HOLD4U	HOLD 4U	1112.9	1112.9	121.60	0.00	10.25	0.0
HOLD5U	HOLD 5U	1112.9	1112.9	104.80	0.00	10.25	0.0
HOLD6U	HOLD 6U	1112.9	1112.9	89.60	0.00	10.25	0.0
HOLD7U	HOLD 7U	1112.9	1112.9	74.40	0.00	10.25	0.0
HOLD8U	HOLD 8U	1112.9	665.7	57.60	0.00	9.14	0.0
Total of TIMBER		6677.3	6111.5	99.62	0.00	10.08	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1439.9	711.8	178.99	0.00	6.82	4790.4
HFO2		761.6	761.6	160.80	0.00	7.73	0.0
HFO3		572.3	572.3	113.20	0.00	7.72	0.0
HFO4		572.3	572.3	66.00	0.00	7.72	0.0
HFO5		400.4	257.1	49.60	0.00	5.86	1105.3
HFO_DAY		62.4	62.4	44.00	0.00	2.98	0.0
HFO_SETT		62.4	62.4	41.60	0.00	2.98	0.0
Total of HEAVY FUEL OIL		3871.4	3000.0	123.51	0.00	7.15	5895.7
LUBRICATING OIL, RHO= 0.900							
LUB		69.7	69.7	39.00	0.00	2.98	0.0
FRESH WATER , RHO= 1.000							
FW		443.8	443.8	18.85	0.00	10.47	0.0
Deadweight			25000.0	104.35	0.00	6.04	5895.7
Lightweight			10700.0	97.60	0.00	8.00	
Displacement (rho=1.025)			35700.0	102.33	0.00	6.63	5895.7

F L O A T I N G P O S I T I O N

Draught moulded	8.923	m	KM	11.36 m
Trim	-0.001	m	KG	6.63 m
TA	8.923	m	GM0	4.73 m
TF	8.922	m	GMCORR	-0.17 m
Trimming moment	-94	tonm	GM	4.57 m

			X	FRAME
SHEAR FORCE (MIN)	-3008.4	t	POSITION: 51.2 m	64
SHEAR FORCE (MAX)	2667.5	t	143.2 m	179
SAGGING MOMENT	-118132	tm	103.7 m	130
HOGGING MOMENT	516.6	tm	24.5 m	31

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM .tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.40	0.017	515.5	0.014
10.0	0.016	0.81	0.070	1031.4	0.029
20.0	0.122	1.68	0.286	2027.3	0.057
30.0	0.372	2.66	0.666	2894.4	0.081
40.0	0.295	3.24	1.188	3409.9	0.096
45.0	0.086	3.33	1.475	3533.9	0.099

LOADING CONDITION LC4

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
LIGHT ORE, RHO= 1.670							
HOLD2L	HOLD 2L	2196.4	2196.4	152.00	0.00	4.10	0.0
HOLD3L	HOLD 3L	2196.4	2196.4	136.80	0.00	4.10	0.0
HOLD4L	HOLD 4L	2196.4	2196.4	121.60	0.00	4.10	0.0
HOLD5L	HOLD 5L	2196.4	2196.4	104.80	0.00	4.10	0.0
HOLD6L	HOLD 6L	2196.4	2196.4	89.60	0.00	4.10	0.0
HOLD7L	HOLD 7L	2196.4	2196.4	74.40	0.00	4.10	0.0
HOLD8L	HOLD 8L	2196.4	2196.4	57.60	0.00	4.10	0.0
Total of LIGHT ORE		15375.0	15375.0	105.26	0.00	4.10	0.0
TIMBER, RHO= 0.800							
HOLD3U	HOLD 3U	1112.9	994.3	136.80	0.00	9.96	0.0
HOLD4U	HOLD 4U	1112.9	1112.9	121.60	0.00	10.25	0.0
HOLD5U	HOLD 5U	1112.9	1112.9	104.80	0.00	10.25	0.0
HOLD6U	HOLD 6U	1112.9	1112.9	89.60	0.00	10.25	0.0
HOLD7U	HOLD 7U	1112.9	1112.9	74.40	0.00	10.25	0.0
HOLD8U	HOLD 8U	1112.9	665.7	57.60	0.00	9.14	0.0
Total of TIMBER		6677.3	6111.5	99.62	0.00	10.08	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1439.9	475.2	178.68	0.00	5.90	4373.1
HFO_DAY		62.4	62.4	44.00	0.00	2.98	0.0
HFO_SETT		62.4	62.4	41.60	0.00	2.98	0.0
Total of HEAVY FUEL OIL		1564.7	600.0	150.42	0.00	5.29	4373.1
LUBRICATING OIL, RHO= 0.900							
LUB		69.7	13.4	39.00	-0.00	2.19	614.5
FRESH WATER , RHO= 1.000							
FW		443.8	88.7	18.96	0.00	6.69	3784.3
Deadweight			22188.6	104.54	0.00	5.79	8771.9
Lightweight			10700.0	97.60	0.00	8.00	
Displacement (rho=1.025)			32888.6	102.28	0.00	6.51	8771.9

F L O A T I N G P O S I T I O N

Draught moulded	8.315	m	KM	11.52 m
Trim	-0.219	m	KG	6.51 m
TA	8.425	m	GM0	5.01 m
TF	8.206	m	GMCORR	-0.27 m
Trimming moment	-14176	tonm	GM	4.75 m

			X	FRAME
SHEAR FORCE (MIN)	-3091.4 t	POSITION:	51.2 m	64
SHEAR FORCE (MAX)	2865.3 t		143.2 m	179
SAGGING MOMENT	-122792 tm		101.7 m	127
HOGGING MOMENT	1000.7 tm		20.8 m	26

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.42	0.018	745.5	0.023
10.0	0.016	0.84	0.073	1395.4	0.042
20.0	0.122	1.77	0.299	2161.6	0.066
30.0	0.431	2.86	0.703	2589.3	0.079
40.0	0.440	3.57	1.274	2923.4	0.089
45.0	0.214	3.67	1.590	3039.8	0.092

LOADING CONDITION LC5

L O A D I N G C O M P O N E N T S

Name		Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
CONTAINERS, RHO= 0.627							
HOLD1CO	HOLD 1co	1731.5	1731.5	168.80	0.00	10.84	0.0
HOLD2CO	HOLD 2co	2304.6	2304.6	152.00	0.00	9.27	0.0
HOLD3CO	HOLD 3co	2304.6	2304.6	136.80	0.00	9.27	0.0
HOLD4CO	HOLD 4co	2304.6	2304.6	121.60	0.00	9.27	0.0
HOLD5CO	HOLD 5co	2304.6	2304.6	104.80	0.00	9.27	0.0
HOLD6CO	HOLD 6co	2304.6	2304.6	89.60	0.00	9.27	0.0
HOLD7CO	HOLD 7co	2304.6	2304.6	74.40	0.00	9.27	0.0
HOLD8CO	HOLD 8co	2304.6	2304.6	57.60	0.00	9.27	0.0
Total of CONTAINERS		17863.6	17863.6	111.42	0.00	9.43	0.0
HEAVY FUEL OIL , RHO= 0.940							
HFO1		1439.9	568.5	178.82	0.00	6.28	4673.4
HFO2		761.6	761.6	160.80	0.00	7.73	0.0
HFO3		572.3	572.3	113.20	0.00	7.72	0.0
HFO4		572.3	572.3	66.00	0.00	7.72	0.0
HFO5		400.4	400.4	49.60	0.00	8.20	0.0
HFO_DAY		62.4	62.4	44.00	0.00	2.98	0.0
HFO_SETT		62.4	62.4	41.60	0.00	2.98	0.0
Total of HEAVY FUEL OIL		3871.4	3000.0	117.30	0.00	7.32	4673.4
LUBRICATING OIL, RHO= 0.900							
LUB		69.7	69.7	39.00	0.00	2.98	0.0
FRESH WATER , RHO= 1.000							
FW		443.8	443.8	18.85	0.00	10.47	0.0
CONTS1							
(CONTS1)		0.0	0.0	180.80	0.00	18.80	0.0
CONTS2							
(CONTS2)		0.0	0.0	168.80	0.00	20.60	0.0
CONTS3							
(CONTS3)		0.0	0.0	152.00	0.00	20.60	0.0
CONTS4							
(CONTS4)		0.0	0.0	136.80	0.00	19.30	0.0
CONTS5							
(CONTS5)		0.0	180.0	121.60	0.00	19.30	0.0

Name	Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
CONTS6						
(CONTS6)	0.0	360.0	104.80	0.00	20.60	0.0
CONTS7						
(CONTS7)	0.0	540.0	89.60	0.00	21.90	0.0
CONTS8						
(CONTS8)	0.0	720.0	74.40	0.00	23.20	0.0
CONTS9						
(CONTS9)	0.0	900.0	57.60	0.00	24.50	0.0
CONTS10						
(CONTS10)	0.0	900.0	44.80	0.00	24.50	0.0
Deadweight		24977.1	104.38	0.00	11.16	4673.4
Lightweight		10700.0	97.60	0.00	8.00	
Displacement (rho=1.025)		35677.1	102.34	0.00	10.21	4673.4

F L O A T I N G P O S I T I O N

Draught moulded	8.918	m	KM	11.36 m
Trim	0.006	m	KG	10.21 m
TA	8.915	m	GM0	1.15 m
TF	8.921	m	GMCORR	-0.13 m
Trimming moment	420	tonm	GM	1.01 m

			X	FRAME
SHEAR FORCE (MIN)	-2097.8	t	POSITION: 48.8 m	61
SHEAR FORCE (MAX)	1102.9	t	128.0 m	160
SAGGING MOMENT	-59737.6	tm	88.4 m	110
HOGGING MOMENT	551.5	tm	24.5 m	31

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.09	0.004	405.3	0.011
10.0	0.016	0.19	0.016	792.9	0.022
20.0	0.122	0.47	0.072	1455.5	0.041
30.0	0.372	0.89	0.199	1984.5	0.056
40.0	0.297	0.97	0.360	2396.2	0.067
45.0	0.087	0.83	0.439	2519.1	0.071

LOADING CONDITION BW1

L O A D I N G C O M P O N E N T S

Name	Max. weight	Mass	Center of gravity cgx	cgy	cgz	Free s. moment
HEAVY FUEL OIL , RHO= 0.940						
HFO4	572.3	74.8	66.00	-0.00	2.31	1658.0
HFO5	400.4	400.4	49.60	0.00	8.20	0.0
HFO_DAY	62.4	62.4	44.00	0.00	2.98	0.0
HFO_SETT	62.4	62.4	41.60	0.00	2.98	0.0
Total of HEAVY FUEL OIL	1097.5	600.0	50.23	-0.00	6.38	1658.0
LUBRICATING OIL, RHO= 0.900						
LUB	69.7	13.4	39.00	-0.00	2.19	614.5
FRESH WATER , RHO= 1.000						
FW	443.8	88.7	18.96	0.00	6.69	3784.3
WATER BALLAST , RHO= 1.025						
BW1	4802.0	4802.0	164.75	0.00	6.47	0.0
BW2	3043.4	2932.9	128.00	0.00	5.00	18253.3
BW3	2815.2	2712.9	97.20	0.00	5.00	16884.3
BW4	4888.6	4545.2	64.69	0.00	5.79	22781.8
BW5	499.7	499.7	6.23	0.00	10.19	0.0
BW6	1180.8	1180.7	21.33	0.00	6.40	0.0
BW7	88.1	88.1	31.69	0.00	1.24	0.0
Total of WATER BALLAST	17317.8	16761.5	104.72	0.00	5.87	57919.5
Deadweight		17463.6	102.37	-0.00	5.89	63976.2
Lightweight		10700.0	97.60	0.00	8.00	
Displacement (rho=1.025)		28163.6	100.55	-0.00	6.69	63976.2

F L O A T I N G P O S I T I O N

Draught moulded	7.264	m	KM	12.01 m
Trim	-1.384	m	KG	6.69 m
TA	7.956	m	GM0	5.32 m
TF	6.572	m	GMCORR	-2.27 m
Trimming moment	-84187	tonm	GM	3.05 m

			X	FRAME
SHEAR FORCE (MIN)	-1099.0	t	POSITION: 158.4 m	198
SHEAR FORCE (MAX)	1524.1	t	28.4 m	35
SAGGING MOMENT	-36.9	tm	195.1 m	244
HOGGING MOMENT	53983.8	tm	101.6 m	127

HEEL degree	MS m	HPHI m	EPHI rad*m	FSMOM tm	DGZ m
0.0	0.000	0.00	0.000	0.0	0.000
5.0	0.002	0.29	0.012	5043.9	0.179
10.0	0.013	0.71	0.054	6322.1	0.224
20.0	0.120	1.69	0.262	7052.5	0.250
30.0	0.431	2.84	0.657	6952.3	0.247
40.0	0.484	3.67	1.235	6531.7	0.232
45.0	0.242	3.78	1.561	6235.6	0.221

REVIEW OF THE REPORT
by Alfred Tunik, American Bureau of Shipping

and

REPLY TO THE REVIEWER
by the Authors

Review

of INSROP reports

"Model Tests in Ice with M-224" and "Design of 40000 and 25000 DWT Ice Breaking Bulk/Container Carrier" by Kvaerner Masa Yards

by Alfred Tunik
ABS, 2 WTC, 106th Floor, New York, NY 10048, USA

The working paper outlines the model testing and design of an ice-breaking bulk/container carrier for year-round navigation along the NSR. Prepared by experts deeply involved in all technical details of model testing and design it gives a good view of the very many aspects of ice model test results, predicted performance and design features for 40K and 25K DWT variants of the vessel. The completeness and detailiness of the report accompanied by numerous ice model test plots and plan drawings/specifications are the report's strongest points. The report leaves an impression of a highly professional work well done by leading experts, which is certainly the case for Kvaerner-Masa Yards Arctic Research Center.

The reviewer's task is, however, not writing a Christmas card but rather focusing on weak points and inspiring further improvements of the report. Since the work itself is generally good, the critical comments listed below refer mainly to what is missing and what appears to be inadequately outlined or explained in the report.

1. For a reader who, like the reviewer, is not intimately involved into other interrelated INSROP studies, the report looks like a separate tile of a mosaic picture with all other tiles missing. The first questions arise about the ship purpose and dimensions. Why the port of Dickson and 40/25K DWT are selected, Modernization of this tiny shallow water port, situated far away from the ports of Dudinka and Igarka (the major staring points of ore and timber export), for accommodation of these bulk/container carries would be a huge international development requiring much more resources then building several Arctic ships. There is no doubt that selecting the port of Dickson as a starting point for marine transportation of ore and timber was based on thorough studies which should include feasibility studies of ore/timber marine transportation to Dickson. Therefore, a brief section should be very helpful for understanding the ship purpose, substantiating her DWT and draft, and how many voyages may be needed in the winter-spring season to transport the cargo .

2. The new DAT concept, recently patented and promoted by Kvaerner, envisions two extremities made as an open water (e.g. conventional bulbous) bow and an icebreaking bow. But what are the reasons for making both ends to be icebreaking ends in a ship which sails at least half of her route in ice-free oceanic waters? The fact that the stern of this ship performs better in icebreaking while her bow is better for maneuvering in ice does not justify the two icebreaking bows yet. It only demonstrates that there is more room for improving ice performance of either extremity by combining their stronger features.

3. The description of hull designs does not include the level of ice strengthening (ice class) and whether the longitudinal framing system will be extended to both ends. There is also an apparent misprint in the page "Main Characteristics of the Vessel" (immediately after the drawings) repeated for both 40K and 25K DWT designs, that the keel plate and shell plating are 10 mm thick. Using a magnifying glass one can find more realistic values (about 30 mm) in the midship section drawings. Selecting an appropriate ice class (level of ice strengthening) and the most rational design of hull structures should be among the key points discussed in the report.

midship section drawings. Selecting an appropriate ice class (level of ice strengthening) and the most rational design of hull structures should be among the key points discussed in the report.

4. The estimate of ship performance in compressive ice (page 6-2 of model test report) appears to be confusing both in the method and in the results. The method (page 4-3) is based on calculating the compressive force per unit length based on thrust-resistance difference and the ice/hull friction along the sides of the parallel midbody. This formulation is appropriate for a ship moving in a closing channel behind an icebreaker, but should include bow components for a ship moving independently in ice fields being under compression. The unstable motion in compressing channel or ice fields includes inevitable stops. Therefore, the use of dynamic friction may result to an over-estimate; while an estimate based the coefficient of static friction would more plausibly characterize the ship ability to progress in compressing ice. And finally, the ice resistance in uncompressed ice already includes ice/hull friction components, i.e. friction is therefore taken into account more than once. The result, presented as the environmental compressive force needed to stop the vessel, provide little, if any, useful practical information since it is not related to environmental parameters or at least to existing gradations of ice compressions (e.g. to the Russian system based on the conversion rates of ice fields or channel's edges).

5. The model tests in floe ice are performed for estimating the ship propulsion in drifting ice floes and in a channel. The selected model floes represent the channel conditions but are too small for modeling propulsion in broken ice fields (small ice floes are 20-100 m across).

6. The model ice ridge was made of the ice 1.2 and 1.8 m thick in full scale. In reality, the ridges, especially first-year ice ridges are typically composed of pieces of much thinner ice (40-70 cm) but almost never of 1.2-1.8 m (see e.g. Romanov, 1995, *Atlas of Ice and Snow of the Arctic Basin and Siberian Shelf Seas*. Backbone Publ., Elmwood Park, NJ). This and other dissimilarities with the natural phenomenon being modeled (e.g. freezing rate and great variety of ridge morphology) may result in considerable ambiguity of the test results.

INSROP II
Box B: SIMULATION OF SHIP NAVIGATING ALONG THE NSR
WP 4: The Service Ships

Reply to the Reviewer

We thank Dr. Alfred Tunik for the effort he put into reviewing our report and the professional comments that we got. We have carefully studied his comments and here is our response:

In the end of this reply the reader can find the basic ice data that was used as a design basis for this project.

Comment on transportation task and port selection

When the design of the two ships started we had no information from other work packages about the cargo flow in the area — in other words we did not have an exact transportation task for INSROP II. To keep the project in schedule we could not wait for detailed cargo flow analysis nor could we put our effort on making one. Therefore we decided to make the ship as versatile as possible and included also one 'neutral' port (Dickson) was included as a reference port. In practice, our opinion is that Dickson is not a probable port selection, when planning for large scale NSR transportation.

Comment on ship size selection and main dimensions

Since there was no exact transportation task, the size for the bulker / container carrier was selected to be a practical one for the NSR. The initial values (40,000 dwt and 25,000 dwt) for the ship came from the University of Tokyo.

Main dimensions were selected by using bulk carrier statistic as a guide line.

Statistics consists of 568 bulk carriers which are launched after 1985. The bulker statistics include only vessels, which were designed for open water conditions. Panamax -type ships (Breadth=32.0-32.3 m, total 321 pieces) have been erased from trendline because they seem to distort the trendline and give lower reliability. Proportions are presented in first three figures (Figure 1, - Figure 3), size of the main dimension box is in figure 4 and each dimension is presented separately in figure 5 - figure 8. Last of the figures contains braked power and service speed (Figure 9, Figure 10).

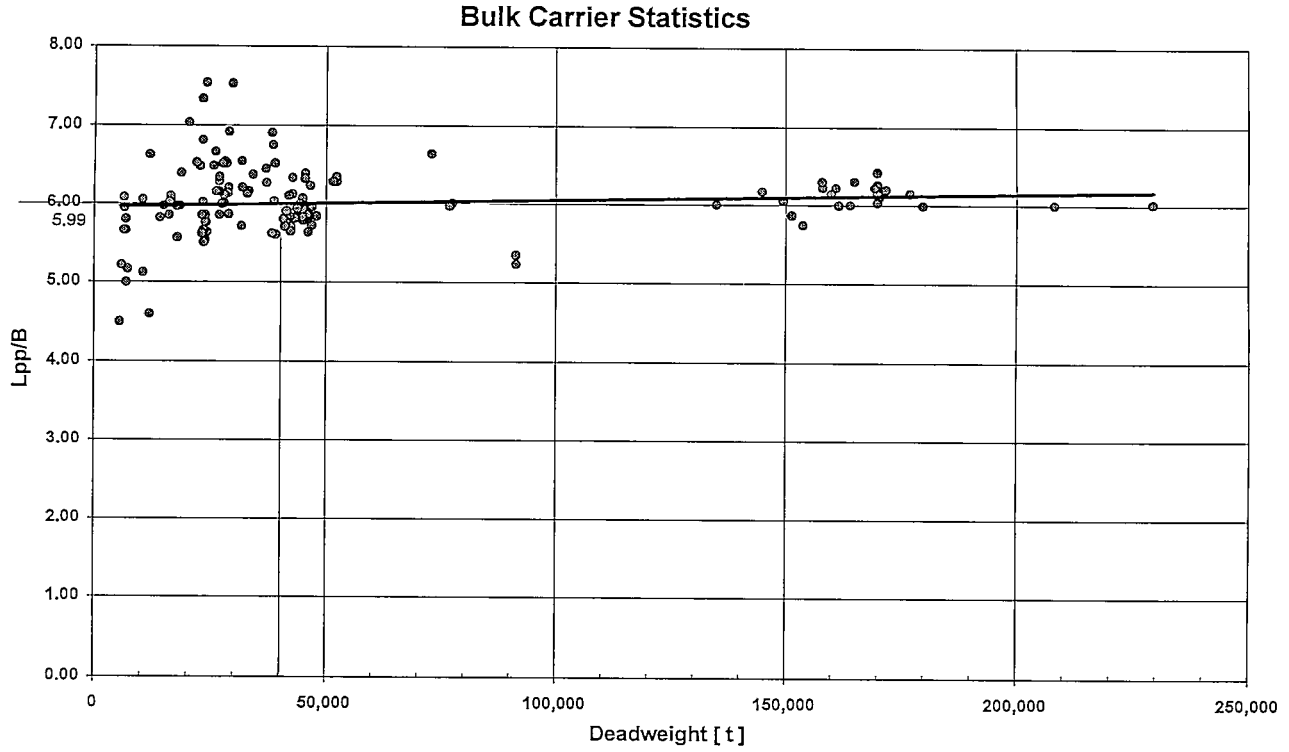


Figure 1. Length between perpendiculars (Lpp), Breadth (B) ratios. Separate given value is calculated from trendline for 40000 dwt ship.

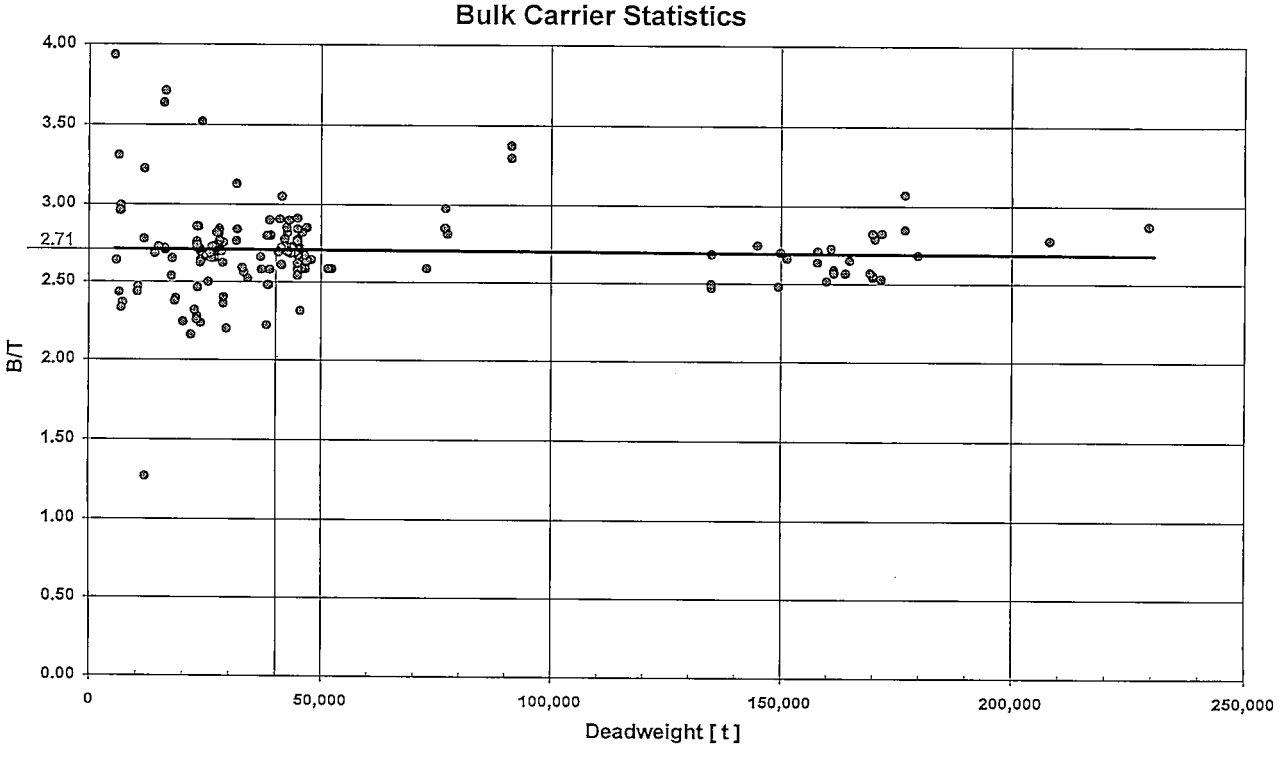


Figure 2. Breadth (B), draught (T) ratios. Separate given value is calculated from trendline for 40000 dwt ship.

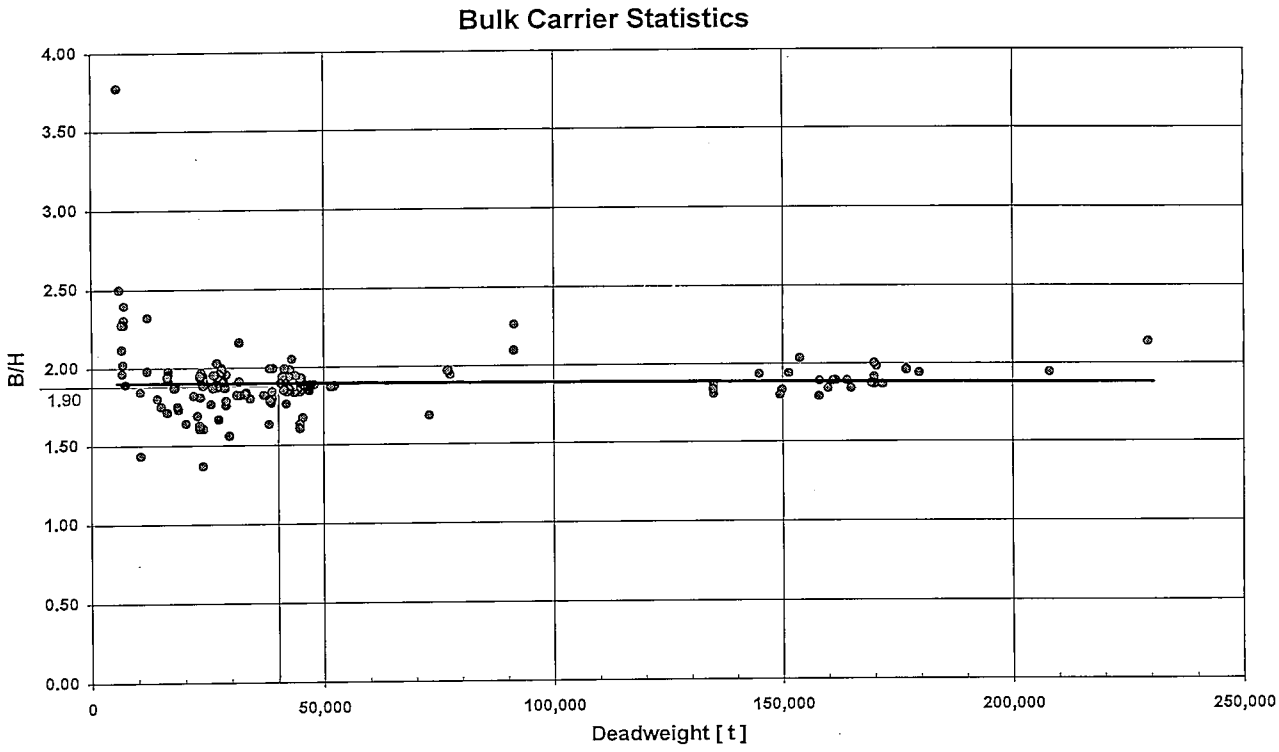


Figure 3. Breadth (B), Depth (H) ratios. Separate given value is calculated from trendline for 40000 dwt ship.

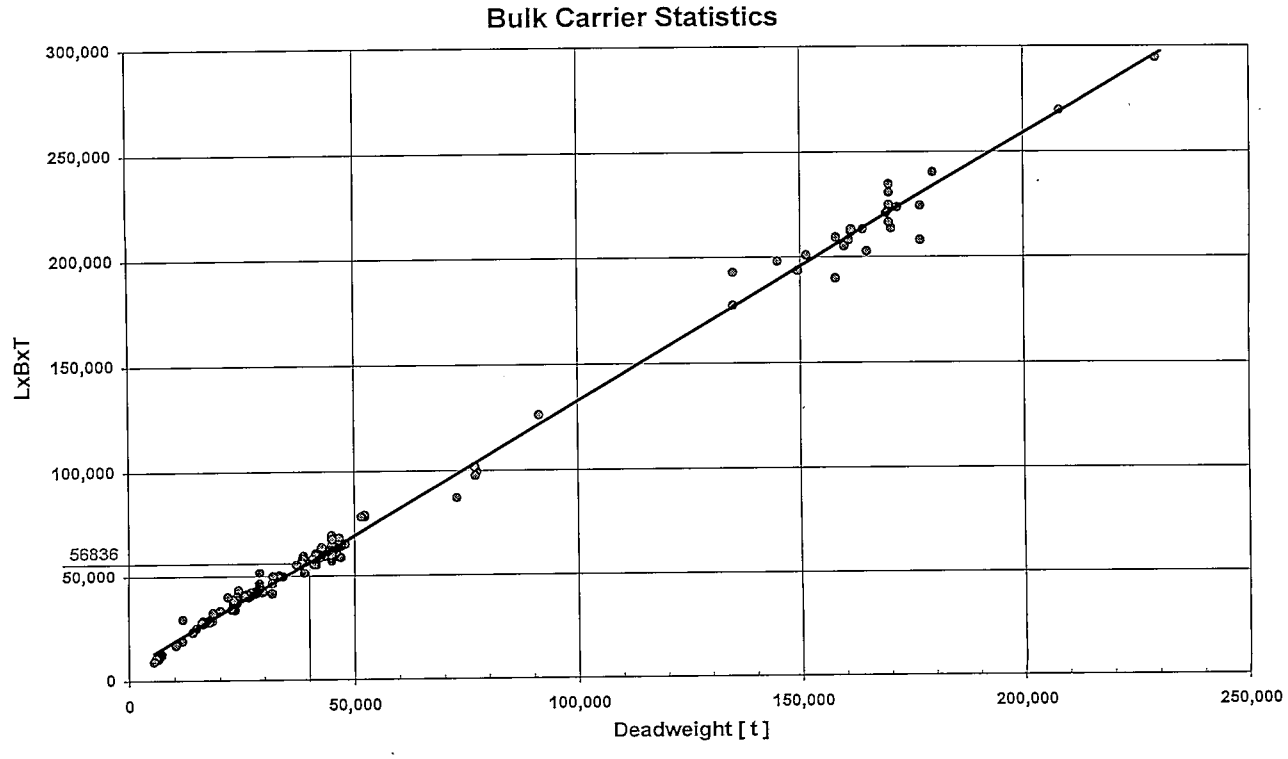


Figure 4. Length between perpendiculars (L), Breadth (B), Draught (T). Separate given value is calculated from trendline for 40000 dwt ship.

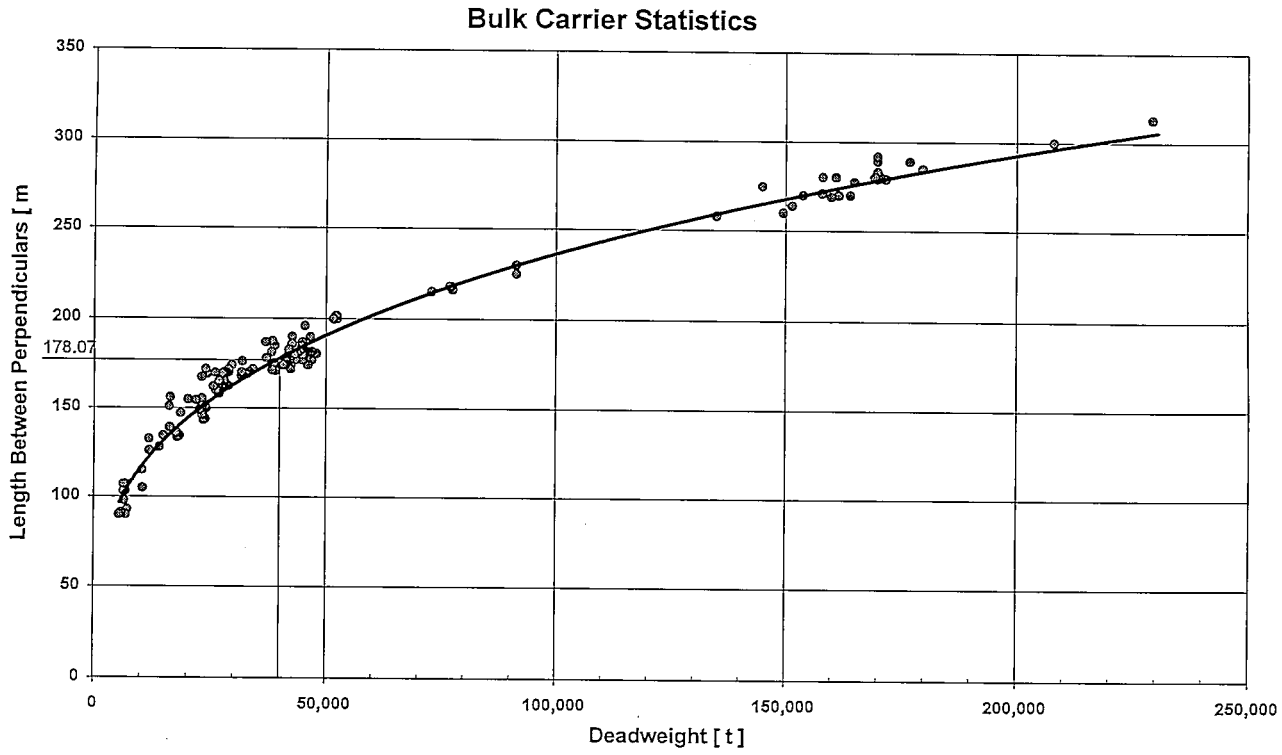


Figure 5. Length between perpendiculars (Lpp). Separate given value is calculated from trendline for 40000 dwt ship.

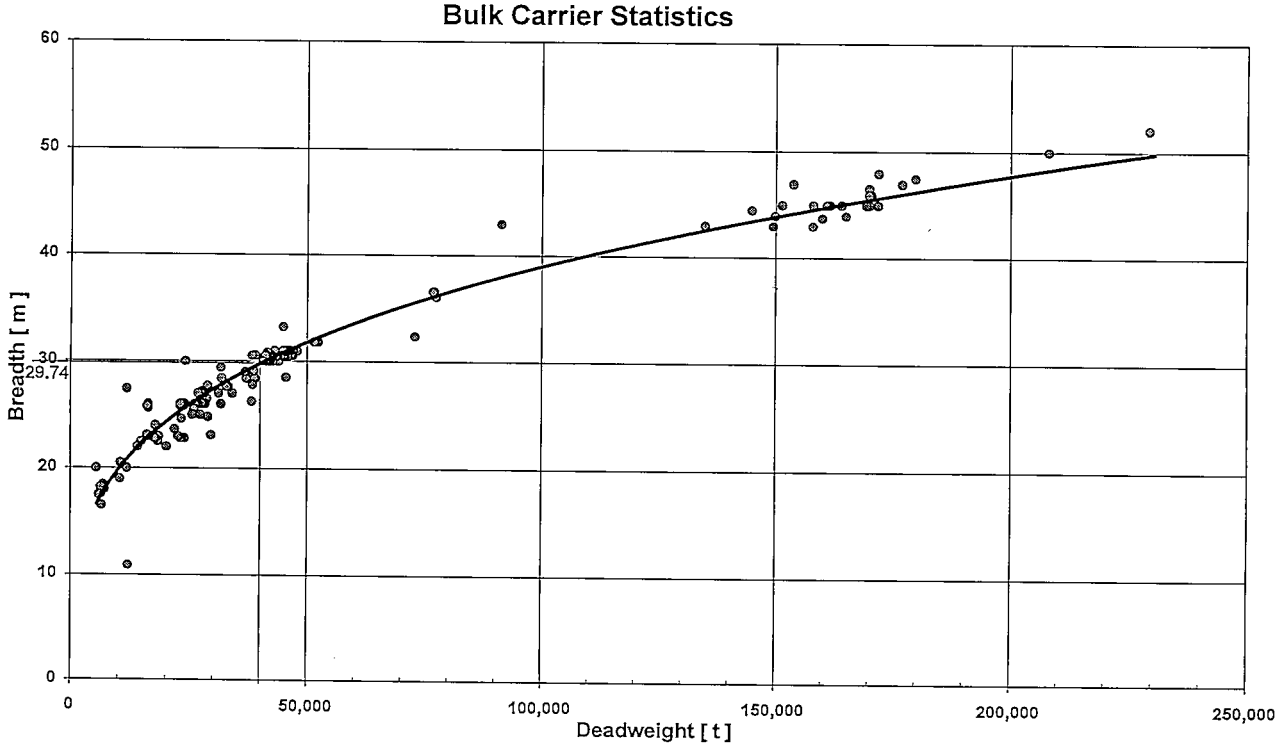


Figure 6. Breadth (B). Separate given value is calculated from trendline for 40000 dwt ship.

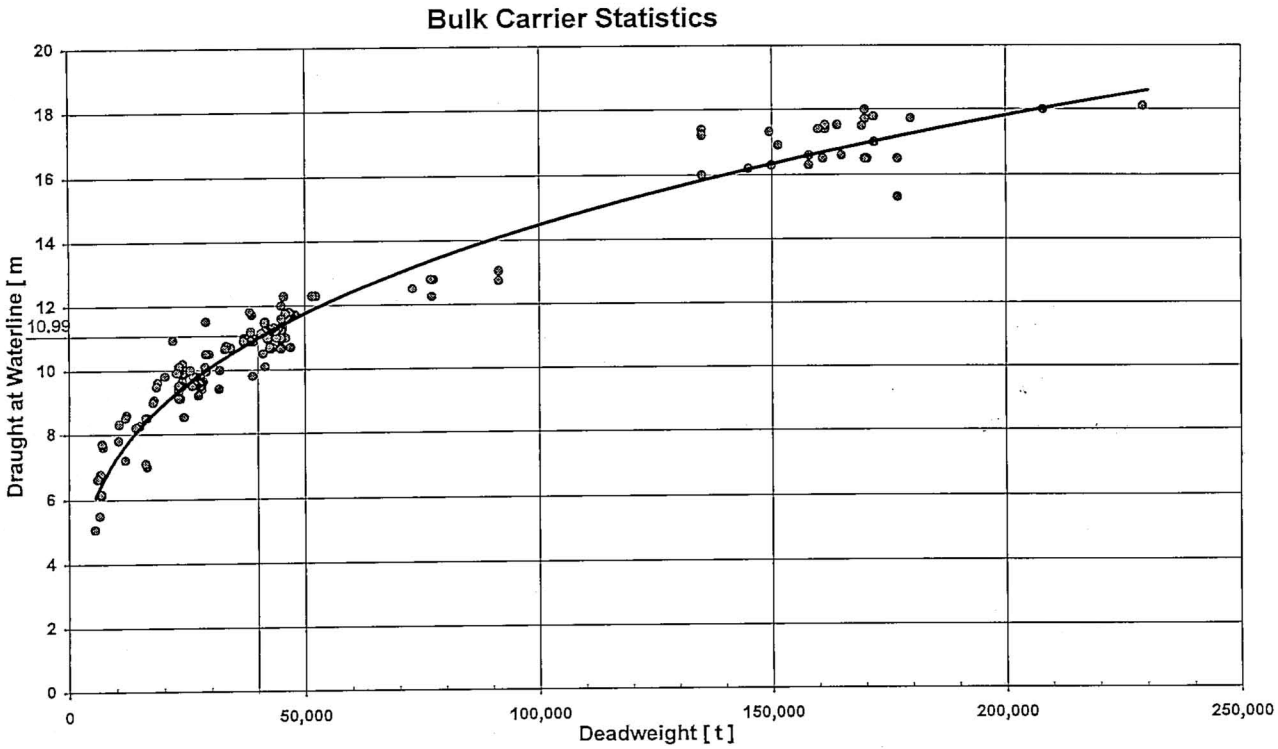


Figure 7. Draught. Separate given value is calculated from trendline for 40000 dwt ship.

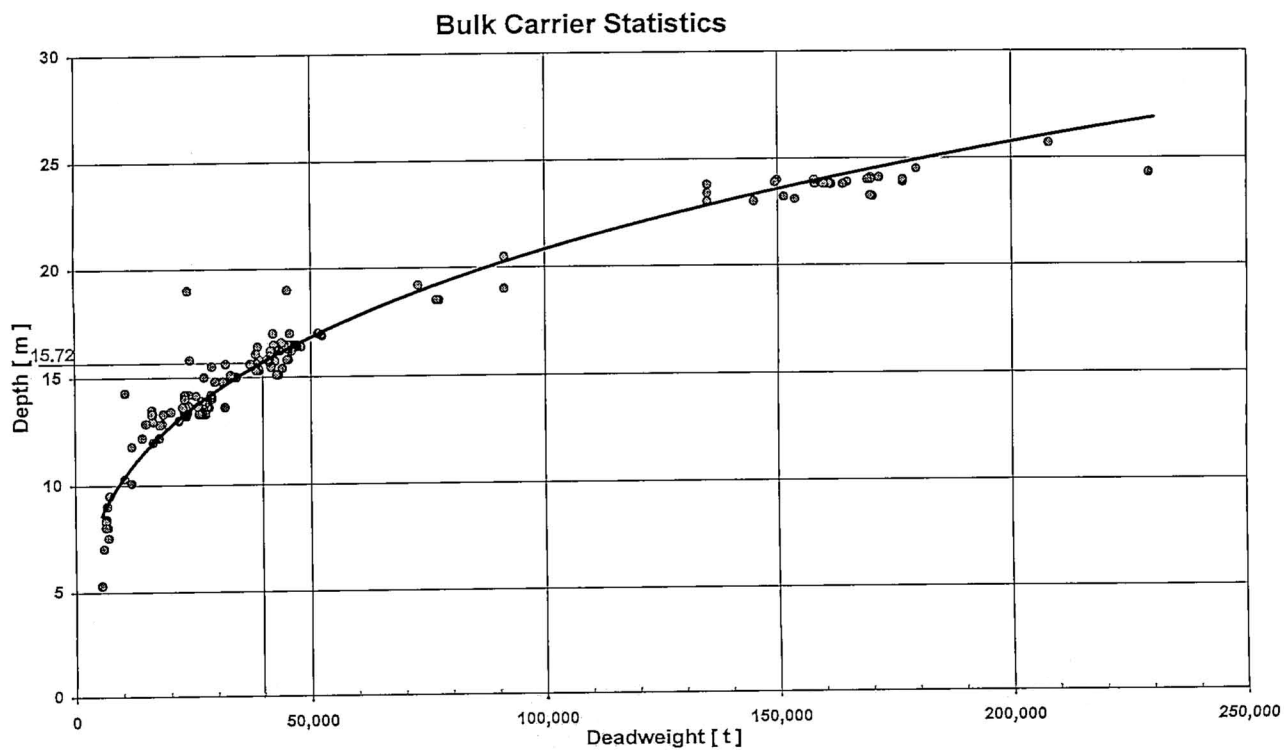


Figure 8. Depth. Separate given value is calculated from trendline for 40000 dwt ship.

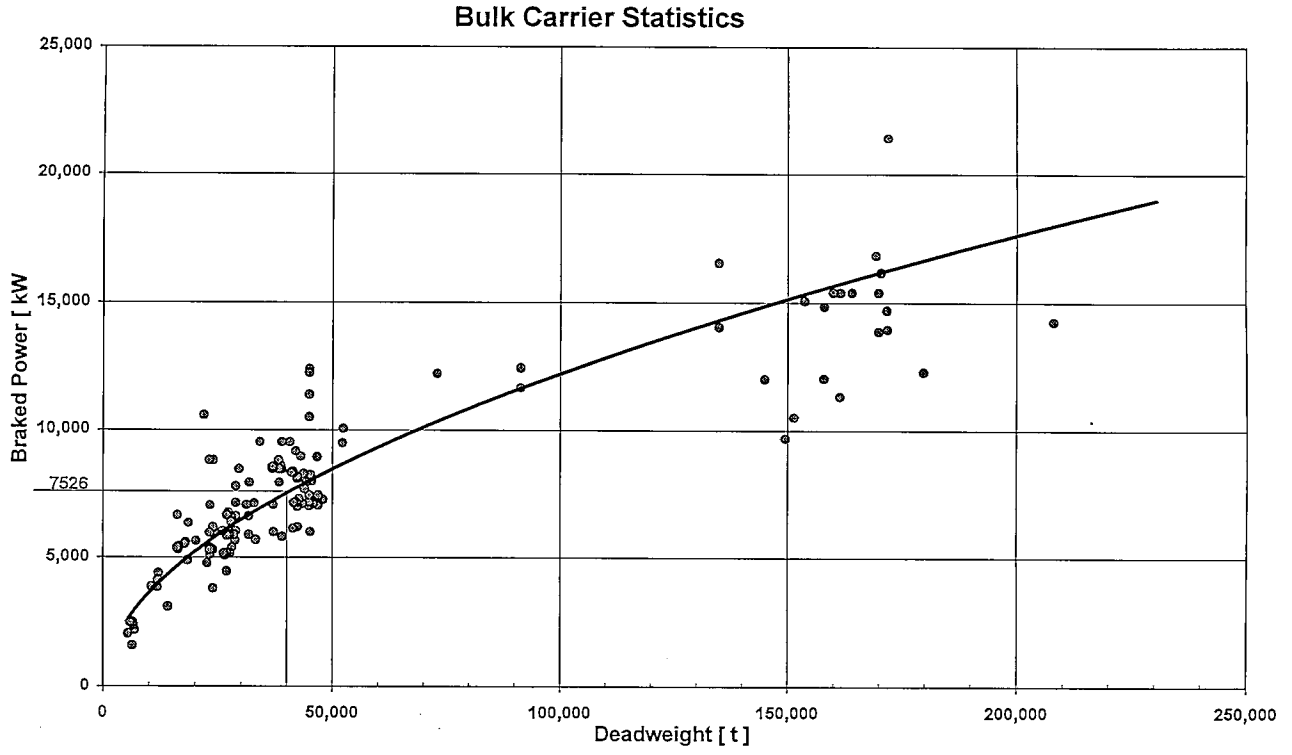


Figure 9. Braked power. Separate given value is calculated from trendline for 40000 dwt ship.

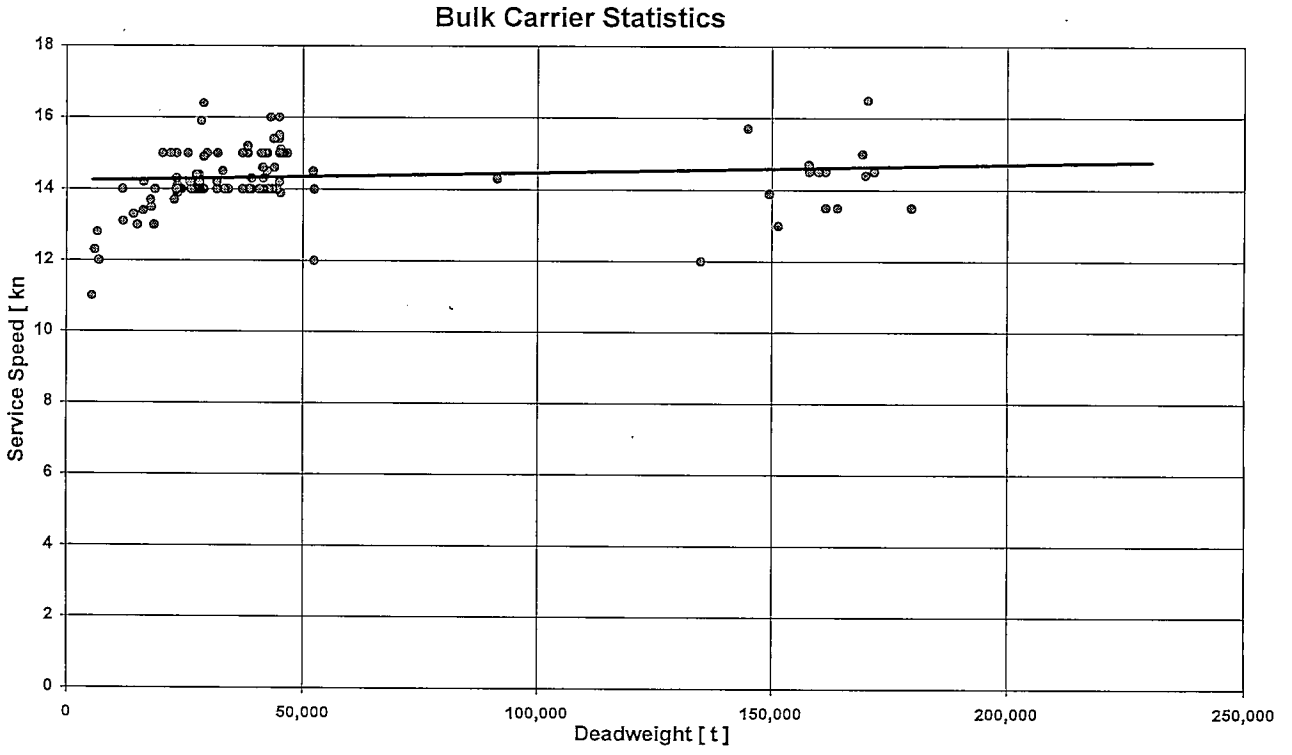


Figure 10. Service speed. Separate given value is calculated from trendline for 40000 dwt ship.

Main dimensions that can be achieved from the statistics are presented in Table 1.

Table 1. Main dimensions (open water vessel) from statistics.

Dimension	values from statistics	chosen value
Lpp/B	5.99	6.91
B/T	2.71	2.2
B/H	1.90	1.70
Lpp x B x T [m^3]	56836	58000
Lpp [m]	178.07	190.0
B [m]	29.74	27.5
T [m]	10.99	12.5
H [m]	15.72	15.75
Braked power [kW]	7526	8900
Service speed (open water) [kn]	14.3	15.0

All chosen values are based on that statistical group and are not calculated. It can easily be seen that chosen values differ from statistical values quite a lot. This is because ships with slender hull and narrow beam will generally cause smaller ice resistance. It is shown in Figure 1 that highest slenderness is near 7 with 40000 dwt. Because it is a built ship, the stability should not be a problem. That will give the first proportion (Lpp/B). B/T is taken from that data point. B/H value is between the data point value and statistical value. Adjusted value will come from cargo proportions.

Hull reinforcement and need of extra power will increase the lightship weight. Breadth and draught will be kept the same so the length will be extended. Rough estimations will give an extra length of about 9 meters. The main dimensions are presented in Table 2. The proportions are near some of the proportions of vessels under 30,000 dwt.

Selection of proportions for restricted draught can not base on statistics. Restricted draught, 9 meters, will make the hull longer and broader. And other restriction, breadth, should be taken into account, too. First the idea was to keep the breadth under the breadth of the assistance ice breakers (max. breadth at water line 28 m). This will make the hull very slender. The maximum breadth was given in the design criteria (32 m). Smaller draught will effect hull lines and therefore also block coefficient. The block coefficient will be bigger compared to the unrestricted vessel. That is why the main dimension box is smaller although the lightship will be heavier.

Table 2. Main dimensions after estimation of effect of ice demands.

Dimension	unrestricted draught	restricted draught	Comparison
Lpp/B	7.24	7.81	108 %
B/T	2.20	3.44	156 %
B/H	1.72	2.70	157 %
Lpp x B x T [m^3]	68406.3	67518.	99 %
Lpp [m]	199.0	242.0	122 %
B [m]	27.5	31.0	113 %
T [m]	12.5	9.0	72 %
H [m]	16.0	11.5	72 %
Braked power, abt. [MW]	31	36.5	118 %

Comment on double acting ship with an icebreaking bow

The double acting concept is not designed to run astern in multi-year ice. The double acting concept is adopted to allow independent mode in ridged ice.

Comment on the ice class of the ship and hull strengthening

Tentative ice class is DNV Icebreaker ICE 15 or similar. The misprint that was in the keel plate thickness is coming from the hydrostatistic calculation data sheet and it is not to be considered as an actual plate thickness.

The original discussion paper that was delivered to INSROP had both A4 and A2 size drawings of the General Arrangement, Linesdrawing Machinery Arrangements and the Midship Section of both designed ships. When we received the discussion paper back, only the A4-size drawings were copied.

The main objective of the work in WP 4 was to design of the selected size ships and to run model scale tests in ice with one of the ships that were designed. It would certainly be useful to have discussion of the design principles of the above mentioned ships, but due to the limited budget and since it did not actually belong to the scope of our work, we did not concentrate on that.

Comment on compressive ice

The reviewer has made good comments in the compressive ice resistance calculations that were presented based on the model scale tests. Ice compression and ships moving in compressive ice is a difficult subject. There is a lot of work that should still be done to be able to convert Russian ball system to actual compressing forces in the ice field.

As the ball scale is dependent on visual impressions of the ice field and not on physically measurable units, it is difficult to correlate the ball scale value with non-visual factors, e.g. driving forces and pressure in the ice field.

For an icebreaker of the Arctica class the MSC results presented in INSROP WORKING PAPER # 110 provides guidance of the correlation between the degree of compression and the ball scale. This is because full scale data points are available.

With a cargo ship that has considerably more parallel midbody the case is somewhat different. The effect of compression is more drastic, but since there is not enough full scale data published to correlate the model scale results to, only an approximation of the compressive force was made.

Here is a brief calculation that takes into account the bow part of the resistance according to the model scale tests that are presented in INSROP WORKING PAPER # 110. The results show that the compressive force that allows the ship to move at 2 knots is 21 % of the compressive force without the bow part included.

Ship dimensions

$B := 27.5\ m$ Breadth

$Lpp := 144\ m$ Length of the parallel midbody

According to MSC tests with segmented model (INSROP WORKING PAPER # 110)

$$\frac{\frac{2 \cdot Fseg}{Lpp}}{\frac{Fbow}{B}} = 0.05 \qquad \frac{2 \cdot Fseg}{Fbow} = 0.26 \qquad Fseg + 2 \cdot Fbow = 1724\,k$$

$Fbow := 1368\ kN$

$$Fseg := \frac{1724 - Fbow}{2} \qquad Fseg = 178\ kN$$

Force per unit length $\frac{Fseg}{Lpp} = 1.236$ kN/m

Friction coefficient $\mu := 0.1$

Compressive force per unit length

$$Fcomp := \frac{Fseg}{\mu \cdot Lpp} \qquad Fcomp = 12.4\ kN/m$$

Comment on model tests in floe ice

The comment the reviewer makes is correct.

Due to the limited budget only run three test days could be run. This allows us to do a certain amount of tests. Also, the kind of tests that can be run during one day is limited. E.g. if we want to run ridge tests, we cannot run floe ice tests made of large ice floes.

Comments on model tests in ice ridge

The comment the reviewer makes is correct.

Here, again, applies the above mentioned comment. If we want to run level ice tests in 1.2 m and 1.8 m thick ice, we cannot make the ice thinner afterwards. If we would want to run ridge tests in thinner ice, it would require more test days, and this was not possible.

ICE DATA FOR INSROP II SHIP

Table 3 Level ice thickness (m).

Winter type	Independent transiting period (July-February) [m]	The whole year [m]
-average	1.75	2.15
-hard	1.86	2.28
-extreme	1.95	2.39
rafted ice	2.8	2.8
second year	2.5	2.5
multi-year	3-4	3-4

Table 4 Ridge data.

	Barents	Kara	Laptev*	East Siberian*	Chukchi
Mean height of the sail (m)	1.3	1.2-1.4	1.3-1.8	1.4-1.9	1.7
Mean depth of the keel (m)	5.9	5.4-6.3	5.9-8.1	6.3-8.6	7.7
Mean total thickness (m)	7.2	6.6-7.7	7.2-9.9	7.7-10.5	9.4
Maximum height of the sail (m)	3	3-5	3	3	2-4.5
Maximum depth of the keel (m)	13.5	13.5-22.5	13.5	13.5	9-20.3
Maximum total thickness (m)	16.5	16.5-27.5	16.5	16.5	11-24.8
Thickness of the consolidated layer (m)	1.5 (2)	2 (2.5)	2.5 (3)	2.5 (3)	2.5 (3)
Porosity (%)	20	15-20	15-20	15-20	15-20
Ridge density (1/km)	5/8	8/17	7/15	8/17	9/18
Ridge spacing (m)					
-mean spacing within a cluster	20-30	20-30			
-mean spacing between clusters	300-3000	300-3000			
-mean cluster length	70-170	70-170			

* also second year and multi-year ridges may occur: maximum sail heights 3-5.5 m
maximum keel depths 9-16.5 m
maximum total thicknesses 12-22 m

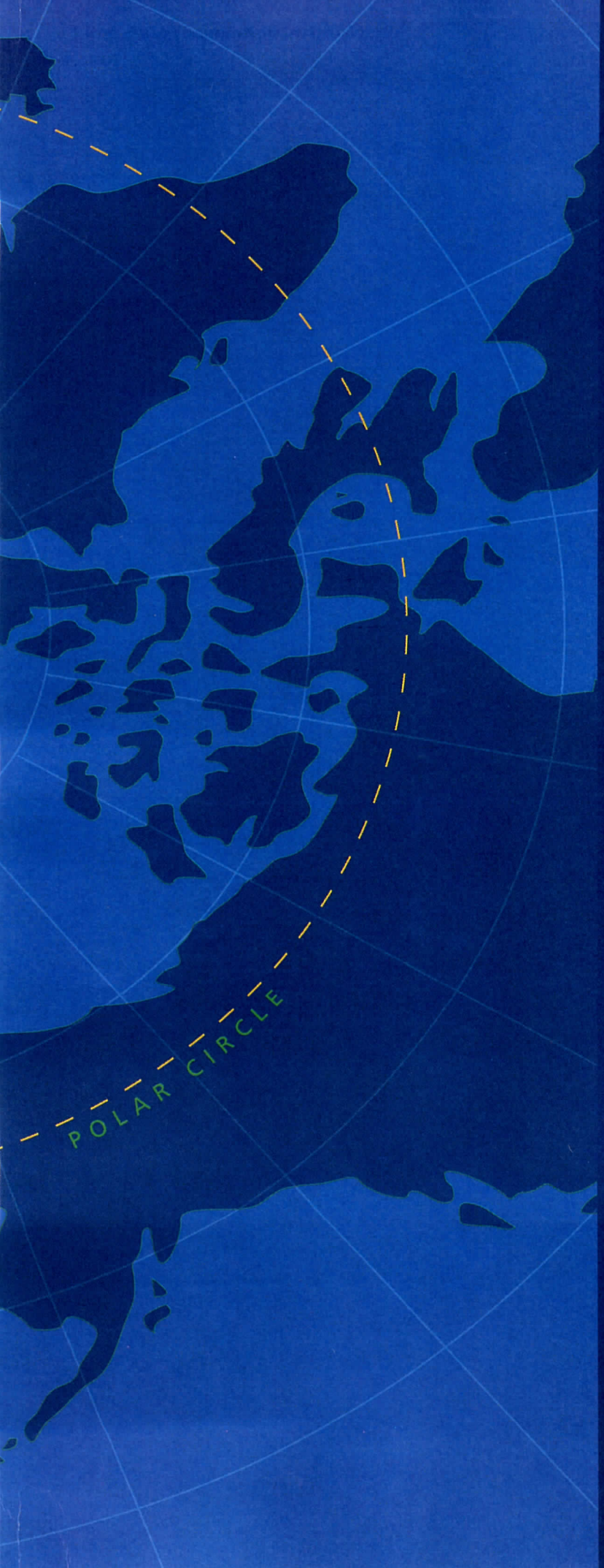
Table 5 Stamukhas (or ridges near the fast ice edge):

	maximum* [m]	maximum** [m]
Maximum height of the sail (m)	5	8-12
Maximum depth of the keel (m)	20	12-22
Maximum total thickness (m)	25	20-34
Porosity (%)	10-15	10-15
Horizontal dimensions (m^2)	50x50	100x100

* met in the Pechora Sea
** met in the Chukchi Sea

Table 6 Mechanical properties of the ice:

Level ice (first-year)	
- flexural strength (kPa)	500 (600)
- compressive strength (MPa)	
- vertical	7 (8)
- horizontal	5 (6)
Level ice (multii-year)	
- flexural strength (kPa)	
- compressive strength (MPa)	
- vertical	8-12
- horizontal	5-8
Ridges (first year)	
- compressive strength (MPa) (cons. layer)	5
- flexural strength (kPa) (cons. layer)	300
- inner friction angle (°)	30-40
- cohesion (kPa)	2-6
Ridges (multi-year)	
- compressive strength (MPa) samples from the vertical profile through the ridge)	4-11
Dynamics of the ice	
- pressure (balls)	1*
- ice drift**	
- ice drift speed, average (m/s)	0.2
- ice drift speed, max (m/s)	0.75
- acceleration of the ice abeam, max (m/hr^2)	



The three main cooperating institutions of INSROP

Ship & Ocean Foundation (SOF), Tokyo, Japan.

SOF was established in 1975 as a non-profit organization to advance modernization and rationalization of Japan's shipbuilding and related industries, and to give assistance to non-profit organizations associated with these industries. SOF is provided with operation funds by the Sasakawa Foundation, the world's largest foundation operated with revenue from motorboat racing. An integral part of SOF, the Tsukuba Institute, carries out experimental research into ocean environment protection and ocean development.

Central Marine Research & Design Institute (CNIIMF), St. Petersburg, Russia.

CNIIMF was founded in 1929. The institute's research focus is applied and technological with four main goals: the improvment of merchant fleet efficiency; shipping safety; technical development of the merchant fleet; and design support for future fleet development. CNIIMF was a Russian state institution up to 1993, when it was converted into a stock-holding company.

The Fridtjof Nansen Institute (FNI), Lysaker, Norway.

FNI was founded in 1958 and is based at Polhøgda, the home of Fridtjof Nansen, famous Norwegian polar explorer, scientist, humanist and statesman. The institute spesializes in applied social science research, with special focus on international resource and environmental management. In addition to INSROP, the research is organized in six integrated programmes. Typical of FNI research is a multi-disciplinary approach, entailing extensive cooperation with other research institutions both at home and abroad. The INSROP Secretariat is located at FNI.