Bericht E 296/99

ARCDEV
"Arctic Demonstration and Exploratory Voyage"

SCHLUSSBERICHT

Zuwendungsgeber:
Bundesministerium für Bildung und Forschung (BMBF)

Berichtsblatt

1. ISBN	2. Berichtsart - Schlußbericht	3.
4. Titel des Berichts ARCDEV "Arctic Demonstration and Exploratory Voyage"		
5. Autor(en) (Name, Vorname(n)) P. Jochmann, Chr. Haas, K.-H. Rupp, K.-U. Evers, J. Schwarz		6. Abschlußdatum des Vorhabens 30.09.99
		7. Veröffentlichungsdatum Nov. 1999
8. Durchführende Institution(en) (Name, Adresse) Hamburgische Schiffbau-Versuchsanstalt GmbH, Bramfelder Straße 164, D-22305 Hamburg		9. Ber. Nr. Durchführende Institution HSVA-Bericht E 296/99
		10. Förderkennzeichen 18S0150
		11. Seitenzahl
		12. Literaturangaben
13. Fördernde Institution (Name, Adresse) Bundesministerium für Bildung und Forschung (BMBF), Heinemannstraße 2, D-53175 Bonn		14. Tabellen
		15. Abbildungen
16. Zusätzliche Angaben		
17. Vorgelegt bei (Titel, Ort, Datum)		

18. Kurzfassung

Das ARCDEV Projekt wurde gefördert durch die Europäische Union, DG VII sowie durch das Bundesministerium für Bildung und Forschung, was den Teil der HSVA betrifft.
Das ARCDEV Projekt hat gezeigt, daß es technisch machbar ist, Öl oder Gas-Kondensat aus der russischen Arktis (Ob-Mündung) nach West-Europa mit Tankern und Eisbrecherunterstützung zu transportieren. Der Konvoi bestand aus dem eisbrechenden Tanker UIKKO (15000 tdw) und zwei russichen Eisbrechern (ROSSIA, KAPITAN DRANYTSIN). Ca. 70 Wissenschaftler aus sieben Ländern (auch Rußland) haben an der 21-tägigen Reise teilgenommen. Das Demonstrationsprojekt zeigte aber noch Defizite, die das Transportsystem z. Zt. noch unwirtschaftlich machen. Forschungsaufgaben wurden daher definiert für zukünftige Entwicklung eines marinen Transportsystems für die Arktis.

19. Schlagwörter

Technische Machbarkeit, Tanker Konvoi, eisbrechende Tanker, Eisbrecher, Demonstration, Wirtschaftlichkeit, Arktisches Marines Transport-System.

20. Verlag	21. Preis

Document Control Sheet

1. ISBN	2. Type of Report Final Report	3.
4. Report Title Arctic Demonstration and Exploratory Voyage (ARCDEV)		
5. Authors (Family Name, First Name(s)) P. Jochmann, Chr. Haas, K.-H. Rupp, K.-U. Evers, J. Schwarz		6. End of Project 30.09.99 7. Publication Date Nov. 1999
8. Performing Organisation(s) (Name, Address) Hamburgische Schiffbau-Versuchsanstalt GmbH Bramfelder Straße 164 D-22305 Hamburg		9. Originator's Report No. HSVA-Report E 296/99 10. Reference No. 18S0150 11. No. of Pages 12. No. of References
13. Sponsoring Agency (Name, Address) Bundesministerium für Bildung und Forschung (BMBF) Heinemannstraße 2 D-53175 Bonn		14. No. of Tables 15. No. of Figures
16. Supplementary Notes		
17. Presented at (Title, Place, Date)		
18. Abstract The ARCDEV-Project was partly sponsored by the EU-DG VII and the HSVA-part within this project also by the German Ministry for Education and Research. The ARCDEV-Project did prove the technical feasibility to transport Oil/Gas Condensate from the Ob-estuary in the Russian Arctic to Western Europe by the tanker convoy consisted of one 15000 tdw icebreaking tanker UIKKO and two Russian icebreaker (ROSSIA, KAPITAN DRANYTZIN). Aprrox. 70 scientiests from seven European countries (incl. Russia) participated in the 21 day voyage. The demonstrating project showed also deficiencies for making such transport system economical profitable. Research tasks were defined for future development of such an Arctic Marine Transport System.		
19. Keywords Technical Feasibility, Convoy, Icebreaking Tanker, Icebreaker, Demonstration Project, Arctic Marine Transport System		
20. Publisher		21. Price

Bericht E 296/99

ARCDEV
"Arctic Demonstration and Exploratory Voyage"

Förderkennzeichen: 18S0150

Zuwendungsgeber:
Bundesministerium für Bildung und Forschung (BMBF)
Heinemannstraße 2
D-53175 Bonn

Hamburg, Oktober 1999

HAMBURGISCHE SCHIFFBAU-
VERSUCHSANSTALT GmbH

Bearbeiter:

Dr.-Ing. J. Schwarz

Hamburgische Schiffbau-Versuchsanstalt GmbH, Bramfelder Straße 164, D-22305 Hamburg, Germany
☎ +49 40 69203 0, Fax +49 40 69203 345, E-Mail <name>@hsva.de

List of Content

I Introduction

II WP 3 Ice Conditions
(HSVA-Report E 297/99; Part 1: Dipl.-Ing. P. Jochmann
Part 2: Dipl.-Ing. Chr. Haas (AWI))

III WP 6 Navigation and Operations
(HSVA-Report E 292/99; Dr.-Ing. K.-H. Rupp)

***WP 6**	**ANNEX A**	Rammings: Murmansk-Sabeta
***WP 6**	**ANNEX B**	Rammings: Sabeta-Murmansk
***WP 6**	**ANNEX C**	Waiting Times: Murmansk-Sabeta-Murmansk

IV WP 11 Environmental Protection
(HSVA-Report E 295/99; Dipl.-Ing. K.-U. Evers)

V WP 13 Trafficability
(HSVA-Report E 293/99; Dr.-Ing. K.-H. Rupp, L. Lübke)

***WP 13**	**ANNEX 1**	Diagrams: Propulsion Power-Speed-Ice Thickness
***WP 13**	**ANNEX 2**	Observed and Predicted Ice Conditions, Ice Charts, NOAA Ice Charts
***WP 13**	**ANNEX 3**	Weather Charts

VI WP 16 Overall Evaluation and Definition of Cluster for 5th FP

VII Summary of ARCDEV-Results and Recommendations

* Working Documents

I Introduction

By the initiative of German and Finnish institutions a proposal was presented to the European Commission, DG VII to carry out the project “Arctic Demonstration and Exploratory Voyage” (ARCDEV) in order to show the technical and economical feasibility of transporting oil or gas condensate from the Russian Arctic (Ob estuary) to western Europe. This project was supposed to define the research and development needs, for an economical shipment of oil from northern Russia to western Europe. In further phases the defined research will be executed and a marine transport system be implemented. The ARCDEV-Project was carried out mainly by scientists from Finland, Germany and Russia together with individual participants from Great Britain, Norway, The Netherlands and Italy (see list of participants). The project consisted of 16 work packages as listed in the following table, showing the title of the work package, the coordinator and the participants. The research project was connected to a commercial voyage of the Finnish icebreaking tanker UIKKO operated by Neste Oy which was shipping approx. 11000 to Gas-Condensate from Sabetta at the Ob estuary to Rotterdam. The tanker was escorted by one of the five 56 MW Russian icebreakers. In our ARCDEV project a second icebreaker, KAPITAN DRANYTSIN, was participating in the convoy voyage as the research platform for the approx 70 scientists.

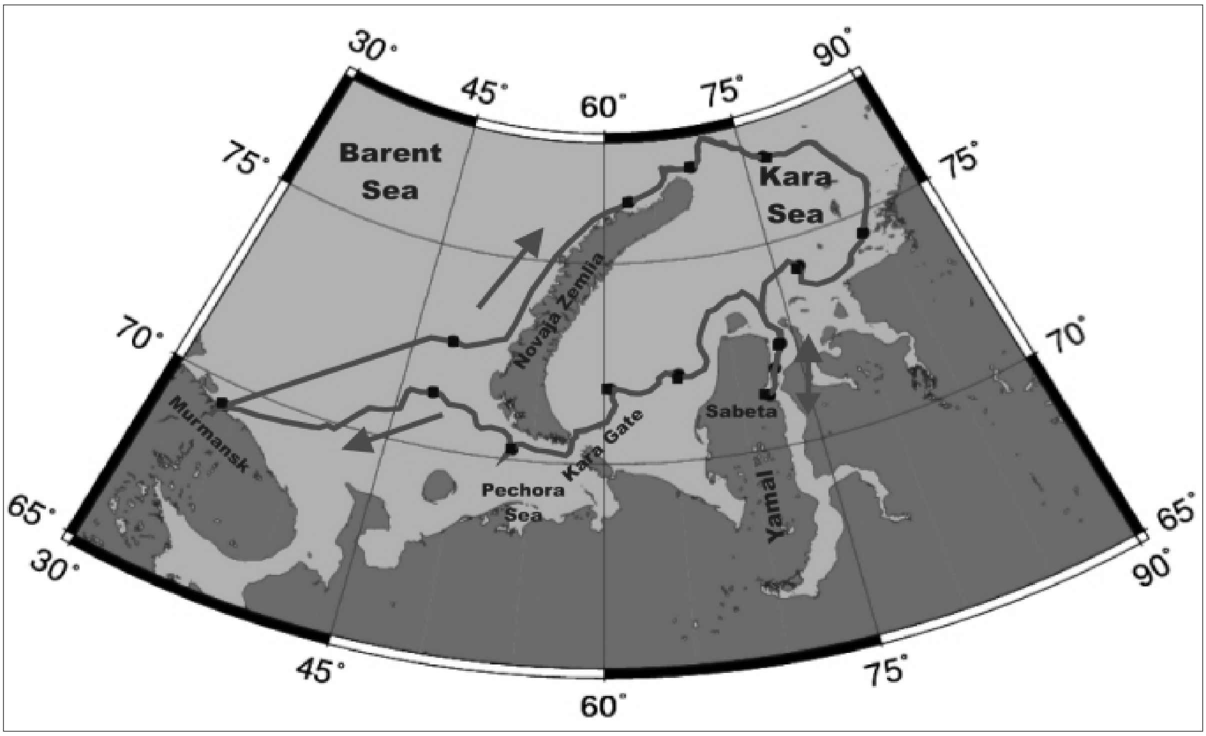
The Steering Committee of the ARCDEV-Project consisted of

Mr. J. Laapio, Neste Oy, Finland (Coordinator)
Mr. H. Wierda, Shell, The Netherlands
Mr. M. Niini, Kvaerner Masa Yards, Finland
Dr. V. Peresypkin, CNIIMF, Russia
Dr. J. Schwarz, HSVA, Germany

The German Team was formed by

Dr. Chr. Haas, AWI
Dr. J. Schwarz, HSVA
Mr. K.-U. Evers, HSVA
Mr. P. Jochmann, HSVA
Dr. K.-H. Rupp, HSVA
Mr. L. Lübke, HSVA
Mr. K. D. Pfeiffer, HYDROMOD
Mr. J. Kuternoga, ISSUS
Mr. Schulz, Aker MTW
Mr. G. Schulte, Aker MTW
Mrs. Gehl, Aker MTW
Mrs. N. Schmelzer, BSH

The ARCDEV-voyage started on April 26th, 1998 at Murmansk (Fig. 1) with tanker UIKKO and icebreaker KAPITAN DRANYTSIN with the destination Sabeta, a small town abt. 150 nm upstream the Ob estuary, where 11000 to gas-condensate were loaded to be transported to Rotterdam. Due to prevailing easterly winds in the north western part of the Russian Arctic prior to our starting date the western part of the Kara Sea and especially the Kara Gate was clocked with compressed ice.



Departure Murmansk	26. April,1998
Nordspitze Novaya Zemlya	29. April,1998
Arrival Sabeta	04. May, 1998
Departure Sabeta	08. May, 1998
Arrival Murmansk	14. May, 1998

Consequently west of Novaya Semlya a wide open water polynia had developed. This situation suggested to navigate with our convoy not directly through the Kara Gate to Sabeta but to use the Polynia west of Novaya Semlya. At the northern trip of this island the ice became too heavy for the convoy; therefore the strong icebreaker ROSSIA, which operated in the Kara Sea, came to lead the convoy to the mouth of the Ob river. The route followed more thinner ice areas with open leads and did not choose the direct way. At the mouth of the Ob river ROSSIA left the convoy due to the shallow water conditions in this river. A navigation channel had been prebroken in the 2.0 m thick ice in the Ob river up to Sabetta. The convoy reached the destination on May 3rd, 1998, loaded the gas-condensate from May 4th till May 7th and departed for Murmansk/Rotterdam. During the loading time the wind had changed direction from east to west causing the ice in the Kara Sea to form leads between large pack ice fields. This allowed the convoy to choose the direct way through the Kara Gate for the way back.

The average convoy speed from Murmansk to Sabeta and back was approx. 11 knots; this was faster than normal navigation speed at this time of the year (winter) and obviously due to excellent route selection and ice pilotage by Russian experts.

In the following chapters those work packages are described and results presented, where HSVA was involved and received financial support from the German Ministry for Education and Research (BMBF).

List of Participants:

Project Co-ordinator: FORTUM OIL AND GAS (Formerly NESTE)

West European Partners:
Kvaerner Masa-Yards Inc. (KMY)
Helsinki University of Technology (HUT)
Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA)
MTW Schiffswerft GmbH (MTW)
Earth Observation Sciences Ltd. (EOS)
Tecnomare S.p.A. (Tecnomare)
Remtec Systems Ltd. (Remtec)
Shell Vankor Development B.V. (SHELL)
Lloyd's Register of Shipping (LR)
Nansen Environmental and Remote Sensing Center (NERSC)
Fachhochschule Hamburg - Institute of Ship Operation, Sea Transport and Simulation (ISSUS)

Russian Partners:
Northern Sea Route Administration (NSRA)
Central Marine Research & Design Institute Ltd. (CNIIMF)
Murmansk Shipping Company (MSCO)
Arctic Shipping Services (ASS)
Krylov Shipbuilding Research Institute (KSRI)
State Research Center of Russian Federation -The Arctic and Antarctic Institute (AARI)

Work packages and partners allocation structure

WP No.	TASK	MANAGER	TEAM
WP 0	Co-ordinator	NESTE	
WP 1	Commercial Aspects	NESTE	KMY, ASS, SHELL, CNIIMF
WP 2	Legal and Regulatory Questions	NESTE	ASS, SHELL, KMY, CNIIMF, NSRA
WP 3	Ice Conditions	KMY	NERSC, HUT, HSVA, AARI, MTW, EOS, KSRI
WP 4	Ship Performance	KMY	HUT, HSVA, KSRI, MTW, REMTEC, NESTE, CNIIMF, AARI
WP 5	Ice Routing	EOS	MSCO, AARI
WP 6	Navigation and Operations	HSVA	MSCO, NESTE, NSRA, CNIIMF
WP 7	Tanker Loading Systems	TECNOMARE	KMY, SHELL, MTW, NESTE, CNIIMF
WP 8	Ice Loads	HUT	KMY, KSRI, AARI
WP 9	Required Ice Class for the NSR	LLOYDS	HUT, KMY, KSRI, AARI
WP 10	Remote Service and Maintenance	REMTEC	NERSC, KMY (*Wartsila Diesel*, *ABB*)
WP 11	Environmental Protection	HSVA	NESTE, CNIIMF
WP 12	Data Management	NESTE	NESTE (*HYDROMOD*)
WP 13	Trafficability	HSVA	KMY, NESTE, CNIIMF
WP 14	Navigation Simulation	ISSUS	HUT, NESTE
WP 15	Russian Participation Co-ordination	KMY	CNIIMF, NSRA, AARI, ASS, MSCO, KSRI
WP 16	Overall Evaluation and Definition of Cluster for 5th FP	HSVA	NESTE, KMY, SHELL, MTW, HUT, CNIIMF, NSRA

II WP 3 Ice Conditions

(HSVA-Report E 297/99)

Part 1: Profiling of Ice Pressure Ridges
Dipl.-Ing. P. Jochmann

Part 2: Ship-Based Ice Thickness Profiling During ARCDEV
Dipl.-Ing. Chr. Haas (AWI)

Report E 297/99

ARCDEV

Arctic Demonstration and Exploratory Voyage

ICE CONDITIONS
WP 3

Part 1: Profiling of Ice Pressure Ridges
Part 2: Ship-Based Ice Thickness Profiling During ARCDEV

Customer:
EC Transport - 4th Framework
WATERBORNE TRANSPORT
Contract - No: WA 97-SC.2191

ICE CONDITIONS
WP 3

Part 1: Profiling of Ice Pressure Ridges

Author: Dipl.-Ing. P. Jochmann

TABLE OF CONTENTS

PROFILING OF ICE PRESSURE RIDGES 2

EXECUTIVE SUMMARY 2

GENERAL 4

MEASURING DEVICES 4

COLOUR IMAGING SONAR SYSTEM 4
LASER LEVELLING DEVICE 6

PERFORMANCE OF MEASUREMENT 8

DATA EVALUATION AND PRESENTATION 8

DATA EVALUATION 8
DATA PRESENTATION 9
PICTURES 13

Profiling of Ice Pressure Ridges

Executive Summary

This report, prepared by **Hamburgische Schiffbau-Versuchsanstalt, The Hamburg Ship Model Basin**, describes the *Determination of the Surface and Subsurface of Pressure Ice Ridges* during the Arcdev voyage in spring 1998 and is part of the *WP3 Final Report Ice Conditions.*

The objective of this task of work package 3 was to deliver information on the geometry of ice ridges like sail height, keel depth and sail to keel ratio along the route of the convoy as input parameters for other work packages. To meet this goal pressure ridges at four locations were profiled by HSVA; for this purpose the convoy stopped for several hours.

The underwater part of the pressure ridges was measured using a Colour Imaging Sonar System. The measuring device essentially consists of two components, i.e. the sonar head and the sonar processor. A portable industrial personal computer was used to control the sonar head and to collect, process and store the data. The screen of the personal computer as well as an external monitor was used for visual control purposes.

The raw data of each sonar profile are stored in ASCII - files in form of polar co-ordinates giving the transducer angle and the range between the sonar head and the target. These data in connection with the known azimuth angle of the sonar head were transformed into ASCII-files containing computed data in the form of x,y,z- co-ordinates.

The data of the ridge sail profiles were manually recorded in a field book and punched into the computer and finally stored in form of ASCII - Files.

By use of both data sets and the standard software *MS Excel* and *Plotit for Windows* 3D-images of the ridge keel as well as several profiles of the surface and subsurface topography of the ridges (2D-images) were produced and the key parameters sail height, keel depth and sail to keel ratio were calculated.

The results like sail height, keel depth and sail to keel ratio are compiled in the following table, By clicking with the mouse on the highlighted file name, the graph will show up on the screen if a graphic viewer is present.

Due to the fact that the ridge sites were mostly located in hummocked areas, the sail to keel ratios are scattering in a wide range between 7.90 and 2.98. Building a mean value of this factor for each location shows ratios of 4.12 for site 3, 5.38 for site 5 and 5.16 for site 6. This is in good agreement with the literature and results measured by the author in other parts of arctic regions which were in the range of 4 to 5.

Comparison of the results of the sonar measurements with those from the thermal drilling show, that the max keel depths determined by the thermal drill method are slightly smaller then those from the sonar device but there is still a good conformity.

RIDGE SITE	FILE NAME	GRAPH TYPE	MAX. SAIL HEIGHT	MAX. KEEL DEPTH	SAIL TO KEEL RATIO
Location No. 3	0305y-10.bmp	X-Slice Y=-10m	1.37 m	6.16 m	4.50
	0305_y0.bmp	X-Slice Y=0m	1.72 m	7.93 m	4.45
	0305_y2.bmp	X-Slice Y=-2m	1.48 m	5.46 m	3.59
	0305_y4.bmp	X-Slice Y=4m	1.72 m	5.13 m	2.98
	0305_y6.bmp	X-Slice Y=6m	1.22 m	4.82 m	3.95
	0305_y8.bmp	X-Slice Y=8m	1.19 m	5.50 m	4.62
	0305_y10.bmp	X-Slice Y=10m	1..06 m	5.05 m	4.76
Location No. 4	0705_y0.bmp	X-Slice Y=0m	Nv	5.30 m	Nv
Location No. 5	1005y-10.bmp	X-Slice Y=-10m	1.46	8.56	5.86
	1005_y0.bmp	X-Slice Y=0m	1.65	9.22	5.58
	1005_x0.bmp	Y-Slice X=0m	1.35	6.35	4.70
Location No. 6	1205y-10.bmp	X-Slice Y=-10m	1.64	6.30	3.84
	1205_y0.bmp	X-Slice Y=0m	3.25	12.17	3.75
	1205_y10.bmp	X-Slice Y=10m	2.11	16.66	7.90

General

During the ARCDEV project first-year ridges were measured at 4 different locations when the convoy stopped. Due to the limited time at each station the investigations were focussed on the determination of the topography of the sail and the keel. Profiles of the sail (surface) were measured by application of the laser levelling technique while for the underwater profile (subsurface) a colour imagine sonar system was used.

Measuring Devices

Colour Imaging Sonar System

The underwater part of the pressure ridges was measured using a Colour Imaging Sonar System. The measuring device essentially consists of two components, i.e. the sonar head and the sonar processor. A portable industrial personal computer was used to control the sonar head and to collect, process and store the data. The screen of the personal computer as well as an external monitor was used for visual control purposes. The components of the measuring devices for the ridge geometry determination are shown in Figure 1.

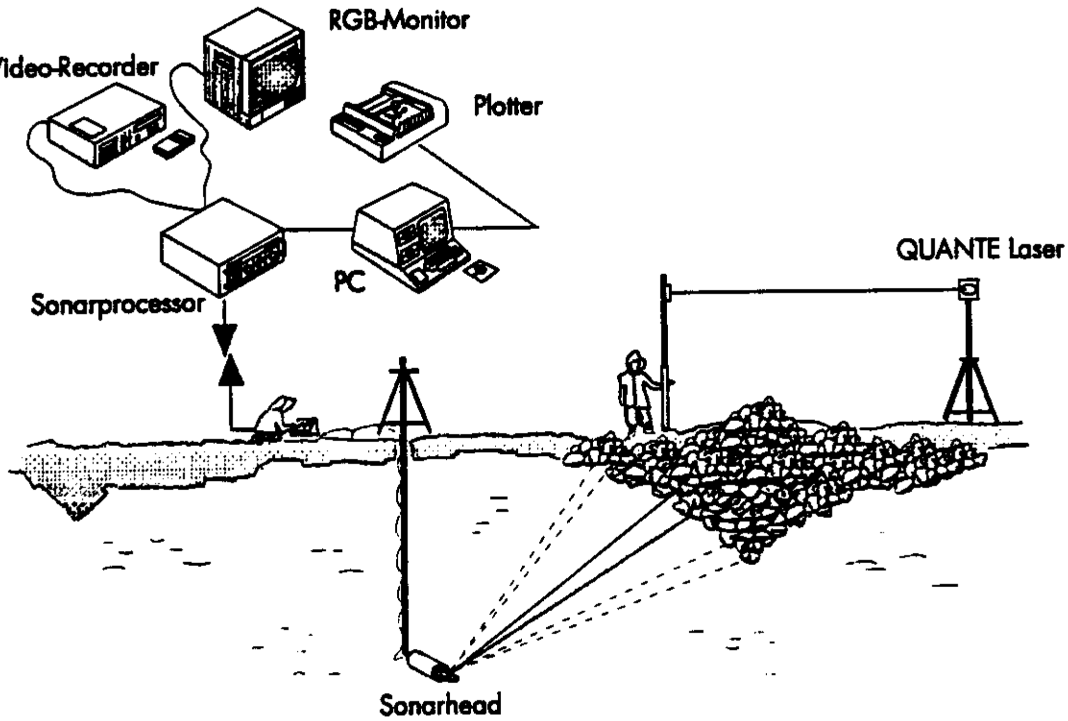


Fig. 1: Components of Sonar and Laser Levelling Equipment

The sonar system operates on an electronically acoustic principle. A short duration high-frequency pulse is transmitted from the transducer in a narrow fan shaped beam with a cone angle of 1.7°. This narrow pattern of the beam is the result of the line source type of transducer element used and defines the azimuth direction in which targets will be detected. Acoustic energy is reflected from targets back to the transducer and is received at a delay time related linearly to their distance and with signal level proportional to their distance, size and reflectivity. A receiver located in the sonar head amplifies and conditions this signal. After A/D – Conversion the data are transmitted via a serial interface to the surface processor. Within the surface processor the raw data (range, angle and signal strength) are transformed, interpreted, visualised on the screen and stored on the hard disc of the personal computer for later data analysis.

Several two-dimensional sonar profiles are generated by rotating the transducer element to obtain data which are scanned within the azimuth angle.

A stepping motor in the sonar head positions the transducer element through successive 0.225 degree steps for each new transmit pulse and receive cycle. The surface processor sends commands to the sonar head to control the stepping and transmit pulse.

The sonar processor, control monitor and the portable personal computer were fitted in aluminium boxes and fixed on a commercial sledge protected by plastic cover (*Figure 2)*

Fig. 2: Electronic Equipment (Processor, PC and Control Monitor

For transportation of the sonar equipment and in order to lower the sonar head below the ice cover, a special aluminium sledge was designed and fabricated in HSVA's workshop. Six aluminium tubes of 70 mm diameter and about 3.0 m length each, can be interconnected and mounted on the sledge. The joints at the ends of the tubes are watertight which causes them to be buoyant when they are lowered into the water. The maximum depth of the sonar head which can be reached is about 16.5 m below the water surface (*Figure 3)*

Fig. 3: Sonar Sledge

Laser Levelling Device

The surface topography of the pressure ridges, ridge sail, was determined by use of a laser levelling system type *QUANTE QL 310 DI* . The QL 310 DI uses a HeNe-Laser with a wave length of λ = 635 nm and has a measuring range of more than 100 m. The laser system levels itself by use of a close loop controlled servomotor system. A laser transducer mounted to a surveyor's rod beeps as soon as the laser beam is picked up. The surface elevation is then to be read from the scale of the surveyor's rod. The following figures illustrate the QL 310 DI laser *(Figure 4)* and the surveyor's rod *(Figure 5) .*

Fig. 4: Laser Levelling Device, Quante QL 310 DI

Fig. 5: Surveyor's Road

Performance of Measurement

Right after finishing the transportation of equipment to the ridge site, the area to be profiled was marked by several flags showing the centre line as well as the border lines at y=±10m.

Two holes were drilled by use of a motor driven ice auger. The sonar head was lowered into the water to a depth of abt. 14m in hole #1 while in hole #2 the sonar reflectors were submerged to a known water depth. The sonar reflectors were used to verify the sonar measurements. Fig. 6 shows an example of a sonar site while in Fig. 7 a screen shot of a centre profile presents the ridge keel and the sonar reflector chain.

Fig. 6 Sonar Site

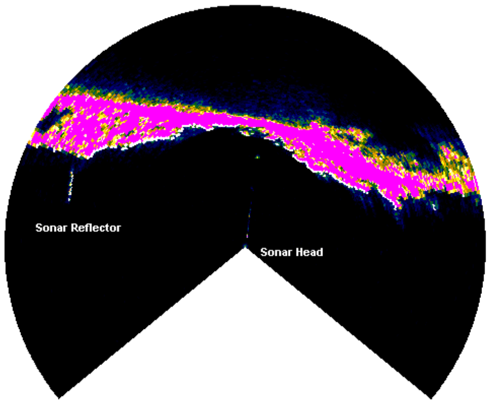


Fig. 7 Centre Profile with Sonar Reflector Chain

DATA EVALUATION AND PRESENTATION

Data Evaluation

The processing and evaluation of the data sampled by the sonar processor and the data describing the surface profiles was carried out by using a Personal Computer and standard software such as *Plotit for Windows* and *MS Excel* as well as programs, especially developed by HSVA, for sonar data processing (*Jochmann, 1990*).

The raw data of each sonar profile are stored in ASCII - files in form of polar co-ordinates giving the transducer angle and the range between the sonar head and the target. These data in connection with the known azimuth angle of the sonar head were transformed by HSVA developed software into ASCII-files containing computed data in the form of x,y,z- co-ordinates.
The data of the ridge sail profiles were manually recorded in a field book and punched into the computer and finally stored in form of ASCII - Files.

By use of both data sets and the standard software *Plotit for Windows* 3D-images of the ridge keel as well as several profiles of the surface and subsurface topography of the ridges (2D-images) were produced.

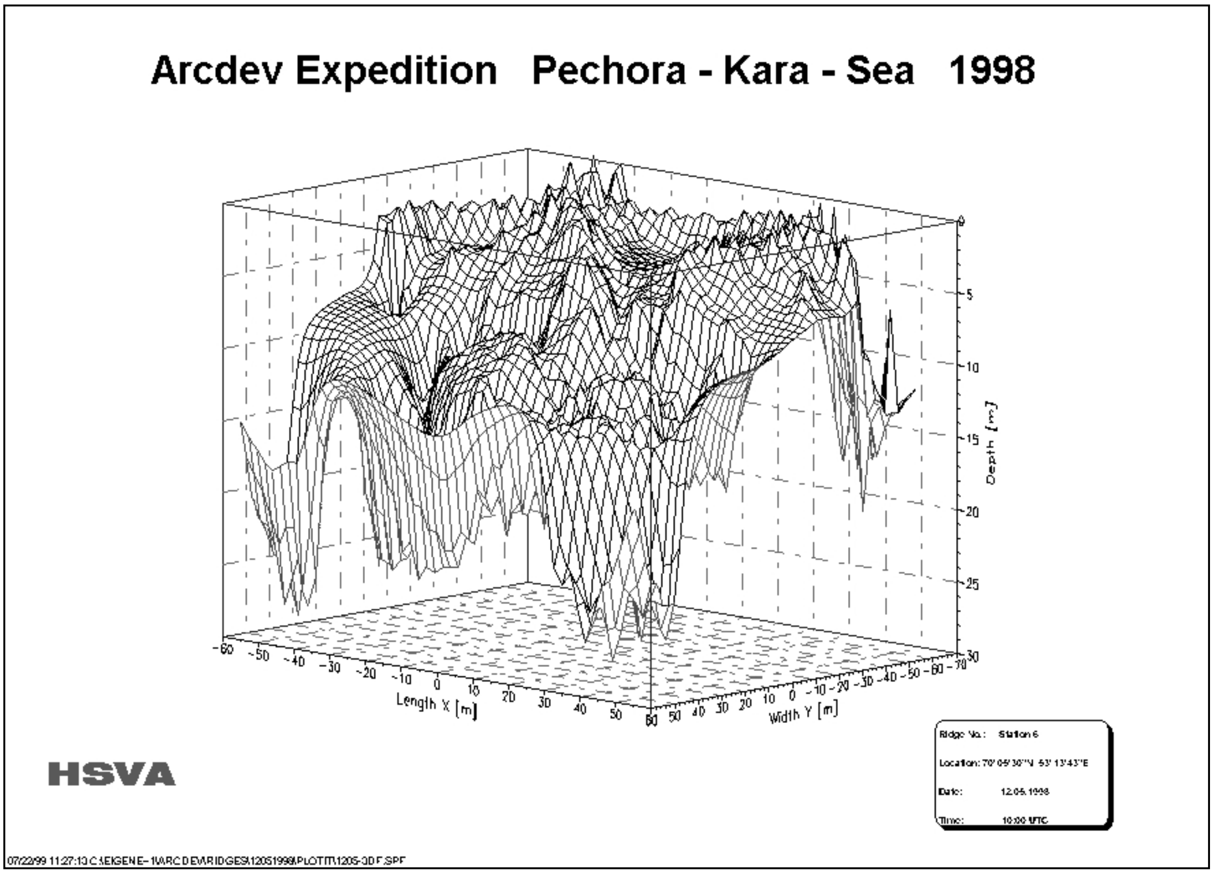
Data Presentation

3D-images of the subsurface topography of the pressure ridges were computed and plotted as x-slices, y-slices and in fishnet as well as contour illustration for each investigated pressure ridge.

Each 3D-illustration contains beside the drawing of surface and subsurface profile lines a table with the additional information:

- Ridge No.
- Y-Slice
- Location
- Station No.
- Date
- Time

An example of a y-slice 3D-plot of the ridge at station No. 6 is given in the following figure.



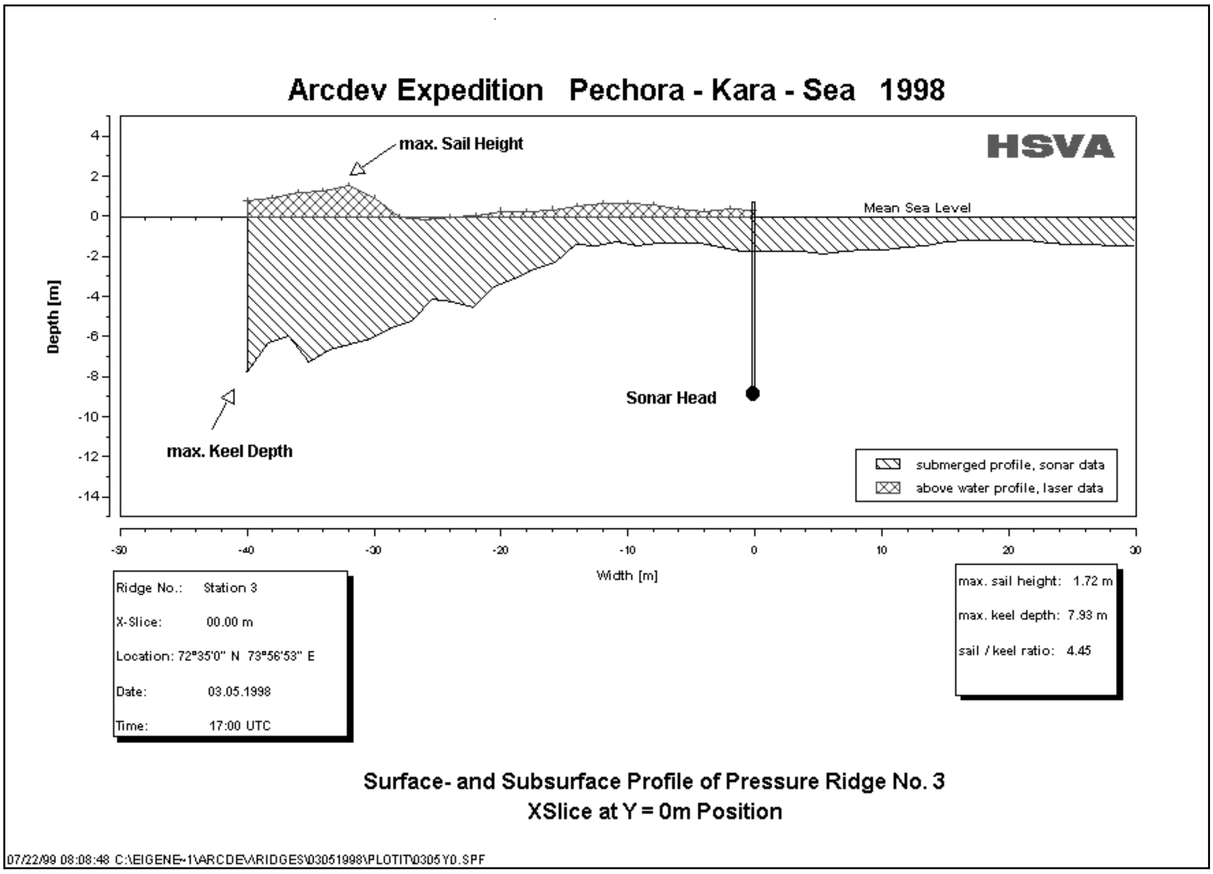
Example of a Y-Slice 3 D-plot

For each investigated pressure ridge the centre-profile as well as 2 parallel profiles, -10 and +10m, are computed and presented in form of 2D-plots. The presented data are extractions of the 3D –Grid data which explains the smooth shape and the possibility to get data points even at acoustic shadow places.

Each profile illustration contains beside the drawing of surface and subsurface profile lines a table with additional information:

- Ridge No.
- Y-Slice
- Location
- Station No.
- Date
- Time
- Sail Height
- Keel Depth
- sail / keel ratio

In the following graph the centre-profile of the ridge at station No. 3 is presented



Example of a Centre-Profile (Ridge No. 3)

The results like sail height, keel depth and sail to keel ratio are compiled in the following table, By clicking with the mouse on the highlighted file name, the graph will show up on the screen if a graphic viewer is present.

RIDGE SITE	FILE NAME	GRAPH TYPE	MAX. SAIL HEIGHT	MAX. KEEL DEPTH	SAIL TO KEEL RATIO
Location No. 3	0305y-10.bmp	X-Slice Y=-10m	1.37 m	6.16 m	4.50
	0305_y0.bmp	X-Slice Y=0m	1.72 m	7.93 m	4.45
	0305_y2.bmp	X-Slice Y=-2m	1.48 m	5.46 m	3.59
	0305_y4.bmp	X-Slice Y=4m	1.72 m	5.13 m	2.98
	0305_y6.bmp	X-Slice Y=6m	1.22 m	4.82 m	3.95
	0305_y8.bmp	X-Slice Y=8m	1.19 m	5.50 m	4.62
	0305_y10.bmp	X-Slice Y=10m	1..06 m	5.05 m	4.76
	0305_3dc.bmp	3D_Contour			
	0305_3df.bmp	3D_Fishnet			
	0305_3dx.bmp	3D_X_Slices			
	0305_3dy.bmp	3D_Y_Slices			
Location No. 4	0705_y0.bmp	X-Slice Y=0m	Nv	5.30 m	Nv
	0705_3dc.bmp	3D_Contour			
	0705_3df.bmp	3D_Fishnet			
	0705_3dx.bmp	3D_X_Slices			
	0705_3dy.bmp	3D_Y_Slices			
Location No. 5	1005y-10.bmp	X-Slice Y=-10m	1.46	8.56	5.86
	1005_y0.bmp	X-Slice Y=0m	1.65	9.22	5.58
	1005_x0.bmp	Y-Slice X=0m	1.35	6.35	4.70
	1005_3dc.bmp	3D_Contour			
	1005_3df.bmp	3D_Fishnet			
	1005_3dx.bmp	3D_X_Slices			
	1005_3dy.bmp	3D_Y_Slices			
Location No. 6	1205y-10.bmp	X-Slice Y=-10m	1.64	6.30	3.84
	1205_y0.bmp	X-Slice Y=0m	3.25	12.17	3.75
	1205_y10.bmp	X-Slice Y=10m	2.11	16.66	7.90
	1205_3dc.bmp	3D_Contour			
	1205_3df.bmp	3D_Fishnet			
	1205_3dx.bmp	3D_X_Slices			
	1205_3dy.bmp	3D_Y_Slices			

Due to the fact that the ridge sites were mostly located in hummocked areas, the sail to keel ratios are scattering in a wide range between 7.90 and 2.98. Building a mean value of this factor for each location, shows ratios of 4.12 for site 3, 5.38 for site 5 and 5.16 for site 6. This is in good agreement with the literature and results measured by the author in other parts of arctic regions which were in the range of 4 to 5.

Comparison of the results of the sonar measurements with those from the thermal drilling show, that the max keel depths determined by the thermal drill method are slightly smaller then those from the sonar device but there is still a good conformity.

Pictures
In the following table file names and descriptions of pictures taken during the Arcdev Expedition are listed. By clicking with the mouse on the highlighted file name, the picture will show up on the screen if a graphic viewer is present.

File Name	Description
PIC035_18.jpg	Installation of Sonar Head; Sledge and Pipes
PIC035_17.jpg	Ridge Sail Profiling using Surveyor's Rod
PIC035_16.jpg	Sonar Site showing Sonar Equipment
PIC035_19.jpg	Installation of Sonar Head, Sledge and Pipes
PIC035_2.jpg	Installation of Sonar Head, Sledge and Pipes
PIC035_20.jpg	Installation of Sonar Head, Sledge and Pipes
PIC035_21.jpg	Installation of Sonar Head, Sledge and Pipes
PIC035_22.jpg	Installation of Sonar Head, Sledge and Pipes
PIC035_29.jpg	Ridge Site at Night
PIC0505_1.jpg	Drilling Team with 300mm Auger
PIC0505_2.jpg	Drilling Team with 300mm Auger
PIC0505_8.jpg	Sonar Site showing Sonar Equipment and Profile Line
PIC105_11.jpg	Quante Levelling Laser QL 310 DI
PIC105_10.jpg	Sonar Sledge
PIC105_13.jpg	Quante Levelling Laser QL 310 DI on Top of Ridge Sail
PIC105_14.jpg	Quante Levelling Laser QL 310 DI on Top of Ridge Sail
PIC105_16.jpg	Ridge Site with Kap. Dranitsyn and Equipment
PIC105_7.jpg	Ridge Site with Kap. Dranitsyn and Equipment
PIC125_11.jpg	Ridge Sail
PIC125_12.jpg	Overview of ridged Area
PIC125_2.jpg	Levelling Surface of Ridge
PIC125_17.jpg	Ridge Site from behind of the Sail
PIC125_16.jpg	Profiling of Ridge Sail
PIC125_15.jpg	Profiling of Ridge Sail
PIC125_18.jpg	Quante Laser + Thermal Drill Group
PIC125_19.jpg	Measuring Snow Thickness
PIC125_24.jpg	Sonar Sledge and Electronic Equipment
PIC125_21.jpg	Ridge Sail
PIC125_22.jpg	Ridge Sail
PIC125_23.jpg	Sonar Sledge and Electronic Equipment
PIC125_20.jpg	Photo Session on Ridge Sail
PIC125_25.jpg	Sonar Sledge and Electronic Equipment
PIC125_26.jpg	Sonar Sledge and Electronic Equipment
PIC125_29.jpg	Equipment infant of Ridge Sail
PIC125_3.jpg	Sonar Equipment
PIC125_4.jpg	Ridge Site with Quante Laser
PIC125_5.jpg	Equipment in front of Ridge Sail and Kap. Dranitsyn

ICE CONDITIONS
WP 3

Part 2: Ship-Based Ice Thickness Profiling During ARCDEV

Author: Dipl.-Ing. Chr. Haas (AWI)

Ship-based ice thickness profiling during ARCDEV

Description of measurements and data formats

Christian Haas, Alfred-Wegener-Institute, Bremerhaven, Germany

subcontracted by HSVA

1. Introduction
2. Method
3. Data processing
    3.1. Laser data: Reconstruction of original height above ice/water surface and derivation of ice concentration
    3.2. EM data: Determination of instrument height above the ice/water interface
    3.3. Calculation of ice thickness
4. Reference
5. Description of file content and format
    5.1. Time series of ice concentration and thickness
    5.2. Frequency histograms of ice thickness for 10 minute intervals
    5.3 Negative ice thicknesses

1. Introduction

From the side of the bow of IB Dranitzyn continuous electromagnetic (EM) ice thickness measurements were performed from May 1-3 and from May 9-11 while the ship was moving through the ice (Figure 1). The locations of the profiles are plotted in Figure 2.

Fig. 1: Photograph of typical conditions during ship-based EM measurements, taken from the bridge of IB Dranitsyn. Rossia is leading (upper right), leaving behind a channel with broken ice. The EM/laser system (lower left) is profiling only broken and disturbed ice. Note the scaffold boom construction which had to be build on the ship to suspend the instruments.

Fig. 2: Map of expedition area and ships tracks (dotted line) showing the sections where continuous ship-based EM ice thickness measurements were performed (bold lines). Dots indicate ships positions at 0:00 UTC each day. Note that much of the ice thickness measurements were performed in front of the Ob and Yenessey estuaries, where sea water salinity was less than 20 or even 10 psu.

As no use could be made of the ships bow crane, we had to build a boom construction extending 6 m to the side of IB Dranitzyn, enabling suspension of the measurement system far away from the ship (Fig. 1). However, the system was still not far enough away to enable to profile the undisturbed ice next to the channel broken by the leading icebreaker Rossia. Thus, almost all measurements were performed over the highly broken and disturbed ice at the boundary between the channel and the original ice floes (Fig. 1). It should be noted already here, that these conditions for the reasons outlined below prohibit a correct interpretation of the measurements. Therefore, the results could at best be interpreted only as 'apparent ice thicknesses'. As such, they may however still be sufficient to be compared with other ships performance data. The data should only be used very carefully to derive true ice thickness distributions.

Although it was always proposed to perform the ship-based measurements from the leading icebreaker to be able to profile undisturbed ice, we had no opportunity to meet this requirement. For future expeditions, our experience during ARCDEV 98 has shown that being on the leading ship would be essential to derive correct ice thickness estimates.

2. Method

All EM measurements were carried out with a Geonics EM31. This is a portable, small-offset loop-loop steady-state induction device which is commercially available and frequently used to solve shallow engineering geophysical problems. The spacing between the coplanar transmitter and receiver antenna coils is 3.66 m, and the operating frequency is 9.8 kHz. The instrument can be operated with either vertically or horizontally aligned coils, corresponding to the horizontal or vertical magnetic dipole (HDM or VDM) mode, respectively. The subsurface apparent conductivity is directly indicated in mS/m.

The measurement method and used instruments are described in detail by Haas (1998). In summary, EM measurements utilize the large contrast in electrical conductivity between sea ice and sea water. The former is well known to range between 0 and 30 mS/m in the Arctic, the latter varies from 2300 to 2900 mS/m. Consequently the conductivity of the sea ice is negligible in comparison to the sea water conductivity. Therefore, a quasi-static low-frequency EM-field generated by the transmitter coil of an EM instrument will induce eddy currents mainly in the sea water below the ice. This, in turn, will result in a secondary field which is sensed by a receiver coil. The secondary-to-primary field ratio can be expressed in terms of an apparent conductivity, a measure of the integrated electrical conductivity of the halfspace underneath the instrument. If ice and water conductivities are considered to be constant, the apparent conductivity is only dependent on the instruments height above the sea surface, which is identical with the sea ice underside. Ice thickness can then be calculated if the height of the

Fig. 3: Sketch of principle of ice thickness calculation from combined EM and laser profiling, as applied for the ship-based measurements.

instrument above the ice surface is known. Here, the latter is determined by means of a laser altimeter which simultaneously profiles the range to the ice surface (Fig. 3).

Over deformed ice, in particular pressure ridges, the accuracy of electromagnetically derived ice thickness can be very poor if results are compared with drill-hole determined values on a point-to-point basis. While mean values for full ridge-cross profiles agree reasonably well, maximum keel depths are generally underestimated. This is mainly due to the extended area over which eddy currents are induced in the water below the instrument (the 'footprint'). The footprint size for different coil configurations is estimated to range between 1.3 and 3.8 times the instrument height above the water surface. Consequently, the lateral resolution of EM measurements decreases with increasing instrument height above the ice surface.

As outlined above, due to the finite extent of the eddy currents of several meters, the thickness measurements are averages over a larger area. This means, that correct results are derived only over undisturbed, level ice. As soon as the ice is rough or disturbed, only average thicknesses are derived. In the case of fragmented ice floes like at the edges of the icebreaker channel, the water (ice thickness = 0) aside the floe fragments always contributes to the average thickness as well. Therefore, the measured thickness will always underestimate the true thickness. This is the case for most of the measurements presented here, and the given ice thicknesses should only be taken as 'apparent ice thicknesses'. However, ice concentration for each data interval is also given with the data.

All measurements were performed with a sampling frequency of 20 Hz. In total, 86 hours of data were acquired during 6 days (Fig. 2).

3. Data processing

3.1. Laser data: Reconstruction of original height above ice/water surface and derivation of ice concentration

As described in Haas (1998), over open water the returned laser signals are only very weak, such that the instrument height above the water level cannot correctly be determined. Therefore, as the first processing step, these erranous data over open water have to be corrected to reconstruct the original systems height over the ice or water surface (Fig. 3). Here, the correction of 'bad' points over open water is performed by interpolation between surrounding 'good' points.

The quality of the laser data however also enables to determine the fractions of open water and ice along the profile, i.e. ice concentration immediately underneath the instrument. Ice concentrations are given for each measurement interval on the data CDROM. It should be noted that these ice concentrations are the in-situ ice concentrations under the EM/laser system. Thus, they are extremely shifted towards low ice concentrations if compared to the 'true' areal ice concentration, as e.g. determined during ice observations from the ships bridge. This is because the instruments often hung above the open water in the channel, or passed over alternating cracks and floe fragments of the icebreaker-broken ice.

3.2. EM data: Determination of instrument height above the ice/water interface

The derivation of the instrument height above the ice underside (Fig. 3) is essentially dependent on the knowledge of the seawater salinity/conductivity. Therefore, seawater salinity was measured at intervals along the cruise track (Fig. 4), and the conductivity was calculated. As can be seen in Figure 4, salinities were highly reduced in the regions off the mouths of rivers Ob and Yenessey. These different salinities had to be accounted for in the transformation of the EM signals into heights above the ice underside. Figure 5 shows model curves for the EM response to different seawater conductivities of 1500, 2000, and 2500 mS/m. As can be seen, for instrument heights in excess of 4.5 m (the actual height above sea level) the resulting differences are only small (Fig. 5). The curves in this Figure were employed to transform the measured apparent conductivity into the instruments height above the ice underside of water surface, respectively.

Fig. 4: Seawater salinity along the ARCDEV cruise track as measured on water samples on board IB Dranitzyn

Fig. 5: EM response to different seawater conductivities. The conductivites of 1500 to 2500 mS/m correspond to typical seawater salinities of 15 to 33 psu encountered during the measurements (c.f. Fig. 4).

3.3. Calculation of ice thickness

The distances of the instruments to the ice surface (Section 3.1) and the ice underside (Section 3.2) were subtracted to derive ice thickness (Fig. 3). As this was performed with the original sampling rate of 20 Hz, a continuous profile of apparent ice thickness along the cruise track resulted. This was averaged for one and 10 minute intervals to yield the data given on the CDROM.

Due to the simple subtraction of the two distances, over very thin ice or open water it can sometimes happen that negative ice thickness values result. This can be caused by wrong assumptions of the seawater salinity, which would lead to wrong estimates of the distance between EM instrument and the seawater surface (Fig. 5). Another reason is the different scale for which the distances are calculated. While the laser value represents a point measurement for an area of a few centimeters in diameter, the EM measurements yield the distance to the water surface for an area of at least some meters in diameter. Thus, particularly over rough ice or around floe edges as well as over open water it can happen that the laser determined distance is greater than the EM value.

Essentially, the negative thicknesses give an impression of the accurathy of the measurements which is probably not better than ±0.2 m. Thus, it is statistically likely that over open water with a true thickness of 0 m a thickness of -0.2 m can be indicated.

Negative thicknesses have been left uncorrected on the CDROM to give an impression of the absolute accuracy of the measurements. This can particularly be seen from the thickness histograms, which often have a maximum to represent zero ice thickness of open water. However, the modes of the distributions are often between -0.2 and +0.2 m.

As negative thicknesses are most likely over open water or very thin ice, they might as well set to zero by the user.

4. Reference

Haas, C., 1998: Evaluation of ship-based electromagnetic-inductive thickness measurements of summer sea-ice in the Bellingshausen and Amundsen Sea. Cold Regions Science and Technology, 27(1), 1-16.

5. Description of file format and content

5.1. Time series of ice concentration and thickness

The data are generally split into two periods, covering the journeys from Murmansk to Sabeta and from Sabeta to Murmansk. However, the files only comprise of data from May 1-3 and from May 9-11, according to the periods when measurements were performed.

For each period, there are files containing time series of average results for one and ten minute intervals (originally called MurmSab_thick.1min, MurmSab_thick.10min, SabMurm_thick.1min, SabMurm_thick.10min).

The one minute files comprise columns for Year, Month, Day, Hour, Minute of each value (GMT). Ice concentration is given in % for the interval, as determined directly underneath the instrument. Mean apparent ice thickness (in m) is the average thickness as derived by the transformations mentioned in Section 3.3. It should be noted that these are average values for a wider area underneath the instrument, i.e. including cracks and the brash ice in the channel.

Finally, the standard deviation as well as the maximum and minimum apparent thicknesses are given. The last column contains the ships speed as derived from the navigation data of HSVA.

The ten minute files comprise columns for Year, Month, Day, Hour, Minute of each value (GMT). Ice concentration is given in % for the interval, as determined directly underneath the instrument. Mean apparent ice thickness (in m) is the average thickness as derived by the transformations mentioned in Section 3.3. It should be noted that these are average values for a wider area underneath the instrument, i.e. including cracks and the brash ice in the channel. Finally, the standard deviation as well as the maximum and minimum apparent thicknesses are given.

As biased results would be obtained if the ship is stationary over a very thick or thin floe, no values are given for ship speeds lower than 2 knts. For the 10 minute data, no data are given if the speed at one minute intervals was lower than 2 knts. For these cases, error flags are given. They are 99.9 for the thickness data and 999 for ice concentration.

It should be noted that the data are referenced to time, rather than to position, and that the are sometimes discontinuous, which is indicated by a blank line. However, the files are fully compatible with the navigation files given by HSVA for 1 and 10 minute intervals, and positions can be gathered there.

5.2. Frequency histograms of ice thickness for 10 minute intervals

For all 10 minute intervals where the ships speed was higher than 2 knts frequency histograms were calculated for thicknesses from -1 m to 10 m, with 0.1 m intervals (Fig. 6). They consist of two columns, thickness [m] and probability of occurrence [%]. The files are consistently labeled with reference to the date, hour and minute:

YYYYMMDD_HHMM.hist

Fig. 6: Exemplary frequency distribution for a 10 minute interval at 15:30 UTC on May 1st, 1998 (File 19980501_1530.hist).

5.3 Negative ice thicknesses

Due to the limited absolute accuracy of the thickness measurements, particularly over open water negative ice thicknesses can occur, which is most obvious in the thickness histograms (see Section 3.3). **Negative values should be set to zero by the user themselves, such that they are always aware of the general quality of the data.**

III WP 6 Navigation and Operation

(HSVA-Report E 292/99; Dr.-Ing. K.-H. Rupp)

Report E 292/99

ARCDEV

Arctic Demonstration and Exploratory Voyage

NAVIGATION AND OPERATION
WP 6

Sponsored by:
EC Transport - 4th Framework
WATERBORNE TRANSPORT
Contract - No: WA 97-SC.2191
and
Bundesministerium für Bildung und Forschung (BMBF)

ARCDEV - Report on “Navigation and Operation”

Copy N^{o}: 0

Deliverable:	Version 1
Work Package:	**06**
Dissemination Level :	
Nature :	Interim Report
Agreed delivery date :	*dd/mm/jj*
Actual delivery date :	*dd/mm/jj*

Technical Abstract:

The report describes navigation and operation during the voyage from Murmansk to Sabeta and back to Murmansk in April and May 1998 (ARCDEV). Rams against the ice, jamming in ice and waiting time are analysed. The track of the icebreaker KAPITAN DRANITSYN are plotted together with course and speed.

Keywords:

Ship

Ice

Navigation arctic water

Operation in ice

Track of rams

Ramming speed and course

Waiting time in ice

ARCDEV - Report on "Navigation and Operation"

Project Co-ordinator:
Capt. Juhani Laapio (Vice President) **NESTE Shipping** Keilaranta 6 P.O. Box 20 **FIN-02151 Espoo** Finland Tel.: +358 20 450 4412; Fax.: + 358 20 450 4293 e-mail: Juhani.Laapio@neste.com; WWW: www.neste.com

Produced by:

Responsible Organisation	Principal Authors
HSVA	Dr. Karl-Heinz Rupp

Contributing Organisations	Contributing Authors
NESTE MSCO NSRA CNIIMF	Cap. Ivan Ivanov Cap. A.G.Gorshkovsky Dr. L.G. Tsoy, Yu. V. Glebko

Separate Report from CNIIMF
Principal Author: Dr. L.G. Tsoy, Yu. V. Glebko

Issued by

HSVA – Hamburgische Schiffbau-Versuchsanstalt GmbH
Bramfelder Strasse 164, D-22305 Hamburg, Germany
Tel. +49-(0)40-692030, Fax +49-(0)40-69203-345

LIST OF CONTENT

1 INTRODUCTION 3

2. ARCDEV 4

3. GPS/GLONASS SATELLITE NAVIGATION RECEIVER 7

4. DESCRIPTION OF SOME TYPICAL SITUATIONS IN ICE 8

5. LOGBOOK OF THE RAMS 12

6. LOGBOOK OF THE WAITING TIME 20

7. GENERAL REMARKS ON COMMUNICATIONS BETWEEN SHIPS, MSCO AND NSRA 24

8. POSSIBLE IMPROVEMENTS FOR TIME SAVINGS 26

9. CONCLUSIONS 27

ANNEX

The Annex includes:

- Track plot, speed and course plots of each day in ice and of each ram. The file names identify the date, the part of the voyage and the plotted time interval . (mmdd_MuSa_hhmimi-hhmimi.xls. m = month, d = day, h = hour in UTC, mi = minutes, Mu = Murmansk, Sa = Sabeta).
- The waiting time was plotted in the same way. Use from Annex of WP13 the
  - Speed, power and partly EM ice thickness vs. the time for each leg, based on one minute average
    (PB_V_Hi_Diagram, Mur_Sab_dia.xls, Sab_Mur_dia.xls (Excel 97))

Note:

The time basis is UTC. In the Report of the Russian partner the time basis is Moscow time.
UTC = Moscow time – 4 hours

1 Introduction

The purpose of this work is to determine the manoeuvring and operation times and techniques during the voyage of the tanker alone and with icebreaker assistance as basis for proposals to reduce the transport time. This investigation should also include the flow of information between tanker and icebreaker and Russian administration.

To fulfil these tasks, the position of KAPITAN DRANITSYN (KD) was measured every second with the help of GPS/GLONASS satellite navigation system. Course, distance and speed were calculated from the measured position. In connection with round the clock bridge observation during the voyage, ramming of ice, waiting times and communication were observed. The KAPITAN DRANITSYN (KD) was manoeuvred from the ship´s crew without any influence from WP 6. Therefore, the manoeuvres of KD indicate how these crew sails with KD in very different ice and convoy conditions.

The track of the rams, course and speed were plotted. Frequency distribution of rams ahead and the maximum speed astern were plotted. Mean values and standard deviation of the maximum speed ahead and astern for different ice conditions and convoy situation were calculated. The waiting time and the reasons for waiting are listed in this report.

Some comments describe possible improvements and time savings.

The report WP 6 consists of this report together with WP 6 report of the Russian partner and the Annex.

2. ARCDEV

The voyage started from the port of Murmansk on April 26, 1998. The route of the convoy (see Fig. 2.1) (Russian icebreaker KAPITAN DRANITSYN (KD) and Finnish tanker UIKKU (U)) led along the west coast of Novaya Zemlya up to the north edge of the island. The shorter way though the Kara Gate was blocked by ice due to the easterly winds. The northern edge of Novaya Zemlya was passed on the 29th of April, 1998 at which time the convoy got stuck in ice. With the help of the Russian nuclear icebreaker ROSSIA (R) the convoy was freed and then guided eastward and southward to the estuary of the river Ob where the ROSSIA left the convoy on May 3rd, 1998. The remaining two ships of the convoy sailed in the channel in landfast ice which had been broken by the Russian icebreaker TAYMIR some days before. KD was then the leading icebreaker on the way to the loading terminal Sabeta which was reached on May 4th, 1998.

Loading was completed on May 8, 1998 and the convoy proceeded back to Murmansk through the Kara Gate. ROSSIA guided the convoy from the Ob estuary through the Kara Sea and the Kara Gate. Murmansk was arrived in the early morning of May 14, 1998.

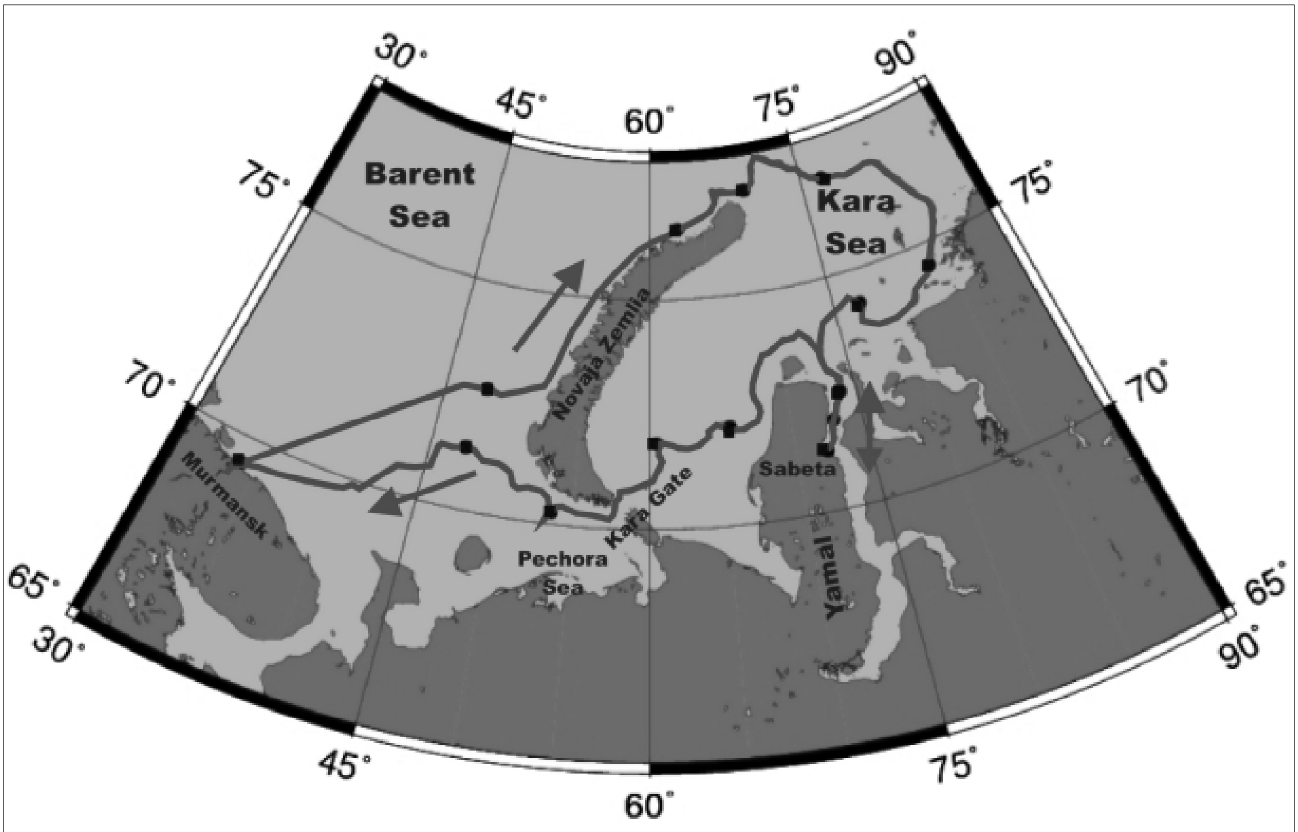


Fig.: 2.1 Route of the convoy

The convoy of the Arctic Demonstration and Exploratory Voyage (ARCDEV) consisted of the Russian icebreaker KAPITAN DRANITSYN, the Finnish motor Tanker UIKKU and the Russian nuclear icebreaker ROSSIA in the area of the Kara Sea. The principal dimensions of the vessels are given in the following table:

			KAPITAN DRANITSYN	ROSSIA	UIKKU
Length over all	Lpp	m	129.06	148.0	164.5
Length of water line	Lwl	m	119.0	136.0	
Beam cwl	Bcwl	m	25.6	28.0	21.5
Draft cwl	Tcwl	m	8.5	11.0	9.5
Displacement or deadweight	DWT	MT	12500	23460	16500
Total installed power	PB	kW	18100	54241	12000
Total shaft power	PD	kW	16200	48324	11400
Number of propeller (FP, no nozzle)			3	3	1 Azipod
Number of blades			4	4	4
Propeller diameter	D	m	4.3	5.3	
Bollard pull		MT	181	483	
Propulsion type			Diesel Electric	Nuclear Steam Turbine Electric	Diesel Electric Azipod
Endurance		nm Days	12000 28	275000 550	
Stated icebreaking ability at 2 kts		m	1.35	2.25	1.0
Maximum OW speed		kts	19.0	20.8	14.5
Operator/Owner			Murmansk Shipping Co.	Murmansk Shipping Co.	Neste Finland
Builder			Wärtsilä Finland	Baltic Shipyard, St. Petersburg, Russia	Nobiskrug Germany
Built in			1980	1985	1976

Table 2.1: Main events of the voyage

References:

1. 1994-1995 Northern Sea Route Directory of Icebreaking Ships, 1994 Backbone Publishing Company, ISBN 0-9644311-0-6
2. Catalogue of the World's Icebreakers, 1998, USCG Engineering Logistics Center, Baltimore, MD, USA

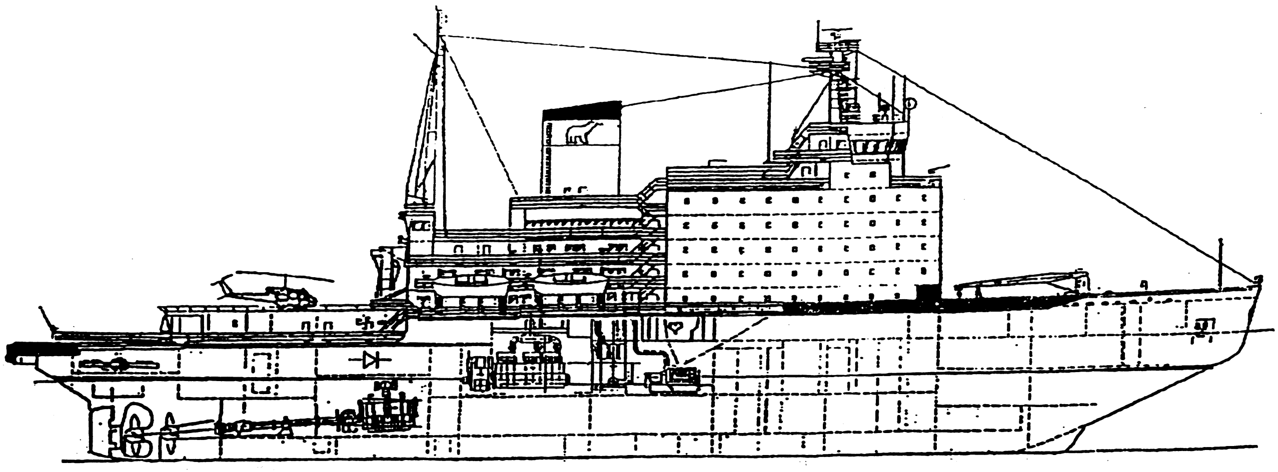


Fig. 2.2 Russian Icebreaker KAPITAN DRANITSYN

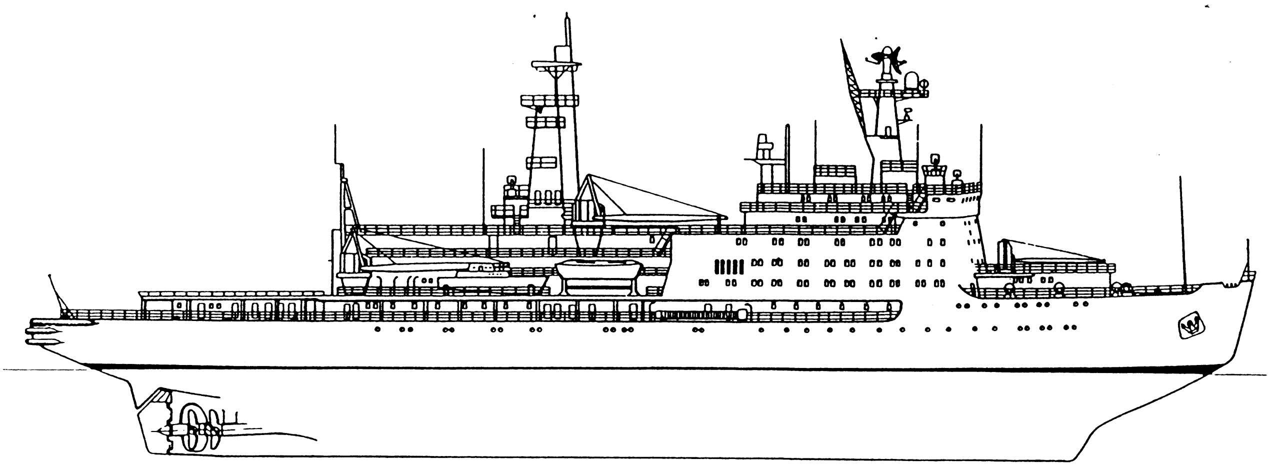


Fig. 2.3 Russian Nuclear Icebreaker ROSSIA (Ref. 2)

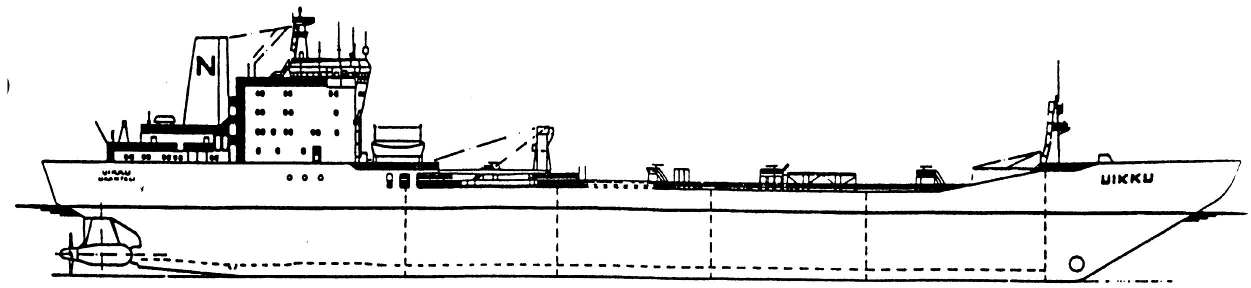


Fig. 2.4 Finnish Tanker UIKKU

(Ref. 3: Electric Propulsion and Power Plants Applied in Recent Tanker Newbuildings, ABB Marine, 1995)

3. GPS/Glonass Satellite navigation receiver

For determination of the geographical position of the ice breaker KAPITAN DRANITSYN, a GPS/GLONASS Satellite navigation receiver was installed. The antenna was mounted on port side at the aft end of the superstructure. With this receiver the position was determined every second.

The GPS/GLONASS receiver was the NR-STA 124 from MAN, Technologie in Germany. It is a 24 channel all-in-view GPS and GLONASS receiver for extreme demands. Adding GLONASS, the Russian counterpart of GPS, to the GPS increases reliability and results in more accurate position and velocity solution. To take advantage of the increased satellite availability and the improved integrity of two independently operated satellite positioning systems, the NR-STA 124 has 12 channels for L1 GPS and 12 channels for L1 GLONASS, providing all-in-view tracking for both systems. With this capacity, the NR-STA 124 will always use the best available system to provide the most accurate position, which should be within 15 meters.

Some technical specifications

- 24 parallel channel continuous tracking
- 12 channel L1 freq. GPS C/A code
- 12 channel L1 freq. GLONASS C/A code
- Standard NMEA-0183 V2.1 protocol
- Raw data output
- Multipath mitigation filter

Observation during ARCDEV

The antenna did not have the optimal position on board the KD. The funnel and part of the bridge superstructure covered the antenna. This was not the main problem with the satellite receiver: Operation of the wireless station of KAPITAN DRANITSYN disturbed the receiver. Presumable the short wave transmitter disturbed mainly the GPS/GLONASS signals.

When position signal jumped away suddenly between measurements, the position was then linearly interpolated between the last and the new "correct" position. A filter was set for a jump of more than 40 m in one second. The interpolated parts are marked in the position listing on the right side of the table.

4. Description of some typical situations in ice

Some general manoeuvres in ice and ice situations are described in this chapter. Detailed information about the manoeuvres in ice during ARCDEV are described in WP 6 Report of CNIIMF and MSCO.

Manoeuvring in ice differs from manoeuvring in open water. Ice has different forms e.g. level ice, ice floes, ice cake and mush ice, hummocks and ridges. An icebreaking vessel has to break, to shift to the side and / or to submerge the ice. Vessels are mainly able to break ice with the bow and with the stern. Therefore, some movements of vessels in ice are impossible or restricted for typical existing ice breaking vessels.

- No traversing (movement of the ship to the side) of the vessel in solid ice. Only restricted traversing in ice floes and mush ice. Possible manoeuvres in ice are breaking over bow and stern and turning.
- No turning in level ice without moving ahead or astern, except if the ice is broken by an azimuth propulsion system.

Steering effect of ice

Another aspects are the steering forces which acts from the ice to the ship. This steering force results from the irregular ice conditions over the beam of a vessel. Stronger ice on starboard side of the bow forces the bow to port, for example. This aspect shows that the ship master has to combine the ice (and wind) observation and ship handling for successful manoeuvres.

One typical example of the effect of ice steering forces occurs when a vessel wants to leave the channel broken by the leading icebreaker. Many ice breaking cargo vessels are unable to get out of that channel when the ice edge is thick and /or the width of the channel is small. With rudder hard over, the vessel slides along the edge of the broken channel without breaking out.

Ice around the submerged hull

During ice breaking, the submerged part of the hull is more or less covered with broken ice. This submerged ice can pass through the propeller (Propeller-ice-interaction) which causes high propeller torque peaks and vibration to the vessel. Ice can also clog the sea chest of the engines and the bow thruster. In a ridge or in similar ice conditions the hull can be totally covered with ice.

Jamming in ice

Jamming on shallow water

Manoeuvring on extremely shallow water, a vessel can beach on its own broken ice floes. This extremely shallow water should be avoided. If this is not possible, the vessel should operate at low speed and with short rams to give most of the ice floes the possibility to shift to the side.

If the vessel beaches on its own broken ice floes she comes to a stop and is jammed. This happened several times during preparation of the ice pier in Sabeta. The KAPITAN DRANITSYN jammed for about 50 minutes while leaving this area.

Jamming in ice on deep water

Jamming: Speed of the vessel is zero, full power and the propeller revolution in the opposite direction to the last movement of the vessel

If a vessel is breaking a ridge or a ridged area, it is common that the vessel comes to a stop. Then the vessel moves backwards between about half to two ship lengths. In this approach run to the ridge, the vessel accelerates up to about 4 – 12 knots ahead and rams the ridge or the ice field until she passes through or comes again to a stop. If the vessel runs at higher speed deep into the ridge or heavy ice field, it is possible that she gets stuck in the ice. That means, that the vessel is unable to move backwards out of the ridge immediately after stopping. This situation can last some hours (in extreme case some days) with backwards running propellers at full power until the propeller wash clears some ice away and greases the gap between hull and ice with water. With time, the ice also creeps so that the ice pressure at the hull is reduced. All these effects help to free a jammed vessel from ice.

Pumping of ballast water from the bow to the stern is one tool to free the vessel faster. Alternating ballasting the vessel to both sides is done sometimes, but the effect is uncertain. Sometimes it is a helpful tool to give full ahead and put over the rudder to hard port and starboard side, and try to turn the vessel to get some space between ice and hull.

To reduce the danger of getting stuck in ice the tactic is to widen the broken channel in the heavy ice field. That means that one ram is on starboard side and the following ram on port side of the broken channel. With this tactic the channel is wider than the ship´s beam. Only the penetration of the last ram can jam the vessel. This tactic allows the use of the rudder as described above.

To get stuck in ice depends mainly on the hull shape of the bow, the coating of the hull, the astern thrust and the ramming speed and the tactic used in ship handling. The last two parameters are the only ones influenced by the navigation officer of the ship.

Ice pressure

In liquid and gases the pressure is in all direction identical in a static case. The ice pressure results, for example, from drifting ice which is pressed against fixed ice. Wind and current are the reasons for the movement of the ice. As ice is a solid material, the pressure has a direction. The pressure direction in ice is indicated by cracks running in the pressure direction.

If possible, the vessel should sail in the ice pressure direction to avoid high ice friction on the side of the ship, which would reduce the speed of the vessel. Following an leading icebreaker, the broken channel closes within a short time when sailing perpendicular to the ice pressure. Under these conditions, the following vessel cannot follow or can only follow at low speed in that partly or fully closed channel, and often comes to a stop. In such situation a close tow (see WP 6 report of

CNIIMF) with the icebreaker is the manoeuvre to continue the voyage. If the ice pressure gets more intensive and the icebreaker is unable to continue, the convoy has to wait for less ice pressure.

In the following paragraphs some practices of navigation in ice are described. For detailed information read:

Guide to Navigating through the Northern Sea Route, No. 4151B,
Administration of the Northern Sea Route State Hydrographic Department of the Ministry of Transport of Russian Federation, Publication of the Head Department of Navigation and Oceanography of the Ministry of Defence of the Russian Federation, St. Petersburg, 1996
Chapter: Practice of Navigation in Ice

Important note:
In the following part some simplified statements are made. Please note that only the Guide to Navigation through the Northern Sea Route is the permitted version.

Convoy operation

In command of the convoy is the captain or his deputies of the strongest icebreaker in a convoy (ARCDEV: ROSSIA – KAPITAN DRANITSYN). ROSSIA gave commands to the following KAPITAN DRANITSYN and UIKKU. UIKKU had ice pilots on board. The command language was Russian during ARCDEV.

Leading

The strongest icebreaker of the convoy (ROSSIA) breaks the ice and the remaining vessels follow in the broken channel. The distance between the vessels depends on the ice conditions. In heavy ice conditions the distance is smaller than in easier ice conditions.

Breaking free a vessel

If one vessel of the convoy becomes jammed in the broken channel all vessels stop. The leading icebreaker or another icebreaker of the convoy breaks a channel parallel to the jammed vessel to make some space so that the vessel can move again.

Close tow

If the weakest vessel cannot follow in the broken channel, close tow operation is usual. During close tow the bow of the towed vessel is towed tight into the stern notch of the icebreaker. Both vessels start moving ahead. The manoeuvrability of this train is reduced. The icebreaker should be able to pass all ice barriers without ramming, to avoid setting back with the stern of the weak vessel first.

Some icebreaking manoeuvres

Breaking out of the broken ice channel bow or stern first

In landfast ice or in ice concentration of 9 to 10/10, many manoeuvres in ice start with "breaking out of the broken channel". With this manoeuvre the vessel leaves the previously broken channel. The reasons for that manoeuvre could be:

- Searching for a new way through the ice
- Breaking a channel parallel to the previously broken one to free a jammed vessel of the convoy
- Beginning of a star manoeuvre (180° course change at the place)

The ability to get out of a channel depends on the hull shape and on the steering forces of a vessel. The steering forces results from the rudder, the bow thruster and the propellers. If the ice is thick and the channel has only a width slightly above the ship´s beam, many vessels are unable to go immediately out of the channel. Such vessels slide with bow and stern along the ice edge of the broken channel. It is then usual practice to set forward and backwards, using inertia of the vessel and the propeller wash to break the ice edge. For many vessels it is easier to go out of the channel with the stern first. If the stern if part of a ship length out of a channel, it is then possible to proceed with the bow in forward motion out of the channel. The angle between ice edge and the centre line of the vessel is then large enough that the bow gets into the unbroken ice. The vessel has started to go out of the broken channel.

Star manoeuvre

A star manoeuvre is the sum of breaking out ahead and astern until a course change of 180° is reached. The more experience the officer in charge has, the less time is required for this manoeuvre. Experience means that the officer knows the behaviour of his vessel under these ice conditions and the knowledge of how to break that ice, as well as to identify weaker and stronger ice conditions. Some time can be saved, if it is possible to break some larger ice floes into the previously broken channel. The vessel is then able to turn better. Another point is to use the sliding of the bow and stern along the broken ice channel edge to guide the vessel back into the channel. This is usually done in the last motion of the vessel before reaching the course change of 180°.

A star manoeuvre was carried out in Sabeta. (see Annex).

5. Logbook of the rams

Definition: A ram begins when the vessel comes to a stop at full power in heavy ice conditions and starts moving backwards. The ram ends after the vessel has passed the ridge (minimum speed) or again comes to a stop.

After the stop of the vessel in heavy ice conditions at full power ahead, the operating levers are set astern, first full astern and then, when the vessel starts moving astern, to a reduced power depending on the ice situation at the stern of the vessel. The vessel accelerates up to the maximum astern speed. At a distance of about one half up to about two vessel lengths, the operation levers are set to full ahead. The vessel comes to a stop and then accelerates to the maximum ramming speed. The heavy ice at the bow slows down the speed of the vessel. Possibly the vessel breaks through the ice barrier or comes again to a stop. Then the operation levers are set again to full astern and the next ram starts.

During ramming ahead, the rudder is used to steer the vessel to one side of the channel made by the previous ram. This tactic widens the channel by a few meters and helps to avoid jamming in ice. The following Figs. 5.1 and 5.2 showed the track of the vessel and the course and speed over time. The Fig. 5.3 shows the track of the KD on the evening of April 29, 1998. This ice barrier was broken from the nuclear icebreaker ROSSIA which freed the KAPITAN DRANITSYN and the UIKKU. All rams of ARCDEV are plotted in the ANNEX of WP 6.

Fig. 5.1: Plot of course and speed over the time, time in UTC

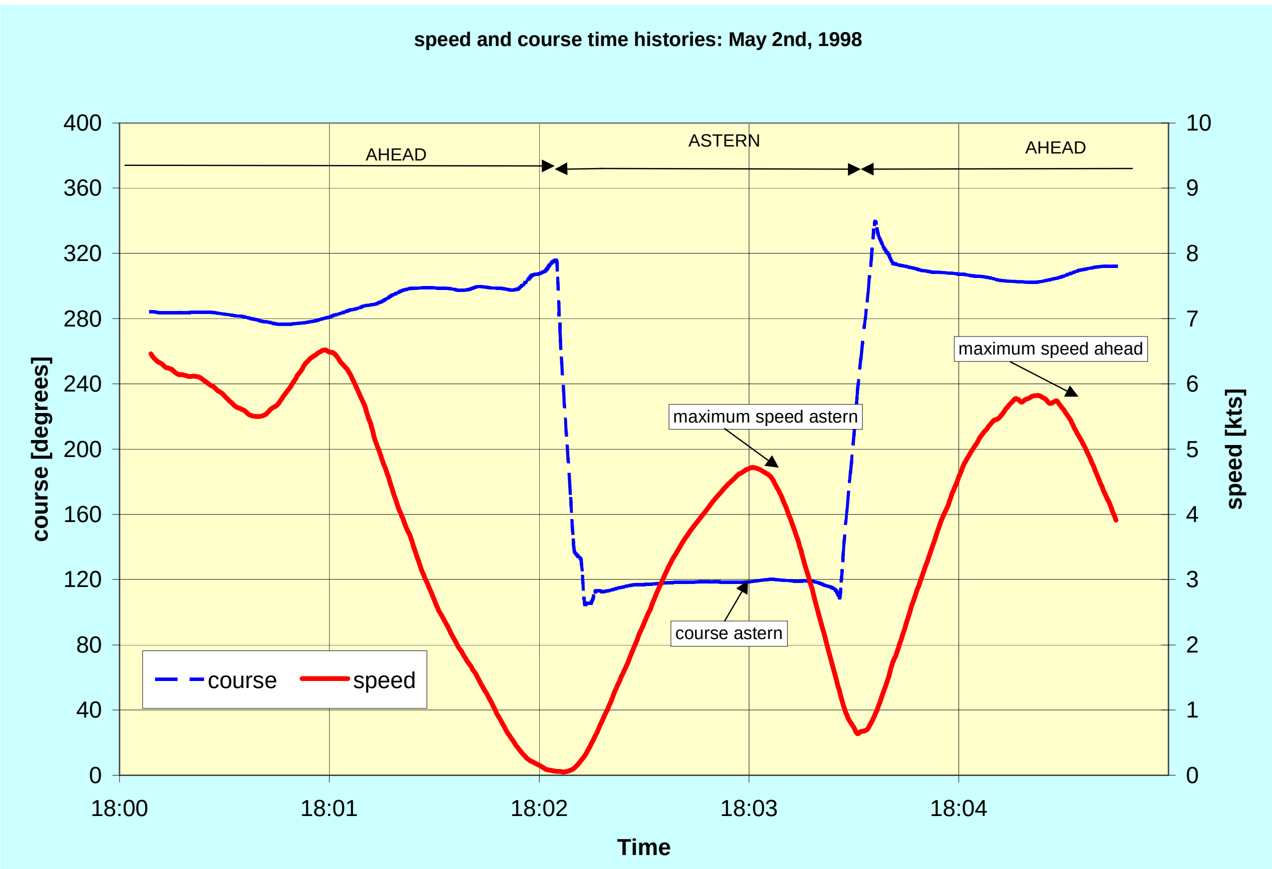


Fig. 5.2: Track of one ram

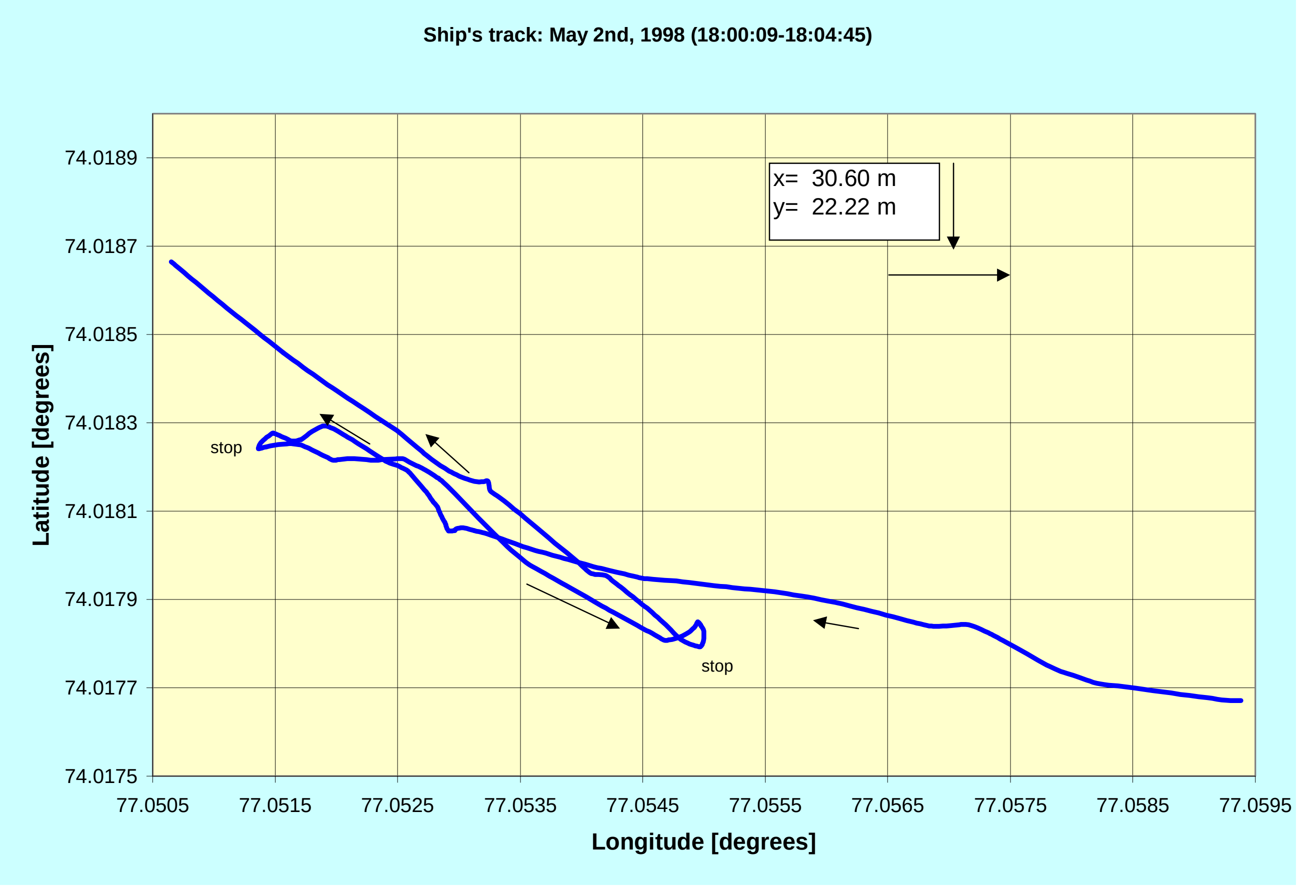
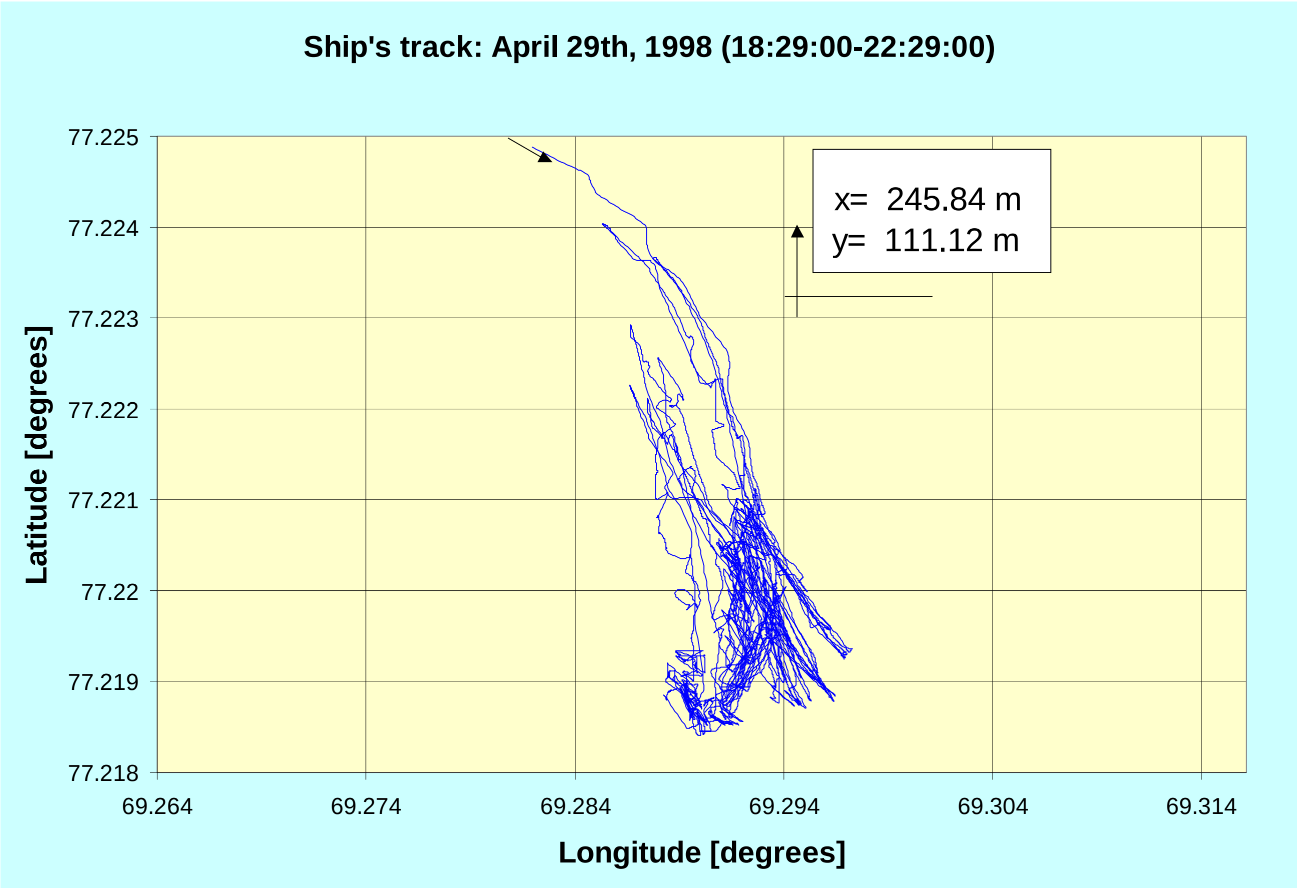


Fig. 5.3: Rams against an ice barrier



In the following tables all rams used in the statistic are listed. A total of 359 rams were counted during ARCDEV, 245 rams on the way to Sabeta and 114 rams on the way to Murmansk. Included in these rams are those used to bring the vessel in a good position for landing scientists on the ice.

Rammings: Murmansk - Sabeta

Date:	Start	End:	Rams:
29.04.98	00:00	24:00:00	
29.04.98	06:10:00	06:21:00	1
29.04.98	11:31:00	11:42:30	2
29.04.98	11:41:00	12:06:00	1
29.04.98	13:13:30	13:28:00	
29.04.98	13:31:30	13:40:45	2
29.04.98	13:55:00	13:58:00	
29.04.98	14:02:30	14:13:10	
29.04.98	14:01:53	15:46:00	22
29.04.98	16:17:51	16:53:00	8
29.04.98	17:27:00	17:30:00	1
29.04.98	17:45:00	18:05:00	1
29.04.98	18:10:30	18:18:30	2
29.04.98	18:23:00	18:27:10	1
29.04.98	18:29:00	22:29:00	49
29.-30.04.	23:00:00	09:00:00	
30.04.98	00:00:00	23:59:00	
30.04.98	09:51:00	10:05:00	4
30.04.98	10:04:20	10:10:40	1
30.04.98	10:11:50	10:21:00	1
30.04.98	10:21:30	10:33:45	
01.05.98	00:00:00	23:59	
01.05.98	00:33:45	01:18:00	2
01.05.98	00:40:45	00:46:50	
01.05.98	01:24:00	01:40:00	
01.05.98	01:50:00	02:05:00	1
01.05.98	03:24:00	03:33:30	1
01.05.98	03:33:20	03:52:00	7
01.05.98	05:47:20	05:51:40	1
01.05.98	06:15:00	06:30:00	
01.05.98	07:15:00	07:30:00	
01.05.98	07:30:00	08:00:00	3
01.05.98	09:40:00	09:53:00	
01.05.98	09:53:12	10:14:50	1
01.05.98	10:25:00	10:55:00	
01.05.98	19:59:30	20:05:30	1
02.05.98	00:00:00	23:59:59	
02.05.98	08:03:30	08:20:30	2
02.05.98	08:20:30	08:52:00	2
02.05.98	09:25:00	10:10:00	
02.05.98	10:55:00	11:19:00	
02.05.98	11:19:00	11:36:00	1
02.05.98	12:05:00	12:16:00	2
02.05.98	12:16:00	12:32:00	5

Date:	Start	End:	Rams:
02.05.98	12:32:00	13:00:00	2
02.05.98	12:41:50	12:45:40	
02.05.98	13:00:00	14:05:00	10
02.05.98	14:08:00	14:30:00	
02.05.98	14:08:00	14:17:10	2
02.05.98	14:19:30	14:29:45	3
02.05.98	14:30:00	15:07:47	11
02.05.98	15:35:20	16:13:00	9
02.05.98	16:27:00	16:31:15	1
02.05.98	16:58:00	17:21:00	7
02.05.98	17:25:50	17:50:20	7
02.05.98	17:50:00	18:00:00	
02.05.98	18:00:00	18:04:45	1
02.05.98	18:10:00	18:16:20	1
02.05.98	18:26:50	18:38:20	1
02.05.98	18:41:45	18:51:30	2
02.05.98	18:49:45	19:03:45	3
02.05.98	19:06:07	19:14:04	2
02.05.98	20:03:50	20:15:30	2
02.05.98	20:19:20	20:26:00	1
02.05.98	20:26:06	20:39:45	2
02.05.98	20:38:30	21:26:00	9
02.05.98	21:55:30	22:34:30	6
02.05.98	22:33:00	23:07:30	6
02.05.98	23:09:00	23:15:00	1
02.05.98	23:15:45	23:36:00	4
02.05.98	23:40:45	23:46:15	1
02.05.98	23:47:00	23:56:30	2
03.05.98	00:00:00	23:59:59	
03.05.98	00:06:30	00:21:00	3
03.05.98	00:21:20	00:30:00	2
03.05.98	00:32:20	00:43:45	2
03.05.98	00:43:10	00:59:10	4
03.05.98	01:10:30	01:58:50	13
03.05.98	10:25:00	10:48:00	
03.05.98	11:00:15	11:07:10	
04.05.98	00:00:00	12:00:00	
04.05.98	06:35:00	10:37:00	
04.05.98	12:50:10	13:11:50	
Murmansk-Sabeta Total Rams			245

Table 5.1: Rammings: Murmansk - Sabeta

Rammings: Sabeta - Murmansk

Date:	Start:	End:	Rams:		Date:	Start:	End:	Rams:
08.05.98	00:00:00	00:00:00			11.05.98	00:00:00	23:59:59	
08.05.98	05:30:25	07:26:33			11.05.98	00:42:30	00:49:30	1
08.05.98	05:30:25	05:35:30	1		11.05.98	00:54:30	01:00:15	1
08.05.98	05:39:30	05:45:00	1		11.05.98	04:57:10	05:10:40	4
08.05.98	05:46:30	06:00:30	1		11.05.98	05:25.15	05:30:10	1
08.05.98	06:01:30	06:09:00	1		11.05.98	06:07:00	06:20:00	1
08.05.98	07:31:19	08:10:00	Star-M.		11.05.98	06:25:30	06:36:00	2
08.05.98	09:51:45	10:01:31	1		11.05.98	07:25:00	08:00:00	2
09.05.98	00:00:00	23:59:59			11.05.98	08:15:50	08:29:00	2
09.05.98	19:37:30	19:42:30	1		11.05.98	08:43:30	08:58:30	1
09.05.98	23:20:00	23:23:50	1		11.05.98	09:13:30	09:30:00	2
10.05.98	00:16:00	00:31:00	4		11.05.98	09:34:45	09:43:30	2
10.05.98	01:08:40	01:18:40	2		11.05.98	10:15:10	10:34:30	1
10.05.98	01:18:00	04:08:00	8		11.05.98	10:38:00	10:42:30	1
10.05.98	04:07:30	04:15:30	1		11.05.98	10:45:20	10:51:15	1
10.05.98	04:16:00	04:41:00	1		11.05.98	15:32:50	15:44:50	1
10.05.98	05:43:00	05:54:00	1		11.05.98	16:19:30	16:32:00	2
10.05.98	05:55:30	06:00:45	1		11.05.98	22:49:30	22:57:30	1
10.05.98	06:17:00	06:22:30	1		12.05.98	01:11:30	01:15:00	1
10.05.98	07:17:30	07:31:00	1		12.05.98	01:19:15	01:26:40	2
10.05.98	08:53:30	09:00:30	1		12.05.98	01:26:00	03:37:00	32
10.05.98	09:01:20	09:24:00	2		12.05.98	11:02:20	11:09:40	1
10.05.98	12:49:45	13:20:15	5		12.05.98	11:17:10	11:20:00	1
10.05.98	13:12:10	13:19:50	3		12.05.98	15:32:50	15:44:40	2
10.05.98	13:20:00	13:22:45	1		12.05.98	22:57:40	23:02:30	1
10.05.98	13:22:30	13:33:10	4		13.05.98	00:00	23:59:59	
10.05.98	13:32:00	13:38:00	2		Sabeta-Murmansk		Total	114
10.05.98	13:37:00	13:45:00	2					
10.05.98	21:20:50	21:25:00	1					

Table 5.2: Rammings: Sabeta - Murmansk

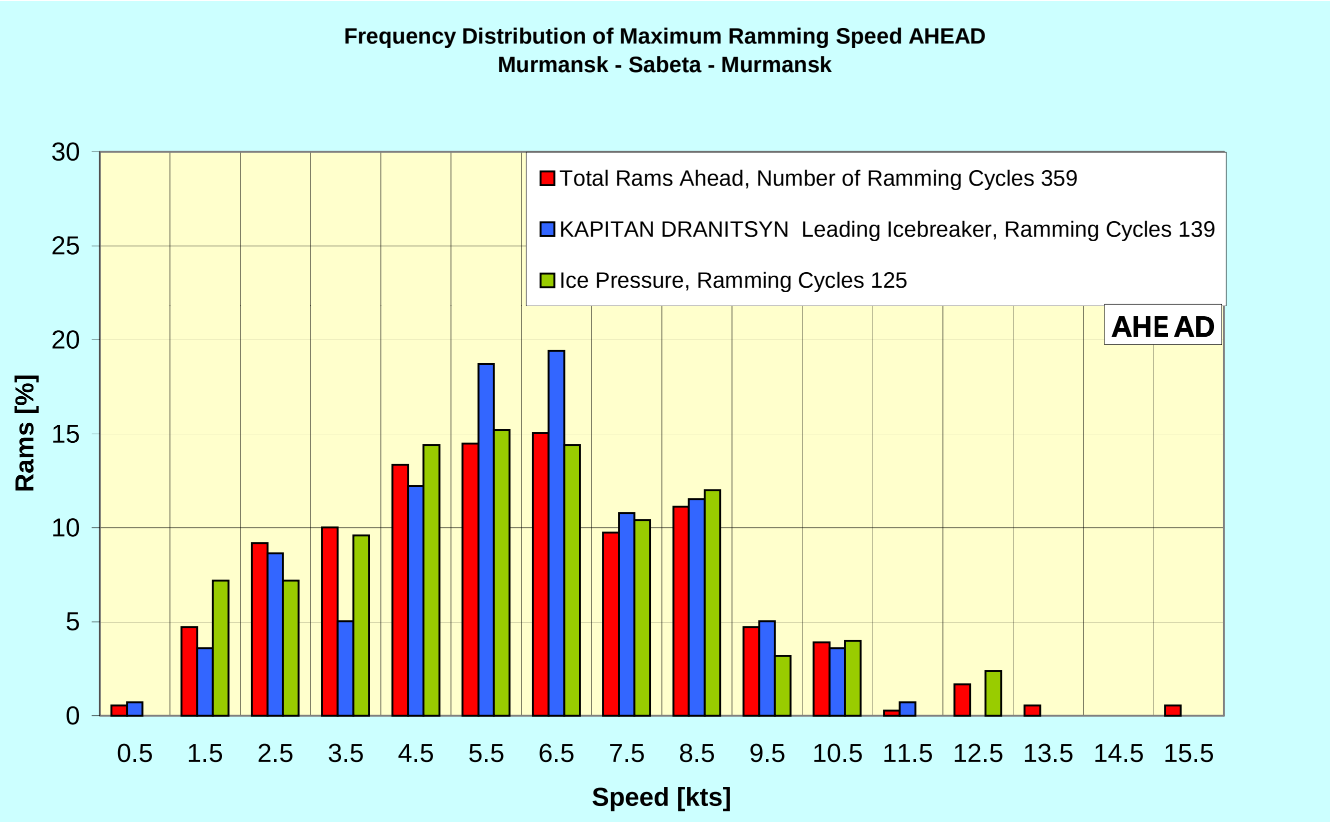
Maximum ramming speed ahead and maximum speed astern

The maximum speed ahead during ramming and the maximum speed during setting back for the next ram where classified in steps of a speed of one knot for all ice and convoy conditions, in order to determine if there exists a difference in the ramming speed when KAPITAN DRANITSYN was the leading icebreaker or when she followed ROSSIA. Another parameter was the ramming speed under ice pressure.

The Fig. 5.4 and Table 5.3 shows the results. There is no practical difference in the maximum ramming speed ahead, between total rams, KD as a leading icebreaker and under ice pressure. Most rams were carried out between 5 and 7 knots; the mean value is about 6 knots. Only some single rams reached a speed of 12 knots and above. With low ramming speed the effect of a ram to break the ice barrier is small.

This single high ramming speed could result from a nearly broken ice barrier which could be passed at this speed. Otherwise the vessel could jam in the ice barrier. Without supporting visual details of the ice conditions, no opinion can be made on a specific ramming speed. Increasing the ramming speed would increase the average speed of a voyage. However, with the increase of the ramming speed the danger to jam in an ice barrier increases too. Jamming on floating ice barriers on deep water happened on the evening of April 29 (UTC time, see also WP6 Report of CNIIMF, Moscow time: April 30). If the vessel jams in the ice the average speed drops drastically, and the gain in an average speed due to higher ramming speed could easily be lost. With new hull shapes for icebreakers and reduced hull-ice friction, together with fast available trim and roll tanks, jamming of the vessel and jamming time could be reduced.

Under the above mentioned parameters the mean value of the maximum speed astern was about 4 knots during setting back for the next ram ahead. There was no real difference in the mean maximum astern speed between total rams, KD as leading icebreaker and under ice pressure.



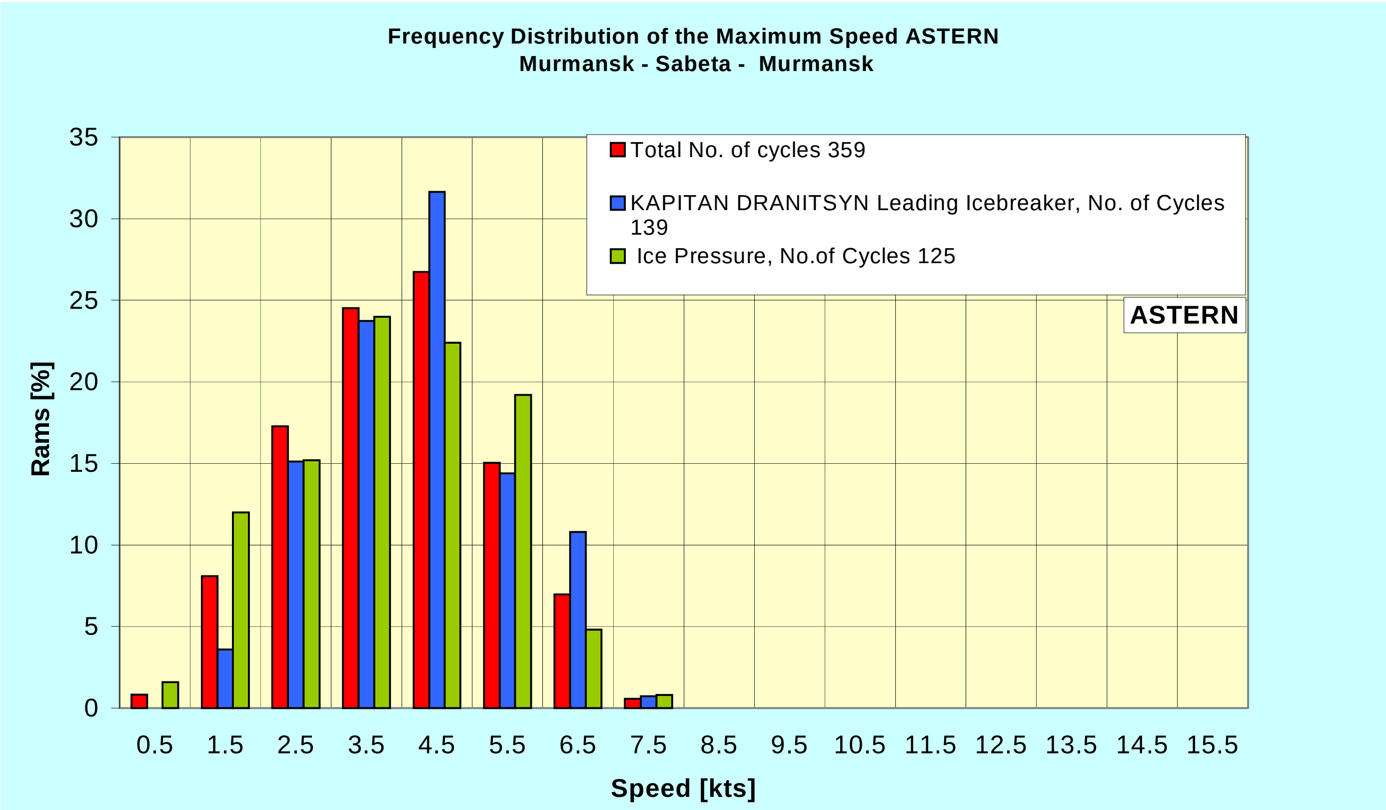


Fig. 5.4: **Frequency distribution of rams ahead and the maximum speed astern for the next ram**

	ARCDEV - VOYAGE (April 27 to May 14, 1998) **Statistical results of the maximum ramming speed ahead and the maximum speed astern**					
	Murmansk - Sabeta – Murmansk		Murmansk - Sabeta		Sabeta - Murmansk	
	Total Values					
	(N = 359)		(N = 245)		(N = 114)	
	astern	Ahead	astern	ahead	astern	ahead
Mean value	3.8736	5.8653	4.0577	5.9321	3.5026	5.8179
Deviation of the mean value	1.1237	2.1041	1.1171	2.1029	1.0342	2.1337
Standard deviation	1.3679	2.6257	1.3728	2.6235	1.2946	2.6787
	Leading Icebreaker "Kapitan Dranitsyn"					
	(N = 139)		(N = 94)		(N = 45)	
	astern	Ahead	astern	ahead	astern	ahead
Mean value	4.1597	5.8993	4.3585	4.3585	3.7444	5.8289
Deviation of the mean value	1.0363	1.7878	1.0055	1.0055	0.8889	1.3978
Standard deviation	1.2881	2.2467	1.2954	1.2729	1.1680	1.8437
	Ice Pressure					
	(N = 125)		(N = 111)		(N = 14)	
	astern	Ahead	astern	ahead	astern	ahead
Mean value	3.7584	5.7544	3.7928	5.6477	3.4857	6.6000
Deviation of the mean value	1.2161	2.0387	1.2221	2.0501	1.1122	1.9286
Standard deviation	1.4427	2.5229	1.4622	2.5266	1.2443	2.3262

Table 5.3: Results of the maximum ramming speed ahead and the maximum speed for setting back in a ram

6. Logbook of the waiting time

In general, waiting time should be avoided, but in all sea transport some waiting time is usual. For a transport in ice covered water there exists some additional types of waiting times:

- Waiting for icebreaker assistance
- Waiting for a convoy
- Waiting for the slowest vessel in a convoy
- Waiting until the icebreaker had prepared a channel through heavy ice barrier
- Engine fallout due to lack of cooling water (sea chest filled with ice fragments)
- Engine fallout due to overload of the engine. One reason could be the propeller-ice–interaction.

And during ARCDEV:

- Stopping at the ice research station
- Approaching the ice research station
- Waiting for guests, boarding and disembarking

Waiting time was defined as follows:
The engine power is reduced to about 4 to 6 MW or totally stopped, the speed is about zero and the time under this conditions are longer than about 3 minutes.

During a short waiting time the diesel electric power plant on board of KAPITAN DRANITSYN was not totally stopped. Two propellers operated with some power ahead and one operated astern. In this way, the total power consumption was the above described 4 to 6 MW. Under these engine conditions the speed is zero in ice but the measured GPS/GLONASS satellite receiver counts the drift speed in ice and/or the drift received from the satellite signals. In ice navigation a vessel frequently comes to a stop, e.g. during ramming. Therefore the time interval of about 3 minutes was set to exclude stopping time during ramming.

	Reasons						
[hours]	1	2	3	4	5	6	Total
Murmansk-Sabeta	11.38	3.23	1.77	17.32 *(12.87)*	3.10		23.95
Sabeta-Murmansk	0.30	0.53	1.02	17.52		0.62	19.98
Total	12.68	3.76	2.79	34.84	3.10	0.62	43.93

Tab. 6.1 Waiting time

1. Waiting time for icebreaker assistance
2. Waiting for UIKKU
3. Waiting for the convoy, leading icebreaker ROSSIA breaks ridges
4. Approach to ice research station, ice research station
5. Waiting for guests, boarding and disembarking
6. Cleaning ice from sea chest

Waiting time was, in some cases, used for research work on the ice *(kursiv)*

Tab. 6.2: Murmansk –Sabeta Waiting Times

Date	Time (hh:mm)		Reasons (minutes)					
(m d)	From	To	1	2	3	4	5	Total
04 29	05:25	05.51		26				26
04 29	11:45	12:02		17				17
04 29	15:55	16:10		15				15
04 29-30	22:51	09:51	660			*660*		660
04 30	10:22	10:33			11			11
05 01	00:59	01:14			15			15
05 01	01:22	01:37			15			15
05 01	03:52	05:44		112		*112*		112
05 01	10:25	10:49		24				24
05 02	08:50	09:13	KD 23					21
05 02	09:30	10:06			36			36
05 02	10:57	11:15			18			18
05 02	11:29	11:33			4			4
05 03	01:28	01:43					15	15
05 03	10:36	10:43			7			7
5 03	12:23	13:27					64	64
5 03	14:44	19:11				267		267
5 04	02:46	03:26					40	40
5 04	04:45	05:15					30	30
5 04	05:36	06:16					40	40
Total	(minutes)		683	194	106	1039	189	1437
						(772)		
	(hours)		11.38	3.23	1.77	17.32	3.10	23.95

Waiting time
1. Waiting time for icebreaker assistence
2. Waiting for UIKKU
3. Waiting for the convoi, leading icebreaker ROSSIA breaks ridges
4. Approach to ice research station, ice research station
5. Waiting for guests, boarding and disembarging
6. Cleaning sea chest from ice

Waiting time was in some cases used for research work on the ice

Tab. 6.3: Sabeta- Murmansk-Waiting Times

Date	Time (hh:mm)		Reasons (minutes)						
(m d)	from	To	1	2	3	4	5	6.	Total
05.08.	11:23	11:43						20	20
	16:53	16:56						3	3
	20:36	20:50						14	14
05.09.	22:39	22:43	4						4
05.10.	01:51	01:57			6				6
	02:37	02:48		11					11
	02:57	03:03			6				6
	04:09	04:14			5				5
	09:13	09:19	6						6
	about:12:45	13:45				60			60
	13:45	21:10				445			445
	22:55	22:59			4				4
	23:26	23:33			7				7
05.11.	01:45	02:04			19				19
	08:46	08:53			7				7
	10:12	10:15		3					3
	10:18	10:32		14					14
	12:35	12:38			3				3
	13:30	13:34			4				4
	15:34	15:42	8						8
	23:18	23:22		4					4
05.12.	About01:30	03:30				120			120
	03:30	10:36				426			426
Total	(minutes)		18	32	61	1051		37	1199
	(hours		0.30	0.53	1.02	17.52		0.62	19.98

Drifting in Ice

During waiting, the KAPITAN DRANITSYN drifted with the ice. Relative to the surrounding ice the ship was not in motion. The following two plots shows the track of the vessel and the drifting speed (Fig. 6.1) from April 29 to April 30, at the first ice station and the track of the vessel on May 12, at the fifth ice station (Fig. 6.2).

The drift of the ice is very important for all loading stations. The ice and ship are in motion, while the loading station is at a fixed position. A ship has to leave the drifting ice to enter the fixed sheltered harbour. Drift and drift direction must be calculated in ship´s manoeuvres.

Fig. 6.1 Drift of the ice station 1

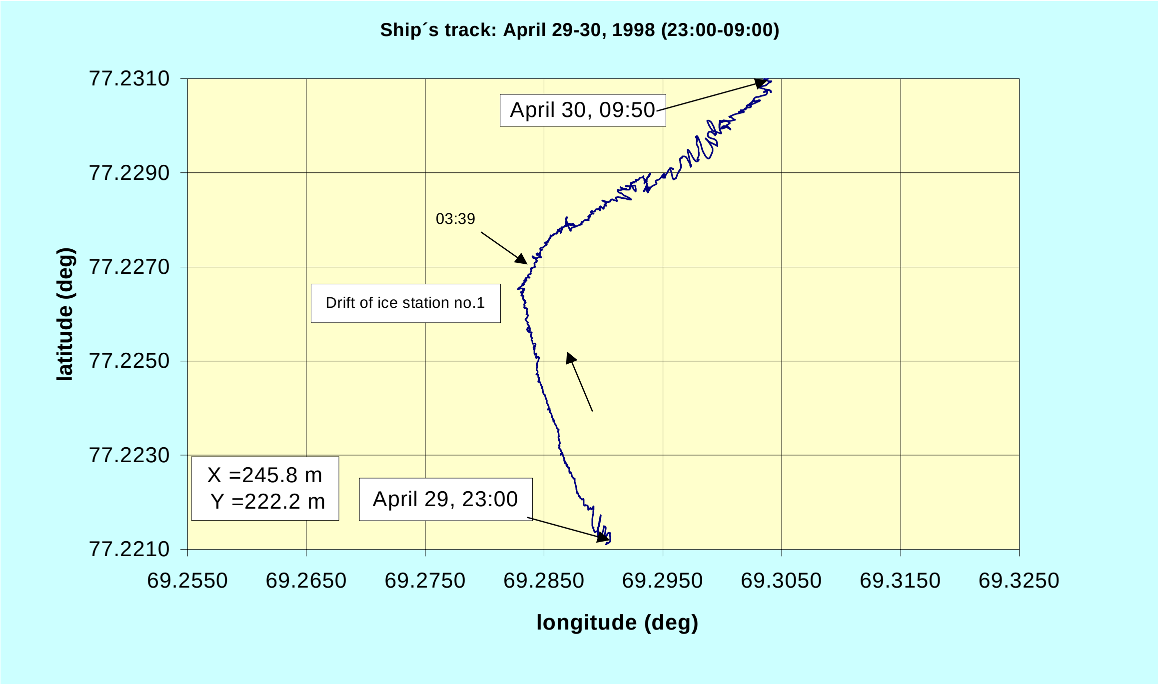
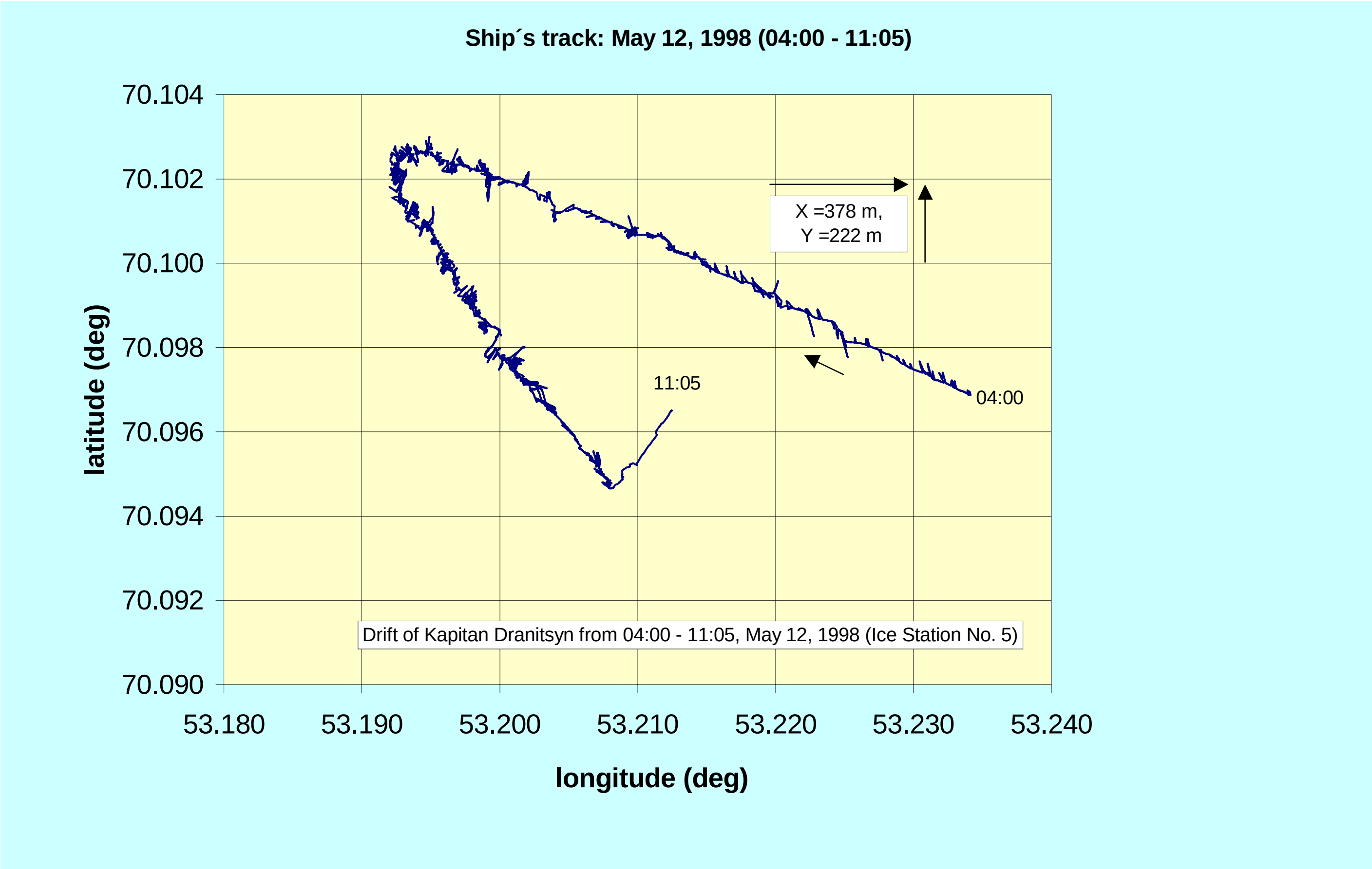
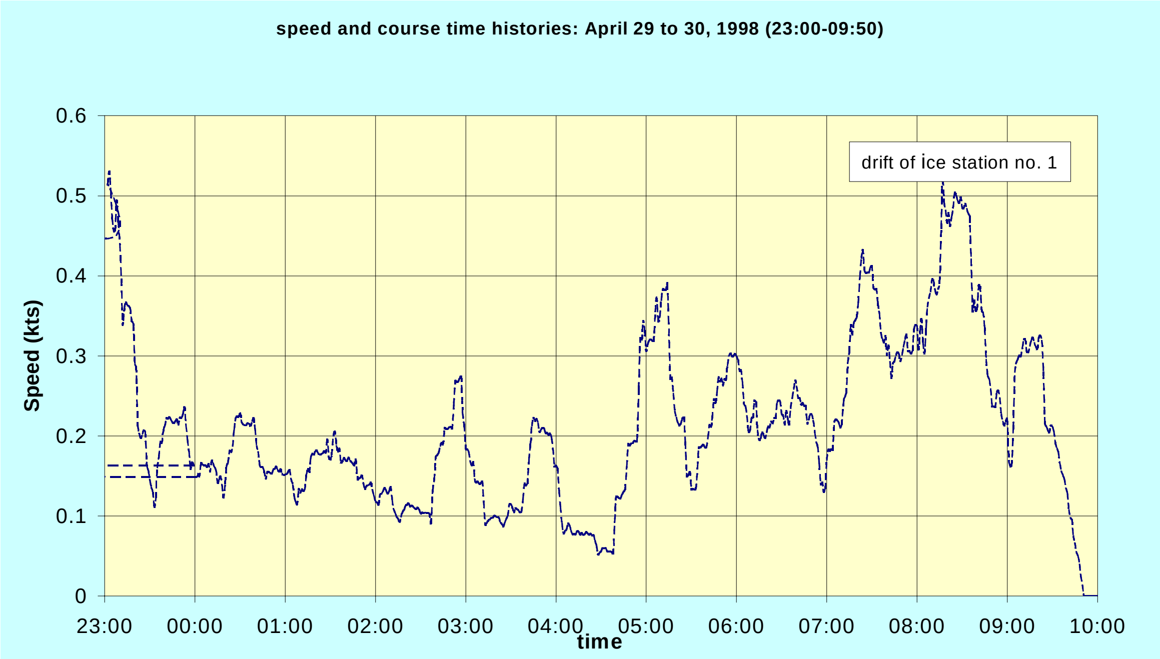


Fig. 6.2: Drift of ice station 5





7. General remarks on communications between ships, MSCO and NSRA

Communication between Ships

For the communication between the ships of the convoy the VHF was used. The language was in Russian., and therefore most of the western scientists could not understand the communications. All communication on board and with the other vessels of the convoy was clear and concise. During ARCDEV there were no communication problems between the ships. The partner from Russia demonstrated that they were able to handle such type of vessels in that ice conditions.

Communication Ship –Shore

About every day we were informed about the latest news from the Northern Sea Route Administration (NSRA). All vessels east of the Kara Gate and west of the Bering Strait are under the control of the NSRA. That means, that position, course and meeting points with icebreakers, etc. are globally organized from NSRA. All environmental and ship data for the western Russian Arctic are collected by the NSRA Murmansk office at Murmansk Shipping. With their long experience, the routes of the vessels are planned by NSRA. The decisions from the NSRA and its representative on board KD during the ARCDEV voyage were very good. In such a vast area with little traffic this central organization could be the only way to organize everything (from emergency ship repair to medical service). When the offshore activities in the Yamal area increase, especially with international oil companies, new tasks arise, which must be solved from a more local organization.

There was only one communication problem between ship and shore. The guests from the EU wanted to fly with the helicopter from Sabeta to KD. The helicopter did not get the position of KD and flew back to Sabeta. The next day the guest came on board.

Ship Repair

All icebreakers have facilities to do some ship repair. This includes welding, machine repairs and sometimes also propeller repair with the use of divers. Transportable pumps are available.

For detailed information see:

Guide to Navigating through the Northern Sea Route, No. 4151B,
Administration of the Northern Sea Route State Hydrographic Department of the Ministry of Transport of Russian Federation, Publication of the Head Department of Navigation and Oceanography of the Ministry of Defence of the Russian Federation, St. Petersburg, 1996

8. Possible improvements for time savings

The report WP6 Navigation and Operation provides some improvements for time savings. For such topics as finding the easiest route through the ice, see WP 5 Routing. If the vessel is on the right route the ships crew navigate through the ice visually or with the help of the ship´s radar. For visual navigation through ice, experience and training is important to see the easiest ice conditions and to select the local easiest course through the ice. During ARCDEV the crew of icebreaker KD showed that they are well trained and experienced. Time saving is in this point not possible. With additional local ice information an easier way may be found.

The ship's crew manoeuvred KD without any influence from WP6. Therefore, the manoeuvres of KD demonstrate how this crew sails with KD in very different ice conditions. The crew manoeuvred KD so that KD normally did not jam in ice. During ramming, the mean maximum ramming speed ahead was only 6 knots; only in some cases she rammed with about 10 knots. The rams were carried out in a way that the broken gap in hummocked and ridged ice was wider than the beam of the vessel by breaking the ice on both ship sides, which is a good practice in ice navigation. However, this tactic was not successful in breaking very heavy ice on the evening of April 29, 1998. The nuclear ice breaker "ROSSIA" broke the KD free.

To increase the average speed towards the port of destination a higher ramming speed is useful only in connection with hull shapes which are not sensitive to jamming. Auxiliaries for reducing the friction at the bow or to trim the vessel within a short time after getting jammed in the ice are useful tools. Further research innovation in this direction is important. Simulation programs for optimal ship handling should be developed.

9. Conclusions

The main part of this WP 6 report describe ramming against ice of the icebreaker KAPITAN DRANITSYN. The icebreaker operated independently or together with the nuclear icebreaker ROSSIA. For all rams, the course, speed and the track of the vessel were plotted (see Annex) with the help of GPS/GLONASS satellite receiver.

Results from the rams are:

- The mean maximum ramming speed ahead was about 6 knot in order avoid jamming in ridges
- No significant difference in the mean maximum ramming speed was found if KAPITAN DRANITSYN operated alone, together with ROSSIA, or under ice pressure.
- The mean maximum speed astern for the above described conditions was about 4 knots.
- Only in two severe ice conditions, KAPITAN DRANITSYN jammed in ice barriers on deep water for some minutes, therefore
- KAPITAN DRANITSYN was handled excellent from her crew without

The co-operation between the ships of the convoy was excellent. No communication problem arose between the vessels of the convoy. Information about ice and meteorological conditions, and the route of the convoy were sent from Northern Sea Route Administration (NSRA) and Murmansk Shipping Company (MSCO) about every day on board. The communication to the shore station of Sabeta and to a helicopter was more difficult, as the visitors from the EU and others could not find the KAPITAN DRANITSYN in the entrance to the Ob estuary during the first helicopter flight.

To increase the average speed towards the port of destination a higher ramming speed is useful only in connection with hull shapes which are not sensitive to jamming. Auxiliaries for reducing the friction at the bow or to trim the vessel within a short time after becoming jammed in the ice are useful tools. Further research innovation in this direction is important. Simulation programs for optimal ship handling should be developed.

The vessels used on ARCDEV are relatively small. Future oil tankers would be about 4 to 6 times larger than the tanker UIKKU. That means that no experience exists for handling a large tanker in ice and how an icebreaker would guide such a tanker. The icebreakers and tanker used during ARCDEV are a good, effective system. With a wider and larger tanker new problems would arise. Today's well proven techniques must then be adapted to the future size of the icebreaking tankers.

ARCDEV - Report on WP 11 “Environmental Protection”

Prepared by:

Responsible Organisation	Principal Authors
HSVA	Dipl.-Ing. Karl-Ulrich Evers

Contributing Organisations	Contributing Authors
FORTUM OIL AND GAS CNIIMF	Capt. Ivan Ivanov Dr. M. Grechin and Dipl.-Eng. V. Somkin

Hamburgische Schiffbau-Versuchsanstalt GmbH
Bramfelder Strasse 164
D-22305 Hamburg
Germany
Tel. +49-(0)40-69203-0
Fax +49-(0)40-69203-345
Email: info@hsva.de

Preface

This report was prepared by K.-U. Evers (HSVA), Capt. I. Ivanov (FORTUM OIL and GAS), Dr. M. Grechin and V. Somkin (both from CNIIMF). The information in this report are considered to be accurate. Neither the authors – nor any company participating in the Work Package 11 "Environmental Protection" - can accept liability for injury, loss or damage of any kind resulting directly or indirectly from the use of information contained in this report whether or not such loss or damage was caused directly or indirectly by their negligence.

LIST OF CONTENTS

Page

1.0 INTRODUCTION 5

1.1 SCOPE OF WORK 5

2.0 ACTIONS FOR CONVINCING THE RUSSIAN AUTHORITIES 7

2.1 GENERAL 7
2.1.1 Negotiations and Discussions with Russian Authorities 7
2.1.2 Discussions and Negotiations with the Environmental Protection Organisation of the Russian Federation 8
2.1.3 Russian Environmental Observer during the Voyage 8

3.0 ANALYSIS OF PROBABLE SOURCES AND EXTENT OF OIL POLLUTION OF THE MARINE ENVIRONMENT FROM SHIPS OPERATING IN ICE CONDITIONS 9

3.1 GENERAL 9

3.2 ADDITIONAL STRUCTURAL AND SURVIVABILITY REQUIREMENTS FOR TANKERS FROM THE POINT OF VIEW OF THE ENVIRONMENTAL PROTECTION DURING THE ICE NAVIGATION 10
3.2.1 Hull of Ship 10
3.2.2 Subdivision and Damage Stability 11

4.0 DESCRIPTION OF PRECAUTION MEASURES 13

4.1 GENERAL 13

4.2 MEASURES FOR THE PREVENTION OF OIL SPILLS IN THE PROCESS OF LOADING OPERATIONS 15
4.2.1 Precaution Measures prior to the Loading Process 15
4.2.2 Precaution Measures during the Loading Process 20
4.2.3 Recommendations for the Improvement of the Environmental Safety for the Ship Navigation in Ice and Loading Operation 22

5.0 OIL SPILL COMBAT PLAN FOR THE TANKER 25

5.1 GENERAL 25

5.2 LIST OF RUSSIAN FEDERATION GOVERMENTAL ORGANISATIONS AND PORT AUTHORITIES TO CONTACT 28

6.0 OIL SPILL CONTINGENCY PLAN FOR THE LOADING TERMINAL 30

6.1 GENERAL 30

6.2 OIL SPILL RESPONSE ORGANISATION 30
6.2.1 Tasks of the Tactical Response Team (TRT) 31
6.2.2 Initial Tasks of the On-Scene Commander 31
6.2.3 Site Management Control 31
6.2.4 Incident Management System (IMS) 32
6.2.4.1 General 32
6.2.4.2 Establishing Command and Control 32
6.2.4.3 Maintaining Command and Control 32
6.2.4.4 Preparing Incident Action Plans 33
6.2.4.5 Preparing the General Plan 34

6.3 DESCRIPTION OF VARIOUS OIL SPILL RESPONSE METHODS WITH RESPECT TO THE ICE LOADING TERMINAL IN SABETA 35
6.3.1 General 35
6.3.2 Description of the Loading Terminal 35
6.3.3 Bearing Capacity of the Ice 39
6.3.4 Oil Recovery Device and Methods (State-of-the-Art) 41

6.4 DESCRIPTION OF DIFFERENT TECHNIQUES AND METHODS WITH RESPECT TO OIL SPILL RESPONSE 46
6.4.1 General 46
6.4.2 Manual Recovery of Lightly Oiled Snow 46
6.4.3 Recovery of Embedded Oil 46
6.4.4 Recovery of Oil-Saturated Snow 47
6.4.5 Flushing of Oil on Tundra or Ice Surface 48
6.4.6 Cutting Ice Slots for Recovery 48
6.4.7 Detection and Delineation of Under-Ice Oil 49
6.4.8 Recovery of Oil Under Ice 49

7.0 SUMMARY AND CONCLUSION 51

8.0 REFERENCES 52

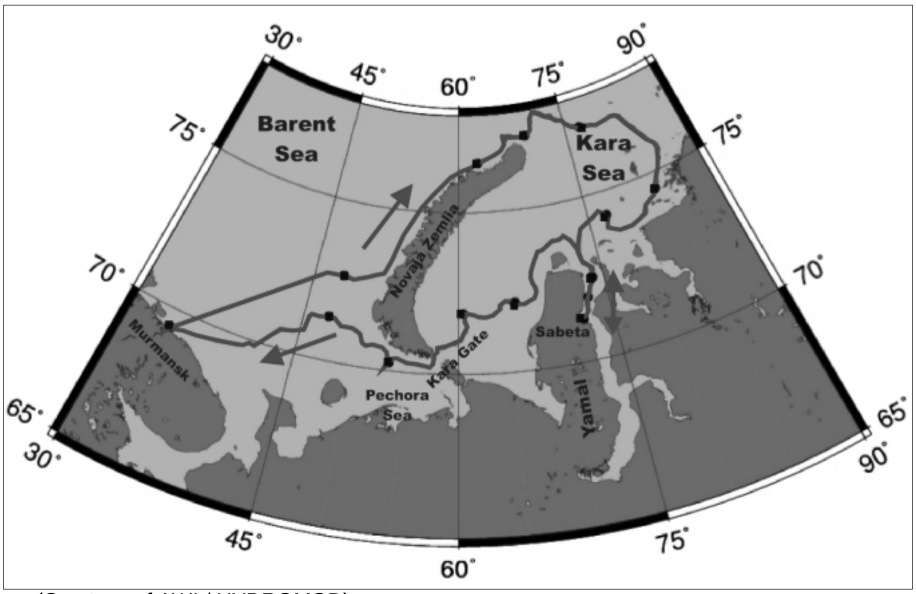
ANNEX 1 Statistics of Ice Damages (prepared by CNIIMF)

ANNEX 2 Summary of Literature Search (prepared by HSVA)

ANNEX 3 Image Gallery (prepared by HSVA)

1.0 INTRODUCTION

Transport of oil and gas by sea from the Arctic has always been a risky and expensive business. The Arctic Ocean with the Russian Arctic shelf areas are the most vulnerable environment on earth due to the low temperatures and the presence of ice. Especially oil spill accidents are considered much more harmful in the ice covered ocean than in warmer climates.
Therefore, it is most important to take every reasonable precaution to prevent an spill of gas condensate or spill with crude oil.
The tanker MT "UIKKU" departed from Murmansk on April 25th, 1998 at 16:00 UTC and sailed towards the Kara Sea. The icebreaker IB "KAPITAN DRANITSYN" left Murmansk on April 26th at 23:00 UTC and proceeded to the rendezvous point with MT UIKKU at the ice edge west of Novaya Zemlya for a month-long round trip to the Ob River in Siberia (Yamal Peninsula). Fig. 1.1 shows the route of the convoy from Murmansk - Sabeta – Murmansk.



(Courtesy of AWI / HYDROMOD)

Fig. 1.1 Route of the Convoy from Murmansk - Sabeta – Murmansk

1.1 SCOPE OF WORK

The ARCDEV project includes several different work packages (WP). The objectives of the Work Package WP 11 "Environmental Protection" are:

1. Preparation of a plan and actions in order to convince the people and local authorities of Yamal Peninsula that the voyage does not violate the environment and that every possible precaution measures are being taken to protect the environment.

2. Reporting on available and promising oil spill combating systems with respect to the use in ice covered waters. This item includes a literature search, a state-of-the-art review in oil spill combating techniques, evaluation of potential combat systems, development of recommendations.

3. Preparation of an analysis of the sources and extent of sea pollution on the basis of experience in coastal transportation in the Russian Arctic and a detailed definition of structural requirements for ships and a composition of the equipment protecting the environment. Development of recommendations to a “Safety Plan” and “Safe Operations Procedures” for the ships on this route.

4. Development of a “Contingency Plan” for the loading terminal. A contingency plan according to the “Shipboard Oil Pollution Emergency Plan” (SOPEP) should be developed considering local conditions at the loading terminal.

5. Evaluation of available technical oil spill combating equipment with respect to its efficiency in cold conditions.

6. A “Combat Plan” should be developed for a small spill to occur in unbroken level ice to prevent or minimise the spreading of oil.

7. As an option it was planned to carry out an “oil spill exercise”, depending on the permission of the local authorities and available technical combating device.

8. The study should be used as a basis for the definition of future research necessities in the field of environmental protection with respect to oil spills.

Fig. 1.2 shows the flow chart of the sub-tasks of WP 11 Environmental Protection.

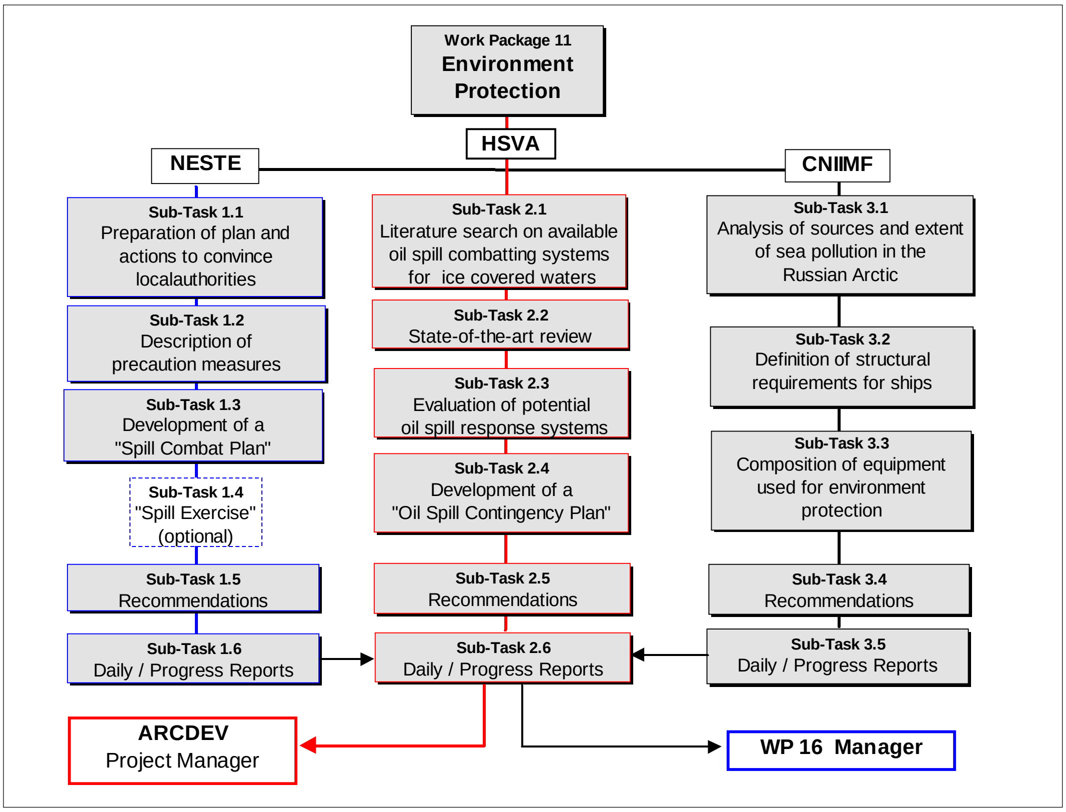


Fig. 1.2 Flow Diagram of the Sub-Tasks of WP 11 Environmental Protection

2.0 ACTIONS FOR CONVINCING THE RUSSIAN AUTHORITIES

2.1 GENERAL

The environmental safe operation concerns two main aspects:

- The environmental safe navigation through the Northern Sea Route.
- The environmental safe ship-shore cargo operation in Yamal peninsula for loading gascondensate.

For the successful completing of the both tasks they were carried out together in a very close and efficient co-operation with the Russian authorities and the Russian teams (crew and scientists) on the ice-breakers and on the shore.
Prior to the start of the voyage from Murmansk to Sabeta (Ob River) with respect to the necessities of WP 11 Environmental Protection the FORTUM OIL AND GAS representative carried out the co-ordination work for convincing the Russian authorities in order to obtain the relevant permission. For the purpose of this task very valuable support was provided by AARI and CNIIMF.
It should be mentioned that these actions were a part of the whole permission-process to obtain the permission for the scientific research and for the Finnish tanker UIKKU to complete the voyage to Yamal peninsula as a commercial demonstration.

The actions for convincing the Russian authorities are briefly summarised:

2.1.1 Negotiations and Discussions with Russian Authorities

Negotiations and discussions with the Chairman of the Environment Protection, Administration of the Yamalo-Nenetsky Autonomous District (YNAD), city of Salekhard

Following information was submitted on the authorities disposal:

- ship’s particulars, specification and equipment
- documentation related to the ship’s pollution prevention capabilities
- ship’s crew qualification and owners training policy
- Latest FORTUM OIL AND GAS ship’s environmental records in accordance to the Environmental Impact Assessment Program of the FORTUM OIL AND GAS Ship Management
- information about the FORTUM OIL AND GAS and FORTUM OIL AND GAS SHIPPING’s environmental records, policy and certification

The Chairman of the Environment Protection of YNAD was invited to a WP-11 meeting planned to be held in Hamburg on 19th-20th March 1998 for discussions focussed on the environmental protection in connection with the loading and transportation of gascondensate from Ob-River estuary.
A representative of YNAD was prevented to attend the meeting, however YNAD supported HSVA and FORTUM OIL AND GAS with a general description of the physical and chemical properties of gascondensate as well as of the procedures for the loading process by the shore personnel in Sabeta.

2.1.2 Discussions and Negotiations with the Environmental Protection Organisation of the Russian Federation, Moscow

On invitation from the Arctic and Antarctic Research Institute (AARI) a representative from FORTUM OIL AND GAS visited for discussions and consultations with Russian researchers the Conference on Barents Sea Impact Study in St. Petersburg. A meeting with representatives from the Moscow Environmental Protection Organisation was foreseen as an option during the conference, but it did not take place.
Contacts and discussions were carried out by the assistance of the Arctic and Antarctic Research Institute (AARI) in St. Petersburg. Russian Environmental authorities on highest level were familiarised with the high safety standards of the participants responsible, and were already convinced in the ability of their environmental safe operation during the execution of the ARCDEV activities. Granting of the permits was already in progress.

2.1.3 Russian Environmental Observer during the Voyage

An observer from the Russian Environmental Authorities was foreseen by the Russian Authorities themselves to arrange the process of permission.

Two different options were discussed and agreed on:

- Observer for the whole sea passage including the loading operations from highest level of the Russian Environmental Authorities

- Observer for the loading of gascondensate in Sabeta from the Environment Protection, Administration of the Yamalo-Nenetsky Autonomous District, Salekhard.

3.0 ANALYSIS OF PROBABLE SOURCES AND EXTENT OF OIL POLLUTION OF THE MARINE ENVIRONMENT FROM SHIPS OPERATING IN ICE CONDITIONS

3.1 GENERAL

Analysis of probable sources and extent of the operational pollution of sea was carried out on the basis of coastal transportation experience in the Russian Arctic. This traffic is intended for the supply of consumers with oil products in many points situated on the coast and islands of the Arctic seas of Russia. The marine oil traffic is carried out as rule from the oil handling terminals of Murmansk and Arkhangelsk in the western Arctic and from the Nakhodka in the eastern Arctic. At present the oil tanker traffic along the Northern Sea Route (NSR) is mainly effected by tankers of the “Samotlor” and “Partizansk” types owned by the Russian Shipping Companies and tankers leased in Latvia “Ventspils” type and Finland. The total volume of annual oil delivery is about $1 \cdot 10^6$ tonnes. About 20% of the delivery is unloaded onto the unequipped shore.
Sea pollution from tankers may be occur due to the emergency oil spillage after the stranding, collision, side or bottom ice damages and operational spillage in the process of cargo handling, ballasting, tank washing and stripping operations.
The majority of tankers operating in the Arctic have double structures; either double bottom and double sides or double bottom, or double sides. Therefore, over the last 30 years no events of the accidental pollution were recorded either in the western or eastern sector of the Arctic, although there were some cases of ice damages of the ships’ hulls with the penetration of water only into the double structures without damage of oil tanks and spillage of cargo. All tankers are provided with segregated ballast tanks and slop tanks having a capacity sufficient to exclude the pollution while pumping out the ballast water and to allow retaining the slops generated by tank washing during the voyage. Besides, one should take into account the fact that under the domestic law any discharge into the Arctic seas of oil or oily mixture from any ship is prohibited except the discharge of processed bilge water from machinery spaces (without cargo pump room bilges) when the oil content of the effluent does not exceed 15 parts per million ($15 \cdot 10^{-6}$).
The discharge of oil with processed bilge water is insignificant. The quantity of bilge water in the machinery space depends on type and power of the engine, technical state of mechanisms and systems, and also on the qualification of crew.
The mean daily accumulation of bilge water with oil content up to 2% may be taken as 3000 litres. Then, the probable discharge of oil with processed bilge water would be $3 \cdot 10^3$ x $15 \cdot 10^{-6}$ = 0.045 litres per day or about 1.5 litres per month. The total quantity of oil discharged into the sea with bilge water from all ships navigating in the Arctic would not exceed 1000 lit. per year.
Bearing in mind the above, the most probable pollution of sea is during the cargo handling and bunkering operations. These kinds of pollution are the results of human errors of the service personnel related to the tanks overflow, disconnection of cargo or bunker hoses without theirs preliminary drainage or as a result of the damage of hoses. For coastal transportation on the Arctic the unloading operations are the most typical ones. With unloading at berth in port the oil pollution of sea is practically improbable. However, during the unloading onto the unequipped shore with the use of hoses or pipelines the pollution is possible in case of the damage of hoses or pipes and leakage through joint between individual sections.
Unloading onto the unequipped shore is carried out when there is stable fast ice or through ice free water. Pipes or hoses are laid through ice or float over water. Hose operations involve also pressure testing at the beginning of unloading and the blow - through at the end of unloading. Unloading is carried out under continuous observation of hoses for the protection of any leakage of oil. Accidental oil outflow can amount in such case to several tens of litres

and depends on the quantity of cargo transferred and on conditions of ice, sea state and weather.
If it is assumed that the accidental oil outflow during one unloading amounts to an average value of 50 litres, with an average quantity of oil discharged onto the unequipped shore of about 500 tonnes and total traffic volume of about 200,000 tonnes the probable accidental oil outflow during unloading onto the unequipped shore will amount to about 20,000 litres per year.
It is obvious, that this evaluation is very approximate as there is no official statistics of such minor outflow. However, it shows that it is necessary to take special precaution measures for the prevention of oil spills in the process of loading operations in ice conditions.

3.2 ADDITIONAL STRUCTURAL AND SURVIVABILITY REQUIREMENTS FOR TANKERS FROM THE POINT OF VIEW OF THE ENVIRONMENTAL PROTECTION DURING THE ICE NAVIGATION

Polar regions are important and especially vulnerable components of the global ecosystem where should be prohibited to discharge any oil products and other hazardous substances. The remoteness of these region as well as severe and dangerous conditions of navigation in ice make rescue or clean up operations difficult. The ships operating under ice conditions are exposed to the additional risk because of the probable hull ice damages. The sinking of any tanker or ship carrying hazardous cargo is ecological catastrophe and is inadmissible.

Therefore all ships navigating in Arctic waters should meet additional structural safety requirements to mitigate and possibly avoid the risk of the hull ice damages and the marine environment pollution.

3.2.1 Hull of Ship

a) Ice resistance and design of the hull should comply the requirements of the Rules of Register of Shipping for ships of ice resistance category “UL” (type of m/s *Samotlor*) or requirements of the Det Norske Veritas (DNV) for ships of ice resistance category “Ice IA Super” (m/s *Uikku*).

b) All tankers should have a double bottom throughout the entire width of ship and over the length between the forepeak and afterpeak bulkheads and double sides over the entire length of cargo tanks.

c) Cargo tanks as well as the fuel and oil tanks should be located at a distance of not less than 0.76 m from the outer shell plating of the ship’s hull taking into account statistical data on the ice damage penetration (Annex 1).

d) Tanks in double bottom and double sides may not be used for storage of petroleum products or other harmful substances. It is allowed to use double bottom tanks within the length of the aft machinery space for the storage of fuel and lubricants when the capacity of any tank not exceeding 20 m^3 .

3.2.2 Subdivision and Damage Stability

a) In accordance to the requirements of the MARPOL Convention, 73/78, every oil tankers of more than 225 m in length shall comply with the subdivision and damage stability criteria after the assumed side or bottom damage applied anywhere in the ship's length. In tankers of more than 150 m, but not exceeding 225 m in length - anywhere in the ship's length, except involving either after or forward bulkhead bounding the machinery space located aft. The machinery space shall be treated as a single compartment, which can be flooded. In tankers not exceeding 150 m in length the damage shall be applied anywhere in the ship's length between adjacent transverse bulkheads with exception of the machinery space.

b) Ships operating under ice conditions run into an extra risk of probable hull ice damages. Probability of getting side damages in the zone exposed to the impact of ice loads is higher than that at the collision of ships sailing in open water.
Therefore for the purpose of reducing the probability of the loss of ships as well as diminishing the risk of the environmental pollution, more strict additional requirements for the subdivision and damage stability should be imposed upon Arctic ships in the case of ice damages. At the same time, one should bear in mind that sizes of ice damages are considerably smaller than those of the damages caused as a result of the collision of ships moving in open water at a higher speed the location of damages over the ship's length and hull height being different.
Therefore, polar class ships, along with meeting the subdivision requirements established by the International Conventions and Codes in force for conventional ships should meet supplementary requirements for the damage trim and stability of ships taking into account location and sizes of ice damages to be determined on the basis of statistical data. Supplementary requirements may be based both on the probabilistic and deterministic approach. At the moment the probabilistic requirements exist only for passenger and dry cargo ships. Therefore at the first stage for all types of ships it is expedient to adopt supplementary requirements based on the deterministic approach.

c) Statistical data on the parameters of ice damages given in the Annex 1 permit to recommend assuming in the calculation of the damage trim and stability the following sizes of ice damages in the zone of their location from the base line up to the level 1.2 d_S within the length L (here L is the length of ship along the waterline corresponding to draft d_S up to the summer load line):

- longitudinal extent is 0.045 L if the centre of damage is located at a distance of 0.4 L from the forward perpendicular and 0.015 L in any other part of the ship
- transverse extent of the damage measured at right angles to the ship's shell plating at any point of the calculated damage area is 0.76 m
- vertical extent is 0.2 d_S in the zone of the location of damage from the base line up to the level 1.2 d_S within the length L

The above ice damages for all Arctic tankers may be located at any place within the zone of ice damages (two compartment standard of subdivision).

With such sizes of ice damages Arctic tankers should meet the damage stability criteria specified by the MARPOL 73/78 (Reg. 25.3.c). Moreover the following additional requirements should be met:

- emergency waterline after equalisation of the ship, and in cases when the equalisation is not provided after flooding, runs below the bulkhead deck and lower edge of any opening through which progressive flooding may take place

- initial metacentric height at the final stage of symmetrical flooding calculated by the constant displacement method before taking measures for its increase should be not less than 0.05 m

- the angle of heel in the case of unsymmetrical flooding should not exceed 20° and after taking measures on the equalisation -12°.

These supplementary requirements are directed towards the prevention of the entry of ice during its shearing onto the bulkhead deck and of the damage of watertight deck structures as well as towards making possible for people to move over decks in the presence of icing.

4.0 DESCRIPTION OF PRECAUTION MEASURES

4.1 GENERAL

Prior to the voyage a questionnaire concerning the gascondensate specifications, the loading procedures, prevention measures etc. has been sent to the Environment Protection Administration of YNAD.

A response of the questions was given in Russian language and can be summarised as:

- *At low temperatures there is an increase in density as well as in viscosity of the gascondensate. In this case there is no evaporation and the gascondensate remains fluid at temperatures as low as -40°C.*

- *In the cases of leakage the gascondensate does not penetrate the ice and remains in ponds on the ice surface and could completely exterminated by burning.*

- *Prior to the installation of the pipeline inspections of the ice road will be carried out.*

- *After installation, the pipeline will be proved by pressing air through the system when the valves at one end are closed. Any decrease in pressure would indicate a leakage of the pipeline. The pressure in this case is about twice of the maximum pressure under working conditions (80 bar). The results will be documented.*

- *During the loading process there will be a radio link 24 hrs/day to respond in time if an emergency case occurs (stop pumping, closing the valves etc.)*

- *A truck of the fire brigade will be on duty during the loading process.*

- *After finishing of the loading process the pipeline will be emptied by pressing air through the tubes and than dismantled.*

- *In case of an spill the gascondensate will be pumped off from the surface into sludge tanks at the deposit.*

- *On shore there will be used two mobile pumps and one stationary pump Type Y8-MA2 in order to pump the gascondensate through two pipelines of 4 in. and 6 in. diameter to the tanker.*

The physical and chemical properties of gascondensate from well no.48 of Kharasaveyskaya square interval (2323-2333 m) produced at the Sabeta site are summarised in Tab. 4.1.

Quality Certificate of Gascondensate of Well No. 48 of Kharasaveyskaya Square Interval 2323-2333 m		
1	Appearance	yellow liquid, opalescent
2	Specific gravity weight at 20°C	0.770 g/cm^3
3	Contents of mercaptanic sulphur and hydrogen sulphide	non
4	Trials on copper plate	stands
5	Contents of real resins	49 mg/100ml
6	Fraction contents	
	Beginning boiling temperature	77°C
	Sublimation temperature	
	10%	105°C
	20%	115°C
	30%	126°C
	40%	140°C
	50%	159°C
	60%	
	70%	
	80%	
	90%	298°C
	Finishing temperature	337°C
7	Mass portion of general sulphur	0.089%
8	Saturated steam pressure at 38°C	23 mmHg
9	Contents of water soluble acids and bases	non
10	Group carbonic contents	
	sum of n-paraphine	22.4%
	sum of iso-paraphine	26.9% up to n-C_9H_{20} incl.
	sum of aromatic (Tuluol, Benzol, Xylol)	6.8%
	sum of naphten	27 %
	sum of hydrocarbons higher n-C_9H_{20} (Nonan)	16.9%
11	Methanol contents	0.4%
12	Lead contents	non
13	Octane number by engine method	36 + 38

Tab. 4.1 Specification of the Gascondensate (SAYBOLT Certificate)

Specification of gascondensate:

- The gascondensate is an opalescent-yellow coloured liquid substance which contains mostly light fractions, i.e. the heavy fractions are less than 5%.
- The condensate does not contain any:
  - mercaptan sulphur
  - hydrogen sulphide
  - water soluble acids
  - lead
- The total mass of sulphur is less than 0.01 %
- If any spill would occur it is expected that a huge extent of spilled gascondensate on the ice evaporates in a few hours. The velocity of evaporation is depending on the predominant temperature of the environment.
- Less than 1% presenting the heavy fractions may remain on the surface of the ice or snow. As an comparative example crude oil can be used , which is in contrary to the gascondensate due to the huge amount of heavy fractions and less evaporation.

4.2 MEASURES FOR THE PREVENTION OF OIL SPILLS IN THE PROCESS OF LOADING OPERATIONS

In addition to the precaution measures taken at the loading terminal site in Sabeta (see section 4.1) comprehensive precaution measures on the tanker have been carried out.

4.2.1 Precaution Measures prior to the Loading Process

a) Preparing the ship and the crew

- Dry docking the vessel
- Full check of all cargo loading/unloading systems and appliances
- Full check of the implementation of the Environmental Impact Assessment Program of FORTUM OIL AND GAS Ship Management / ISO 14001
- Checking the vessel's equipment and preparedness for the expedition
- Selecting an experienced crew with operation in Arctic conditions
- Training the crew to make them familiar with certain special precaution measures for the cargo operation in Arctic conditions involving ship-shore communications, flexible hoses – steel pipelines connections on ice, pressure control device etc.
- Enhancing the oil pollution prevention preparedness of the crew by intensive instructions about the additional risks and hazards when operating in Arctic conditions before and during the expedition voyage.
- Four additional 20 m long flexible hoses of 6 in. diameter (test pressure 10 bar) for connecting the ship's manifold to the end of the shore to the terminal pipeline were supplied to the vessel. The hoses were tested and certified before the voyage.

b) Main equipment available on the tanker MT UIKKU for oil pollution prevention

The main equipment is summarised in Tab. 4.2

MAIN EQUIPMENT FOR OIL POLLUTION PREVENTION ON BOARD MT UIKKU	
Type of Eqipment	**Location / Quantity / Capacity / Type**
Adsorbent (Sawdust)	**Cargo and Bunker Manifolds: 2 x 100 dm^3** **Stores - Fore: 10 x 150 dm^3** **Stores - Aft: 5 x 100 dm^3**
Portable Wilden Pump (air driven)	**Capacity: 4 m^3 / hr** **Location: main deck, port side, aft part**
Degreasant and Solvent	**Type: NESTE Oil AND GAS Shampoo** **Quantity: 600 litres**
Floating Oil Booms	**Length: 400 m** **Location: store - fore**
Fixed Line Draining Pump	**Capacity: 8 m^3 / hr**

Tab. 4.2 Main Equipment for Oil Pollution Prevention on Board MT UIKKU

c) M/T UIKKU's Pollution Management

The pollution management is organised, implemented and controlled on board by the nominated ship's Environmental Protection Officer in accordance to the FORTUM OIL AND GAS Ship Management Environmental Impact Assessment Programme under the supervision of the FORTUM OIL AND GAS Ship Management certified with ISO 14001 and in full compliance with ISM Code.

- MT UIKKU has not discharged any quantities of garbage, grey waters or sewage over board during the whole passage through the Northern Sea Route. The ship has the capacity and is certified for storing on board grey waters for at least 30 days - in compliance with the requirements of that particular Arctic navigation area.

- The ship had carried out at least one additional total ballast water change after leaving Norway and before approaching Ob estuary for loading respectively before commencing deballasting operations in Sabeta (total ballast quantity of about 6000 m^3)

- Ship's Oil Pollution preparedness :

  Vessel's Pollution Contingency Muster List (see Tab. 4.3 a-c)

- FORTUM OIL AND GAS Ships Environmental Preparedness :

  FORTUM OIL AND GAS Ship Management Environmental Impact Assessment Program

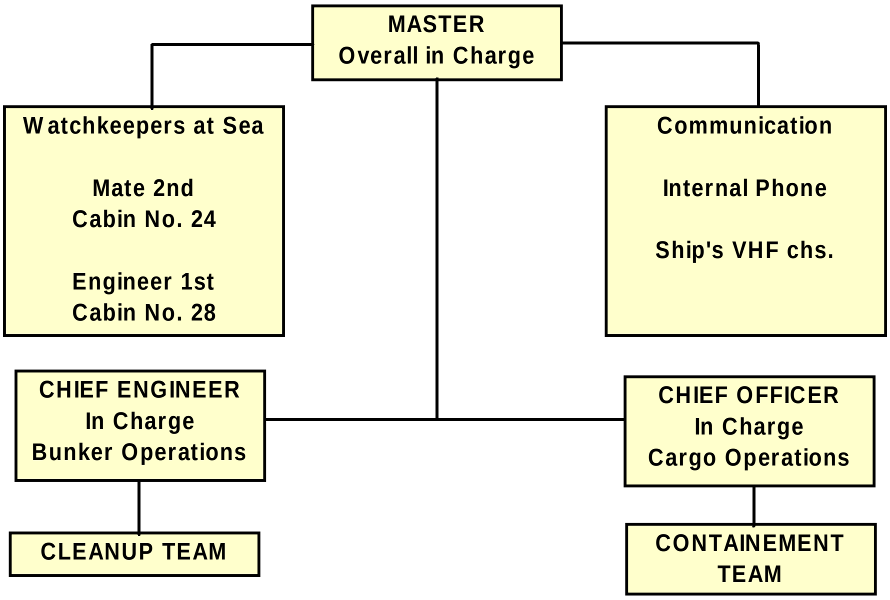
VESSEL' S POLLUTION CONTINGENCY MUSTER LIST for MT UIKKU

ACTION:

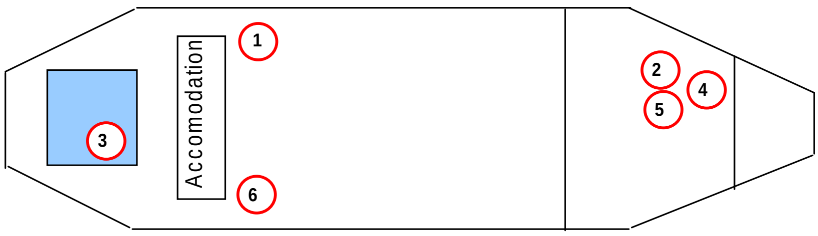
1.) IN PORT: ON ALARM SOUNDING; ALL CREW TO MUSTER AT THE COMMON MUSTER STATION
AT SEA: ALL CREW OTHERS THAN WATCHSTANDERS TO MUSTER AT THE COMMON MUSTER STATION

2.) STOP OR MINIMISETHE SOURCE OF POLLUTION AND NOTIFY THE RELEVANT AUTHORITIES

3.) INITIATE THE CLEANUP RESPONSE



EQUIPMENT LIST:



1 Absorbent
2 Portable Pump
3 Liave
4 Portable Wilden Pump with hoses
5 Floating "Oil Booms"
6 Fixed line Draining Pump

Tab. 4.3a Muster List of MT UIKKU

VESSEL' S POLLUTION CONTINGENCY MUSTER LIST for MT UIKKU (cont'd)

ALARM:

THE GENERAL FIRE ALARM TO BE USED
CONTINUOUS OR INTERMITTENTENT RINGING OF THE ALARM BELL

IMPORTANT TELEFON NUMBERS:

1..................................		or	
2..................................		or	
3..................................		or	
4..................................		or	
5..................................		or	

Additionally, on arrival all relevant contact numbers for the duration of the vessels stay in port should be obtained displayed at the cargo control room and/or bunker station, bridge, engine room and other locations

RESPONSIBILITIES

1 COMMUNICATION
Notification to all concerned authorities should be made by the fastest available channel of communication

2 CONTAINMENT TEAM
Carry out emergency procedures to stop or minimise the source of spill, by operating pumps, valves etc. Where oil has spilled into the water, all effort will be made to limit the extent of the spill by ringing around the ship, temporary booms made from, for example, old mooring ropes, air filled hoses etc.

3 CLEANUP TEAM
Carry out emergency cleanup procedures using all available proper material on

REMEMBER

1 The oil should never be wasted overboard

2 Chemicals should not be used unless authorized, to treat oil already in the water as this could contravene local regulations

3 Danger of fire exists until the cleanup is completed and every precaution to this effect must be taken

LOCATION OF CLEANUP GEAR

	ABSORBENT or SAWDUST DISPERSANT Quality Type + Qty DEGREASANT liav of 800 l aft
1. Cargo Manifold	sawdust
2. Bunker Manifold	sawdust
3. Stores	sawdust
4. Portable Pumps located:	Fwstore portside

Tab. 4.3b Muster List of MT UIKKU (cont'd)

VESSEL' S POLLUTION CONTINGENCY MUSTER LIST for MT UIKKU (cont'd)

CONTAINMENT / CLEANUP TEAM	
RANK	**DUTY**
MASTER	Informs terminal, agent and local P&I Club representative. Keep everyone updated at regular intervals of any changes in status of the vessel. Request assistance as deemed necessary. Co-ordinates with Ch.-Officer how to prevent additional damages
CH.-OFF.	Runs the deck operation from cargo control room. Shall keep Master informed and updated on the situation and the results of steps taken to limit outflow by using pumps/valves or if possible isolation of damaged tank(s).
1st OFF.	**On duty**: Alerts and informs Chief Officer of the situation. Overflow - opens up to empty or slack tanks. Mobilizes off duty deck hands as necessary. **During operations:** Keeps contact with Chief Officer and takes care of safety on deck. Checks Ex.gases, oxygen and that there is no danger of ignition. Runs operation with 2nd Officer.
2nd OFF.	**On duty**: Alerts and informs Chief Officer of the situation. Overflow - opens up to empty or slack tanks. Mobilizes off duty deck hands as necessary. **During operations:** Keeps contact with Chief Officer and runs operations on deck with 1st Officer.
CH. ENG.	Runs the engine room operations Organizes use of oil spill detergent. As Fire Chief in charge of possible fire fighting
1st ENG.	Assists Ch.Eng. Operates fire and foam pumps as required Checks engine room bilge and tank soundings Operates Inert Gas Plant as required.
PUMPMAN	Limits outflow by operating valves manually as/if required. Ensures that air driven (Wilden) pumps are properly rigged and that there is sufficient air pressure on deck. Responsible for recovering oil by operating the air driven pumps. Assists Chief Officer as required.
BOATSWAIN A.B. A.B.	**On duty**: Alerts immediately by all possible means if oil leakage is detected. Inform Officer on duty immediately Opens valves from air driven pumps to slop tanks or an available emty or slack tank and starts pumps as/if required. **During operations:** Prepares for cleaning up with sawdust. Prepares for cleaning up with Nescleaner and Liav 230 as/if required.

Tab. 4.3c Muster List of MT UIKKU (cont'd)

4.2.2 Precaution Measures during the Loading Process

a) *Precaution measures on board of the vessel*

The ship was prepared for loading in all respects according to the international practice and regulations including also enhanced safety and operational precautions considering operation in Arctic conditions.

- All emergency and fire equipment was in position, clearly marked and ready for use.
- The persons involved in the cargo operation were briefed regarding the cargo to be loaded and the hazards.
- All persons involved in the cargo- and deck operations were equipped with the relevant protection gear.
- The deck was clean from obstructions, watertight doors were kept closed, scuppers blocked, emergency pumps ready for operation.
- Before loading the international “Ship-Shore Check List” according to the ISGOTT (International Safety Guide for Oil Tankers and Terminals, last edition) was completed and countersigned by both parties.
- There was a 24 hours deck watch for the ship’s safety and to supervise the successful performance of the of the loading operations.

b) *Watch organisation on the shore site*

- A continuous watch was organised at the pump station in Sabeta and at the end of the pipeline at the „loading terminal“ in order to control the cargo pumping capacity, pumping pressure and to be on duty for emergency readiness.
- A duty motor vehicle was used for periodical supervision along the approximately 4 km long pipeline between the shore facilities (pump station) at Sabeta and the loading ice-terminal respectively the ship.

c) *Communications between ship and shore*

- Operational communications: VHF radio
- Emergency communications: VHF radio
- Wireless connection between Ship and Shore
- Priority language used between ship and shore personnel: Russian
- Translation Russia-English-Russian
- 24 hours availability of the Ice-Pilot and the Russian Radio Officer on board the ship

d) *Other precaution measures*

Special precaution measures for preventing accidental oil spillage and leakage especially into the ice free water and on ice surface should be taken during loading operations.

These measures include as follows:

- During loading of tankers in ice conditions the cargo hoses are used for ship to shore cargo pipelines connection. Loading operations should be carried out under permanent observations the hoses in order to prevent any oil leakage.

- Hoses and pipelines shell be manufactured out of materials retaining their specification characteristics at open air temperature of -30^{o}C. The hoses should be of sufficient length to avoid over-stressing and to compensate for possible movement of ship during loading operations.

- All the joints of hoses and pipelines used for the transportation of oil or gascondensate from ship ashore and vice versa should have capacities to collect probable spillages.

- Loading hose should be properly balanced by the lifting gear to avoid chafing and kinks. The minimum bending radius should be not less than 6 nominal bore of the hose (in accordance with the recommendation of ICS and OCIMF).

- During loading operations the ship to shore communications should at all time be in satisfactory working order for immediate suspending of all operations in cases that can lead to oil spillage.

- For safe cargo loading operations it is necessary regularly to check the pipeline and hose pressure in addition to the estimated quantity of cargo loaded. Any drop in pressures or any marked discrepancy between tanker and ashore estimates of quantities could indicate pipeline or hose leaks and require that cargo operations be stopped until investigations have been made.

- Procedures for protection of environment under accident ice conditions should be included into the complement of "Shipboard Oil Pollution Emergency Plan" (SOPEP) by sections taking into account the peculiarity of ice navigation.

4.2.3 Recommendations for the Improvement of the Environmental Safety for the Ship Navigation in Ice and Loading Operation

From the experience made during the ARCDEV voyage in April-May 1998, it is proposed to take the following minimum requirements into account:

- Improvement of the efficiency of the communications
    - VHF-radio link (one additional set for redundancy)
    - Use of a portable satellite telephone on the shore to be considered also as a future option for emergency communication
- Improving the communications' reliability for carrying out cargo operations and completing the relevant documentation:
    - Improving the understanding between ship and shore personnel during cargo operations. So far the Russian ice pilot and the radio officer on board the foreign ship have served as interpreters. They are not necessarily specialised in oil tankers and terminals operations and in case of emergency situation misunderstandings may possibly occur during the translation.
    - A translator or interpreter familiar with the terminology of oil tanker and terminal operations should assist the communications between ship and shore during the loading operations and the completion of the official cargo documents as well.
    - For correct understanding and completion of the International Ship-Shore Check List according to the **ISGOTT** (International Safety Guide for Oil Tankers and Terminals) it should be officially translated into Russian language and the translation should be attached to the check list. An other option is the preparation of an official two languages Ship-Shore Check List.
- Improvement of watch procedures
    - A round the clock shore watch should be established at the loading terminal site respectively near to the ship for operational and safety procedures (inspection of flexible hoses, leakage control, de-icing of valves, to give the alarm for stop pumping in emergency case, etc.).
    - For continuous watch at the loading terminal site by shore personnel a shelter should be provided. The electric power supply could be provided from the tanker.
    - A duty motor vehicle equipped with VHF radio for periodical inspection of the approximately 4 km long pipeline should be foreseen.
    - Sufficient flexible hoses in number and length should be provided in order to avoid a small bending radius during handling. Too short flexible hoses between the ship's manifolds and the shore pipeline ends may often experience tension, which may cause leakage of cargo at the connections.

- According to the international practice and regulations the loading terminal on the ice is a part of the oil terminal onshore and therefore under the responsibility of the shore personnel and not of the ship's crew. Thus operational and environmental safety actions therefore should be carried out at first by the shore personnel themselves.

- It is recommended for oil tankers to carry out regular ballast water change before entering the Western Siberian ports for deballasting and loading their cargo.

  - Recovery device (scraping device, pumps, hoses, absorbents and sludge tanks of sufficient capacity should be available close to the terminal.

  - For cleaning up the spilled gascondensate: adsorbents as sawdust or other appropriate material, mechanical means for cleaning the contaminated ice-surface and snow as spades, shovels and proper tight containers for its collection and transportation should be provided at the terminal site.

  - Four-wheel drive trucks, tracked vehicles, crane vehicles, caterpillar track and fire-fighting truck as well as fire extinguishers should be on stand-by at the terminal site.

  - At the terminal the valves between pipeline and hoses should be insulated and kept warm to avoid freezing.

  - Responsibilities

    - Ship's deck watch is responsible for combating the part of the spill, if any, on the ship's deck according to the Ship's Oil Pollution Emergency Plan (SOPEP). For the „loading terminal" an „Oil Spill Contingency Plan" should be available.

    - In case of a spill, the crew has to meet their obligations according to the Ship's Response Plan with the highest priority.

    - The crew may assist the shore personnel only, if it is possible at all under certain emergency circumstances, but nevertheless their main obligation is to be responsible for the ship's safety.

    - The personnel working at the shore site respectively terminal is responsible for the terminal's safety.

    - Equipment at the terminal site should be provided for the personnel working at the shore site respectively the loading terminal.

  - If burning of gascondensate is unavoidable, this should not take place in the dangerous vicinity of the oil tanker and terminal.

According to the operational practice in the Russian Arctic, the icebreaker is on a stand-by close to the tanker, when she is alongside the ice terminal.

- For enhancing the icebreaker’s preparedness for assisting the loading terminal in oil pollution prevention operations additional appropriate equipment should be provided on the icebreaker.

- For the future benefit of both parties the oil tankers and the oil terminals representatives of the Russian Environmental Authorities could assist the monitoring of the environmentally safe cargo operations until more sophisticated loading facilities will be established in the Arctic.

5.0 OIL SPILL COMBAT PLAN FOR THE TANKER

5.1 GENERAL

A combat plan is necessary for the „tanker“ and should be available to be prepared in any emergency case or accident at the terminal site. The facilities of the actual loading terminal are of low technical standard and improvements are required for more safety operations in the future. Regarding the SAYBOLT Certificate at least primitive mechanical means, e.g. shovels, pumps etc. should be provided as combat device to be prepared if small quantities of gascondensate spill on the ice or snow surface . After collecting the residue in suitable containers it could be transported away from the area to larger residue- or sludge tanks or even to recycling facilities if necessary.

In case of impossible response an oil spill by means and reserves of crew of the ship which is a source of the spill and taking into consideration impossible usage of special ships being under control of Regional Marine Rescue Salvage Centres for oil skimming from the sea surface in real ice conditions it is necessary to contact the icebreaker escorting the ship for help in oil spill recovery actions.
In this connection an icebreaker is to be additionally equipped by arrangements for oil spills recovery and the icebreaker’s SOPEP should be reviewed with respect to her participation in actions connected with oil spills fighting.
Except for equipment and materials intended for usage during own emergency oil spills recovery ice breaker is to be equipped by arrangements for skimming of spilt oil from sea surface and boom defence for localisation of oil spill.
Icebreaker’s SOPEP is to be added by a section stating actions of the icebreaker connected with recovery operations in case of emergency oil spill from escorted ship.
Upon discovery of oil leakage during cargo handling operations on tanker or upon receiving a report from tanker about an incident concerned with oil leakage into the sea following actions are to be taken onboard the icebreaker (see Tab. 5.1).

ACTIONS TO BE TAKEN	RESPONSIBLE PERSON
Sound emergency alarm with the kind of alarm and spillage location being indicated	Officer on Duty
Start the fire pump and prepare for operation the foam smothering system, equipment designed for boom defence disposition and skimming the oil from sea surface	Officer on Duty Chief Engineer
Go to the tanker or to the place of oil leakage as close as possible	Master
To prevent the spilt oil being spread over a large surfaces arrange boom defence	Chief Officer Chief Engineer
Help the tanker to recover the oil leakage source	Master
Inform the shore authorities and ship owner of the incident after permission by Master of the tanker	Master
Begin skimming spilt oil from sea surface by arrangements available on board of the ship	Chief Officer
Should oil catches fire it will be handled under the Ship’s Fire Plan	Chief Officer
Make a relevant statement in the Ship’s Logbook	Officer on Duty

Tab. 5.1 Action Plan for the Icebreaker

Upon discovery of oil leakage from cargo loading manifolds during cargo handling operations and also in case of oil tank overflows following actions according Tab. 5.2 are to be taken.

ACTIONS TO BE TAKEN	RESPONSIBLE PERSON
Sound emergency alarm with the kind of alarmed spillage location being indicated	Officer on duty
Cease the operation	Chief Officer
Start the fire pump and prepare the foam smothering system for operation	Engineer on duty
Organise scooping of oil spilt upon the deck or ice and take every measure to avoid oil discharge into the sea	Chief Officer
Keep watch over the water surface and if an oil slick is detected to inform the shore authority	Officer on duty
If oil has been spilt to the sea then to prevent it being spread over a large surface arrange, if the weather conditions permit it, containment of the oil slick with a synthetic rope or with boom defence	Chief Officer
If oil spillage cannot be recovered by the ship's crew with the use of shipboard facilities request assistance of a surface skimmer	Chief Officer
Assess the quantity of the oil spilt and size of the oil slick	Chief Officer Chief Engineer
Should oil catches fire it will be handled under the ship's Fire Plan;	Chief Officer
Should cargo tank overflow occur transfer of excess oil from the overflowed tank to an empty or slack tank, or to shore should be made	Chief Engineer Chief Officer
Record the composition and number of staff and equipment involved in dealing with the oil spill in harbour waters and the time spent	Officer on Duty Chief Officer
Make a relevant statement in the Ship's Logbook and Oil Record Book	Chief Officer Chief Engineer

Tab. 5.2 Action Plan for the Tanker

During the ARCDEV expedition observations were made with respect to the peculiarity of loading operations and measures concerning the prevention of pollution. The evaluation was carried out for eventual conditions and places, where operational oil spill is most likely to occur and with respect to the sufficiency of the composition of ship’s equipment for the environmental protection. The ship operation and the cargo handling in the Arctic area have a series of peculiarities involving:

- use of ships in severe ice and weather conditions such as low air and sea water temperature, strong winds, currents, restricted visibility in winter etc.
- sailing in convoy and operations with icebreaker assistance
- small number of ports and places where special salvage units and oil spill response equipment are located
- difficulties in approaching ships in case of emergency and with respect to oil recovery actions
- loading operations under conditions where no sufficient infrastructure exists

The above mentioned peculiarities may cause additional oil pollution emergency situations. During the ARCDEV expedition the use of unsophisticated shore loading appliances resulted in the low loading speed because of:

- small diameter cargo pipes
- relatively long distance of about 4 km between shore tanks and the ship
- low capacity of shore pumps
- cleaning up and blow-through of pipes at the end of loading consumed considerably time

From observations made during the loading process it can be summarised:

There were no damages of hoses or steel pipes, no leakage through joints between individual sections. A sludge basin having a volume of 1.2 m^3 was installed underneath the valves between hoses and shore pipelines to collect probable spillages in the process of hose-pipe connection operations. The precaution measures taken by the ship's and a shore personnel for the prevention of probable oil spills were sufficient. Therefore, there was no accidental oil outflow during loading of tanker.

However, it should be noted that the locations where loading operations occur are almost far away from the maritime rescue co-ordination centre, where special salvage units are located. Due to long distances as well as severe and dangerous ice navigation conditions rescue and clean up operations are difficult.
The minor oil spills due to operations, caused by damages of hoses or leakage through joints between individual sections or e.g. by the tank overflow during the cargo handling and bunkering operations should be eliminated, as a rule, by the ship's crew in accordance with the "SOPEP" for the following cases of operational spillage:

- tank overflow and pipe leakage with oil spilled upon the deck

- cargo pipe leakage into the ice free water near the board of ship

- cargo pipe leakage with oil spilled upon the ice

In the case when oil spillage cannot be recovered by the ship's crew using shipboard facilities, in general the SOPEP provides for the call of oil skimmer. However, this may lead to difficulties, because special oil recovery equipment for ice conditions is frequently not available. The clean up operations may be carried out by an escorting icebreaker, if she is provided with appropriate equipment. It is proposed, that tankers of independent ice navigation without the icebreaker assistance also should have aboard analogous technical means for combating the oil spills.
Bearing in mind the above, all icebreakers and tankers of independent navigation in ice conditions apart from the equipment specified in paragraph 3 should be provided with booms to block oil spillage and at least with portable systems for collecting and pumping oil from the sea surface and from the ice.
Accordingly, the SOPEP for the icebreaker should be completed with recommendations on measures to be taken, when a pollution incident has occurred on the escorted ship.

5.2 LIST OF RUSSIAN FEDERATION GOVERNMENTAL ORGANISATIONS AND PORT AUTHORITIES TO CONTACT

1. Contact information to transfer initial notification when the ship operates on the waterway of Northern Sea Route (NSR).

RUSSIAN FEDERATION

Marine Pollution Control and	Tel:	+7 095 926 9474/9302/9251
Salvage Administration (MPCSA)		+7 095 926 1052 (after 24 hrs)
1/4 Rozhdestvenka	Fax:	+7 095 926 9038
Moscow, 103759		+7 095 926 9128 (24 hr)
	Tx:	411197 MMF RU

Language(s) understood: Russian / English

The masters of the vessels should communicate with the following state authorities respectively institutions, which operate 24 hours:

1.	**State Maritime Rescue**	Tel:	+7 095 926 10 52
	Co-ordination Centre	Fax:	+7 095 926 90 38
			+7 095 926 91 28
		Tx:	411 197 MMF RU
2.	**MRCC Murmansk**	Tel:	+7 815 25 5 50 65
			+7 815 25 5 05 21
		Fax:	+7 815 25 5 23 93
			+7 815 25 5 54 70
		Tx:	126 113
3.	**MRCC Arkhangelsk**	Tel:	+7 818 244 7100/39968
			+7 818 243 0121
			+7 818 243 8310
		Fax:	+7 818 00 3 83 10
		Tx:	242 111

2. Contact information to inform the marine Operations Headquarters:

Dikson	Call signal "Dikson-Radio-2" on channel 16, 24 hr Satellite-communications stations Nos. 1402724, 1402723 and answer-back units MMPI (INMARSAT), 1401514 MMPA (Horizon)
Pevek	Call signal "Pevek-Radio-19" on channel 16, 24 hr Satellite-communications stations No.1400343 DUMV and answer-back unit 1402645 DUMC (INMARSAT)

3. Contact information in the ports of NSR:

Murmansk, General Director	Tel:	52 61 61
	Fax:	23 09 95
	Tx:	126167 SKALA
Hatanga, Port Manager	Tel:	21 697
Pevek, Manager of the Merchant Port	Tel:	22 473
	Tx:	145470 VOLNA
Tiksi, Manager of the Merchant Port	Tel:	52 649
	Fax:	53 469
Dikson, Manager of the Merchant Port	Tel:	4120
	Tx:	28853 PORT
Salekhard, Port Manager	Tel:	3547

4. Contact information to contact coastal states in other areas in compliance with MEPC6/Circ.3 of 20.01.98.

6.0 OIL SPILL CONTINGENCY PLAN FOR THE LOADING TERMINAL

6.1 GENERAL

Detailed source of information is required concerning oil spill response variables in the Arctic environment. Tactical measures on spill response in various ice conditions and seasonal variations and an „Incident Management System“ are important to respond successfully spill events. All measures, activities and individual operator contingency plans should be compiled in a Technical Manual which provides the detailed information to spill response.
In the current report an example of the structure of a contingency plan is presented, which refers on the Technical Manual prepared by Alaska Clean Seas (ACS). However the presented contingency plan in the current report does not claim to be complete.

The response performance is affected by variables which are almost out of control of the response organisations and could interfere with the response performance. These variables include for example:

- weather, sea conditions, visibility, temperatures
- location of spill, type of oil spill, rate of discharge
- condition of available appropriate equipment
- site-specific conditions (type of wildlife, sea mammals etc.)

It should be noted that the human health and the safety of the public is of highest importance and has to override all other considerations in response operations.

Incidents (e.g. oil spills) generally occur unexpectedly and interrupt or interfere with normal operations should be noted that the safety of humans, employees and the public is of highest importance and has to override all other considerations in response operations. Most incidents generate emergency response operations directed at protecting human life, wildlife, minimising the damage of property and maximising protection of the environment.
The goal of incident response operations is the restoration of normal operations while minimising impacts to people, property, and the environment. To achieve this goal the personnel must be able to move from a reactive to a proactive mode of operations by establishing and maintaining command and control over the incident situation.
The application of standard operating procedures allows efficiently incident response operations.

6.2 OIL SPILL RESPONSE ORGANISATION

Several teams have to be built to carry out spill response operations. Members of the teams should have predefined roles and responsibilities.

- Tactical Response Team (TRT)
- Incident Management Team (IMT)
- Crisis Management Team (CMT)

Most of the incidents happens without warning, thus the members of the different teams begin their work in a reactive mode. However the first priority for the teams (TRT, IMT and CMT) is to move to a proactive mode of operation, as quickly as possible. To co-ordinate the teams an Incident Management System is required for the establishment and maintenance of command and control over the incident, emergency response operations.

6.2.1 Tasks of the Tactical Response Team (TRT)

The main task of the TRT is the conduct of tactical response operations (e.g. fire fighting, oil spill response, medical , rescue, safety , security and wildlife protection). Each team has a Team Leader (e.g. *Fire Chief*, *Spill Chief* and *Rescue Captain*) who is responsible for the team´s response efforts during the initial stage of tactical response operations. These duties include:

- recruiting team members
- initial briefing on the incident
- ensuring that an appropriate number of properly equipped team members and amount of equipment are dispatched to the incident site in time
- tracking and providing regular updates on status of team mobilisation efforts up to their check-in at the incident site
- supervising the check-in of team members and resources at their check-in destination
- documenting initial team members assignments to the tactical response organisation

6.2.2 Initial Tasks of the On-Scene Commander

On scene the TRT comes under the control of the On-Scene Commander (OC), and Team Leaders normally assume a subordinate role in the Incident Command System (ICS). The On-Scene Commander co-ordinates the movement of TRT resources into, within, and out of the incident scene.

The primary responsibilities of the On-Scene Commander are:

- ensure that on-scene tactical response operations are carried out in a safe effective and efficient manner.
- define the overall strategy and tactics to be employed.
- co-ordinate the work of tactical response personnel.
- provide information, through the Operations Section Chief, to the IMT.

6.2.3 Site Management and Control

At the incident site the On-Site Commander must establish the site management and control. The OC should ensure that all individuals not directly involved in emergency response actions are moved a safe distance away from the incident site.
The OC and Site Safety Officer should supervise ongoing site characterisations designed to identify and quantify the chemical and physical hazards.

The site characterisation should lead to:

- A decision regarding the need for additional protection (e.g. evacuation or shelter-in-place)
- The establishment of clearly identified and demarcated hazard-control zones (i.e. hot or exclusion zone, warm or decontamination zone, and cold or support zone)
- Determination of the level of personal protective clothing and equipment
- Decontamination procedures in the warm zone

- Response personnel operating in the hot / warm zones should be:
    - Properly trained
    - Properly equipped
    - Operating with the knowledge of the OC and the OC's direct reports (e.g. fire, spill etc.)
    - Operating not without backup personnel

The OC or his deputies should be aware of all personnel entering and operating within the hot zone.

6.2.4 Incident Management System (IMS)

6.2.4.1 General

The Incident Management Team (IMT) / IMS addresses four key tasks that directly impact the organisation and management response operations:

- During the initial hours of response actions, the IMS explains what should be done to get organised and establish command and control over incident response operations.

- When command and control are established specific actions must be taken by the IMT to maintain command and control and to sustain ongoing incident response operations.

- The IMT / IMS must be prepared to engage in short-term planning, which results in the preparation of „Incident Action Plans“ as well as in long-term planning resulting in the preparation of a „General Plan“.

6.2.4.2 Establishing Command and Control

IMT emergency response operations normally are carried out by personnel working in an Emergency Operation Centre (EOC) which is geographically removed from the site where incidents may occur. When IMT personnel arrives at the incident site, tactical response operations are already underway. In a first step the IMT personnel should be getting organised (e.g. offices, space for the Command, Operations, Planning, Logistics, Finance and Communication Sections).

In most cases the Incident Management Team members come from different organisations (oil companies, contractors, specialists, government agencies etc.) and will arrive at different times. Thus, it is necessary that all individuals check-in at the Emergency Operation Centre in order to receive their assignments:

- Section-specific organisation charts should be distributed to the Resource Units
- A „Unified Command Structure“ and integrated response organisation should take shape
    - A clear chain-of-command should emerge
    - Everyone should become familiar with the Command and General Staff structure
    - Gaps in the organisation should be identified and addressed

To get the responders focussed on the incident and tactical response operations briefing meetings should be conducted covering following topics:

- Status of people impacted by and responding to the incident.
- Background information on the incident
- Nature and status of the source (controlled / uncontrolled)
- Location and status (i.e. contained or uncontained) of discharged or emitted materials
- Results of site characterisations and the locations of Hazard Control Zones
- The strategy and tactics being implemented by tactical response personnel, and tasks underway
- Incident potential
- TRT incident-specific organisational structure
- Progress being made and problems being encountered
- Additional help needed

Based on the information provided, the Incident Commander (IC) should finish by reviewing the strategic objectives and the initial actions to build upon ongoing tactical response operations.

6.2.4.3 Maintaining Command and Control

Once command and control are established, it should be maintained until the end of the operations. This tasks should be carried out by the Incident Management Team (IMT), which could be done by:

- Receiving periodic Field Reports from the On-Scene Commander (OC)
- Maintaining an Information Centre
- Continuing to hold periodic Assessment Meetings

6.2.4.4 Preparing Incident Action Plans

An Incident Action Plan (IAP) should be prepared in response to stated objectives and should primarily consist of field assignments designed to address the objectives.
An example of the Information on Incident Action Plan Forms is given in Tab. 6.1.

After approval of an IAP its implementation should begin. The plan should be forwarded to the OC for further distribution to tactical responders . In addition status reports and actual maps should be updated immediately before the beginning of the Next Operational Period (NOP).

INFORMATION ON INCIDENT ACTION PLAN FORMS (after ACS Techn. Manual Vol. 3, Incident Management System)		
	Contents	**Responsible Function**
1	"Incident Action Plan (IAP) Cover Page" provides information on fore-casted weather and general safety considerations, and a place for approval signatures	Small Team
2	Incident Objectives for the NOP	Small Team
3	"IMT Organisation and Contact Chart" provides information on personnel assignments for the NOP	Resource Unit Leader
4	"Field Assignment (IAP)" provides information to Task Force Leaders on task-specific safety and environmental considerations, the work to be performed, and assigned resources for the NOP	Small Team
5	"Field Assignment Change Sheet" provides information to Team and/or Task Force Leaders on changes made in existing field assignments for the NOP	Small Team
6	"Field Assignment Safety Message" provides information to Team and/or Task Leaders on task-specific safety hazards and mitigation measures	IMT Safety Officer
7	"Field Assignment Environmental Message" provides information to Team and/or Task Force Leaders on task-specific environmental considerations	Environmental Unit Leader
8	"Incident Communication Plan" summarizes the Command, Operations and Support Networks for the NOP	Communication Unit Leader
9	"Medical Plan" lists the resources available and procedures to be followed to deal with response-related medical emergencies that may occur during the NOP	Medical Unit Leader IMT Safety Officer
10	"Air Operations Plan" list the assignments for the fixed-wing and helicopter resources available to response operations during the NOP	Air Operations Branch
11	"Environmental Unit Summary" provides a forecast of initiatives to be taken in the following areas: wildlife, permits, wastemanagement, and other environmental matters	Environmental Unit Leader

NOP=Next Operational Period

Tab. 6.1 Information on Incident Action Plan (Example)

6.2.4.5 Preparing the General Plan

Incidents that require emergency response operations for more than a couple of days tend to be complex, resource-intensive, and costly in nature. According the Incident Action Plan a General Plan (GP) should be prepared to address objectives approved by command. The GP should identify the major tasks , i.e. emergency response operations, duration of tasks, major equipment and personnel resources. After approval of the GP , it should be implemented on a day-to-day basis until the end of emergency response operations. The General Plan , which should be updated daily, could be used as a basis for all subsequent Incident Action Plans.

6.3 DESCRIPTION OF VARIOUS OIL SPILL RESPONSE METHODS WITH RESPECT TO THE ICE LOADING TERMINAL IN SABETA

6.3.1 General

On May 4th, 1998 the convoy reached his destination at 71° 18.2' N and 072° 8.6' E about 2 Nm off-shore Sabeta. First IB DRANITSYN prepared a berth for MT UIKKU in the landfast level ice of about 1 to 1.2 m thickness. After finishing the ice harbour preparation IB DRANITSYN removed to a stand-by position of about 10 ship lengths behind MT UIKKU.

Two steel pipelines from shore to the "loading terminal" along an ice road have been already prepared and were connected with flexible hoses to the manifolds of MT UIKKU. The flow rate of the gascondensate was about 185 m^3/hr. The loading capacity of MT UIKKU is about 16,000 tons. The loading was finished on May 8th and MT UIKKU left Sabeta at 05:20 UTC.

6.3.2 Description of the Loading Terminal

The "loading terminal" as well as the onshore pump station and tankfarm is documented by images taken from accessible areas, which were not off limits. The images are compiled in the image gallery in ANNEX 3A-I. In the following only selected images are presented.

(←Fig. 6.1) „Ice harbour" respectively berth of MT UIKKU prepared prior by IB DRANITSYN

The brown colour of the water is due suspended sediments, because the water depth at the berth is about 8 to 10 m.

(HSVA)

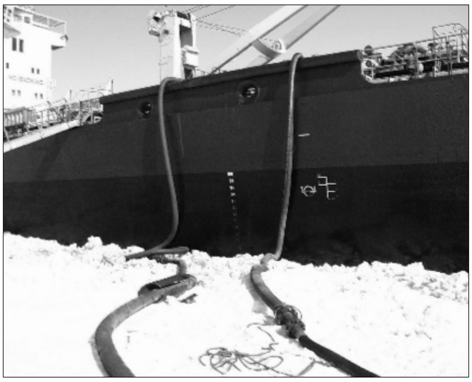
(← Fig. 6.2) "Loading Terminal"

Snow covered landfast level ice. The snow thickness is about 30 cm. The surface of the ice is relatively smooth. The steel pipelines have been laid directly on the ice surface without any foundation and were mostly covered by drifting snow. At the end of the 4 to 4.5 km long steel pipelines hand driven valves were installed where the hoses from the tanker have been connected. A cylindrical storage tank of about 40 m^3 was set right beside the slush basin (2.5 x 1.2 x 0.4 m).
(HSVA)

(← Fig. 6.3) Hoses connected to the hand driven valves of the pipeline

A rectangular slush basin (2.5 x 1.2 x 0.4 m) is foreseen to collect any leakage from the valves during the pumping process.

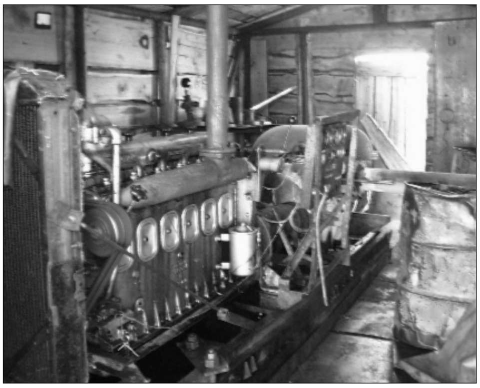
(HSVA)



(← Fig. 6.4) Connection between end of pipeline to the manifolds of MT UIKKU

The hoses should be hauled in straight line (like the right hose in the picture) in order to avoid kinks.

(HSVA)



(← Fig. 6.5) Stationary Pump (Type Y8-MA2)

The gascondensate is pumped with a stationary pump Type Y8-MA2 through the pipelines of 102 mm diameter (4 in) and 152 mm diameter (6 in).
The working pressure is about 40 bar.

(HSVA)

(← Fig. 6.6) The onshore Pump Station

It is proposed to clean the hoses and pipes from snow. A sludge tank underneath the valve is strongly recommended.

(HSVA)

(← Fig. 6.7) The onshore tank farm

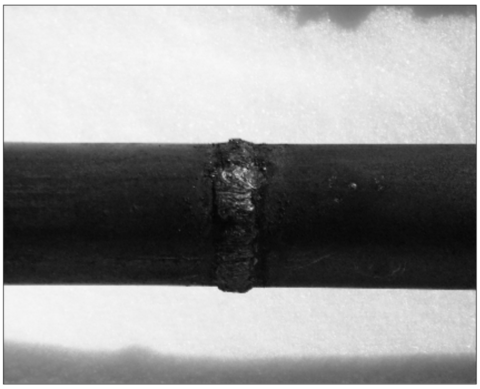
Due to low temperatures icing of the hull of the storage tanks occurred.

(HSVA)

(← Fig. 6.8) Truck transferring the tubes of the pipeline

This truck could also be use as a dump truck for oiled snow, however the loading capacity is little.

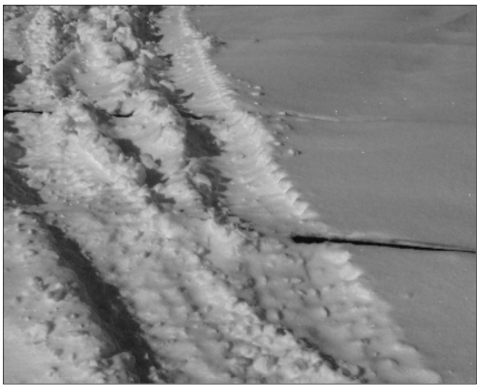
(HSVA)



(← Fig. 6.9) Welded steel pipeline

The single tubes of the steel pipeline are either welded or fixed together by couplings.

(HSVA)



(← Fig. 6.10) Steel pipeline partly covered with drifted snow

The picture shows tracks of chain driven vehicles.
It is recommended to mark the pipeline alignment with flags in order to avoid damages by heavy vehicles.

(HSVA)

(←Fig. 6.11) View on the main deck of MT UIKKU

The picture shows the manifolds and the two blue hoses leaving the deck on starboard side to the "Loading Terminal".

(HSVA)

(← Fig. 6.12) View on the main deck of MT UIKKU

The picture shows the fire gun on the main deck.

(HSVA)

(← Fig. 6.13) Floating oil booms stored in the forecastle of MT UIKKU

The picture shows the floating oil booms, which are about 400 m long.

(HSVA)

A more detailed image gallery of the loading terminal is presented in ANNEX 3 A-I.

6.3.3 Bearing Capacity of the Ice

When working on ice one have to make sure that the ice thickness is known. Concerning the bearing capacity, Vaudrey (1977), estimated the sea ice thickness to support loads taking different parameters (e.g. ice temperature, physical properties, time of load application etc.) into account.
In Fig. 6.14 and Fig. 6.15 curves of recommended ice thickness versus load are shown for sea ice and freshwater ice respectively.
Fig. 6.14 applies to operations on a continuous undisturbed free-floating ice sheet. Small surface cracks in the ice sheet due to thermal stresses are negligible. However for wet "active" cracks where they join to form a wedge the risk of breaking through becomes acute.
If there are any doubts concerning the bearing capacity of the ice sheet vehicle operations should not focus on local points until the integrity of the ice is determined.
Travel over unprepared sea ice incurs risks due to the nature of the ice material and unpredictable environmental factors (e.g. warm temperatures, hidden cracks, under ice currents etc.). In the past vehicles have gone through the ice with no warning, even when operating within conservative guidelines. Thus an experienced technician should accompany vehicles moving over unprepared sea ice.
Fig. 6.14 applies to moving loads and/or short term parking up to about 5 hours. The thickness shown in the diagram are not adequate for extended storage of heavy loads. The curves are based on recommended bearing capacities developed for wheeled vehicles and aircraft. Tracked and terra-tired vehicles may be able to operate safely over thinner ice sheets early in the winter by distributing the load over a greater area, to reduce the pressure on the ice.
Approximately 50 cm of sea ice is recommended as a starting ice thickness to begin conventional vehicle operations with wheeled vehicles such as small truck. Lighter equipment like ditchwitches and snowmachines can operate on ice 30 to 50 cm thick. For workers to be sent out on the ice, the thickness should not be less than 30 cm.

Early season operations require strict safety measures, continuous ice monitoring and evacuation plans. Rapid break-up of young sea ice can occur due to increasing strong winds. Heavy equipment operations on ice less than 30 cm thick is limited to areas with shallow water less than about 1.5 m in depth.

For planning purpose the required ice thickness can be estimated :

Sea Ice Thickness:

Required Ice Thickness $\cong 16.2 \times \text{Load}^{(0.4985)}$ (Winter: January to mid April)
Required Ice Thickness $\cong 67.7 \times \text{Load}^{(0.2666)}$ (Spring: mid April to late May)

Freshwater Ice Thickness:

Required Ice Thickness $\cong 13.6 \times \text{Load}^{(0.5455)}$

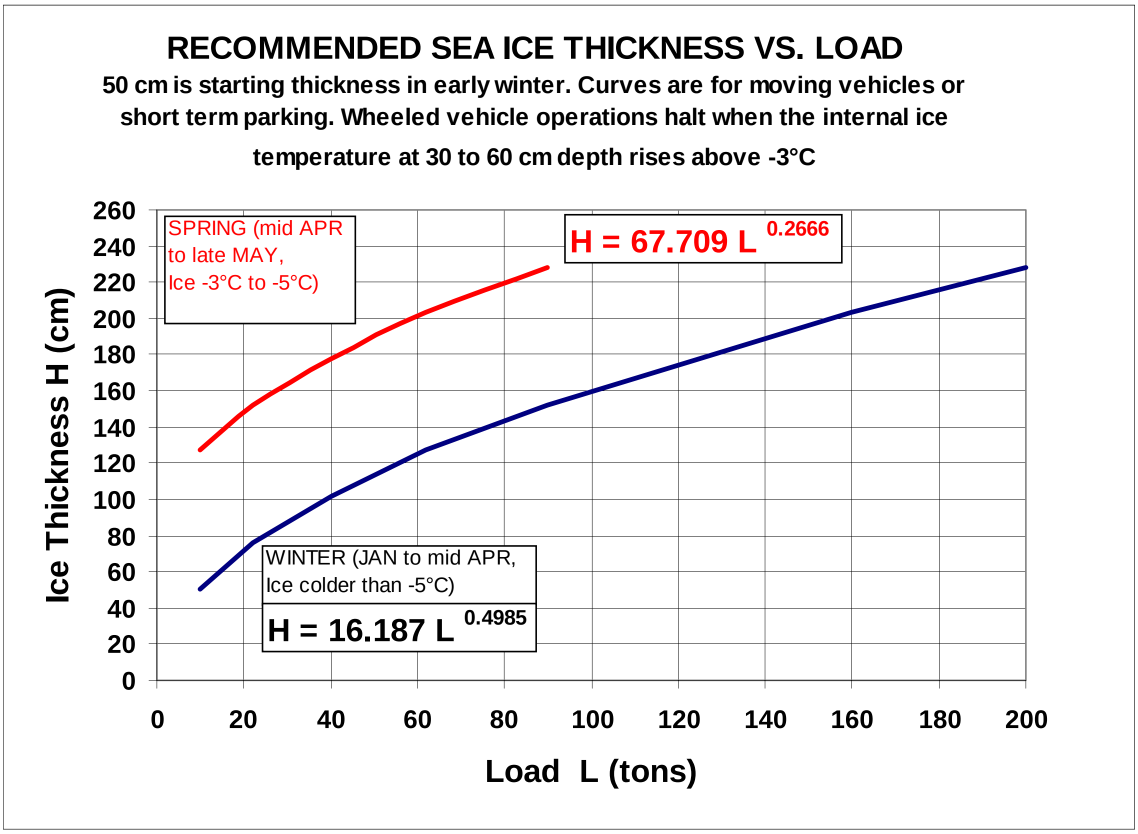


Fig. 6.14 Recommended Ice Thickness vs. Load on Sea Ice

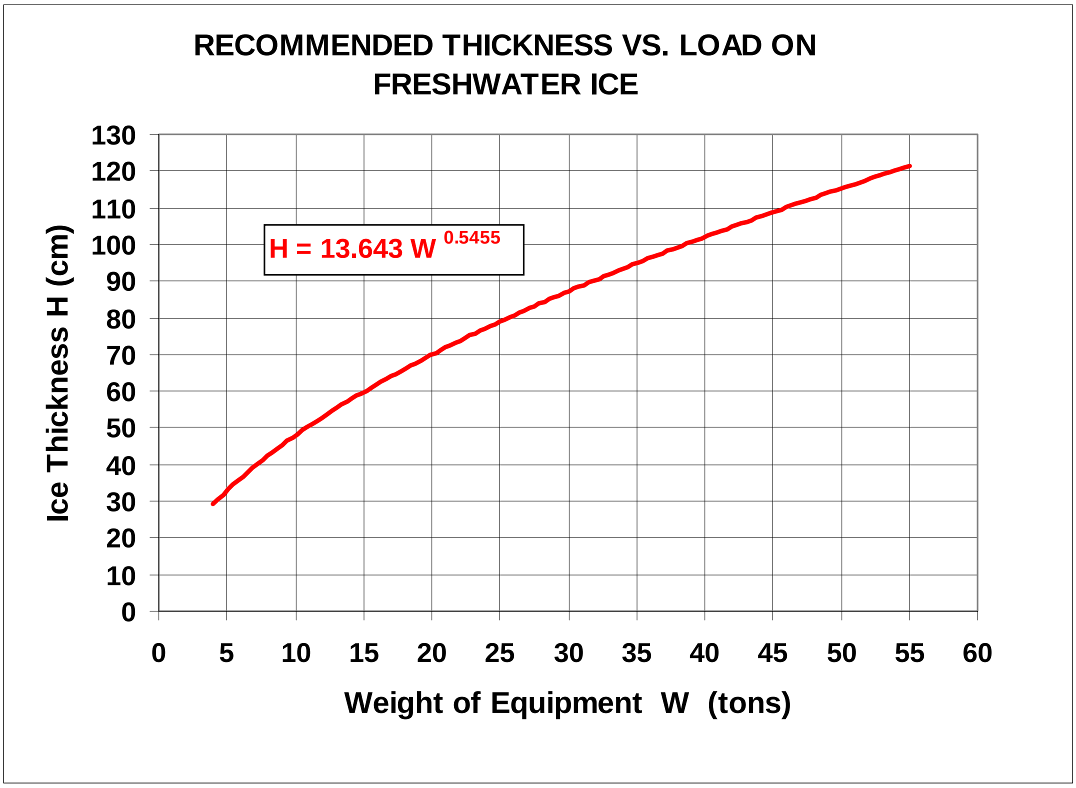


Fig. 6.15 Recommended Ice Thickness vs. Load on Freshwater Ice

6.3.4 Oil Recovery Device and Methods (State-of-the-Art)

Since the mid 1970s, extensive research has been directed at developing methods removing oil from ice. Although many programmes have been initiated only few commercial devices or widely accepted methods have resulted. A literature search of technical reports and conference papers on the recovery of oil in ice has been carried out. The relevant publications are compiled in ANNEX 2.
In addition a list of different oil recovery equipment and methods like:

1. Disc and drum skimmers
2. Rope mop skimmers
3. Sorbent belt skimmers
4. Submerging plane skimmers
5. Vacuum skimmers
6. Weir skimmers
7. Combination skimmers and other concepts

has been prepared and is summarised in Tab. 6.2.

SUMMARY OF MECHANICAL OIL RECOVERY EQUIPMENT CAPP-TFOSP/TR 92-02				
	Type		**Ice Type**	**Development Potential**
		Disc / Drum		
1	**Elastec**	**Drum**	**small pieces, untested**	**medium**
2	Framo	Drum	slush, no large chunks	low
3	IOOET	Disc	small ice forms	low
4	Lockheed Clean Sweep		broken ice up to 0.2 m thick, 2 m diameter	low
5	Morris	Disc	broken ice may prevent oil flow into skimmer	low
6	Porous Drum	Drum	brash ice, small ice pieces	low
7	**WP-1**	**Drum**	**small ice pieces , brash ice**	**high**
		Rope Mop		
8	**Arcat II**	**Rope Mop**	**smaller ice pieces, ice edges, optimum recovery in < 5/10, transit in up to 9/10 decaying ice**	**medium**
9	**Foxtail V.A.B.**	**Rope Mop**	**wide range of broken ice conditions**	**high**
10	**Rotating Brush-Rope Mop**	**Rope Mop**	**smaller ice pieces, ice built-up may occur**	**medium**
11	IOOET Mop	Rope Mop	small, thin ice pieces	low
12	Oil Mop Arctic	Rope Mop	40 cm ice, <5/10 ice cover	low
13	Oil Mop Dynamic	Rope Mop	light ice, floes, larger pieces may catch prow	low
14	Oil Mop (Mark Series)	Rope Mop	cracks/leads, broken ice fields, slush ice, on top or below ice	low
15	Oil Mop Remote	Rope Mop	smaller ice pieces, brash ice	low
16	OSI Brill	Tube	broken ice, threaded beneath solid ice cover	low
17	SWAMP	Rope Mop	smaller ice pieces, between floes	low
18	**Vertical Mop Wringers**	**Rope Mop**	**large range of ice conditions**	**high**
19	Puller Wringers	Rope Mop	broken ice, limited by working platform to transit ice	low
		Sorbent Belt (SB)		
20	Marco Class I Harbour	SB	broken ice field of moderate sized ice, slush ice	low
21	Marco Class V Ocean	SB	small ice forms	low
22	Slicklicker	SB	large quantities of chunk ice	low
23	ZRV Sorbent Belt	SB	small ice forms will pass under belt but no ice/oil separation	low
		Submerging Plane (SP)		
24	Bennett MK 3	SP	limited application to broken ice cover	low
25	JBF DIP	SP	not suited to oil in ice	low
26	LPI	SP	small ice pieces	low
27	Porous Plane	SP	may apply to brash mulched ice, not suited for use in large floes	low
28	Versatile (Bennett) Arctic	SP	ice free leads	low
		Vacuum (V)		
29	Under-ice Vacuum	V	under ice operation	low
30	**Vacuum**	**V**	**small ice pieces, best suited for use in open leads and rafted ice pools**	**low - medium**
	Weir / Screw Auger (SA)			
31	Destroil (Screw Auger)	SA	small pieces, oil collection in brash, frazil or mulch ice results in high water content	low
32	Halliburton FRU	Weir	potential use in light ice, jamming might be a problem	low
33	Oil Skimming Bow		variety of ice forms	low
34	PEDCO	Weir	operation in slots cut through the ice cover minimal ice processing ability	low
35	Soviet Harbour	Weir	brash and mulch ice	low

File:OILRECOVERY.XLS

Tab. 6.2 Summary of Oil Recovery Equipment

SUMMARY OF MECHANICAL OIL RECOVERY EQUIPMENT (cont'd) CAPP-TFOSP/TR 92-02				
	Type		**Ice Type**	**Development Potential**
	Concepts and Combinations			
36	**Arcticskim (Deflector and Skimmer)**		**ice in deflectable sizes (brash, frazil), large ice floes could damage deflector**	**medium**
37	Bulk Removal		ice large enough to be moved by I-beam	low
38	Clowsor (Paddle/Ramp)		ice would raft at bottom of ramp, small ice pieces may be drawn up by paddles	low
39	Little Giant (Conveyor)		capable of collecting ice pieces that are block-like in form	low
40	**Lori Ice Cleaner (Brush)**		**operates in extensive ice thickness and cover and in range of broken ice conditions**	**medium - high**
41	**Transrec (Disc/Belt/RopeMop)**		**between ice floes, operation possible but less efficient in small ice forms**	**low - medium**

File:OILRECOVERY.XLS

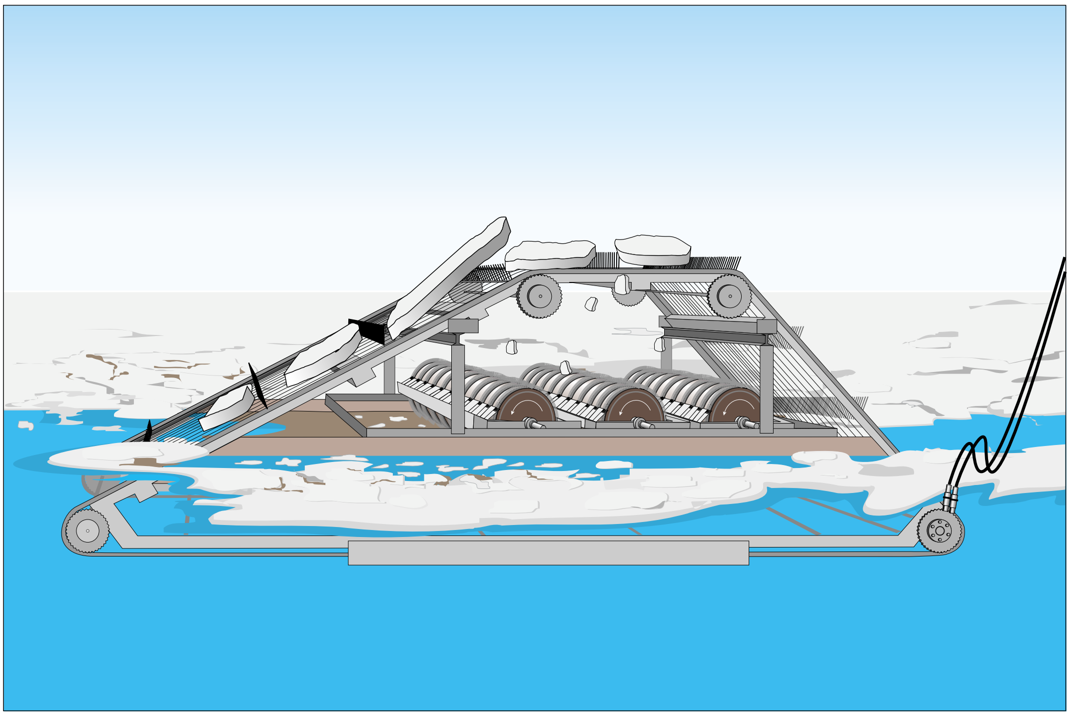
Tab. 6.2 (cont'd) Summary of Oil Recovery Equipment

From the systems summarised in the Tables the rope mop skimmer represent the most versatile approach, because they can be easily deployed from vessels and can be readily positioned in oil in ice.
The disc/drum skimmers can be used most effective in low currents and calm water.
Ice processors and deflectors could be applied to belt, weir and disc skimmer in order to enhance the performance.

Comprehensive tests on mechanical oil recovery systems like the Lifting Grated Belt and a Brush/Drum Skimmer and combinations of them have been carried out in HSVA's Arctic Environmental Test Basin under the TMR-Programme "Access to Large Scale Facilities" of the European Commission DG XII .

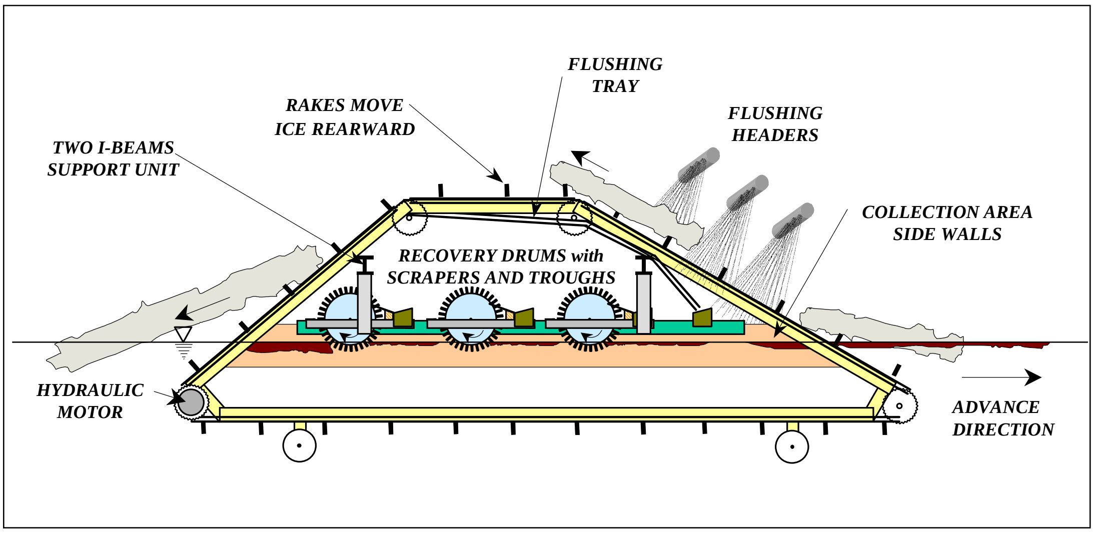
Fig. 6.16a-b and 6.17 show the Lifting Grated Belt (LGB) under test conditions. Broken ice pieces of about 20 cm thickness, which are oil contaminated, are transferred by a conveyor underneath a flushing system in order to clean the ice from the oil. However the cleaning effectiveness is reduced, if the ice is contaminated with high viscous oil.

"An oil recovery unit may then recover oil contained in the collection area. In the present phase, an oil recovery unit for the LGB collection area consisting of three small brush/drums was used for the first time. Other oil recovery units may be considered for use under the LGB. In this unit, as oil passes from the front to the rear of the collection area due to the action of the rotating brush drums, oil adheres to and is lifted by each drum. The oil is then scraped off, slides into the drum's respective trough and is subsequently sucked out by an air conveyor and transferred to a separate collection barrel" (Jensen, 1999).



Courtesy of SINTEF, Norway

Fig. 6.16a Principal Sketch of the Lifting Grated Belt Oil Recovery Device



Courtesy of SINTEF, Norway

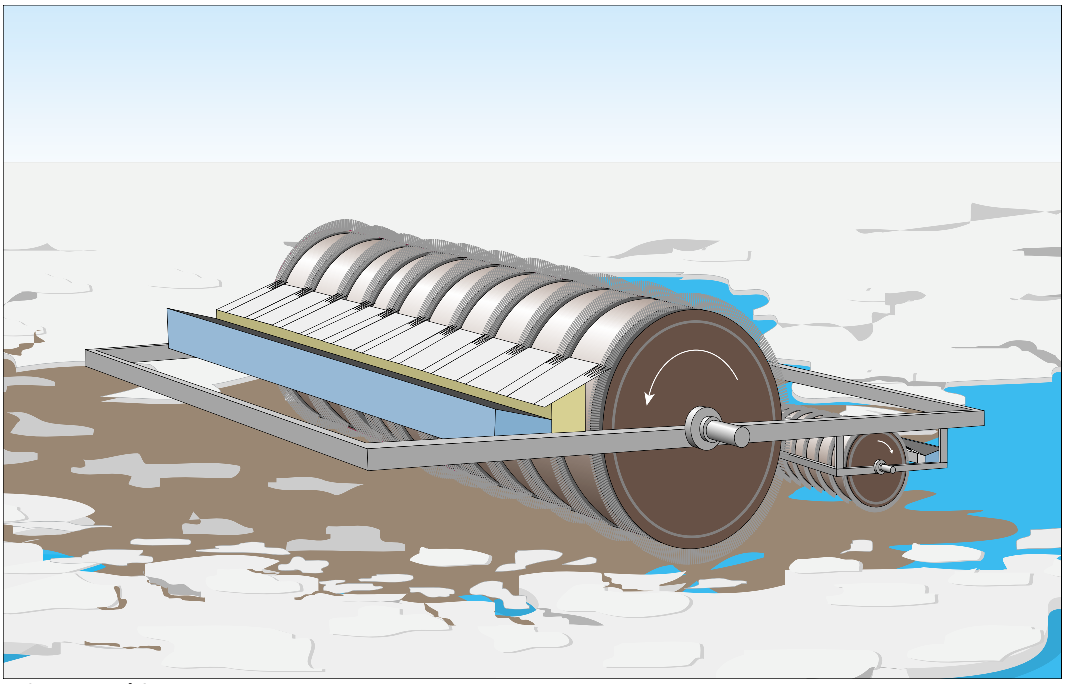
Fig. 6.16b Principal Sketch of the Lifting Grated Belt Oil Recovery Device

Fig. 6.17 Lifting Grated Belt (LGB) Oil Recovery Device with Flushing System (tested in HSVA's *Arctic Environmental Test Basin*)

"The brush/drum concept includes a range of combinations of the brush and the drum principles, both of which are widely used in oil recovery operations.
In this concept it was tried to combine the advantages of each principle to produce a unit suitable for ice conditions. The brush skimmer is an effective oil recovery device that performs well in viscous oils and has the ability to operate relatively undisturbed in debris. Drum skimmers, on the other hand, get easily obstructed by debris but have higher oil recovery efficiency and can have a high buoyancy, thus reducing the need for additional flotation "(Jensen, 1999).

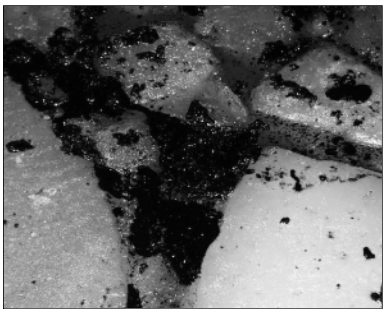
It can be concluded, that under the given conditions, both concepts are considered to provide effective methods to deal with oil spills in ice. Recovery rates were good for the conditions and the amount of oil present, and recovery rates may be expected to increase with a greater amount of oil present under similar conditions.

Fig. 6.18 and 6.19b show the Brush Drum Skimmer under test conditions.



Courtesy of SINTEF, Norway

Fig. 6.18 Brush Drum Skimmer for Oil Recovery in Ice



(HSVA) Oil in Ice

(HSVA) Brush Drum Skimmer

Fig. 6.19a-b Brush Drum Skimmer for Oil Recovery in Ice
(tested in HSVA's *Arctic Environmental Test Basin*)

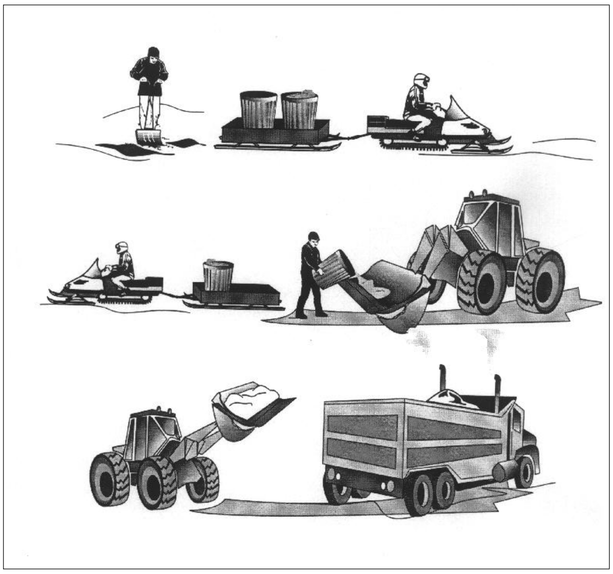
6.4 DESCRITION OF DIFFERENT TECHNIQUIES AND METHODS WITH RESPECT TO OIL SPILL RESPONSE

6.4.1 General

Depending on the prevailing environmental conditions (ice conditions, weather, wind, current, water depth, soil condition in tundra areas etc.) suitable equipment and methods have to be applied in order to respond an oil spill.
In the following several scenarios respectively methods of response measures are briefly described taking into account the peculiarities with respect to available technical device, trained personnel, existing infrastructure etc. of the “Loading Terminal” .
However the presented examples (item A to G) do not claim to be complete.

6.4.2 Manual Recovery of Lightly Oiled Snow

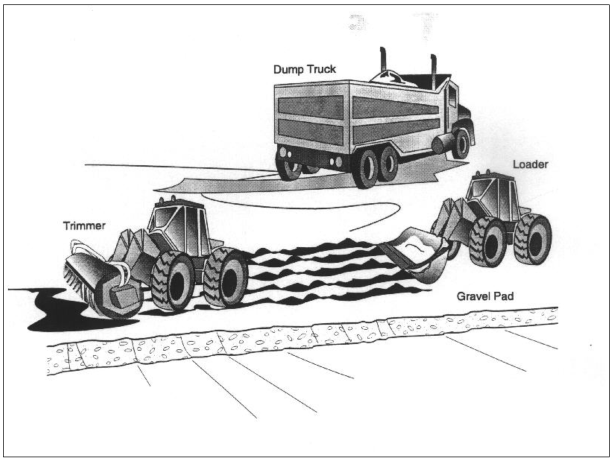
When the ice surface is contaminated with lightly oiled snow the surface can be cleaned by mechanical means like brooms and shovels.



(← Fig. 6.20) Broom and shovel the oiled snow into piles. The piles are then transferred to garbage cans or similar containers. When the container are filled they can transported by a snow-machine to a “assembly point” where a front-end loader transfers the oiled snow into dump trucks.

(←Courtesy of ACS)

6.4.3 Recovery of Embedded Oil

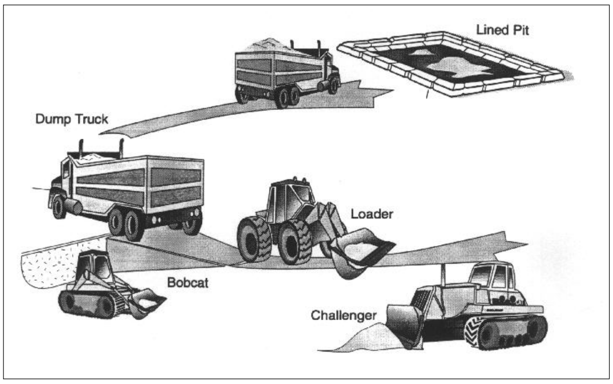


(← Fig. 6.21) A brush-type trimmer can be used to recover oil embedded in the ice surface.
A rotating steel blade system is used to chop and collect the surface material at varying depths. Then the material is collected with a front-end loader and transported to a dump truck.
In areas where a trimmer can not operate, a scratcher can be used to break up the ice surface. A scratcher is a front-end loader attached with a fork.
(←Courtesy of ACS)

Where the embedded oil is not recovered, the area is stabilised and the perimeter is bermed and sealed until melting. Melting in the contained area can be accelerated by covering with black plastic sheets or synthetic materials. The cover sheet is lifted as necessary and the pools of oil can be removed with direct suction, portable skimmers or burning.

6.4.4 Recovery of Oil-Saturated Snow

Snow provides a good sorbent material for oil and forms a mulch-like mixture that is easily removed with heavy equipment, e.g. front-end loaders, bobcats and dump trucks.



(↑ Courtesy of ACS)

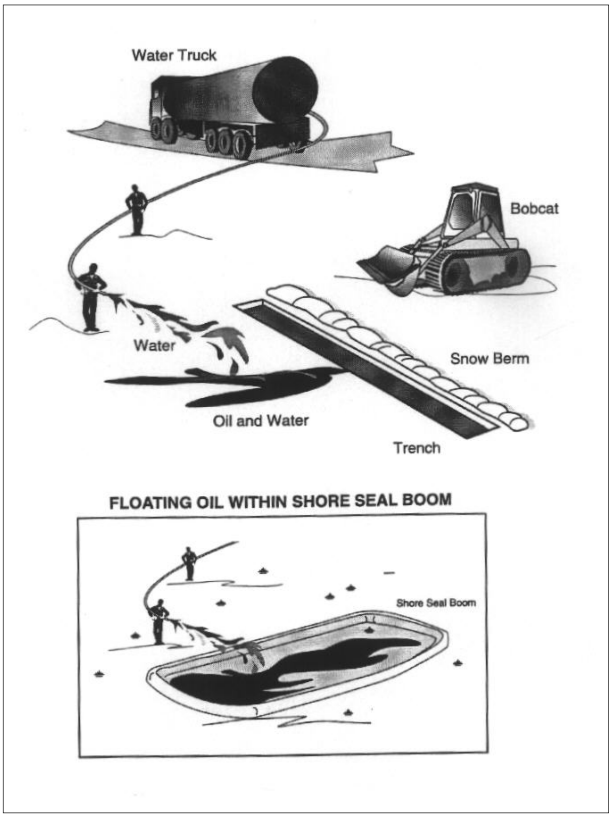
(← Fig. 6.22) Access the oiled snow with dozers and loaders, pile the contaminated snow with dozers, and than load it into dump trucks. After a front-end loader has filled a truck, the truck hauls the oiled snow off for disposal, typically to snowmelters in lined pits.

If heavily oiled snow needs blending to ease recovery, loaders and dozers should push nearby lightly oiled snow into the heavily oiled area for recovery.

One can also use clean snow for blending. Oil in areas inaccessible by vacuum trucks or heavy equipment is recovered by sorbent materials and manual labour. The sorbents are collected in garbage cans, bags or containers and transferred with snow machine or pick-up truck to a front-end loader, which transported the waste into a dump truck for removal and disposal.

6.4.5 Flushing of Oil on Tundra or Ice Surface

In spring or fall , i.e. when the air temperatures a higher than in winter time, flushing is used to concentrate oil into pits or trenches, where the oil is collected with direct suction, using a Manta skimmer head, sorbents or portable skimming systems.

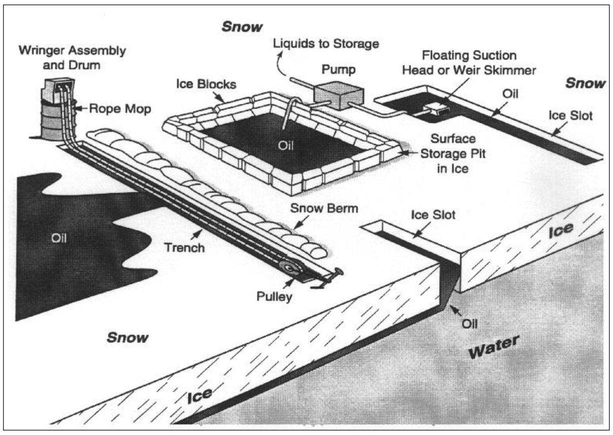


(← Fig. 6.23) The pits or trenches can be constructed by cutting slots in the ice, using natural depressions with sandbags or shore seal booms. Constructed pits or trenches are lined with plastic sheeting.
The water source for the flushing unit is a water truck or an auger hole can be drilled through the ice. Flushing usually occurs after pooled areas and contaminated snow have been removed. The flush should consist of high-volume, low-energy flushing with water less than +40°C.
This is essentially a mop-up technique after the majority of oil and oiled snow has been removed.

(←Courtesy of ACS)

6.4.6 Cutting Ice Slots for Recovery

When oil is moving both on the ice surface and underneath it can be concentrated in slots cut in the ice and recovered by skimming with rope mops or other types of skimmers (e.g. brush drum systems). If the oil layer in the slot is thick enough, it can be removed by direct suction or wire skimmers.



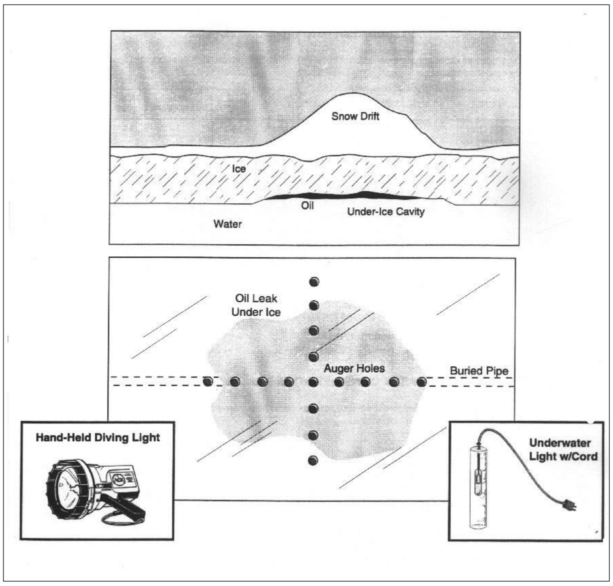
(HSVA) (Fig. 6.24b)

(←Courtesy of ACS) (Fig. 6.24a)

Oil entrapped in subsurface pockets can be reached by drilling holes with ice augers and pumping the oil directly to storage containers such as drums or bladders. Temporary storage can also be provided by excavating shallow pits in the ice surface using chain saws and chipper bars. The collected oil can be pumped of or burned.

6.4.7 Detection and Delineation of Under-Ice Oil

Oil released under a solid sea ice sheet or that finds its way under the ice through cracks , polynias and open leads will spread under the ice an concentrate in under ice pockets, e.g. under ice melt ponds. The underside of sea ice contains many of these pockets that reflects snow drifts on the ice surface (reduction of ice growth due to insulation effects). If oil is trapped in a pocket it will tend to stay in place, since it takes a current of about 0.25 m/s (= 0.5 knots) to push the oil out of these pockets.

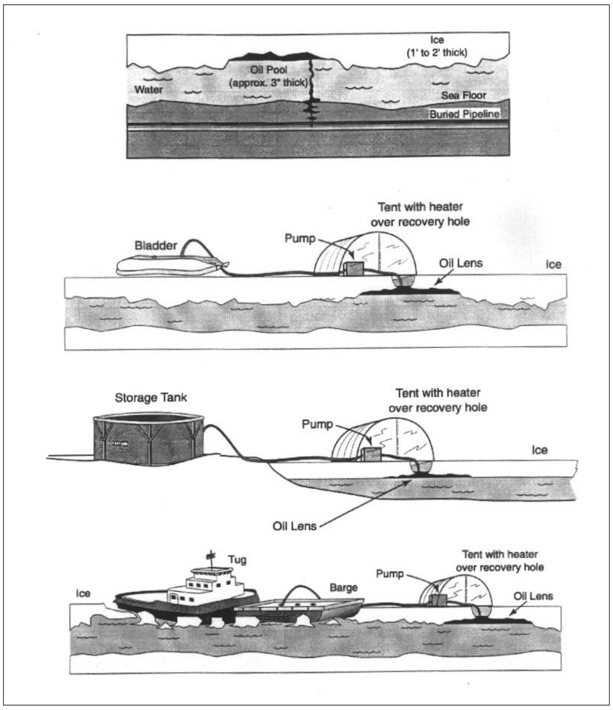


(← Fig. 6.25) An ice auger can be used to drill holes through the ice sheet and place underwater lights to shine up through the ice (snow must first be removed from the ice surface).
A series of auger holes can be drilled in a line from the source to delineate the extent of under-ice oil contamination.

(←Courtesy of ACS)

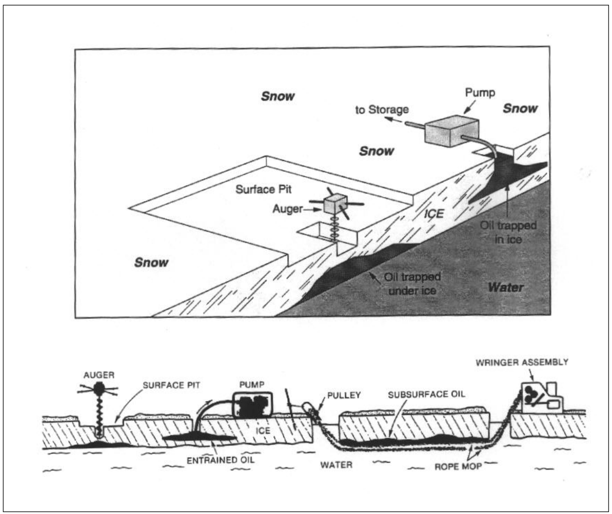
6.4.8 Recovery of Oil Under Ice

Oil trapped under a solid ice sheet or in lenses within the ice sheet can be removed by augering directly into the oil lenses and pumping out the oil. In case the ice is thick enough to support heavy equipment, the oil can be pumped directly into bladders or other portable small tanks and hauled to shore.



(← Fig. 6.26) In case of thin nearshore ice, the oil can be pumped to storage containers on shore. If the site can be reached by an ice-strengthened tug-and-barge system, the oil can be pumped directly into the barge. It is recommended to provide a portable shelter to the site, which should be place over the auger holes to protect personnel and pumps.

(←Courtesy of ACS)



(← Fig. 6.27) A sump is dug in the ice around an auger hole drilled through the ice to pockets of oil under the ice or encapsulated in the ice. The oil can be pumped directly to temporary storage tanks. It is recommended to install a tent or shelter over the sump. Another option is to deploy rope mop through holes in the ice to recover oil trapped in under ice depressions. At least two holes must be drilled through the ice by augers or chain saws, and the rope mob is strung under the ice between the holes.

(←Courtesy of ACS)

7.0 SUMMARY AND CONCLUSION

Sea transportation of oil and gas from the Arctic is upcoming and will be a more risky and expensive business compared to transportation in open water. The Arctic Ocean with the Russian Arctic shelf areas are the most vulnerable environment on earth due to the low temperatures and the presence of ice. Especially oil spill accidents are considered much more harmful in the ice covered ocean than in warmer climates. Therefore, it is most important to take every reasonable precaution to prevent an spill of gascondensate or spill with crude oil.

Previous to the month-long round trip of MT UIKKU from Murmansk - Sabeta - Rotterdam with respect to the necessities of WP 11 Environmental Protection the FORTUM GAS and OIL representative carried out the co-ordination work for convincing the Russian authorities in order to obtain the relevant permission. For the purpose of this task very valuable support was provided by AARI and CNIIMF. Effort has been made to avoid any violation on the environment and every possible precaution measures have been considered in order to protect the environment.

The environmental safe operation concerned two main aspects, i.e. a) the environmental safe navigation through the western part of the Northern Sea Route and b) the environmental safe ship-shore cargo operation on Yamal peninsula for loading gascondensate. The successful completion of these tasks was carried out in co-operation with the Russian authorities and the Russian teams (crew and scientists) on the icebreakers and on the „loading terminal“.

A literature search and review of oil spill response equipment and methods in ice covered waters was carried out. An analysis of the sources and extent of sea pollution on the basis of experience in coastal transportation in the Russian Arctic and a detailed definition of structural requirements for ships and a composition of the equipment protecting the environment was prepared. Recommendations to a “Safety Plan” and “Safe Operations Procedures” for the ships on this route were made.

The facilities of the loading terminal and the tanker is well documented and recommendations have been made where necessary. A “Contingency Plan” for the loading terminal is proposed, and different techniques are given as examples to respond oil spills in ice and snow covered areas.

During the voyage as well as the loading process there was no incident concerning environmental violation observed, however it is expected that with upcoming activities in arctic regions the risk of oil spills will increase. Future research is necessary with respect to the improvement of environmental protection, e.g. additional structural requirements for the ships of different Polar Classes taking into account the probability of oil spill in the event of ice damages. The Ship Oil Pollution Emergency Plan (SOPEP) should be complemented by additional sections taking into account specific cases of operational emergency spillage in various ice conditions.

Comprehensive oil spill response management systems taking the peculiarities of the loading sites into account are required for an effective oil spill response. Since there is a certain precariousness in the behaviour of gascondensate / oil concerning the penetration and distribution into snow or ice, detailed basic laboratory investigations for different types of hydrocarbons should be carried out.

Existing oil spill recovery equipment has to be improved, prototypes of suitable oil spill recovery device and adsorbent materials for the operation in cold climate conditions has to be developed, designed and tested in laboratories and under realistic conditions in the field.
Feasibility studies and research projects e.g. ice model tests of various types of loading terminals for different ice conditions should be initiated.

8.0 REFERENCES

Alaska Clean Seas — North Slope Spill Response Technical Manual
Volume 1: Tactics Description
Volume 3: North Slope Incident Management
1998

Chen, A.C.T — Planning Guide for Oilspill Response Equipment and Vessels
Exxon Production Research Company, EPR.2PR.98, October 1998

Exxon Production Research Company — Oil Spill Response Field Manual
USA, May 1993

Grechin,M.
Somkin,V. — Working Report WP-11 "ENVIRONMENTAL PROTECTION" on the ARCDEV Project , 1998, unpublished

Ivanov,I. — Working Report WP-11 "ENVIRONMENTAL PROTECTION" on the ARCDEV Project, 1998, unpublished

Jensen, H. et al. — Status of the Program Mechanical Oil Recovery in Ice Infested Waters (MORICE)
Proceedings of the 22nd Arctic Marine Oil Spill Technical Seminar June 2nd to 4th , 1999, Calgary, AB, Canada

Leo,R.
Lilie,R. H. — Ölwehrhandbuch – Bekämpfung von Ölunfällen im Inland und auf See
K.O. Stork Verlag, Hamburg, 1987

Solsberg, L.B.
McGrath, M. — State of the art review: Oil in Ice Recovery
CAPP Task Force on Oil Spill Preparedness (TFOSP)
TR 92-02, May 1992

Van Bernem, C.
Lübbe, T. — Öl im Meer – Katastrophen und langfristige Belastungen
Wissenschaftliche Buchgesellschaft, Darmstadt, 1997

Co-ordinator of WP 11 “Environmental Protection”:

HAMBURGISCHE SCHIFFBAU-VERSUCHSANSTALT GmbH
Dipl.-Ing. Karl-Ulrich Evers
Bramfelder Straße 164
D-22305 Hamburg
Germany
Phone +49 40 69203-0
Fax +49 40 69203-345

Partner of WP 11 “Environmental Protection”:

CENTRAL MARINE RESEARCH & DESIGN INSTITUTE (CNIIMF)
Dr. M.Grechin & Dipl.-Eng. V. Somkin
Krasnoykonnitsy Str. 6
St. Petersburg 193015
Russia
Phone +7 812 271-1005
Fax +7 812 271-1283

FORTUM OIL AND GAS
Capt. Ivan Ivanov
P.O. Box 100
Fin-00048 Fortum
Finland
Phone +358 (0)10 4524108
Fax +358 (0)10 4528566

ANNEX 1

Prepared by:
CENTRAL MARINE RESEARCH & DESIGN INSTITUTE (CNIIMF)
Dr. M. Grechin & Dipl.-Eng. V. Somkin
Krasnoykonnitsy Str. 6
St. Petersburg 193015
Russia

STATISTICS OF ICE DAMAGES

Statistical data on the parameters of ice damages are based on the information covering 200 cases of side ice damages of cargo ships in their navigation under ice conditions along the Northern Sea Route. In all the cases of ice damages the water penetrated into the ship and compartments were flooded.
There is no information on the bottom ice damages. Therefore the statistical data given below refer only to side damages while navigating through ice.

1. Distribution of damage locations over the length of ship.

Histogram of the dimensionless location of the middle of damages and the corresponding integral distribution function F (x/L) are given in fig. 1 (L - ship's length over the waterline at a draft d_s up to the summer load line). As one can see from Fig. 1, ice damages principally occur in the forebody of ship at a distance of 0.4 L from the forward perpendicular (about 90% of damages).

2. Distribution of damage length

Integral function F (1/L) of the distribution of the dimensionless length of damages presented in Fig. 2 shows that 90% of ice damages have a length less than 0.04 L with 57% of damages of a small length (1/L < 0.005) being located between frames and 43% of damages affecting frames. Bearing in mind the fact that the number of frames is considerably larger than that of transverse bulkheads one may assume that events of the ice damage of transverse bulkheads are highly rare and this is confirmed by the practice of operation of ships.
Analysis of the statistical data has also shown that average length of damages in the forebody located within 0.4 L from the forward perpendicular is three times as large as in the aftbody.

3. Distribution of damage penetration

Integral function of the distribution of the depth of damages F (b_i) presented in Fig. 3 shows that 99% of ice damages have a depth not exceeding 0.5 m. Proceeding from this it would be possible to assume standard depth of ice damages as being equal to 0.5 m. Due to the technological considerations, however, taking into account the necessity of the maintenance of protecting cofferdams it is advisable to assume depth of damages equal to 0.76 m.

4. Distribution of vertical location and the extent of damages

Integral functions of the distribution of the lower edge of damage F (z_1) and of its upper edge F (z_u) are given in Fig. 4. They show that about 60% of damages are located within the change of the lower boundary z_1/d_s from 0.1 to 0.4 the upper damage boundary z_u/d_s being

located within the range from 0.13 to 0.55. Such concentration of ice damages in the area between the upper edge of the bilge strake and the ballast draft (below the ice strake) may be attributed to a lesser damageability of sides within the ice strake which has a higher thickness of plating. Maximum vertical extent of damages in this area at $z_i/d_s = 0.5$ is about 0.15 d_s.
Fig. 5 shows the integral distribution function of an absolute vertical extent of damages. The function shows that 97% of damages have a vertical extent up to 2.0 and only 1% - more than 3.0 m.

Distribution Functions for Side Ice Damages

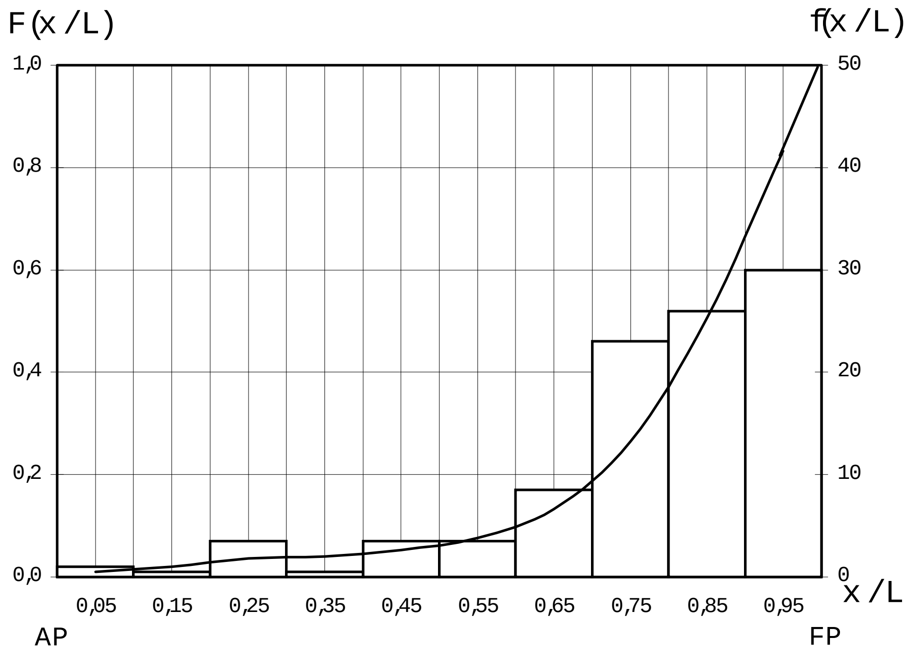


Fig. 1 Longitudinal Location

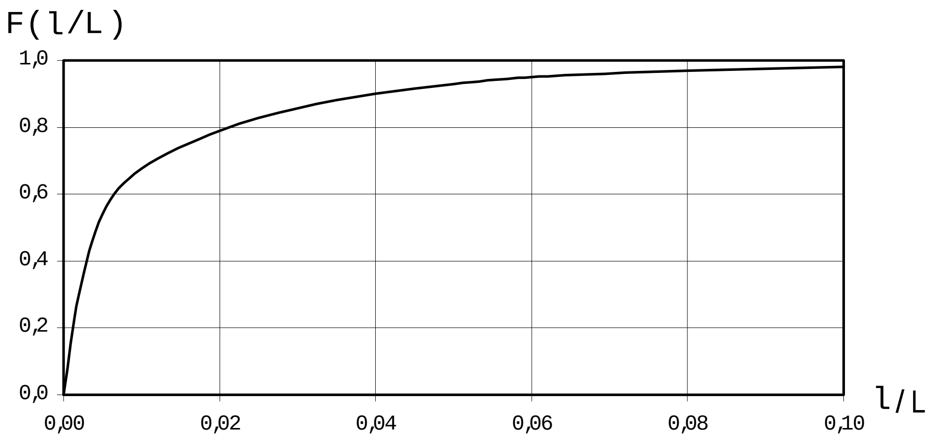


Fig. 2 Longitudinal Extent

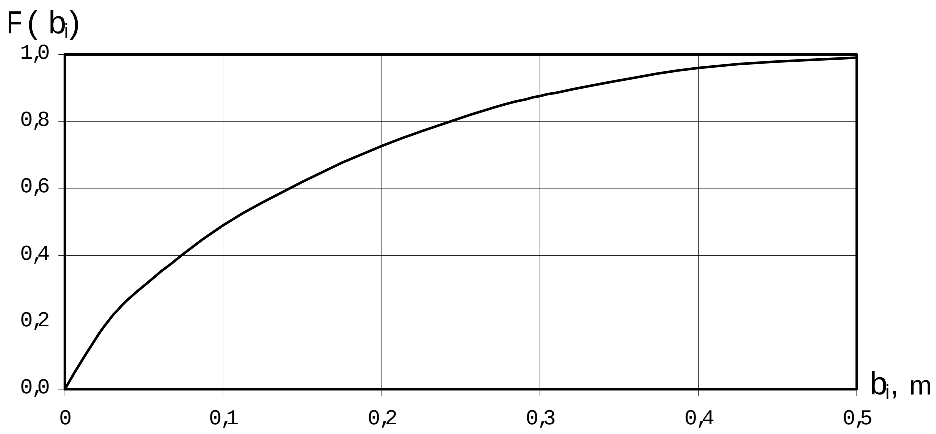


Fig. 3 Transverse Penetration

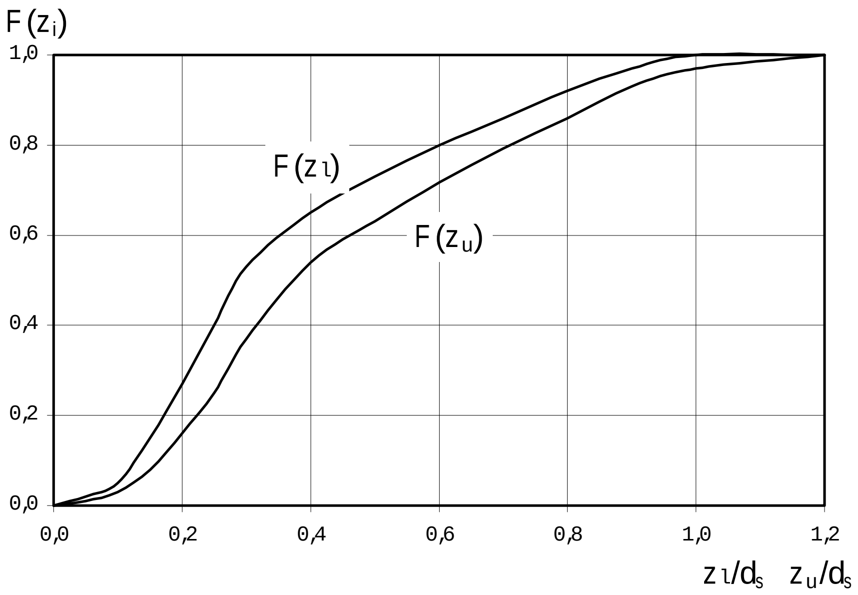


Fig. 4 Vertical Location

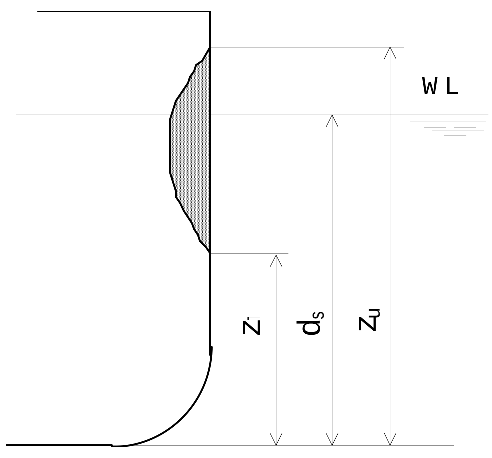


Fig. 4a Vertical location of damage to Fig. 4

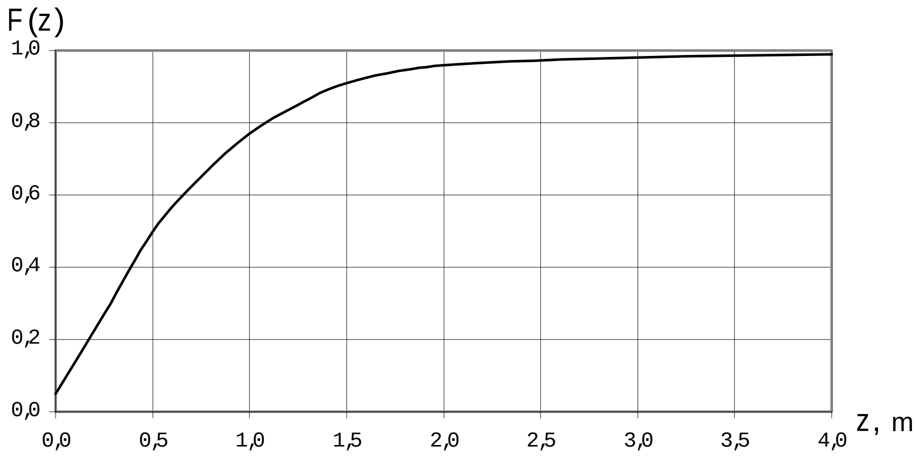


Fig. 5 Vertical Extent

POSSIBILITY OF USE DOUBLE BOTTOM TANKS WITHIN THE LENGTH OF THE MACHINERY SPACE FOR THE STORAGE OF FUEL AND LUBRICANTS

The draft of the "International Code of Safety for Ships in Polar Waters" submitted by Canada to IMO (DE 41/10, paragraph 3.3.1) does not permit use of double bottom tanks in the area of the machinery space for the storage of fuel and lubricants. The requirement of prohibition for ship to carry any pollutant next to the outer shell is in our opinion groundless strict at least with reference to double bottom tanks of the machinery space that are usually used for storage of fuel, draining lubricants and draining bilge water tanks, etc.

Experience in design of ships for ice navigation in Arctic waters shows that this requirement does not make sure for acceptable structural solutions, complicates the arrangement of equipment and leads to increase of the machinery space length. When the main dimension of the ship are fixed the ship's cost increases and deadweight decreases. Arrangement of cofferdams in the double bottom of the machinery space of at least 760 mm in height separating fuel or oil tanks from the outer shell plating leads to the complication of the operation of ship because of the difficulties in the maintenance of cofferdams and their corrosion.

Bearing in mind the above it is additionally necessary to examine the matter in relation to possibility of use double bottom tanks of the machinery space for the storage of fuel and lubricants taking into account the last statistical data of IMO for parameters of bottom damages due to stranding [Res. MEPS 66(37), 14.09.95], but there is no information on the bottom ice damages.

The results of the evaluation calculations (see ANNEX 1 A) show that in all cases the probability of the bottom damage within the double bottom of the machinery space is low. By this the probability for the aft machinery space is in two times as smaller than one for middle machinery space. Presence of cofferdam essentially decreases the probability of damage of the double bottom tanks especially for small ships. However it may not be considered in practice as important factor ensuring the environmental protection because of the probability of such accident is very low. Thus, for the ship of 20000 tonnes deadweight with aft machinery space having relative length of 0.20 the probability of damage of the double bottom tanks is 0.00125 with cofferdam and of 0.00336 without cofferdam for 20 years of the operation of the ship. The probabilities of damage for the middle machinery space accordingly are 0.00246 and 0.00662.

By this, it is necessary to take into account that in accordance with Res. MEPC 66(37), paragraph 5.1.5.6, for tanks bounded by the bottom shell the oil outflow should be assumed equal to 1% of the volume of the damaged tank taking into account the principles of hydrostatic balance. Therefore, even in damage cases the oil outflow on account of small volume of tanks will be insignificant and not result in essential marine pollution.

The practice of ship's operations on the Northern Sea Routes in ice conditions confirms the low probability of damage of double bottom of the machinery space. There are no cases in Russian practice of the ice holes of bottom for the aft machinery space. Bearing in mind the above it is worth deleting the requirement on prohibition for ship to carry the storage of fuel and lubricants in double bottom tanks of the machinery space as this requirement is groundless and leads to many problems for the designers and operation of the ship. Therefore, it is suggested to include in the Chapter 3 the following: "It is allowed in ships of Polar

Classes 5-7 to use double bottom tanks within the length of the aft machinery space for the storage of fuel and lubricants the capacity of each tank not exceeding [20], [50] cubic m.

The limitation of capacity of double bottom tanks of [20] or [50] m^3 may be accepted taking into account the possible determination in future of “little spillage” for polar waters.

ANNEX 1A

EVALUATION OF PROBABILITY OF THE BOTTOM DAMAGE OF DOUBLE BOTTOM TANKS OF THE MACHINARY SPACE

Statistical data on the parameters of bottom ice damages for cargo ship operating in polar water are lacked for probabilistic analysis. Therefore, it is worth to use the damage density distribution functions recommended by IMO and taken on the base of statistical data on tanker's damages (Res. MEPC 66(37), 14.09.95) for calculations.

For bottom damage due to stranding the following density distribution functions are taken.
Function for longitudinal location of damage on bottom:

$f_{b1} = 0.2 + 0.8x$ for $x \leq 0.5$
$f_{b1} = 4x - 1.4$ for $0.5 < x \leq 1.0$

where x - Dimensionless distance from AP relative to the ship's length between perpendiculars.

Function for longitudinal extent of damage:

$f_{b2} = 4.5 - 13.33y$ for $y \leq 0.3$
$f_{b2} = 0.5$ for $0.3 < y \leq 0.8$

where y - Dimensionless longitudinal extent of damage relative to the ship's length between perpendiculars.

Function for vertical penetration of damage:

$f_{b3} = 14.5 - 13.4z_v$ for $z_v \leq 0.1$
$f_{b3} = 1.1$ for $0.1 < z_v \leq 0.3$

where z_v - Dimensionless vertical penetration extent relative to the ship's depth.

Graphs of the functions f_{b1}, f_{b2} and f_{b3} are shown accordingly in Fig. 1, 2 and 3.
The probability of marginal random event is determined by the integral function

$$F_{bi} = \int_{11}^{12} f_{bi}\, dl$$

for any given range of change x, y and z_v.

To simplify evaluation it is assumed that the damage extents in transverse without limitation, i.e. the probabilities for transverse extent and location equals 1.0.
The probability of damage taking into account its longitudinal location, extent and penetration is determined by multiplying the probabilities of aforesaid damages.

1. Probability of longitudinal location of damage within the length of the machinery space, P_1.

The calculations were carried out for the aft and middle machinery space having three dimensionless length relative to the ship's length between perpendiculars. For aft machinery space the distance from aft perpendicular to the aft bulkhead of machinery space was taken 0,05, for middle machinery space the centre of its was located at middle of the ship. The following results came out.

Dimensionless of machinery space, y	0.15	0.20	0.25
Probability of damage:			
for aft machinery space, P_{1a}	0.050	0.069	0.090
for middle machinery space, P_{1m}	0.099	0.136	0.175

2. Probability longitudinal extent of damage within the length of the machinery space, P_2.

Dimensionless of machinery space, y	0.15	0.20	0.25
Probability of damage, P_2	0.525	0.633	0.708

3. Probability of damage of double bottom tanks with cofferdam of 0.76 m in height, P_3.

The density distribution function for probability of vertical penetration of damage f_{b3} allows to determine the probability that the double bottom over cofferdam not be damage. Then the probability of damage of the double bottom tanks arranged above cofferdam equal $P_3 = 1 - P_{3c}$.

The calculations P_3 were carried out for the range of change the dimensionless penetration of damage $z_v = 0{,}002 \div 0.1$ that, for height of cofferdam of 0.76 m, corresponds to change of the ship's depth from 38 m to 7.6 m and ship's deadweight approximately from 400,000 t. to 5,000 t.

Penetration of damage, z_v	0.02	0.04	0.06	0.08	0.10
Ship's depth, m	38	19	12.7	9.5	7.6
Approximate deadweight, thousand t.	400	100	20	6	5
Probability, P_{3c}	0.263	0.473	0.628	0.731	0.780
Probability, $P_3 = 1 - P_{3c}$	0.737	0.527	0.372	0.269	0.220

One can see that the efficacy of cofferdam decreases as increase the ship's depth and deadweight.

If there is no cofferdam the probability $P_3 = 1.0$.

For further consideration three basis deadweight with corresponding probabilities of the damage of double bottom tanks are taken.

DW1 = 6,000 • $P_{31} = 0.269$
DW2 = 20,000 • $P_{31} = 0.372$
DW3 = 100,000 • $P_{31} = 0.527$

The results of the evaluation calculations are just for case of stranding with probability equal to 1.0. However, the actual probability of such accidents is essentially low. Therefore, for correct evaluation of the probability of oil outflow from double bottom tanks it is necessary to take into account the probability of such accident. Approximately, it may be considered that average relative quantity of ship accidents due to stranding with bottom damage for one year λ is constant for all period of ship's service T and may be presented by stationary Poisson's law distribution. Then mathematical expectation of the number of such accidents is $a = \lambda T$ and probability of accident is $P = 1 - e^{-\lambda T}$.

According to the statistical data on the accidents of the world fleet the quantity of strandings with bottom damage equals about 0.004 that corresponds to the probability of bottom damage $P_T = 0.0769$ for 20 years of ship's operation i.e. for all period of the ship's service life. Then, the general probability of stranding with double bottom tanks damage is as follows:

$$P = P_1 \cdot P_2 \cdot P_3 \cdot P_T$$

The results of the calculations are summarised in the following Table.

Probability of the damage of double bottom tanks within the length of the machinery space

Length of the machinery space		0.15	0.20	0.25
P_1 (P_{1a}/P_{1m})		0.050/0.099	0.069/0.136	0.090/0.175
P_2		0.525	0.633	0.708
P_3	DW 6000		0.269	
	DW 20000		0.372	
	DW 100000		0.527	
P_T			0.0769	
Probability of the damage of double bottom tanks with cofferdam, $P=P_1 \cdot P_2 \cdot P_3 \cdot P_T$	DW 6000	0.00054/0.00107	0.00090/0.00178	0.00132/0.00256
	DW 20000	0.00075/0.00149	0.00125/0.00246	0.00182/0.00354
	DW 10000	0.00106/0.00210	0.00177/0.00349	0.00258/0.00502
Probability of the damage without cofferdam, $P= P_1 \cdot P_2 \cdot P_T$		0.00202/0.00399	0.00336/0.00662	0.00490/0.00952

Density Distribution Functions for Bottom Damage due to Stranding

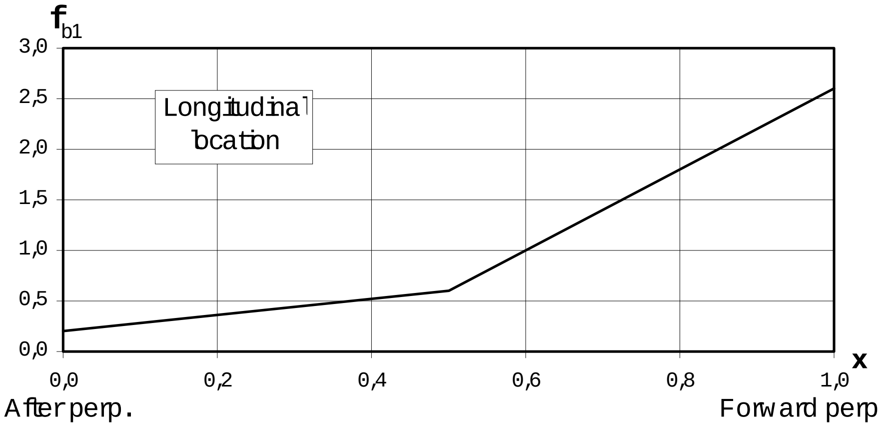


Fig. 1

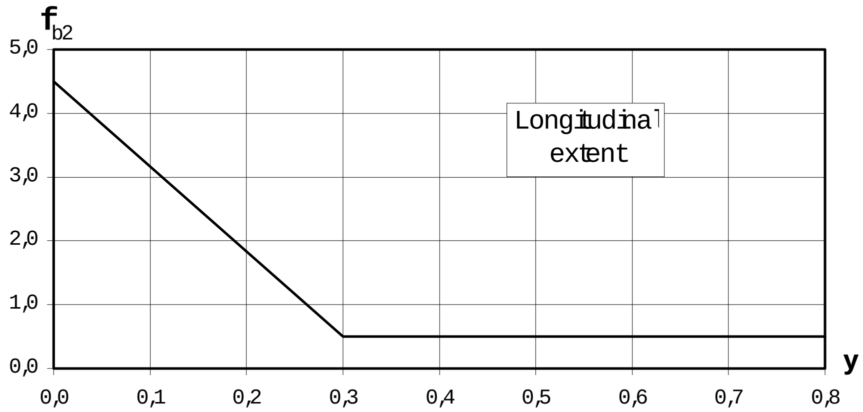


Fig. 2

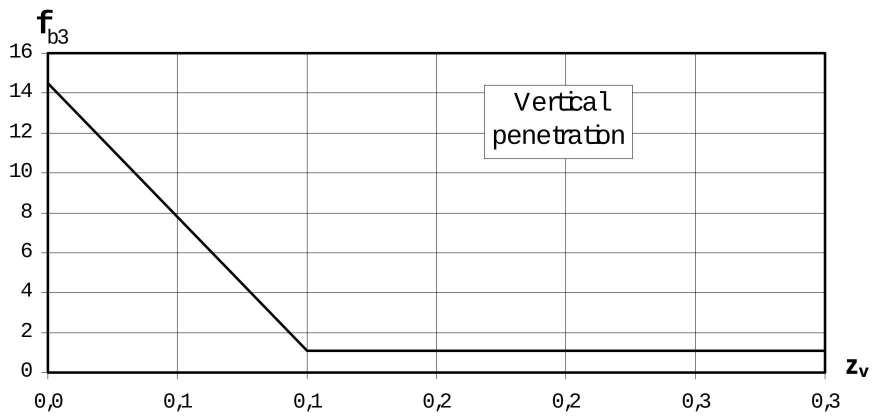


Fig. 3

ANNEX 2

SUMMARY
OF
LITERATURE SEARCH

Prepared by:

HAMBURGISCHE SCHIFFBAU-
VERSUCHSANSTALT GmbH
Dipl.-Ing. Karl-Ulrich Evers
Bramfelder Straße 164
D-22305 Hamburg
Germany

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
1	Laboratory testing of an oil skimming boom in broken ice fields	Abdelnour, R., Johnstone, T., Howard, D.	AMOP 1985, pp 131-148	1985	CP			X						
2	Laboratory testing of an oil-skimming bow in broken ice	Abdelnour, R., Johnstone, T., Howard, D. Nisbett, V.	Environmental Studies Revolving Funds Report No. 013	1986	TR			X						
3	A field evaluation of oil skimmers	Abdelnour, R., Roberts, B., Purves, W.F. Wallace, W.	AMOP 1980, pp 252-261	1980	CP	X								
4	Workshop on Alaska Arctic Offshore Oil Spill Response Technology		Alaska Arctic Offshore Oil Spill Response Technology, Proceedings (AAOOSPRT)	1988	CP				X					
5	Containment and recovery techniques for cold weather, inland oil spills	Allen, A.A.	Oil Spill Conference 1981, Atlanta, Georgia	1981	CP				X					
6	Oil spill demonstrations in broken ice Prudhoe Bay, Alaska - 1983	Allen, A.A.	AMOP 1984, pp 347-349	1984	CP	X								
7	SOCK- an oil skimming kit for vessels of convenience	Ayers, R.R., Barnett, A.V.	Oil Spill Conference 1977, New Orleans	1977	CP	X								
8	Oil spilled with ice: some qualitative aspects	Barber, F.G.	Oil Spill Conference 1973, pp 133-137	1973	CP				X				X	X
9	Oil spill recovery in brash ice	Black Sea Central Planning and Design-ing Bureau	Odessa	1977	TR		X		X	X				
10	The BIOS project-frontier oil spill countermeasures research	Blackall, P.J., Sergy, G.A.	Oil Spill Conference 1981, Atlanta, Georgia	1981	CP	X								
11	Evaluation of the LIC Lori ice cleaner	Bowen, S.J.	Alaska Clean Seas	1991	TR	X								

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
12	Heavy oil skimmer tests	Brown, H.	Esso Wave Basin, Calgary	1990				X						
13	Heavy oil skimmer trials in Scandinavia	Brown, H.		1991	TR	X								
14	Arctic field testing of the Lockheed Clean Sweep and VEP Arctic Skimmer	Buist, I.A., Potter, S.G., Swiss, J.J.	AMOP 1983, pp 85-96	1983	CP	X								
15	Tank testing of skimmers with waxy and viscous oils	Buist, I.A., Potter, S.G.	AMOP 1989, pp 193-225	1989	CP			X						
16	Cleanup and containment of a diesel fuel spill to a sensitive water body at a remote site under extreme winter conditions	Burns, R.C.	AMOP 1988, pp 209-220	1988	CP		X							
17	Proceedings of a brainstorming workshop on recovery of oil in an ice environment, project report	Canadian Offshore Oil Spill Research Asso-ciat. (COOSRA)	Prepared by S.L. Ross Environment Res. Ltd.	1982	TR				X					
18	Oil recovery from under river ice	Canadian Petroleum Associat.		1978	TR	X								
19	An oilspill in pack ice	Centre for Cold Ocean Res. Eng	Prepared for Environment Canada, date unavailable		TR		X			X				
20	Containment systems brochure				MI				X					
21	Field manual for cold-climate spills	Deslauriers, P.C., Morson, B.J., Sobey, E.J.C.	Prepared for U.S. Environmental Protection Agency, EPA-3-05-009-8, data unavailable		TR				X					
22	Elastec Brochure			1991	MI				X					
23	Testing of an oil recovery concept for use in brash and mulched ice	Environmental Studies Revolving Funds Report No. 018	Prepared by S.L. Ross Environmental Research	1986	TR			X						

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
24	A winter evaluation of oil skimmers and booms	Environment Canada	EPS 4EP-84-1	1984	TR	X								
25	Frank Mohn Brochure			1991	MI				X					
26	Tests of oil recovery devices in a broken ice field	Getman, J.H., Shultz, L.A.	Eight Annual Offshore Techn. Conf., Houston, Texas, Paper No. OTC 2695	1976	CP			X						
27	Oil removal techniques in an arctic environment	Golden, P.C.	MTS Journal v.8n.8		TR	X								
28	Cold water testing at OHMSETT	Griffiths, R.A., Desiauriers, P.C.	AMOP 1981, p 295-300	1981	CP			X						
29	USNS Potomac oil spill	Grose, P.L. et al.	Joint NOAA and USCG report	1979	TR					X				
30	ABSORB: A three year update in arctic spill response	Hillman, S., Shafer, R.V.	Oil Spill Conference 1983, San Antonio, Texas	1983	CP	X								
31	• Arctic Skimmer•	Huston, D.A.C.	AMOP 1979, pp 130-134	1979	CP	X								
32	Testing of the Navy• s Cold Oil Modifi-cations to the Marco Class V Skimmer	Kilpatrick, R.D., Saecker, A.J.	AMOP 1981, pp 219-242	1981	CP			X						
33	Oil skimming vehicle for ice-infested waters	Kivisild, H.R., Milne, W.J., Jackson, P.	AMOP 1978, pp 131-133	1978	CP				X					
34	Lake Champlain: A case history of the cleanup of #6 fuel through five feet of solid ice at near-zero temperatures	Lamp• l, H.J.	Applied Control Technology, pp 579-582	1975	CP					X				
35	Oil spill 1978 west coast of Sweden	Maare, M.		1978	TR					X				
36	Cold regions spill response	March, G.D., Schultz, L.A., DeBord, F.W.	Oil Spill Conference 1979, Los Angeles, California	1979	CP	X			X					

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice – Field exp.	Use of mechanical recovery in ice – Real spill	Use of mechanical recovery in ice – Lab test	Use of mechanical recovery in ice – Theor. Assessm.	Histori-cal oil spills	Information on specific areas – Env. cond.	Information on specific areas – Oil activ.	Oil beha-viour	Spill scena-rios
37	Development of Morris skimmers for arctic use	Morris, D.	AMOP 1979	1979	CP			X						
38	Oil-spill-response measures for Alaskan offshore oil and gas operations	Murrell, T., Levine, J.R., Regg, J.G., Tennyson, E.	OSC Report MSS 86-0000	1986	TR				X					
39	An investigation of techniques for the pumping of oil from under solid ice cover	Norcor Engineering and Research Limited	Prepared for Panarctic Oils Limited	1975	TR	X								
40	Oil spill response in the Arctic, Part 2, field demonstrations in broken ice			1983	TR	X								
41	Oil spill response in the Arctic, Part 3, technical documentation			1984	TR				X					
42	Dome Petroleum• s oil spill research and development program for the Arctic	Pistruzak, W.M.	Oil Spill Conference 1981, Atlanta, Georgia	1981	CP	X								
43	Ice exercise North Saskatchewan River	Prairie Region Oil Spill Containment and Recovery Advisory Committee		1976	TR	X								
44	A background to countermeasures for a Beaufort Sea well blowout	Purves, W.F.	Prepared for Environment Canada Countermeasures Innovation Session	1977	TR				X					
45	Spill experiences in the St. Lawrence River	Rivet, C.	AMOP 1985, pp 400-401	1985	CP					X				
46	Design & development of an oil re-covery vehicle (skimmer) to operate in ice-infested water	Roberts, D.	AMOP 1978, p. 128	1978	CP				X					

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
47	Evaluation of Industry• s oil spill countermeasures capability in broken ice conditions in the Alaskan Beaufort Sea	Ross, S.L.	Prepared for Alaska Department of Environmental Conservation	1983	TR	X			X		X	X		
48	Oil recovery systems in ice	Ross, S.L.	Prepared for COOSRA	1984	TR				X					
49	Development of an oil spill recovery system for arctic operations	Scharfenstein, C.F., Hoard, M.G.	Oil Spill Conference 1977, New Orleans, Louisiana	1977	CP				X					
50	Cleanup efficiency of a fuel oil spill in cold weather	Schrier, E., Eidam, C.	Oil Spill Conference 1979, Los Angeles, California	1979	CP					X				
51	Tests of oil recovery devices in broken ice fields phase II	Schultz, L.A.	Prepared for U.S. Department of Transportation, United States Coast Guard, Report No. CG-D-76	1976	TR	X								
52	Application of existing oil spill abatement equipment to cold regions	Schultz, L.A., Deslauriers, P.C.	Oil Spill Conference 1977, New Orleans	1977	CP				X		X			
53	Systems for arctic spill response, Volume II - appendices	Schultz, L.A., Deslauriers, P.C., DeBord, F.W., Voelker, R.P.	Prepared for U.S. Department of Transportation, United States Coast Guard, Report No. CG-D-44-78	1978	TR	X								
54	Tests of the arctic boat configuration of the lockheed clean sweep oil recovery system in a broken ice field	Schultz, L.A.	Prepared for U.S. Department of Transportation, United States Coast Guard, Report No. CG-D-108-76	1976	TR	X								
55	Oil spill response scenarios for remote arctic environments	Schulze, R.H., Grosskopf, W.G., Cox, J.C., Schultz, L.A.	EPA 600/2-82-036	1982	TR				X					

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
56	An oil spill response system for an offshore ice environment	Schulze, R.H., Zah, P.	AMOP 1982, pp 151-176	1982	CP				X					
57	Performance tests of four selected skimmers	Schwartz, S.H.	Oil Spill Conference 1979, Los Angeles, California	1979	CP			X						
58	Shallow water access platform (SWAMP)	Shafer, R.V., Glenn, D.	AMOP 1988, pp 201-203	1988	CP				X		X			
59	ARCTICSKIM: An oilspill skimming system for broken ice and shallow waters	Shafer, R.V., Bown, S.J.	AMOP 1988, pp 205-208	1988	CP				X					
60	Test of a skimmer in ice-infested waters at OHMSETT	Shum, J.S.	Draft report prepared for US EPA	1984	TR			X						
61	Summary of U.S. Environmental Protection Agency• s OHMSETT testing, 1974-1979	Smith, G.F., Lichte, H.W.	EPA-600/9-81-007, pp 141-142	1981	TR			X						
62	A catalogue of oil skimmers	Solsberg, L.B.	Environment Canada	1983	TR				X					
63	Design and development of oil recovery devices for ice-infested waters - oil mop arctic skimmer	Stewart, P.	AMOP 1978, pp 129-130	1978	CP				X					
64	Construction of a prototype arctic off-shore oil mop skimmer	Steward, P.	AMOP 1979, pp. 159-164	1979	CP	X								
65	Testing of oil skimmers developed in Japan for use in cold climates	Suzuki, I., Miki, K.	AMOP 1984, pp 96-118	1984	CP			X						
66	Research and development of oil spill control devices for use in cold climates in Japan	Suzuki, I., Miki, K.	Oil Spill Conference 1987, Baltimore, Maryland, pp 349-352	1987	CP			X						

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
67	Recent results from oil spill response research	Tennyson, E.	Oil Spill Conference 1991, San Diego, California, p 674	1991	CP				X					
68	Field evaluation of oil mop and preheat unit	Tidmarsh, G.D., Solsberg, L.B.	Fisheries and Environment Canada, EPS-4-EC-77-12	1977	TR	X								
69	Field trials of the ARCAT II in Prudhoe Bay	Williams, R.E., Bowen, S.J., Glenn, D.H.	AMOP 1984, pp 119-126	1984	CP	X								
70	Study of viscosity and emulsion effects on skimmer performance	Lorenzo, T., Therrien, R., Johannessen, B.O.	AMOP 1985, pp 705-729	1995	CP			X (no ice)						
71	Adhesion of oils to plastics, stainless steel and ice	Liukkonen, S., Koskivaara, R., Lampela, K.	AMOP 1995, pp 69-90	1995	CP			X						
72	Sea ice over-flooding: A challenge to oil spill countermeasure planners in the outer MacKenzie Delta, NWT	Webb, R.	AMOP 1995, pp 243-256	1995	CP						X			
73	Analysis of the Komineft pipeline oil	Lambert, P. et al.	AMOP 1995, pp 1187-1231	1995	CP					X				
74	Fate of oil determinations under arctic conditions: the Komi pipeline oil spill experience	Nadeau, R.J., Hansen, O.	AMOP 1995, pp 1163-1174	1995	CP						X	X		
75	Behaviour of spilled oil at sea (BOSS): Oil-in-ice fate and behaviour	DF Dickins Associates Ltd, Fleet Techn. Ltd		1992	CP TR				X					
76	Experimental oil spills in the Barents Sea marginal ice zone	Johannessen, B.O., Jensen, H.	Alaska Conf. on Oil Spill Response in Dynamic Broken Ice	1994	CP	X								

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
77	Experimental spills of crude oil in pack ice	Buist, I.A., Dickins, D.F.	Alaska Conf. on Oil Spill Response in Dynamic Broken Ice	1994	CP	X (no rec.)								
78	Behaviour of oil spills in cold and ice-infested waters - analysis of experimental data on oil spreading	El-Tahan, H., Venkatesh, S.	AMOP 1995, pp 337-354	1995	CP				X (oil in ice)					
79	Fate and behaviour of oil spilled in the presence of ice - a comparison of the results form recent laboratory, meso-scale flume and field tests	Singsaas, I., Brandvik, P.J., Daling, P.S., Reed, M., Lewis, A.	AMOP 1994, pp 355-370	1994	CP	X		X			X			
80	Testing of the Lori • Stiff Brush• skimmer sweep system	Guenette, C.C., Buist, I.A.	AMOP 1993, pp 451-476	1993	CP	X (no ice)		X						
81	New test basin for experimental studies on oil spill in ice	Wessels, E.	AMOP 1992, pp 271-279	1992	CP			X lab						
82	State of the art review: Oil in ice recovery	Solsberg, L.B., McGrath, M.	Canadian Association of Petroleum Producers	1992	TR				X					
83	Evaluation of the Foxtail skimmer in broken ice	Counterspill Research Inc.	Canadian Association of Petroleum Producers	1992	TR	X								
84	Mechanical recovery of oil in ice	Solsberg, L.B., McGrath, M.	AMOP 1992, pp 427-437	1992	CP	X			X	X				
85	Evaluation of inshore skimmers	Counterspill Research Inc.	Canadian Coast Guard	1993	TR			X (no ice)						
86	CISPRI Various newsletter, undated, anon.				TR	X	X		X			X		

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
87	Spill Prevention News, Alaska Clean Seas, Various newsletters			1992 1994	TR	X	X		X	X		X		
88	Rotating Brush Skimmers	Aqua Guard		1995					X (no ice)					
89	Oil spill recovery systems in ice, Part A - Feb. 1984, Part B - Jun 1985	Canadian Offshore Oil Spill Research Association		1984 1985	TR									
90	The 1979 Baltic oil spill	Dept. of Environ-mental Protection	A:2 Report ISBN 951-4864-1, Helsinki, Finland	1979	TR					X				
91	Environmental impact statement for hydrocarbon development in the Beaufort Sea - Mackenzie Delta Region, Volume 6 - Accidental spills	Dome Petroleum Limited, Esso Resources Canada Limited, Gulf Canada Resources Inc.		1982	TR									
92	Field research spill to investigate the physical and chemical fate of oil in pack ice	Ross, S.L. Env.Research, Dickens, D.F. Associates Ltd.	Environmental Studies Revolving Funds Report No. 062	1987	TR								X	
93	Cold water oil spills	Etkin, D.S.	Cutter Information Corp., Arlington, MA	1990	TR									
94	Oil spillage in Antarctica	Kennicutt, II, M.C. et al.	Environ. Sci. Technol. Vol. 24, No. 5	1990	TR									
95	Oil spill countermeasures for the southern Beaufort Sea	Logan, W.J., Thornton, D.E., Ross, S.L.	Beaufort Sea Technical Report #31a, Department of Environment, Canada	1975	TR									

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
96	Oil spill response in the Arctic Part 1, An assessment of containment, recovery and disposal techniques			1983	TR				X					
97	Oil spill in Stockholm Archipelago 1979. Combat and cleanup	Sanering, Skonsult AB	Report to 1977 Govt. Commission for Combatting Oil Spills, Göteburg, Sweden	1979	TR		X			X				
98	Theory, development and testing of an ice-oil boom	Tsang, G., Vanderkooy, N.	EPS-4EC-79-2	1979	TR			X	X					
99	Response to oil spills in the Arctic environment: A review	Morson, B., Sobey, E.	pp 407-414	1979					X	X				X
100	A spill response system for breakup	Schulze, R., Thayer, W., Zahn, P.	pp 154-160						X		X (Beau fort)			X
101	An overview of potential large oil spills offshore Canada and possible response strategies	Ross, S.L.									X	X		X
102	Decision regarding the oil industry• s capability to clean up spilled oil in the Alaskan Beaufort Sea during broken ice periods	O• Brien, P.S., Hayden, G., Butts, R., Van Dyke, W.	pp 355-366								X	X		X
103	Oil spill in the ice-covered water of Buzzards Bay	Deslauriers, P.C.	Journal of Petroleum Techn., The Bouchard No. 65	1979	J		X			X				
104	The grounding of the imperial St. Clair - a case history of contending with oil in ice	Beckett, C.J.	Oil Spill Conference 1979, pp 371-375	1979	CP		X			X				
105	Oil in pack ice: The Kurdistan spill	Reimer, E.	AMOP 1980, pp 529-544	1980	CP		X			X	X			X

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
106	The development of countermeasures for oil spills in Canadian Arctic waters	Ross, S.L.	Ass. Europe Oceanic Petrol & Marine Environment Conf., pp 377-399	1981	CP				X		X	X		X
107	Absorb: A three year update in arctic spill response	Hillman, S.O., Shafer, R.V.	Oil Spill Conference 1983, pp 219-226	1983	CP						X			
108	Arctic marine oil spill research	Hume, H.R., Buist, I., Betts, D., Goodman, R.	Cold Regions Science and Technology, 7, pp 313-341	1983	J				X		X	X		
109	Arctic spill response improvements: a 1985 review of arctic research and development	Hillman, S.O.	Oil Spill Conference 1985, pp 411-414	1985	CP									
110	Oil spill demonstrations in broken ice Prudhoe Bay, Alaska - 1983	Allen, A.A.	AMOP 1988	1988	CP	X (no oil)								
111	Oil pollution problem in the Baltic marine environment	Hirvi, J.-P.	AMOP 1989	1989	CP					X	X			X
112	Ice drift and under ice currents in the Barents Sea	Johansen, Ø., Mathisen, J.P., Skognes, K.	POAC, Luleå	1989	CP						X			
113	Oljevern i nordlige og arktiske farvann (ONA) - Status: Volum I (In Norwegian)	Løset, S., Singsaas, I., Sveum, P., Brandvik, P.J., Jensen, H.	SINTEF NHL Report STF60 A94087	1994	TR	X		X	X		X			X
114	Oljevern i nordlige og arktiske farvann (ONA) - Status: Volume I (In Norwegian)	Løset, S., Singsaas, I., Sveum, P., Brandvik, P.J., Jensen, H.	SINTEF NHL Report STF60 A94064	1994	TR	X		X	X		X			X

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
115	Spreading of crude petroleum in brash ice: Effects of oil`s physical properties and water current	Sayed, M., Kotlyar, L.S., Sparks, B.D.	ISOPE	1994	CP			X					X	
116	Ohmsett tests of a rope-mop skimmer in ice-infested waters	Shum, J.S., Borst, M.	Oil Spill Conference 1985, pp 31-34	1985	CP			X						
117	A safety and reliability analysis of arctic petroleum production and transportation systems - a preliminary study	Fenco Consultants Limited, Calgary, Alberta	Environment Canada, EE-44	1983	TR						X	X		X
118	Simulation tests of portable oil booms in broken ice	Suzuki, I., Tsukino, Y., Yanagisawa, M.	Oil Spill Conference 1985, pp 25-30	1985	CP			X						
119	Development of a novel ice oil boom for flowing waters	Tsang, G., Vanerkooy, N.	Oil Spill Conference 1979, pp 377-385	1979	CP	X		X	X					
120	Cold environment tests of oil skimmer	Wessels, E.	POAC• 93, pp 741-751	1993	CP			X						
121	Laboratory testing of a flexible boom for ice management	Løset, S., Timco, G.W.	Proc. of the 11th Intern. Conf. on Offshore Mechanics and Arctic Engineering, pp 289-295	1992	CP			X						
122	Muligheter og begrensninger for eksisterende oljevernutstyr ved bruk i is (In Norwegian)	Jensen, H. Johannessen, B.O.	SINTEF NHL Report STF60 F92127	1993	TR			X						
123	Experiences of coping with oil spills in broken ice	Rytkönen, J.	Petro Pioscis II• 92-H-4	1992	CP	X	X	X		X	X			
124	Oil spill research in the cold environment laboratory at SINTEF NHL	Johannessen, B.O., Løset, S., Jensen, H.	AMOP 1994	1994	CP			X						

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
125	Experimental oil spill in the Barents Sea - drift and spread of oil in broken ice	Vefnsmo, S., Johannessen, B.O.	AMOP 1994	1994	CP	X							X	X
126	A winter evaluation of oil skimmers and booms	Environment Canada	Technology Development, Report EPS 4-EP-84-1	1984	TR	X								
127	Oil in pack ice: preliminary results of three experimental spills	Buist, I.A., Bjerkelund, I.	AMOP 1986, pp 379-397	1986	CP								X	
128	A synopsis of Canadian cold water environmental research	Mobil Oil Canada, Mobil Exploration Norway Inc.		1988	TR									
129	Oljens egenskaper. Volum 1: Havklima og isforhold (In Norwegian)	Løset, S., Torsethaugen, K. Johansen, Ø.	SINTEF NHL Report STF60 A89072	1989	TR								X	
130	A review of countermeasures for a major oil spill form a vessel in arctic waters	Environment Canada	Economic and Technical Review, Report EPS 3-EC-83-2	1983	TR				X	X	X	X		X
131	Oil spill response in the arctic. An assessment of containment recover, and disposal techniques - draft	Industry Task Group		1983	TR				X					
132	Behaviour of spilled oil at sea (BOPSS): Oil-in-ice fate and behaviour, draft version	DF Dickins Associated Ltd., Fleet Techn. Ltd		1992	TR								X	
133	Oil spills in leads: Tank tests and modelling	Buist, I., Joyce, S., Dickins, D.F.	Environment Canada, EE-95	1987	TR								X	
134	Eksperimentelle forsøk med olje i den marginale issonen - MIZ• 93. Volum 1: Toktrapport (In Norwegian)	Jensen, H., Løvås, S.M.	SINTEF NHL Report STF60 F93048	1993	TR	X							X	

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
135	Experimental spills of crude oil in pack ice	Buist, I.A., Dickins, D.F.	Oil Spill Conference 1987, American Petroleum Institute, pp 373-381	1987	CP								X	
136	Laboratory and field studies related to oil spill behaviour	El-Tahan, M.	Report submitted to SINTEF NHL	1992	TR								X	
137	Oil spill scenario for the Labrador Sea	LeDrew, B.R., Gustajtis, K.A.	Environment Canada, Environment Protection Service, EPS 3-EC-79-4	1979	TR									X
138	Oil in sea ice	Lewis, E.L.	Pacific Marine Science Report, Inst. of Ocean Sciences, Environment Canada	1976	TR									
139	The application of existing oil spill abatement equipment to cold regions	Schultz, L.A., Deslauriers, P.C.	Oil Spill Conference 1977	1977	CP									
140	A field guide for Arctic oil spill behaviour	Schultze, R.	Arctic Ins., Columbia, Md.	1984	TR								X	X
141	An overview of a field guide for arctic oil spill behavior	Schulze, R., Lissauer, I.	Oil Spill Conference 1985, pp 399-403	1985	CP								X	X
142	The physical interaction and cleanup of crude oil with slush and solid first year sea ice	Nelson, W.G., Allen, A.A.	pp 37-59			X							X	
143	Cold water oil spills	Etkin, D. S	Cold Water Oil Spills, ISBN 0-943779-55-3	1990	TR				X				X	

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
144	Bibliography, Canadian Petroleum Association Publications	Canadian Petroleum Association	Canadian Association of Petroleum Producers	1992										
145	Oil-spilled cause by MT Antonio Gramsci 6th February in 1987 - summary of events		National Board of Waters and Environment, Helsinki, Finland	1987	TR		X			X			X	
146	Behaviour of oil spilled in ice-covered rivers	Chen, E.C., Keevil, B.E., Ramseier, R.O.	Environment Canada, Scientific Series No., 61	1976	TR								X	
147	Oil spill at Deception, Bay, Hudson Strait	Ramseier, R.O., Gantcheff, G.S., Colby, L.	Environment Canada, Scientific Series No. 29	1973	TR					X			X	
148	Oil on ice. How to melt the Arctic and warm the world	Ramseier, R.O.	Environment Canada, Reprint No. 314.	1974	TR					X	X	X		X
149	Combatting marine oil spills in ice and cold conditions	National Board of Waters and the Environment	Proceedings from seminar in Helsinki, Finland	1992	TR	X	X	X	X	X			X	
150	Oil pollution in ice-infested waters	Ramseier, R.O.	Inland waters branch, Dep. of the environment, Reprint No. 163		TR					X			X	X
151	Statistical description of pack ice in the Beaufort Sea, Lancaster Sound and the Labrador Sea	Dickins, D., Diskinson, A., Humphrey, B.	Environment Canada, May 1985, AA 00 62	1985	TR						X			
152	Site visit of oil spill under multi-year ice at Griper Bay, N.W.T.		Environment Canada, January 1983, AA 00 42	1983	TR					X			X	
153	Ice Conditions		Environment Canada, March 1982, AD 81 8	1982	TR						X			

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
154	Oil, ice and gas		Proceedings ,Workshop in Toronto, Canada, 10 - 11 Oct 1979, CZ 79 1	1979	CP									
155	Oil recovery systems in ice	Ross, S.L.	S.L. Ross Environmental Research LTD., Feb. 1984, DB 84 1	1984	TR									
156	Model tests of various oil/ice separation concepts by Arctec Canada Ltd.	Arctec Canada Ltd.	Video, April 1978, HG 78 1	1978				X						
157	Research needed to respond to oil spills in ice-infested waters - findings and recommendations of the U.S. Arctic Research Commission	U.S. Arctic Research Commission	May 1992, DB 92 02	1992	TR									
158	LORI ice cleaner trials and equipment evaluation - trip report	Latour, J.	Canadian Coast Guard, Jan. 1991, DI 91 02	1991	TR	X								
159	Novel countermeasures for an Arctic offshore well blowout	Abdelnour, R., Nawwar, A.M., Hildebrand, P., Purves, W.F.	Environment Canada, Aug. 1977, AB 00 28	1977	TR									X
160	Development and testing of a high tensile strength spill containment barrier for use in a protected sea ice environment		DI 92-09	1992	TR	X								
161	Crude oil spreading in brash ice - data report	National Research Council of Canada, PERD	DA 93-03	1993	TR								X	
162	Evaluation of pumps and separators for Arctic oil spill cleanup		Environment Canada, April 1979, AB 00 55	1979	TR									

#	Title	Author	Source	Year	Ref. type	TOPICS								
						Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
163	Arctic oil spill countermeasures logistics study: summary report		Environment Canada, Dec. 1978, AB 00 48	1978	TR									X
164	Probabilities of blowouts in Canadian arctic waters		Environment Canada, Oct. 1978, AB 00 46	1978	TR						X	X		X
165	A study of on-board self help oil spill countermeasures for arctic tankers	Ross, S.L.	S.L. Ross Environmental Research LTD., March 1983, DB 83 1 (c.2)	1983	TR									
166	Development of an offshore self-inflating oil containment boom for arctic use - Part II - Boom fabric testing	McAllister Engineering	DI 00 01		TR									
167	United States Coast Guard Arctic Oil-Pollution Program	Getman, J.H.	Oil Spill Conference 1975	1975	CP									
168	Kurdistan - an unusual spill successfully handled	Duerden, F.C., Swiss, J.J.	Oil Spill Conference 1981	1981	CP					X				
169	Oil spill countermeasures in landfast sea ice	Allen, A.A., Nelson, W.G.	Oil Spill Conference 1981	1981	CP									
170	KOMI oil spill: an assessment by a multinational team	Devenis, P. and associates	AMOP 1995	1995	CP					X	X	X		
171	Response and management strategies utilized during the Kenay pipeline crude oil spill, Nikiski, Alaska	Sienkiewicz, A.M., O• Shea, K.	AMOP 1992	1992	CP		X			X				
172	Deflection of open pack ice in oil spill recovery area	Løset, S., Carstens, T., Jensen, H.	AMOP 1991	1991	CP			X	X					
173	Environmental atlas for Beaufort Sea oil spill response	Dickens, D.F., Bjerkelund, I.	AMOP 1987	1987	CP						X			

#	Title	Author	Source	Year	Ref. type	TOPICS: Use of mechanical recovery in ice				Histori-cal oil spills	Information on specific areas		Oil beha-viour	Spill scena-rios
						Field exp.	Real spill	Lab test	Theor. Assessm.		Env. cond.	Oil activ.		
174	Countermeasures for dealing with spills of viscous, waxy crude oil	Potter, S.G., Ross. S.L.	AMOP 1987	1987	CP									
175	The Alaskan clean seas research, development and engineering program	Shafer, R.V.	AMOP 1987	1987	CP									
176	Oil spreading in broken ice	Schulze, R.	AMOP 1985	1985	CP								X	
177	Tests of oil skimmer at low temperatures	Schwarz, J.	Proc. Intern. Conf. on Technologies for Marine Environment Preservations (MARIENV• 95), Vol. 1, pp 295-298, Tokyo, Japan	1995	CP			X						
178	Research on oil spill in HSVA’s new environmental test basin for cold regions	Wessels, E.	HELCOM-Seminar “Combating Marine Oil Spills in Cold and Icy Conditions”, Helsinki, Finland	1992	CP									
179	Cold environment tests of an oil skimmer	Wessels, E.	Proceedings 12. Int. Conf. on Port and Ocean Engineering under Arctic Conditions (POAC), Vol. 2, pp 741-751	1993	CP			X						
180	Cold water oil spills		State-of-the-art information, Cutter Information Corp., 37 Broadway, Arlington, MA 02174-5539 USA, Oil Spill Intelligent Report	1993	TR									

*) TR = Technical Report CP= Conference Proceedings J= Journal MI= Manufacturer´s Information

ANNEX 3

IMAGE GALLERY

Prepared by:

HAMBURGISCHE SCHIFFBAU-
VERSUCHSANSTALT GmbH
Dipl.-Ing. Karl-Ulrich Evers
Bramfelder Straße 164
D-22305 Hamburg
Germany

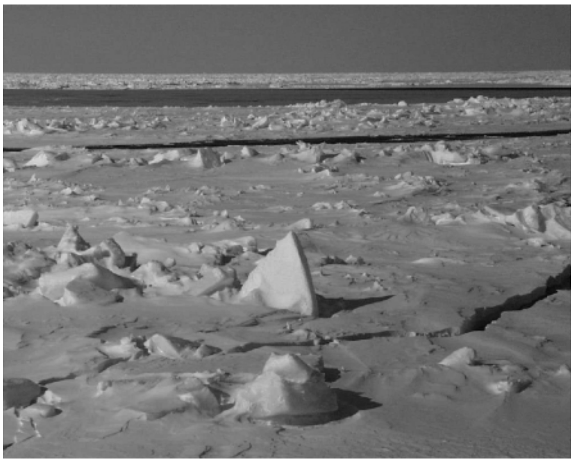
ANNEX 3-A

HSVA_PI015_16.JPG

New ice formation at the marginal ice zone

HSVA_PI025_1.JPG

Nuclear Icebreaker ROSSIA in level ice, which is covered by 10-15 cm of snow

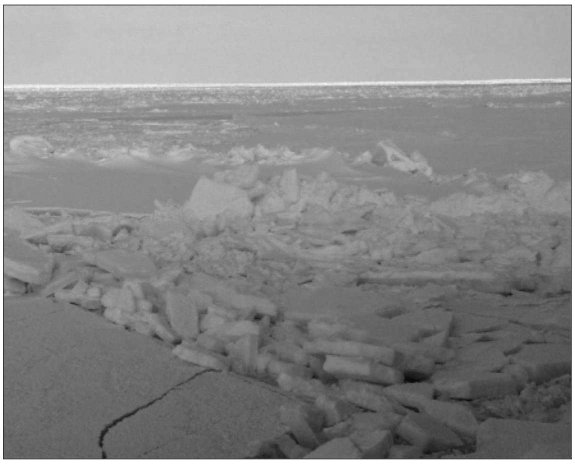


HSVA_PI025_13.JPG

Open leads and major cracks in a smooth ice rubble field

HSVA_PI025_3.JPG

MT UIKKU follows IB DRANITSYN in the broken channel surrounded by level ice



HSVA_PI025_27.JPG

Accumulation of broken ice floes of 20-30 cm thickness

HSVA_PI045_36.JPG

Broken channel in snow covered level ice

ANNEX 3-B

HSVA_PI045_52.JPG

MT UIKKU in the artificial ice harbour at the “terminal site” previously prepared by IB DRANITSYN. The brown colour in the water indicates the suspended sediment due to water depth of about 8 to 10 m.

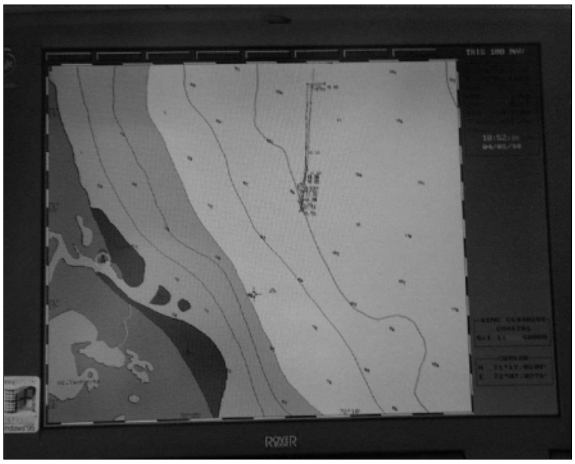
HSVA_PI045_26.JPG

Level ice covered by a ~30 cm thick snow layer

HSVA_PI045_48.JPG

MT UIKKU in level ice with weathered“ snow cover in the Ob River close to the off-loading terminal site

ANNEX 3-C



HSVA_PI045_53.JPG

Location of the „off-loading terminal“ site (71°18.2‘ N 072° 8.6‘ E) ; water depth at the site is about 8 - 10 m.

HSVA_PI045_32.JPG

The „off-loading terminal“ on the ice. The two pipelines to the tank farm onshore are about 4 km long

HSVA_PI045_31.JPG

Open sludge basin at the pipeline's end and a 40 m^3 sludge tank at the "Loading Terminal" site

KMY_2.JPG (courtesy of KMY)

MT UIKKU reached the „Loading Terminal“ . The mobile crane leaves the site.

KMY_10.JPG (courtesy of KMY)

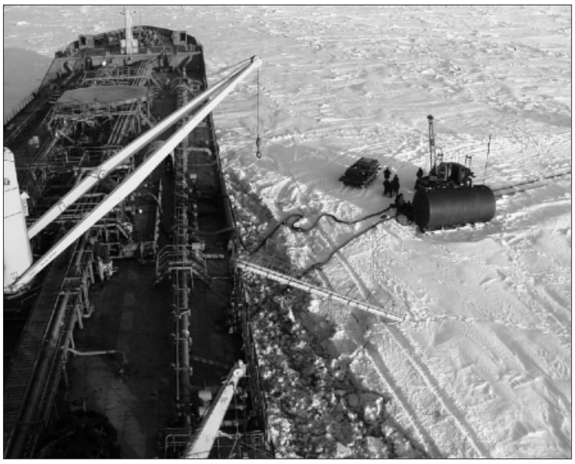
Hoses from MT UIKKU are connected to the 4 and 6 inch steel pipelines.

KMY_12.JPG (courtesy of KMY)

Hose connection to the pipeline – using a heavy mobile crane.

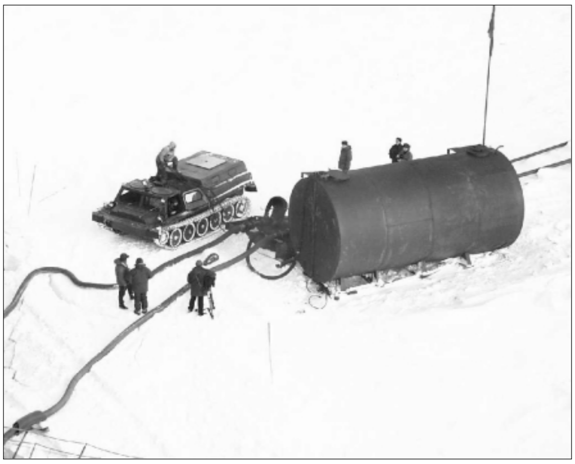
KMY_13.JPG (courtesy of KMY)

Connection of hoses to the pipeline. The valves are positioned above the sludge box.



KMY_5.JPG (courtesy of KMY)

MT UIKKU on her final “loading position”



KMY_9.JPG (courtesy of KMY)

Hoses from MT UIKKU are connected to the 4 and 6 inch steel pipelines. Left of the sludge tank a chain driven vehicle.

ANNEX 3-D

HSVA_PI065_1JPG

The hoses are connected to the pipeline.

HSVA_PI065_11JPG

Installation work on the valves.

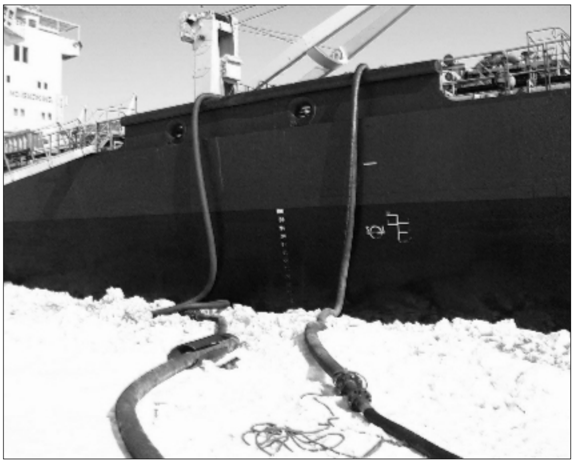
HSVA_PI065_12JPG

Partly snow covered steel pipeline along the ice road laying on the ice surface without foundation.

ANNEX 3-E

HSVA_PI065_3.JPG

Hose from MT UIKKU is fixed to the valve.



HSVA_PI065_2.JPG

Hoses from the tanker.

HSVA_PI065_38.JPG

Sludge basin below the connection points.

HSVA_PI065_16.JPG

Tank farm in Sabeta – about 4 km away from the „Loading Terminal“

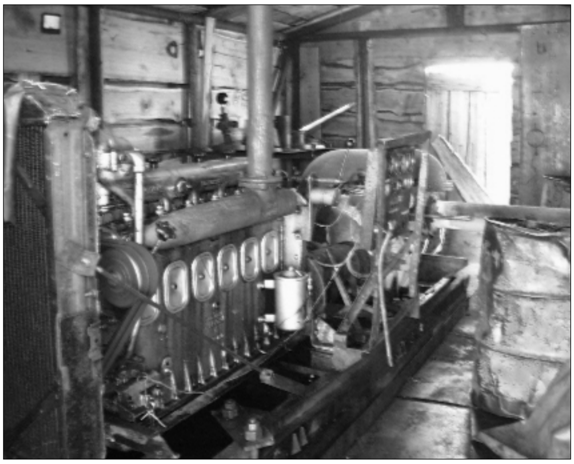
HSVA_PI065_36.JPG

Storage tanks in Sabeta – Due to low temperatures there is ice on the hull of the tanks. The tundra is covered with 30 to 40 cm thick snow.

HSVA_PI065_29.JPG

Heavy truck is used for pipeline installation

ANNEX 3-F



HSVA_PI065_37.JPG

Stationary pump of Type Y8-MA2 in Sabeta.

HSVA_PI065_32.JPG

Stationary pump of Type Y8-MA2 in Sabeta.

HSVA_PI065_33.JPG

Stationary pump of Type Y8-MA2 in Sabeta.

ANNEX 3-G

HSVA_PI065_34.JPG

Pump housing in Sabeta.

HSVA_PI065_35.JPG

Pump housing in Sabeta.

HSVA_PI065_39.JPG

Pipelines of 4 in. and 6 in. At the "Loading Terminal".

HSVA_PI065_38.JPG
End of pipeline

HSVA_PI065_40.JPG

Hand driven valve.

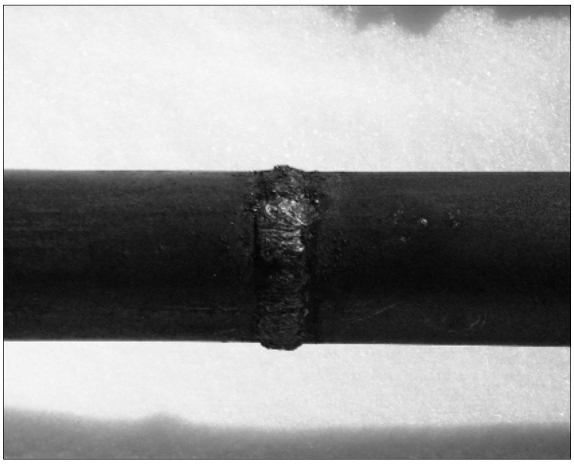
HSVA_PI065_42.JPG

Kinking of hoses should be avoided.

ANNEX 3-H

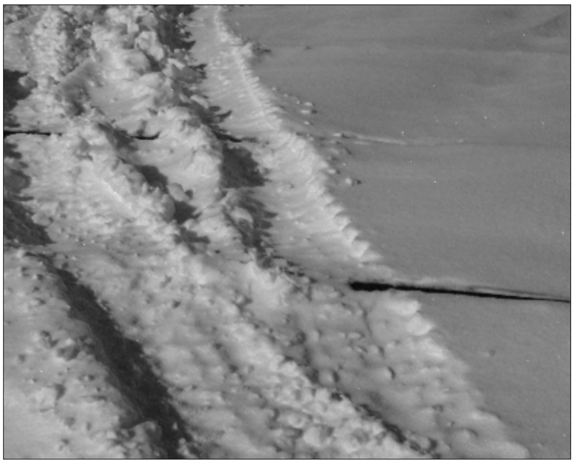
HSVA_PI065_5.JPG

A few litres of gascondensate are collected in the sludge basin.



HSVA_PI065_7.JPG

Welded pipeline.



HSVA_PI065_8.JPG

Tracks of chain driven vehicles after crossing the pipelines.

ANNEX 3-I

HSVA_PI075_3.JPG

Manifolds on the port side of the tanker.

HSVA_PI075_4.JPG

Fire gun on the main deck of UIKKU.

HSVA_PI075_1.JPG

400 m long floating oil boom onboard of MT UIKKU.

V WP 13 Trafficability

(HSVA-Report E 293/99; Dr.-Ing. K.-H. Rupp, L. Lübke)

Report E 293/99

ARCDEV

Arctic Demonstration and Exploratory Voyage

TRAFFICABILITY
WP 13

Sponsored by:

EC Transport - 4th Framework

WATERBORNE TRANSPORT

Contract - No: WA 97-SC.2191

and

Bundesministerium für Bildung und Forschung (BMBF)

ARCDEV

Arctic Demonstration and Exploratory Voyage

EC Transport - 4th Framework
WATERBORNE TRANSPORT
Contract - N^{o}: WA-97-SC.2191
Project: ARCDEV

TRAFFICABILITY

WP13

Report

June 1999

ARCDEV - Report on “TRAFFICABILITY”

Copy N^{o}: 0

Deliverable:	Version 1
Work Package:	**13**
Dissemination Level :	
Nature :	Interim Report
Agreed delivery date :	*dd/mm/jj*
Actual delivery date :	*dd/mm/jj*

Technical Abstract:

Comparison of the measured and calculated ship velocity in varied ice conditions. The calculations are based on ice data from observations, from ice prediction and from electromagnetic (EM) ice thickness data.

Keywords:

Ship

Ice

Navigation arctic water

Trafficability

Velocity, ice

Velocity, prediction

Ice observaton

Ice charts

Electromagnetic ice thickness

ARCDEV - Report on "TRAFFICABILITY"

Project Co-ordinator:
Capt. Juhani Laapio (Vice President) **NESTE Shipping** Keilaranta 6 P.O. Box 20 **FIN-02151 Espoo** Finland Tel.: +358 20 450 4412; Fax.: + 358 20 450 4293 e-mail: Juhani.Laapio@neste.com; WWW: www.neste.com

Produced by:

Responsible Organisation	Principal Authors
HSVA	Dr. Karl-Heinz Rupp, Lars Lübke

Contributing Organisations	Contributing Authors
KMY NESTE CNIIMF	A. Uuskallio Ivan Ivanov Dr. L.G. Tsoy, Yu. V. Glebko, S.M. Ponomarev

Separate Report from CNIIMF
Principal Author: Dr. L.G. Tsoy, Yu. V. Glebko, S.M. Ponomarev

Issued by

HSVA – Hamburgische Schiffbau-Versuchsanstalt GmbH
Bramfelder Strasse 164, D-22305 Hamburg, Germany
Tel. +49-(0)40-692030, Fax +49-(0)40-69203-345

Distribution List:

Copy No.	Recipient	Status	Location
0	Generated locally		uncontrolled Copy
1	Prof. Dr. Sergey M. Priamikov		AARI
2	Mr. Mikhail Pakholok		ASS
3	Dr. Christian Haas		AWI
4	Dr. Loly G. Tsoy		CNIIMF
5	Dr. Neil McIntyre		EOS
6	Dr.-Ing. Joachim Schwarz		HSVA
7	Prof. Dr. Kaj Riska		HUT
8	Mr. Klaus D. Pfeiffer		HYDROMOD
9	Prof. Dr. Jens Froese		ISSUS
10	Mr. K. Juurmaa		KMY
11	Dr. Yuri A. Simonov		KRSI
12	Mr. E. Lefteris Karaminas		LLOYD'S REGISTER
13	Capt. Anatoly Gorshkovsky		MSCO
14	Mr. Guido Schulte		MTW
15	Mr. Lasse Herbert Pettersson		NERSC
16	Capt. Markus Karjalainen		NESTE
17	Mr. Charles Sederholm		REMTEC
18	Mr. Charles A. Shotton		SHELL
19	Mr. Giovanni Busetto		TECNOMARE
20-24		DG VII	CEC

LIST OF CONTENT

1 INTRODUCTION 4

2 ARCDEV 4

3 INPUT DATA FOR CALCULATING THE SPEED OF THE VESSEL IN ICE 8

3.1 ENVIRONMENTAL DATA 8
3.1.1 Ice conditions 8
3.1.2 Ice and weather charts 9
3.2 SHIP AND CONVOY DATA 11

4 BRIEF PROGRAM DESCRIPTION 12

5 RESULTS 13

5.1 COMPARISON: IMPROVED PROGRAM AND BASIC PROGRAM 13
5.2 RELATIVE ERROR DISTRIBUTION AND THE NUMBER OF LEGS 14
5.3 RELATIVE ERROR DISTRIBUTION WITH THE PREDICTED ICE DATA FROM NOAA 15
5.4 COMPARISON OF RELATIVE ERROR DISTRIBUTION BETWEEN EM AND OBSERVED ICE DATA 16
5.5 SUMMARY OF THE RESULTS 18

6 CONCLUSIONS 20

7 RECOMMENDATION FOR FUTURE RESEARCH 21

ANNEX

The Annex includes:

- Speed, power and partly EM ice thickness vs. the time for each leg, based on one minute average
  (PB_V_Hi_Diagram, Mur_Sab_dia.xls, Sab_Mur_dia.xls (Excel 97))
- Observed and predicted ice conditions
  (Mur_sab_forecast.xls and sab_mur_forecast.xls (Excel97))
- NOAA ice charts
  (Kara Sea: karsYYmmdd.gif, Barents Sea: barsYYmmdd.gif)
- Weather charts
  (Surface: ddmmyys.tif and 500hPa chart: ddmmyyp.tif)
- ice charts plotted from ice observations (karteco.doc)

1 Introduction

Predicting the speed of a vessel in ice covered water is more difficult than for open water. The environmental open water conditions are usually described by sea state, wind and water depth. The environmental ice conditions have several more parameters such as ice concentration, ice thickness, age of the ice, strength, hummocked or ridged areas, open leads, snow etc. Each of these different ice conditions results in a different resistance of the icebreaking vessel, which must be overcome by the propeller thrust. The ice resistance depends mainly on the forebody hull shape.

Propulsion power and speed are indicators for the resistance of a vessel in the prevailing ice conditions. Therefore, the vessel can be used as an indicator for the severity of the ice conditions. However, many different ice conditions can exist which lead to the same resistance. Therefore you cannot define the ice conditions based only on the speed and power of the vessel.

The target of WP 13 is to improve existing computer programs which calculate the speed of a vessel in different ice conditions taking different modes of icebreaker assistance into account. In order to do achieve this target within the ARCDEV project, measurements of speed and power were made together with observations of the ice conditions.

The main goal in ice navigation is to find the shortest path (with regards to time) to the port of destination. This ice routing is carried out both before and during a voyage, and is supported by calculations of the vessel's speed under the ice conditions expected along the route. Within this project the subject of ice routing is handled within WP 5, whereby programs suitable for calculating the vessel's speed are being improved in WP 13.

In this report the actual speed of the Russian icebreaker KAPITAN DRANITSYN (KD) as measured during ARCDEV is compared with the calculated speed. The speed calculations (using the measured power of KD) are based on both the actual observed ice conditions as well as on those given in available ice charts.

Independent calculations of the same scope were also carried out by the Russian partner of WP 13 (refer to the CNIIMF report for WP 13). The reports of both partners together make up the complete report for WP 13.

2 ARCDEV

The voyage started from the port of Murmansk on April 26, 1998. The route of the convoy (see Fig. 4.1) (Russian icebreaker KAPITAN DRANITSYN (KD) and Finnish tanker UIKKU (U)) led along the west coast of Novaya Zemlya up to the north edge of the island. The shorter way though the Kara Gate was blocked by ice due to the easterly winds. The northern edge of Novaya Zemlya was passed on the 29th of April, 1998 at which time the convoy got stuck in ice. With the help of the Russian nuclear icebreaker ROSSIA (R) the convoy was freed and then guided eastward and southward to the estuary of the river Ob where the ROSSIA left the convoy on May 3rd, 1998. The remaining two ships of the convoy sailed in the channel in landfast ice which had been broken by the Russian icebreaker TAYMIR some days before. KD was then the leading icebreaker on the way to the loading terminal Sabeta which was reached on May 4th, 1998.

Loading was completed on May 8, 1998 and the convoy proceeded back to Murmansk through the Kara Gate. ROSSIA guided the convoy from the Ob estuary through the Kara Sea and the Kara Gate. Murmansk was arrived in the early morning of May 14, 1998.

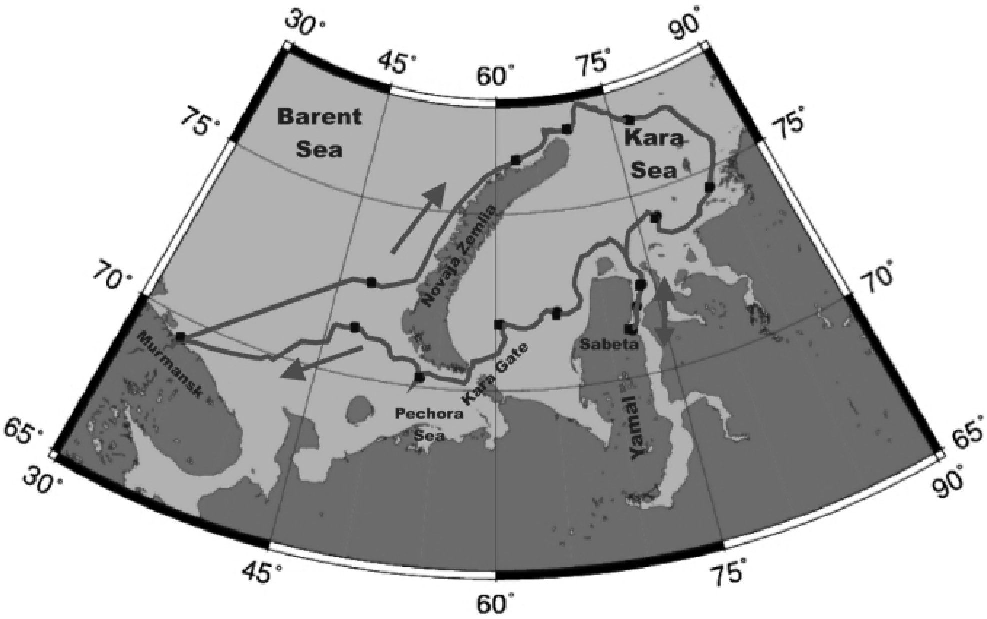


Fig. 2.1 Route of the convoy

The convoy of the ARCDEV Demonstration Voyage consisted of the Russian Icebreaker KAPITAN DRANITSYN, the Finnish motor Tanker UIKKU and the Russian nuclear icebreaker ROSSIA in the area of the Kara Sea. The principal dimensions of the vessels are given in the following table:

			KAPITAN DRANITSYN	ROSSIA	UIKKU
Length over all	Lpp	m	129.06	148.0	164.5
Length of water line	Lwl	m	119.0	136.0	
Beam cwl	Bcwl	m	25.6	28.0	21.5
Draft cwl	Tcwl	m	8.5	11.0	9.5
Displacement or deadweight	DWT	MT	12500	23460	16500
Total installed power	PB	kW	18100	54241	12000
Total shaft power	PD	kW	16200	48324	11400
Number of propeller (FP, no nozzle)			3	3	1 Azipod
Number of blades			4	4	4
Propeller diameter	D	m	4.3	5.3	
Bollard pull		MT	181	483	
Propulsion type			Diesel Electric	Nuclear Steam Turbine Electric	Diesel Electric Azipod
Endurance		nm Days	12000 28	275000 550	
Stated icebreaking ability at 2 kts		m	1.35	2.25	1.0
Maximum OW speed		kts	19.0	20.8	14.5
Operator/Owner			Murmansk Shipping Co.	Murmansk Shipping Co.	Neste Finland
Builder			Wärtsilä Finland	Baltic Shipyard, St. Petersburg, Russia	Nobiskrug Germany
Built in			1980	1985	1976

Table 4.1: Main events of the voyage

References:

1. 1994-1995 Northern Sea Route Directory of Icebreaking Ships, 1994 Backbone Publishing Company, ISBN 0-9644311-0-6
2. Catalog of the World's Icebreakers, 1998, USCG Engineering Logistics Center, Baltimore, MD, USA

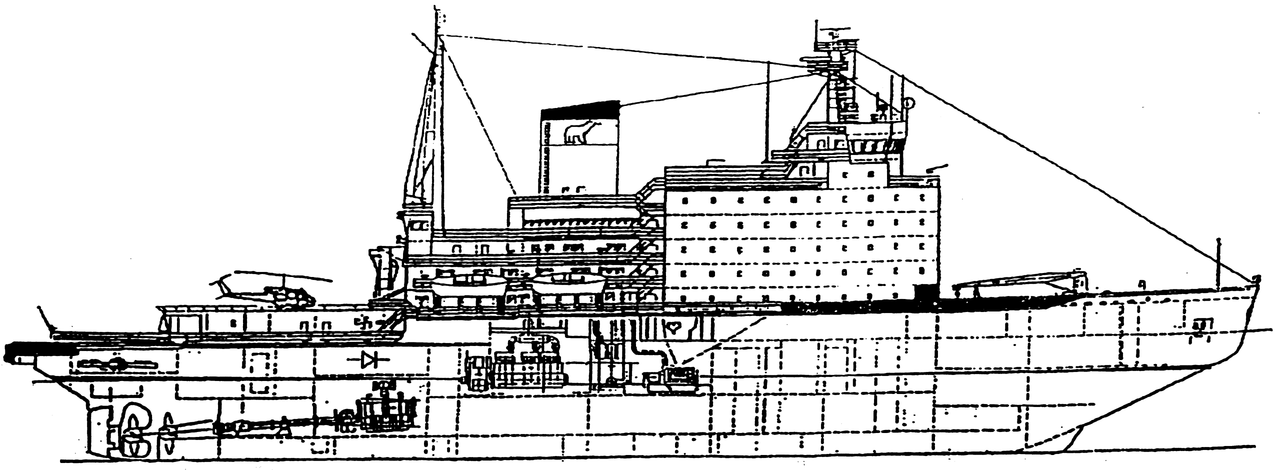


Fig. 2.2 Russian Icebreaker KAPITAN DRANITSYN

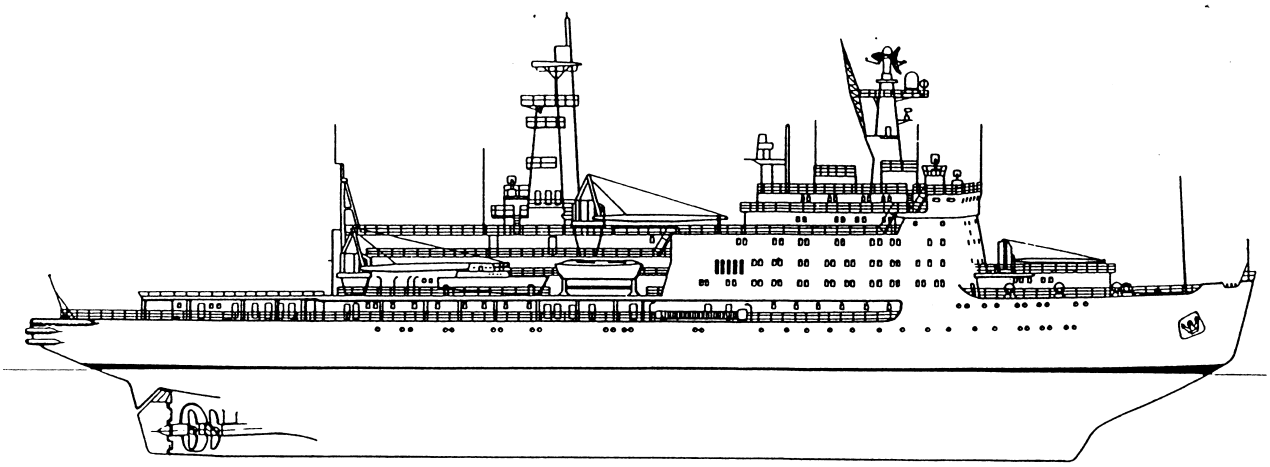


Fig. 2.3 Russian Nuclear Icebreaker ROSSIA (Ref. 2)

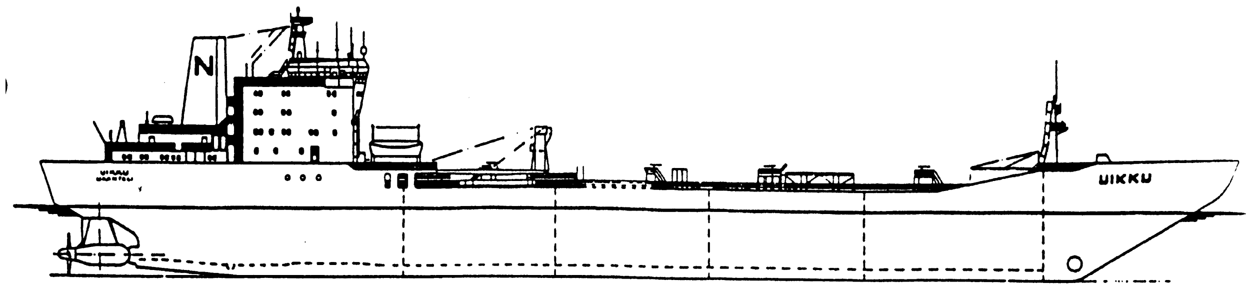


Fig. 2.4 Finnish Tanker UIKKU

(Ref. 3: Electric Propulsion and Power Plants Applied in Recent Tanker Newbuildings, ABB Marine, 1995)

3 Input Data for Calculating the Speed of the Vessel in Ice

The purpose of the program is to calculate the speed of the vessel based on the ice conditions as well as on the icebreaking and powering performance of the vessel. The input data are described in detail in the following sections.

3.1 Environmental Data

3.1.1 Ice conditions

The ice conditions were observed and documented during ARCDEV by the German group, by AARI and by CNIIMF (see also WP 3). The data taken by the German group are given in the Annex to this report and in Fig. 2.1. The format is accordance with the World Meteorological Organisation (WMO)-Standard. For the following calculations only the observation data from the German group has been used.

The complete voyage is broken down into a number of legs. In each such leg the ice conditions are taken to be constant. One aid for determining the ice conditions for a leg is to use the WMO Standard for ice charts, the so called "egg code". In these charts, each "egg" describes the average ice conditions within a specific limited area. The definition of the "egg code" is available in internet (http://www.natice.noaa.gov/egg.htm).

Please note that ice observation data is subjective as it is based on the impressions of individual persons. Therefore for the same ice conditions, the observed ice condition data will scatter between the different observers.

Not only the ice condition is important for speed calculations but also the area for which it is observed. For calculating the speed only the ice conditions directly in front of the bow of the vessel are important. Ice which will not be broken by the vessel is not of interest for calculating the speed. This is a very important point when making ice observations. For example when passing the Kara Gate on the way back to Murmansk during ARCDEV, the observer described the very impressive hummocked ice around the ship. However in reality the ship followed cracks and open leads at relatively high speed with reduced power. The calculated speed based on the observation was much lower than that actually measured.

During ARCDEV the icebreaker "KD" spent most of the time following the icebreaker ROSSIA. The ice observer could only see the broken channel of the icebreaker sailing ahead and also the ice beside this broken channel. It was not possible to see the ice that was being broken by the leading icebreaker. Therefore it would be better if the ice observer could observe from the leading icebreaker.

The ice observation (or ice condition data from another source) is one main input for calculating the speed of the vessel. Mistakes in the observation cannot be compensated for by the computer program. This is one reason why the results of the speed calculations scatter (see Chapter 5).

3.1.2 Ice and weather charts

Ice charts are one basic source of information both before and during a voyage through ice covered water. Ice charts from the American "National Ice Center" for the actual time of the voyage were used to calculate the speed of the vessel along the ARCDEV route (http://www.natice.noaa.gov/pub/East_Arc..).

The predicted ice conditions along the ARCDEV route together with the observed ice conditions are included in the Annex to this report.

Information from weather charts was not taken into account in the program for calculating the speed in ice. When calculating the speed for observed ice conditions this information is not necessary. However, when predicting ice conditions, the wind (force and direction) has a significant influence on the movement of the ice, ice pressure and hummocking can therefore not be neglected (see Annex).

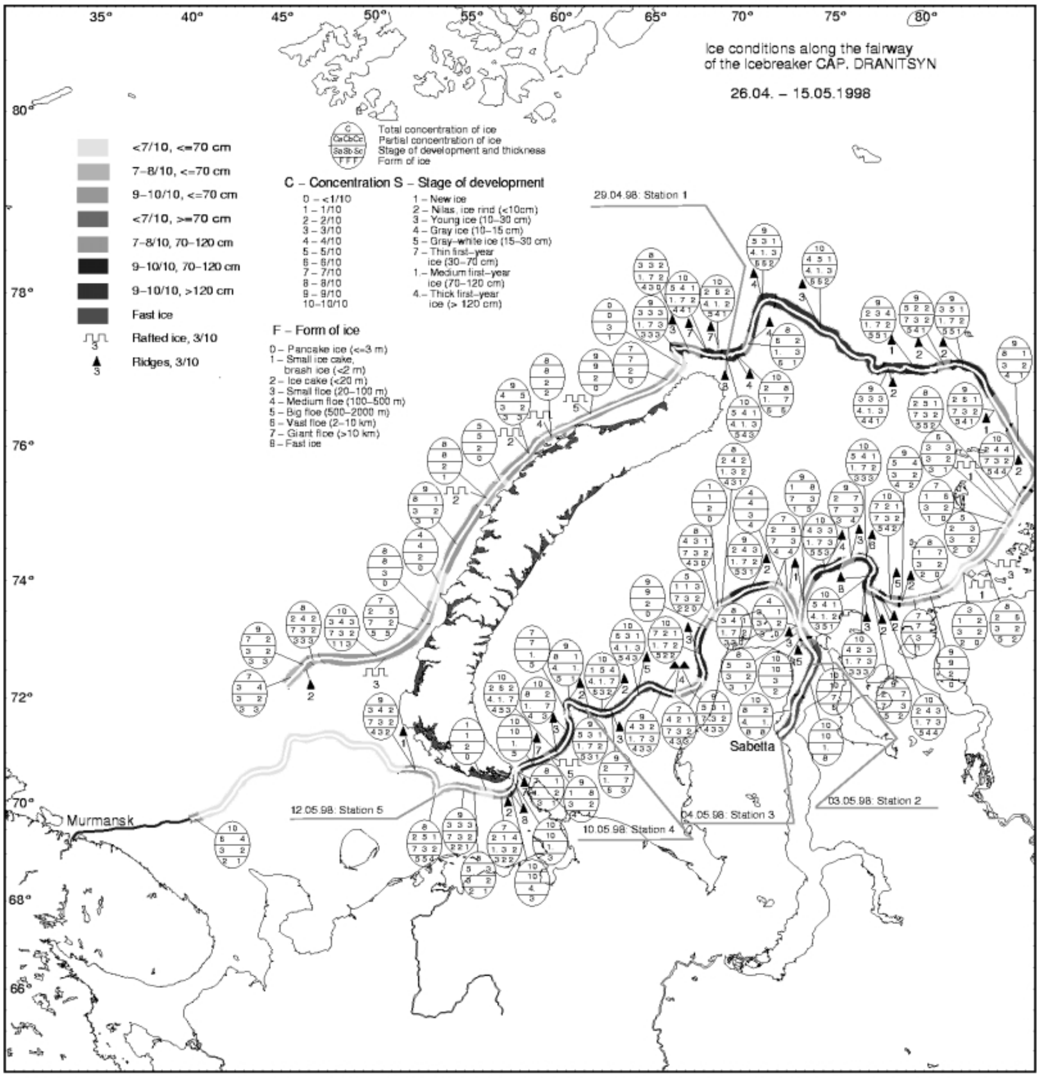


Fig. 2.1 Ice conditions along the route of KAPITAN DRANITSYN

3.2 Ship and Convoy Data

The program requires the following ship data for calculating the icebreaking performance of the vessel:

- main dimensions of the vessel (length, beam, draft)
- forebody geometry:
  - Stem angle and buttock angles at several positions over the entire beam of the vessel as well as waterline angles at the same positions
- friction coefficient between the ice and the hull surface
- correction functions for tuning the influence of different ice conditions on the resistance of the ship
- power of the vessel and maximum allowed speed
- order in the convoy
- lead icebreaker's ice clearing capability
- position of the ship

An important parameter for the speed of the vessel is whether or not it is following an icebreaker in a broken channel. The ice conditions for the following vessel are greatly different from those that the icebreaker is encountering. The following ship is sailing in broken ice and ice cake. An observer on the following vessel should describe the ice conditions in the channel and not those of the natural ice beside the channel. For calculating the ship's speed in the newly broken channel the size and thickness of the broken floes in the channel were the input data. The thickness of ice was taken from observations of the ice next to the broken channel. The size of the floes was set to 5 m.

One additional input parameter describes the ice clearing effect of the leading icebreaker. This parameter can be used for distinguishing between different lead icebreakers and/or the number of vessels ahead in the channel.

When predicting the vessels speed under given ice conditions for a leg of a voyage, either the maximum achievable speed or the maximum allowable speed is used, whichever is smaller. The maximum achievable speed is calculated based on the maximum available power. The maximum allowable speed is input data. It is based on good ice seamanship and takes the construction strength of the vessel into account.

For calculating the vessel's speed during the ARCDEV voyage, the average measured propulsion power of each leg was used as input data. A maximum allowed speed was not applicable.

The length of a leg is calculated based only on the positions of the ship at the beginning and end of the leg. The speed for the leg is taken to be the length of the leg divided by the total time required to cover it. Please note that the length of a leg according to the above definition is always shorter than the sum of shorter distances making up the leg. The reason is that during ice navigation the vessel follows the easiest ice conditions, changing course and sometimes ramming and setting back or searching for a new, more easy path.

4 Brief Program Description

From the ice observation data for each leg an equivalent level ice thickness is calculated based on parameters such as:

- level ice thickness
- ice concentration
- ice floe size
- ridge or hummock occurrence
- ice pressure

Correction functions are used for each of the above mentioned ice conditions to calculate the equivalent ice thickness. The correction functions influence the ice thickness so that the resistance under the above ice conditions causes the same ship resistance in an equivalent level ice thickness. Therefore the correction functions are specific for each ship.

With this equivalent ice thickness the resistance is calculated according to G. Lindqvist, "A straightforward method for calculation of ice resistance of ships", POAC 1989. This method has been improved by HSVA.

The open water resistance is calculated according Holtrop/Mennen and added to the ice resistance (Holtrop, J.; Mennen, G.; An approximate power prediction method; ISP 1982).

The delivered power and thrust are calculated with the help of empirical formulae. Both can be adapted to the actual vessel if model or full scale prediction data are available.

The program delivers the following results for each leg:

- distance and course for the leg (great circle calculation between start and end of the geographic position of the leg)
- average speed
    - case 1: Operating with maximum power and/or maximum allowable speed
      Results: speed and propulsion power for the leg
    - case 2: ARCDEV voyage, using the average measured power of icebreaker KD
      Result: speed and the time required for the leg.

The difference between the time measured for a leg during the ARCDEV voyage and the calculated time for the same leg is an indicator for the reliability of the calculations.

5 Results

5.1 Comparison: Improved Program and Basic Program

Calculating speed and used power of icebreaking ships in ice covered waters is important for the prediction of the economy of a transport in that area. Input data for such calculations are statistical ice data or ice charts of some years. By the ARCDEV voyage the prediction programs have been improved and shortcomings of the program eliminated.

A comparison between the calculation with the original HSVA program and the improved version was carried out. Fig 5.1 shows the relative error distribution (difference between calculated and true time for a leg in percentage) over the relative temporal deviation.

If the relative temporal deviation would be in a narrow range, the program and the observed ice data are correct. If the values scatter widely, the program and/or the input data of the ice observation have shortcomings or mistakes. The ice observation of ARCDEV have shortcomings as described in Chapter 3. One clearly identified mistake is the ice observation in the Kara Strait (observed thick hummocked ice, but the vessels followed cracks and open leads). The calculated time for passing this area was some 100% wrong. This calculation is included in the column > 100%.

The subjective ice observation prevents the improvement of the program. The input ice data are not fully true, therefore the basis for improvements is weak. Nevertheless, program improvements were carried out. All these differences brought the error distribution closer together but still the scattering is large. Further variation of the correction functions helped to reduce the error in some legs but the total error and the scattering increased.

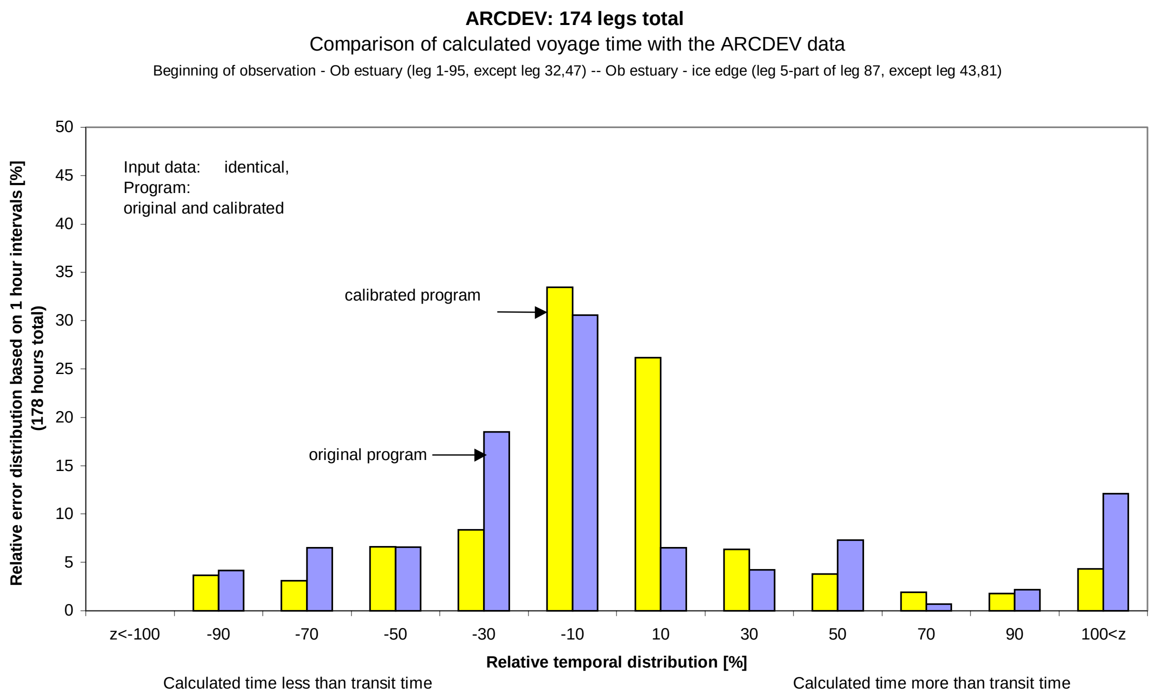


Fig. 5.1 **Comparison: Improved and basic program, relative error distribution vs. relative temporal deviation**

5.2 Relative Error Distribution and the Number of Legs

In Part 3.1 175 legs of the voyage from the ice edge to the Ob estuary and back from the Ob estuary through the Kara Gate to the ice edge were calculated. Larger legs were formed, so that totally 29 legs for the voyage were established. The only difference in the calculation between 175 legs and 29 legs was that the distance in the longer legs was the sum of the distance of the old shorter legs.

The error distribution showed a concentration around zero. The maximum errors were reduced from -90% to -70% and from >100% to 50% (Fig. 5.2). This result indicates that errors in the ice observation could be partly neglected by increasing the length of a leg.

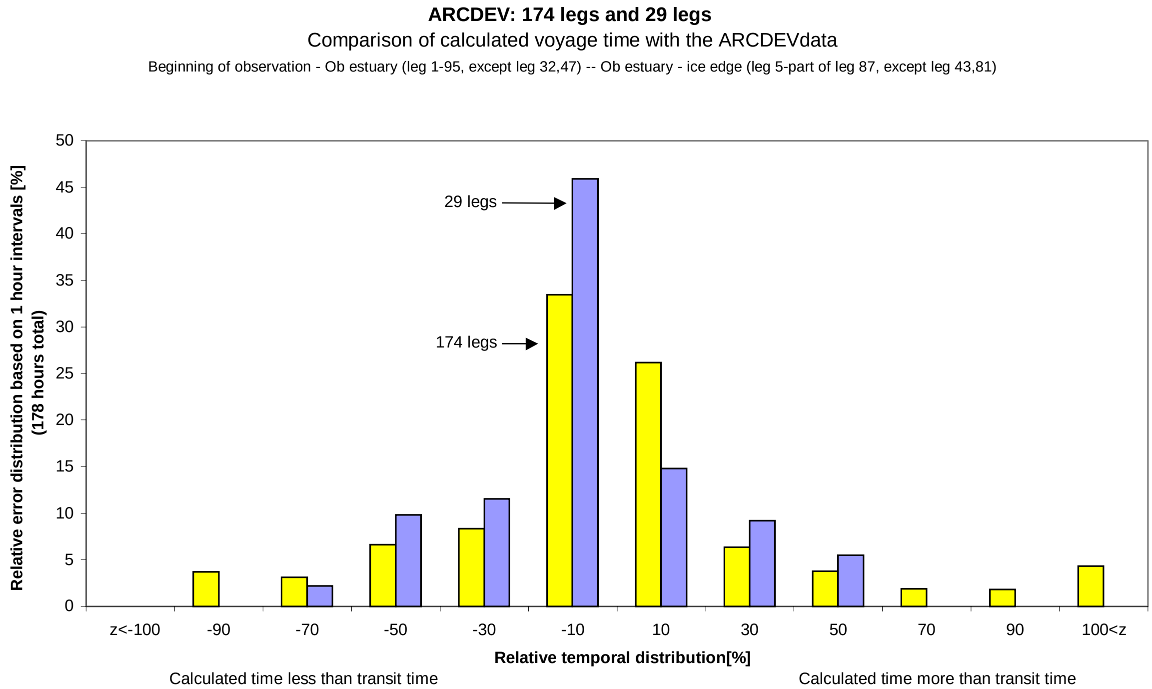


Fig. 5.2 Comparison of the number of legs on the relative error distribution

5.3 Relative Error Distribution with the Predicted Ice Data from NOAA

The ice charts from NOAA (see Annex) were used as input data for the ice conditions along the ARCDEV route. With these predicted ice data and the used power of KAPITAN DRANITSYN the speed was calculated. The legs were identical with the legs in part 5.2. The comparison between NOAA ice data ("egg-code"), NOAA ice data + observed ridges and hummocks observed by HSVA showed that in the predicted ice conditions the vessel would sail faster. One reason for this result are the ridges and hummocks which cause a low average speed. They are not clearly marked in the egg-code. Ridges and hummocks reduce the speed of a vessel very strongly and are often the reason that a vessel gets stuck, cannot ram through and searches for an easier but longer way around this obstacles. Another shortcoming in the egg code are the large steps in the ice thickness. It would improve the calculation, if the ice thickness would be given in steps of 0.1 m.

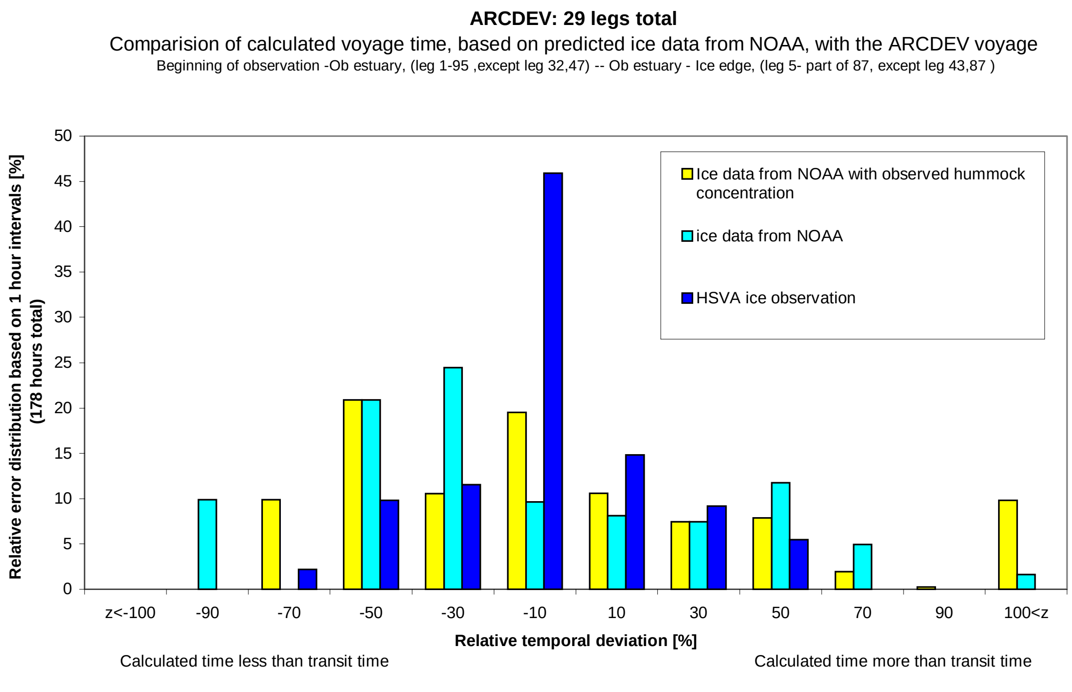


Fig. 5.3 Comparison in the distribution between predicted ice data from NOAA and observed ice data

5.4 Comparison of Relative Error Distribution Between EM and Observed Ice Data

During ARCDEV extensive continuous electromagnetic (EM) ice thickness measurements were performed along the route on board of the icebreaker **K**APITAN **D**RANITSYN. The measurements were compared with the ship´s speed and power (see the plots in Annex). The ice thickness was measured over port side in the area of the wave breaker on board of KD. When KD was the leading icebreaker the real ice thickness was measured at this position. But during ARCDEV voyage KD followed mostly in the broken channel of the leading icebreaker ROSSIA. Therefore the EM measures the thickness of the ice edge of the broken channel which is thicker than the unbroken ice. Furthermore, the ice thickness was measured at different distances from the edge of the broken channel.

For the speed calculation of KD the average ice thickness measured with the EM was used for a leg. The ice thickness was reduced by 0.75 to compensate the thicker ice thickness of the ice edge of the broken channel. This reduced ice thickness was used as equivalent ice thickness. It should be noted that all corrections have now the same influence on the equivalent ice thickness. This should be used as a very early step to use the EM measured ice thickness and to calculate from this information the ship´s speed.

Further development should include ice thickness classes to filter out ridges, open water etc. to make more use of the measured information. But it would be the best to write a new program using the measured ice thickness and calculating in very short steps the resistance of the vessel with acceleration and deceleration, so that a speed profile is calculated for the ice thickness profile.

In Fig. 5.4 the relative error distribution is plotted using the EM ice thickness and the observed ice thickness. The result shows that with EM measured ice thickness the results scatter less than with the observed ice thickness. Especially the distribution > 100 % is clearly reduced.

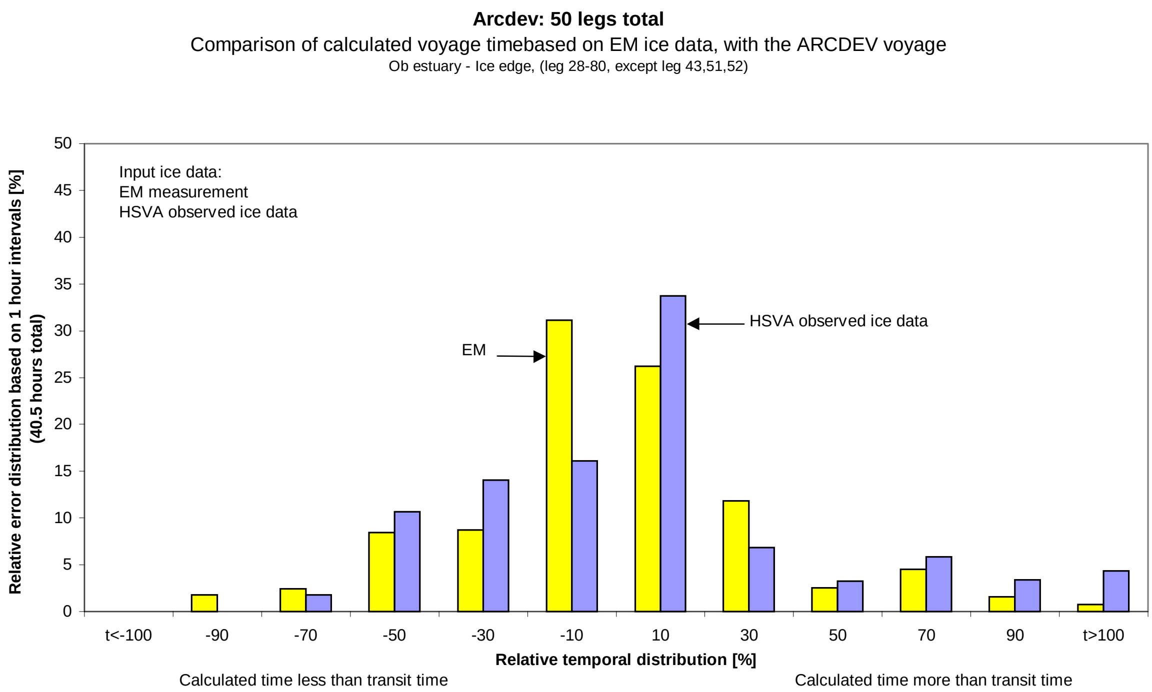


Fig. 5.4 Comparison of relative error distribution between EM and observed ice data

5.5 Summary of the Results

The results of the trafficability calculations based on ice observation and on predicted ice charts are listed in the Tables 5.1 to 5.3. Two program versions were used. The program version 1 was available at the voyage, the version 2 is the improved and calibrated version. This version was calibrated without the leg "Kara Strait" where the ice observation is wrong. No changes in the program or of the calibration of the program were carried out when calculating the different cases.

Ice data	No. of legs (-)	Real Time (minutes)	Calculated Time (minutes)	Difference Calc.-real (minutes)	Error (%)	Remarks
observed	174	10660	12224	1564	14.67	Without calibration and improvements Version 1
observed	173	10600	11519	919	8.67	* - " -
observed	174	10660	11201	541	5.08	Improved and calibrated program (Version 2)
observed	173	10600	10736	136	1.28	* - " -
observed	29	10660	10004	-656	-6.15	Version 2
predicted NOAA with observed ridges & hummocks	29	10660	10007	-653	-6.13	Version 2
predicted NOAA	29	10660	9280	-1380	-12.95	Version 2

* excluded the leg in the Kara Strait

Table 5.1 Results for the voyage from the edge to the Ob estuary and from the Ob estuary to the ice edge on the way back to Murmansk

Ice data	No. of legs (-)	Real Time (minutes)	Calculated Time (minutes)	Difference Calc.-real (minutes)	Error (%)	Remarks
observed	93	6861	7276	415	6.05	Without calibration and improvements
observed	93	6861	7088	227	3.31	Improved and calibrated program
observed	20	6861	6638	-223	-3.25	Improved and calibrated program
predicted NOAA with observed ridges & hummocks	20	6861	6032	-829	-12.08	Improved and calibrated program
predicted NOAA	20	6861	6049	-812	-11.84	Improved and calibrated program

Table 5.2 Voyage from the ice edge to the Ob estuary

Ice data	No. of legs (-)	Real Time (minutes)	Calculated Time (minutes)	Difference Calc.-real (minutes)	Error (%)	Remarks
observed	81	3799	4948	1149	30.24	Without calibration and improvements
	80	3739	4243	504	13.48	* Without calibration and improvements
observed	81	3799	4113	314	8.27	Improved and calibrated program
	80	3739	3648	-91	-2.43	* Improved and calibrated program
observed	9	3799	3366	-433	-11.40	Improved and calibrated program
predicted NOAA with observed ridges & hummocks	9	3799	3975	176	4.63	Improved and calibrated program
predicted NOAA	9	3799	3231	-568	-14.85	Improved and calibrated program

* excluded the leg in the Kara Strait
(-) calculated time for the voyage shorter than the measured time

Table 5.3 Voyage from the Ob estuary to the ice edge through the Kara Strait on the way back to Murmansk

6 Conclusions

The calculation of voyage time showed that it is possible to reduce the time error from about 15.3 hours through calibration and improving the program to a minimum of 2.3 hours for the part of the route from the ice edge to the Ob estuary and back to the ice edge on the way to Murmansk. This voyage was divided in legs of about one hour.

The distribution scatters in a wide range from -100% to 100% and above. This indicates that the ice observation and/or the program for calculating the time and speed have shortcomings.

Improvements are necessary in ice observation and in the calculation of the ship´s speed.

Reducing the number of legs by adding single legs to one larger leg the error distribution was improved. Using only some legs the error can be reduced close to zero. Through the calibration of the program and adding single short legs to a larger leg the errors of the short legs neutralize one another, but this does not solve the problem.

Comparison of continuous EM ice thickness profiling and observed ice data with the ship performance data showed that the EM data have a smaller error distribution. It could be shown that the ice thickness measured with the EM is more reliable than the observed ice data. Using the EM ice thickness profiles as input data a new program with shorter time legs should be investigated to calculate continually the resistance and speed of the vessel.

Using the actual ice charts of the “National Ice Center” (USA) as input data for ARCDEV the error distribution scatter in a wider range. One reason is that the difficult hummocked and ridged ice is not identified in the “egg-code”. But hummocks and ridges do effect the ship´s speed, significantly. Nevertheless these charts are a good basis for pre-calculating the duration of a voyage. It would improve the speed prediction, if the ice thickness would be noted in 0.1 m steps.

It would be useful to have better information about the ice conditions along a proposed route. It would then be possible to calculate more accurately the expected time of arrival (ETA). With improved ice information also the computer program for speed calculation of the icebreaking ship could be further improved. But during each voyage in Arctic waters some new surprises can occur. It is the target for the future to minimize this unknown Arctic surprises.

7 Recommendation for Future Research

1. The prediction of the vessel‘s „eta“ could be improved by detailed forecasts of ice conditions such as ice thickness, ridges, hummocks and ice pressure zones.

2. Investigation of influence of heavy traffic in shallow water and river ice conditions on the trafficability.

3. Modification of the model for calculating the velocity in ice for the use on board of icebreaking vessels.

4. Combine routing forecast modelling with trafficability models in order to predict the economy of a transportation system.

5. Modelling the operation of the European Arctic Marine Transportation System based on GIS-technology. The simulation models will include the operation of cargo vessels, icebreakers, terminals and loading facilities and all the economy effecting parameters. The environmental conditions will be provided by the historic data base.

6. The improved trafficability models should be tested on board of a leading vessel.

VI WP 16 Overall Evaluation and Definition of Cluster for 5th FP

ARCDEV

Arctic Demonstration and Exploratory Voyage

OVERALL EVALUATION AND DEFINITION OF CLUSTER for 5th FP
WP 16

Sponsored by:
EC Transport - 4th Framework
WATERBORNE TRANSPORT
Contract - No: WA 97-SC.2191
and
Bundesministerium für Bildung und Forschung (BMBF)

Contents

I. Introduction

II. WP-Contributions

III. Other Contributions

WP 16

VII. Overall Evaluation and Definition of Cluster for 5th FP

WP-manager: HSVA
Conclusions and Recommendations For Future Research

I. Introduction

The objective of this Workpackage in to overall evaluate the results of the technical and scientific investigations carried out during the demonstration and exploration voyage. This information will be used to define the necessary research to be executed in order to satisfy the requirements for an economical and safe transportation system in the Russian Arctic. In order to do so, it is important to know from the operators the definition of those transport conditions which satisfy their demands, taking into account that we cannot change the harsh environment of the Arctic.
It is, therefore, recommended that some members of the WP 16-Team meet the operators as soon as possible and define these requirements.
After establishing such a basis, it will be possible to describe realistic research needs for improving the transportation system in a more realistic way.

KMY recommends:
The overall results of ARCDEV should be summarized and conclusions made before the final recommendations for any future activities. The best way to do the summary and conclusions is to reflect the results against a transportation scenario made for the Russian Arctic.
This scenario would help us to better understand if the data collected is sufficient for evaluating the technical and economic feasibility of larger volume marine transportation on the NSR. It would also reveal the lack of infrastructure and legislation there might be to handle that kind of transportation.
The scenario would also produce the cost structure of this imaginary transportation scheme and thus reveal the weak points. On basis of the analysis the project could give proposals for accrual basis for icebreaker assistance fees, port fees channel fees, etc.
Thus it is recommended that the first step in the future work would be a smaller project with participants from let’s say Shell, Neste and Nemarc to develop the scenario and to try to utilise the collected data to evaluate the needs. Based on this the final recommendations for additional data collection or other activities would be made. Russian participation for the scenario development could come from the NSR administration or some Russian oil / energy company.

WP 16

II. WP-Contributions

WP 3	Ice Conditions	WP-manager: Uuskallio, KMY

Preliminary Conclusions

General summary of ice condition measurements is that it is difficult to do basic ice property data gathering during a voyage with commercial interests. On the other hand measurements and observations, which are directly related to ship transit and do not delay the convoy speed are relatively easy to arrange. A continuous automatic ice state follow-up / measurement systems, which can operate during commercial voyages should be developed and implemented on ships operating in the Arctic.
Pre-planning and scheduling of in situ ice measurements during the voyage was difficult because in most cases the plans did not materialize for one reason or the other. When the opportunity to go on ice did come, it was sometimes hasty and not well planned.
During in situ measurements the co-operation between different groups worked well and despite of various difficulties the field work was successful and enjoyable. Results of the work will be seen in near future.
The greatest drawback in WP 3 during the ARCDEV voyage was that EM measurements could not be done from the leading icebreaker.

Proposals for future activities

Problem with ice research is that ice conditions vary with the weather and therefore an ice situation at one location at a certain time is not likely to last very long. When planning continuous winter operations, one has to keep in mind that ice conditions are prone to change with external influence (e.g. frequent ship traffic). This is especially the case in shallow and narrow places — such as harbours and offshore loading points.

Thus, to get a picture of probable ice conditions at a specific location, systematic ice observations and measurements are needed. Data gathering is to be made during several consecutive years, which comprise both hard and mild winters. Measurements should be carried out with different methods to check for inconsistency and to backup the results.

Due to the time consuming nature of thorough ice measurements, comprehensive ice measurements cannot be done over a large sea area, but the investigations should be concentrated to specific, limited areas. The amount of data gathered should be large enough to enable statistical analyses. This is especially needed for the ice ridges.

WP 16

However, there is also a great need to understand the general ice condition to be able to handle transportation tasks and to better understand the development of the local conditions.

It is recommended that the development of ice conditions throughout a winter in a smaller area is needed to better understand also lighter conditions and the ice movement. New data on the life cycle of stamukhas (grounded ridges) would be of great interest. Testing of new methods and equipment could be done in this context.

JERIS could serve as the first platform for additional data gathering. The start up of the plan should look for winter 1999—2000. More detailed ideas for the JERIS project are presented in Section III.

Large scale ice conditions (satellite imaging and air reconnaissance flights) should be studied simultaneously to be able to provide calibration data for remote sensing measurements.

Based on the data gathered during the field work, an Ice Forecast Model should be developed to enable planning and operation of large scale transportation in the Arctic Sea. The model should also have a connection between ice state and the transportation logistics planning.

The **Nansen Center** considers the following items of importance to further develop the satellite information for use in sea ice navigation.
Basic sea ice understanding:

1. USE the huge amount of satellite SAR data (since 1991) available for various parts of the Arctic to improve our knowledge on the sea ice regimes - their regional characteristics, seasonal and inter annual variability.
2. Apply this knowledge to better prepare for sea ice navigation and other operations, e.g. in desicriteria for building of constructions, and navigation support systems.

Technical issues:

1. Improve methods for extraction of sea ice information from SAR data using statistical information, meteorological data, advanced numerical methods etc..
2. Prepare and develop classifications methods tuned towards the future developments within satellite observations of sea ice, including multi-frequency and polarization radar system (e.g. the European ENVISAT), use of several satellite sensor systems together (e.g. Russian and European satellites) etc..
3. Contribute to the current developments towards and specifications of satellite sensor systems to measure sea ice thickness (e.g. iceTopo mission). This is a long term goal and no such sensors are currently designed for launch. The space agencies are looking for both how to design and who will use such information, among other a call is out for industrial partners this fall, although the Space Agencies will not pay for this type of development, but will need both scientific and industrial partners.
4. Improve methods for high latitude data communication - cheap systems for fisheries and more advanced systems for off-shore and transportation.

5. Integrated systems including satellite based sea ice information in the onboard ship navigation systems.

AARIs Recommendations

ICE CONDITIONS (by V.G .Smirnov).

1. It will be necessary to analyse all satellite images and ice maps to check them with the use of additional information from the AARI's Ice Service and visual ice observation data to improve and to get new characteristics for decoding of satellite images (especially RADARSAT images).
2. To prepare the report under the WP3 with emphasis on the use of different satellite information for the support of the ARCDEV voyage.
3. To compare the data of ship based IR -measurements with NOAA IR -information

ICE PROPERTIES (BY I.V. STEPANOV) -

A lot of ice properties measurements have been done in Arctic previously. Considerable part of this information was obtained by specialists of AARI. Unfortunately, actually available data are comparatively scanty. This drawback can be overcame by creating a computer data base. This data base may contain raw data and results of there analysis which provide input information for engineering, navigation and other applications. Problem of reliability and comparability of the data requires special attention. Form of data presentation should meet requirements of the particular applications.

WP 16

WP 4	Ship Performance	WP-manager: Uuskallio, KMY

Conclusion

In general —despite some problems— the ship performance measurements worked well during the hole voyage. However, more attention should still be put on time synchronisation during the measurements. It is always more time consuming and error prone to try to do the synchronisation afterwards. The subject was emphasised prior to the voyage, but for some reason not all cameras, videos and measurement devices were in the UTC time.

Pre-planning of the measurements onboard the Russian icebreakers was very difficult due to the lack of information of the instrumentation onboard. The fact that there was no continuous measurements onboard the leading icebreaker is the major deficiency in WP 4.

Information shortage of the electric parameters for the machinery measurements caused that the rpm-signal of the centre shaft could not be measured. In addition, when the propeller shafts were reversing, no rpm signal (=0-signal) was received from both BB and SB shafts.

Inexplicable errors during the measurements onboard IB Dranitsyn, which have been explained in detail in daily summary reports of WP 4, made the analysis of the data more difficult and time consuming. These difficulties could be overcome and the data covers almost the whole voyage in ice.

Machinery measurements onboard MT Uikku were successful. Only drawback has been a small bug in the program of the DAT-instrument recorder that was used to record all machinery and hull strength data onboard MT Uikku. This bug caused some delay in the data retrieval and caused insignificant data losses. The data loss is in most cases only a few seconds.

GPS position measurements from both ships worked well. Onboard MT Uikku there were some breaks in the measurements, but in general the data is good. The main drawback with the position measurements was that onboard IB Dranitsyn the measurements had to be suspended, when the ship came to the Russian territorial waters (=12 nm from the shore). This happened in the Gulf of Ob and in the Kara Gate.

Proposals for future activities

Data collection for ship performance should be collected on a more continuous basis. Here the focus should be not on an individual vessel but rather on the performance of convoys and the fleet in general to give better understanding of the present operations and the performance of the traffic management system. Correlation between convoy overall performance and general ice conditions should be developed.

One key element for ship performance over the hole route is ice navigation. Computer aided ice navigation should be developed further from the Ice Routes project. The new navigation guide would base its information not only on radar satellite images. Other satellite image data would be incorporated with real ice observations from other ships in the area. Also information of the performance of other convoys / ships should be utilised.

Influence of heavy traffic in ice conditions in shallow water and river areas should be investigated.

It is recommended that an automatic data gathering system is installed and kept in operation on for instance M/T Uikku visiting frequently the Russian Arctic and this data is then reflected against the overall traffic situation on the NSR. This data gathering system could be designed according to the recommendations in the Maritime Black Box (MBB) project, which is an EU project set out to design an automated voyage data recording and evaluating system.

WP-4. Ship Performance (AARI)

Within the scope of the fulfillment of works on **WP-4** three stages are envisaged:

- At the first stage prior to the beginning of the experimental voyage, anticipated speeds of tanker *Uikku* under the assistance of icebreakers *Kapitan Dranitsyn* and *Rossia* on the sea stretch of the route and *Vaigach* (of the *Taimyr* type) – on the river stretch – were estimated. For this purpose the use was made of the mathematical model of the movement of ship in ice developed by CNIIMF in package **WP-13**. Similar calculations were performed for Russian tanker *Vilyisk* (of the *Samotlor* type).
- As a part of the second stage, during the expedition, actual speeds and power of tanker *Uikku* as well as of icebreakers *Kapitan Dranitsyn* and *Rossia* during the movement under different ice conditions independently and within the convoy were recorded. As to icebreaker *Vaigach* there is no information about the power consumption because the channel was made in advance before the approach of the convoy to the Ob Gulf. Dynamics of the breaking through of the channel in the fast ice was traced following the reports sent from the icebreaker to the Headquarters of marine operations.
- The third stage, on the completion of voyage, is dedicated to the processing of data of full-scale measurements and their comparison with calculated estimates. Results of such comparison for tanker *Uikku* are presented in Table 1.

Table 1

Comparison of the calculated and actual net time consumption of tanker *Uikku* for making voyage Murmansk – Sabeta – Murmansk, h

Route sections	Duration	
	calculated	*actual*
Murmansk – Sabeta	159.8	154.6
Murmansk – ice edge	24.4	28.0
Ice edge – cape Zhelania – fast ice of the Ob Gulf	63.4	114.8
Fast ice of the Ob Gulf – Sabeta	72.0	11.8
Sabeta – Murmansk	128.4	114.3
Sabeta – fast ice of the Ob Gulf	20.8	19.8
Fast ice of the Ob Gulf – Kara Strait	56.0	51.9
Kara Strait – ice edge	37.8	21.7
Ice edge – Murmansk	13.8	25.0

Analysis of the results points to a sufficiently high degree of compliance between calculated and actual data. Considerable disparity for certain route sections is due to deviations of the specific synoptical and ice situation from the average statistics as well as to the organization of work of icebreakers escorting the tanker. Selection of the easiest route resulted in the fact that its length had increased more than by 50 % in the outward journey and more than by 20 % on the way back. However, thanks to the preliminary breaking through of the channel in the Ob Gulf and fairly easy ice conditions in the Barents Sea these losses were compensated.

Proposals on further investigations

Results obtained in the course of the experimental voyage may be used in the substantiation of the required level of ice performance (propulsion, strength, manoeuvrability) and main parameters of the prospective icebreaking cargo ships intended for the efficient all the year round operation in the western area of the Arctic under assistance of powerful Russian icebreakers.

WP 16

WP 5	Ice Routing	WP-manager: AARI

Conclusions and Recommendations for Future Research on WP-5 "ICE ROUTING" (AARI's participation)

Prepared by Sergey Frolov (AARI),

Conclusions

- The ARCDEV expedition was successfully performed in prearranged terms, specified transport and scientific problems were solved. Works performed by AARI specialists in the frame of WP-5 significantly contribute to this success. The long-term synoptic forecast, development of ice processes in region, where the expedition had worked, was well justified. The strategic selection of optimum version executed on preparation stage of expedition also completely was justified. The definition of optimal version of convoy movement on some areas was based on methodical principles, developed in AARI, and total real and forecast hydrometeorological information arriving aboard the icebreaker.
- Method (algorithm) to select an optimum way of navigation in ice developed in AARI showed its efficiency and reliability.
- Model of quantitative accounting of navigation difficulties, as the main algorithm of specialization of hydrometeorological information, requires tuning for particular ice classes and convoy, which are considered to use for transportation of hydrocarbon from Ob bay. Reference point data, obtained in ARCDEV expedition, of distribution of ice cover parameters on the navigation route and their influence on movement speed and other operational parameters of tanker movement (data of specific ship ice observations performed in the frame of WP-3) are the base of such tuning. The model verification should be performed in frame of WP-4.
- The selecting process of optimal route requires an information about distribution of such important ice cover characteristics, which essentially influence to speed of vessel movement, as follows: the dominant forms, hummock, thickness and age of ice, presence and intensity of ice compression, some types of which may not be accurately identified by modern means of remote sounding.
- Included to data base the results of scientific observations of ARCDEV expedition can be used as a system element to select the navigation route. The special value of this data base is, that it consist of synchronized information about ice conditions in the region and on navigation route, speed of convoy movement, characteristics of marine engines operation, dynamic loads on hull. This information can be used hereinafter as reference point data to create the automated computer system for selection optimal navigation routes in ice.
- It is necessary to take into consideration not only real hydrometeorological information, but also the processes of redistribution of an ice cover within the period of operation performance on the stage of planning the marine operation.

- To select the optimal route, except real and forecast hydrometeorological information, it is necessary also to consider information about location of icebreaking fleet and its industrial plans.
- Mounting of automatic receiving station of satellite images onboard the ice breaker made it possible to provide the expedition by operating information about general distribution of ice cover in navigation region to select the optimal route and to perform the operational control of marine operation directly.
- The automatic meteorological station should be mounted onboard the icebreaker. It will allow operatively to observe changing of important meteorological parameters (for example - speed and direction of wind) and to take into account these changes to develop navigational recommendations.

Recommendations for further research

A. **The process of selecting of the optimal route can be divided into two points:**

1. Strategic selection of the route. Definition of a general location of optimal navigation route (for example - navigation toward north from Zhelaniya cape or through the Kara Gate Strait)
2. Tactical selection of the route. Development of concrete route of sailing within the frame of general location of optimal version.

To select the route strategically it is necessary to have the hydrometeorological information from all probable sources (satellite information and resolution of a various types, data from ships and polar stations etc.), and forecast ice and meteorological information also. This problem should be solved by a special constant structure conditionally named «Ice and Weather Information Service Center». Creation of such Center is possible and expedient on the base of the AARI which has highly skilled specialists and many years experience of such kind of activities on the NSR route.

The tactical route selection may and have to be done by group of the experts onboard the icebreaker (vessel), including a ship hydrologist. Route selection is made by interpretation of operating information arriving aboard a vessel, by study of operation ice/vessel system and also by performing of tactical helicopter ice exploration.

B. Methods to forecast ice-navigation parameters with a different period in advance, especially for the winter, are necessary to develop. The first priority methods include short-and medium-range numerical and physical-statistical forecasts of the total ice cover redistribution, ice compression forecasts, forecasts of orientation of discontinuities in the ice cover (fractures and leads) and forecasts of the optimal navigation route location. In the future research within the frame of the ARCDEV program it is considered to estimate of efficiency and informativity of the existing forecasting methods and development of requirements to the new methods.

C. The efficiency of the optimal navigation route selecting depends on improving of existing algorithms and development of these new of hydrometeorological information specialization consisting of not only operational, but also economic navigation aspects.

In this connection, work on modeling of operation of arctic marine transport systems on the base of GIS technologies is proposed to perform. This work will be directed on development of the methodology and software for imitative components modeling of arctic marine transport systems (cargo vessels of ice class, icebreakers, coastal and coastwise cargo systems) using the description and analysis of environment data (first of all, ice conditions) by Geographical Information System (GIS). Such key parameters as volume of goods traffic, time necessary for freight traffic and handling operations, periodicity of delivery, operating expenses, etc. are to be simulated. The ice conditions information consists of both long-term archive data and forecast or hypothetical (for example, extreme) navigation conditions.
The solution of given problem means the creation of rather universal tool, which can be used to solve some applied problems as follows:

- ·Estimation of economic efficiency and strategic planning of marine transportation;
  - · Optimization of parameters both transport system as a whole, and its separate components (vessels, terminals etc.) on a stage of their designing;
  - · Definition of optimal navigation routes and preferable convoy structure.

The acting model of a simulation system for the area as Murmansk – Ob'Bay may be developed to the ARCDEV project. The first system part, which may be used in practice, can be completed within the year due to additional financing. The work will be performed due to close interaction with work in WP-3 and WP-4.

According to all items described above the following project is suggested:
Project title: Assessment of efficiency and informativity of the existing forecasting methods and development of requirements to the new methods
Project contents: Methods to forecast ice-navigation parameters with a different period in advance, especially for the winter, are necessary to develop. The first priority methods include short-and medium-range numerical and physical-statistical forecasts of the total ice cover redistribution, ice compression forecasts, forecasts of orientation of discontinuities in the ice cover (fractures and leads) and forecasts of the optimal navigation route location.

Project title: GIS-technologies based simulation of arctic maritime transportation system
Project contents: Modelling of operation of European Arctic Maritime Transportation System based on GIS-technologies application is proposed. This study will be aimed at development of the methodology and computer software for time-domain simulation of operational parameters of the basic components of transportation systems such as cargo vessels, icebreakers, onshore and offshore terminals and loading facilities. The simulated parameters are cargo flows, time of delivery, maintenance and operational expenses and other characteristics that are required for trafficability and economical analysis. An essential part of

the simulating will be use of historical data on environmental conditions (mainly, ice conditions) on the Northern Ice Route.

WP 16

WP 6	Navigation and Operations	WP-manager: RUPP, HSVA

Determination of Ship Handling and Operation Between Tanker and Icebreaker, and Potentials for Improvements

Conclusions

1. Maneuvering and operation times:
The path of all maneuvers and the course and the speed are plotted vs. the time.
The preliminary results of the maneuvers are:
The IB Kapitan Dranitsyn (KD) rammed 222 times on the way to Sabetta and rammed 109 times on the way back to Murmansk. Included in the number of rams are rams used to bring the KD in a position to land scientists for an ice station.

The KD was maneuvered from the ship´s crew without any influence from WP6. Therefore, the maneuvers of KD shows the way how these crew sails with KD in very different ice conditions. The crew maneuvered KD so that KD did not get stuck in ice. During ramming, the ramming speed was small, only in some cases she rammed with about 10 Knots. The rams were carried out in a way that the broken gap in hummocked and ridged ice was wider than the beam of the vessel by breaking the ice on both ship sides which is a good practice in ice navigation. This tactic was not successful to break very heavy ice on the evening of April 29, 1998. The nuclear ice breaker "ROSSIA" broke the KD free.

To increase the average speed towards the port of destination a higher ramming speed is useful only in connection with hull shapes which are not sensitive in getting stuck. Auxiliaries for reducing the friction at the bow or to trim the vessel within a short time after getting stuck in the ice are useful tools. Further research innovation in this direction is important. Simulation programs for optimal ship handling should be developed.

2. **Leading of IB ROSSIA**

The ROSSIA leaded the convoy consists of the vessels KD and the tanker UIKKU through the Kara Sea. The communication between the three vessels was without any problem. The leader of the convoy was the ROSSIA which gave the order to the following vessels. This clear command structure in the convoy leads to save handling of the vessels in the convoy.

3. Northern Sea Route Administration (NSRA)

All vessels east of the Kara Gate and west of the Bering Strait are under the control of the NSRA. That means, that position, course and meeting points with icebreakers etc are globally organized from NSRA. All environmental and ships data are collected in NSRA Murmansk office at Murmansk Shipping for the western Russian Arctic. With their long experience, the routes of the vessels are planned by NSRA. The decisions from the NSRA and her representative on board KD during the ARCDEV voyage was very good. In such a large and lonely area with less traffic this central organization could be the only way to organize everything (from emergency ship repair to medical service). When the offshore activities in the Yamal area increase, especially with international oil companies, new tasks arise, which must be solved from a closer-by organization.

Recommendation:

1. Developing of hull shapes which have reduced ability to get stuck in ridged and hummocked ice and are able to break these ice at higher speed than KD
2. Developing of a numerical model to find out a ramming cycle with maximum advance speed
3. Testing the numerical model in full scale by handling the vessel according to the results of the numerical model. Calibration of the numerical model.
4. Testing of berthing maneuvers on offshore structure in ice in model scale
5. Operation modes of a large tanker with one or two icebreaker, close tow, pushing the tanker, following in the channel of two icebreaker, towing on long towing rope with two icebreaker. Target: How to handle large tanker in ice with a beam of the tanker larger than the icebreaker. Model tests
6. Developing of maneuvering aids to improve the ability of the tanker to turn in close ice

WP 16

WP 7	Tanker Loading Systems	WP-manager: G. Busetto TECNOMARE

1. Preliminary Results/Conclusions

During the period **from 27.04.98 to 03.05.98**, i.e. the navigation from Murmansk to the Ob Bay, the research activity mainly consisted of the acquisition of knowledge and of the observation of:

1) the local ice conditions encountered along the route and of the techniques used by the teams involved in:

- the acquisition and interpretation of the satellite images received to support the ice route and to map sea ice parameters,
- the execution of visual observations from the research icebreaker,
- the execution of the field measurements at the sea ice stations,
- the execution of the tests to determine ice mechanical properties;

2) the techniques and methods adopted, by the convoy, to proceed along the route and by the icebreakers to provide assistance to the tanker;

3) the techniques adopted by the teams involved in the acquisition of the navigation parameters from the instruments of the research icebreaker.

Coordination meetings were held within the WP work team, to discuss how to collect data during the loading operation of the tanker.

A part of WP team was also involved in parallel activities relevant to other WPs (mainly KMY, Aker MTW, CNIIMF and KSRI, which, after voyage start, asked to contribute to the work for WP7).

On **04.05.98**, the activity consisted of:

- the observation of the procedures for approach of the convoy formed by the i/b Kapitan Dranitsyn and the m/t Uikku to the loading point of Tambey/ Sabetta,
- the observation of the technique used by the i/b for preparation of the channel alongside the pipeline manifold, widening of the evolution basin and arrival of the m/t,
- the measurement of the time spent for the various operations.

On **05.05.98**, the activity consisted of:

- a visit to m/t Uikku and interview to the duty Officer, to acquire data on the loading operation in progress,
- an inspection of the manifold equipment on the ice and of the equipment of the cargo control room of the m/t.

On **06.05.98**, the following was carried out:
- a visit to the pipeline manifold and hose arrangements,
- a visit to the tank farm and to the pump station, located on the shore, at about 2 miles from the loading point,
- acquisition of data regarding the proceeding loading operation.
- a meeting within the WP work team, to discuss the collected data.

On **07.05.98**, during continuation of the loading operations, the activity consisted of:
- a complete visit to the m/t, accompanied by the Captain, for acquisition of general information regarding the vessel,
- the acquisition of data regarding the progress of the loading operations.

On **08.05.98**, the following was carried out:
- observation of the procedures for departure of i/b and m/t from the loading point,
- a meeting with Mr. Babitch, MSCO's Deputy Manager of the Icebreakers Fleet Dept., to discuss some ideas regarding suitable loading systems for the future and considerations and constraints regarding the SBAM system,
- acquisition of the loading plan of the m/t,
- discussion, within part of the WP team, of ideas regarding future loading systems.

During the remaining period **from 09.05.98 to 14.05.98**, i.e. navigation from the Ob Bay back to Murmansk, similar activities to those executed during the outward journey have been carried out.

The preparation of the report describing the loading operations was started.

In a coordination meeting within the WP team, the course of action was agreed for continuation of the work, according to the description detailed in the PQA form for WP7 (Table "Task 1 - Work Description for WP no. 7).

2. Recommendations for Future Research

The method adopted for loading at Tambey/Sabetta Terminal is very rudimentary and probably adequate for that specific purpose, after taking into account better measures for environmental protection (see also WP 11), but cannot be considered suitable for year-round operation and for high loading rates required by larger tankers and continuous operation.

WP 16

The evaluation of a permanent system for tanker mooring and loading requires the knowledge of the spectrum of environmental conditions on year-round basis. Moreover, the need to identify the extreme conditions requires the availability of long term data.
Obviously, the voyage could not allow the acquisition of such type of information, therefore the results of the observations and field measurements can be used only:

- to find a correlation with measured effects on the vessels, such as speed of advance or ice resistance,
- to compare the predictions based on available long term data with the actual observed and measured data,
- to observe the difficulties encountered in carrying out operations with ice conditions corresponding to a defined return period according to long term statistics obtained from available databases.
-

Therefore, the future research work should be addressed to obtain a general environmental characterization of the potential locations of future loading systems, for what concerns the water depth, ice conditions, tide, wind, wave, current and temperature.
Information regarding:

- areas of the rivers where ice cracks occur due to tidal effects,
- soil characteristics at the potential location of the loading systems and presence in these areas of permafrost

should also be collected, to select the most suitable locations for installation and to establish sound design bases.
Once this information has been acquired, a scenario for evaluation of loading systems can be prepared.

The scenarios of interest for potential location of future offshore loading systems should correspond to the areas from where the export of gas condensate and oil produced from local hydrocarbon fields is envisaged.. Locations of interest are the Kara Sea, the Pechora Sea and the estuaries of the Ob and Yenisey rivers. Some of these locations are close to the sites where the ARCDEV ice stations were selected.

Regarding the loading operation which has been carried out by the m/t Uikku, although the current level and scope of the gas condensate production justify the simplicity of the adopted method of loading, it is apparent that such method cannot be taken as example for future systems when export on an industrial scale is required by the development of the oil and gas fields.

Therefore, the research work should be addressed:

- to identify and evaluate configurations of loading systems able to serve tankers on a year-round basis,
- to define economical size and equipment of ocean and river going tankers to be used in conjunction with the loading system,
- to determine the required capacity of storage tanks, loading rates and pump types for the exported volumes under consideration,

- considering low cost, absence of continuous interaction with the ice cover, ease of connection operations and communications with shore, to work out proposals for use and improvement of the SBAM. In particular, the following additional studies should be undertaken:
  *analysis of possible damages to the underwater pipeline in the recommended installation sites;
- behaviour in thick ice cover;
  *development of various modifications to the SBAM system consistent with specific conditions of the considered loading point location.

Alternatives have been preliminarily identified for investigation, as follows:
1. Gravity type pontoon, towed to location and lowered on the sea bottom by ballasting. The unit should be:

- positioned in an area with waterdepth sufficient to receive the river going tankers,
- connected to the river bank by submerged loading pipelines,
- equipped with sufficient bollards to moor the tanker,
- strengthened against ice loads,
- fitted with bank linked manifold equipment, like valves, blind flanges, booster pumps, sludge tank.

2. Single point mooring station, kept in position by piling. The structure should be:

- positioned in an area with waterdepth sufficient to receive the river going tankers, and to allow weathervaning,
- connected to the river bank by submerged loading pipelines,
- equipped with a mooring line to allow the tanker to weather vane,
- strengthened against ice loads,
- fitted with bank linked manifold equipment, like valves, blind flanges, etc.

The SBAM represents this category of systems.
3. Jetty . It should be:

- located alongside the bank, in a water area dredged to sufficient depth to allow mooring of the loaded tankers,
- fitted with bank linked manifold equipment, like valves, blind flanges, booster pumps, sludge tank
- equipped with sufficient bollards and fenders to moor the tanker
- connected to the river bank by a loading pipeline.

Preliminary list of aspects that should be taken into account in the evaluation of the systems:

- presence of components subjected to forces and impacts by ice floes (such as surface elements, pipes and hoses),
- risk of damage of components for tanker or icebreaker collision,
- sensitivity of the system to the environment,
- sensitivity of the system to the tanker size,

WP 16

- sensitivity of the system to the waterdepth and to waterdepth variations (implication on freeboard requirements for jetty and gravity type pontoon),
- vulnerability to deposit of sediments on the seabed and need of dredging,
- protection against scouring induced by the ridges,
- protection against scouring induced by the propellers,
- ease of approach of the ice breaker and tanker,
- ease of connection and disconnection of the tanker,
- reliability and standtime of underwater components (e.g. buoys and transponders, hoses or pipes),
- effects of the low temperature on the above water and underwater components (e.g. freezing and ice formation around pipes and hoses),
- capability of the tanker to weathervane
- system downtime due to failure of the flowline or mooring system components.

Final recommendations for future research work will be provided as conclusions of the WP.

WP 16

WP 8	Ice Loads	WP-manager: P. Kuyala,HUT

Introduction

This preliminary report contains description of ice load measurements done onboard Uikku during the Arctic Demonstration and Exploratory Voyage (ARCDEV).
The aim of the measurements was to study the ice induced loads on the ship hull when the ship navigates in various ice conditions. Basic data for the analyses was maximum load and stress values of 20 minutes periods. These extreme loads are analyzed statistically. Also time histories of measured signals were recorded during the voyage.

Instrumentation

The measurements included following items onboard MS Uikku:

- load on the shell transverse frame at bow area, at bow shoulder area, at midship area and at aftship area (measured by shear strain gauges)
- load on the shell longitudinal frames at midship area (measured by shear strain gauges)
- stresses on the shell plating and frames at waterline at bow area, at bow shoulder area, at midship area and at aftship area
- the longitudinal bending stresses on deck plating
- vertical accelerations at the bow and stern ship and longitudinal accelerations at bow

Instrumentation was made by following Task WP 8 Detailed Plan (PRE-WP8-001) except on midship area where instrumentation moved to the frames 63.5...66. The detail location of the instrumentation has been given on appendix 1. The used abbreviation in the drawing mean:

FFR load on the frame

FB stress on the frame
PL stress on the plating

HB bending stress of the hull

The ice loads were evaluated by measuring shear strains from the frame. Shear strain gauge pairs (marked in appendix 1 with A and B) were connected so that load between gauges could be measured by using one recording channel. From each instrumented frame were loads measured separately on the upper, middle and lower part of the frame.

20 minutes maximum load measurements

Preliminary results presented here are based on 20 minutes periods maximum values. These 20 minutes extreme loads and stresses are presented on appendix 2. Loads are presented by using kN/m, where m is a meter in ships longitudinal direction. These 20 minutes periods extreme values were analyzed statistically and this statistical analysis will be presented on final report.

Maximum loads during the voyage

Maximum loads on various areas of the ship divided to different sea areas and different kinds of operation are presented on Fig. 1.

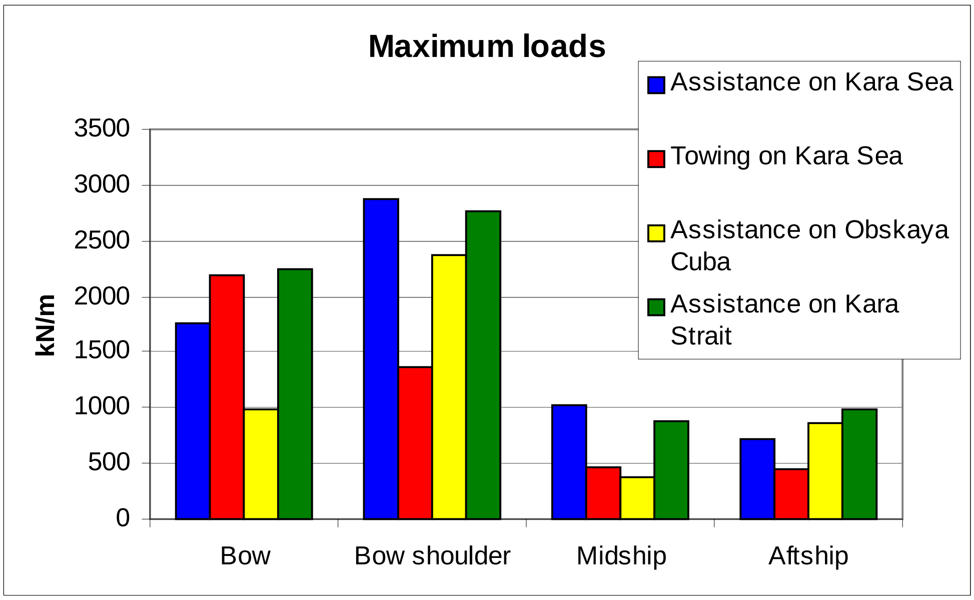


Figure 1: Maximum loads on different areas of the ship measured during the voyage.

As expected, were highest loads measured from bow shoulder area except when Uikku was towed. Radius of turnings had a big influence to the loads on midship and aftship area of the ship. That can be seen loads on Kara Strait and loads on Kara Sea, where ship avoided to hit to the thickest ice floats and biggest ridges, there fore convoy made strict turnings.

Permanent transformations

During the voyage were permanent transformations found from each instrumented area of the ship. Most of them were so small that sensors could be balanced after transformation without loss of the sensitivity of the sensor. Permanent transformations founded are presented on table 1. Time on the table 1 is ending the time of 20 minute period when transformation were found. Table 1 presents also remaining transformation after the 20 minute period. Where remaining transformation was out of the sensors measuring range are values marked with bold letters. That means that in these cases permanent transformation is at least the presented value. On the strain values has to be noticed that value is the sum of the arm of the sensors. There were one arm on the bending sensors (FB) and two on the plate and force sensors.

WP 16

Table 1: Found permanent transformations.

Date	Time (UTC)	Sensor	Offset MPa	µm/m
29.4	13:20	PL 7	29	281.55
30.4	10:20	FFR 12	21.4	0.27
30.4	14:20	FFR 23	57.6	721.80
2.5	15:40	FFR 25	**455**	**5701.75**
4.5	0:40	FFR 24	**440**	**5513.78**
4.5	0:40	FB 26	47.5	230.58
4.5	12:20	PL 34	73.5	713.59
4.5	12:20	FFR 37	**298**	**3734.34**
4.5	12:20	FFR 38	78	977.44
4.5	12:20	FB 39	-17.5	-84.95
4.5	12:20	PL 40	120.5	1169.90
9.5	4:00	FB 21	34.5	167.48
9.5	4:00	FFR 20	307.8	3857.14
9.5	16:40	FFR 18	93.6	1172.93
9.5	16:40	PL 22	65.5	635.92
9.5	17:00	FFR 18	222	2781.95
9.5	17:00	PL 22	155.5	1509.71
11.5	4:00	FFR 19	210	2631.58

WP 16

WP-9. Required ice class for polar navigation (CNIIMF)

Within the framework of the package **WP-9** of the project ARCDEV under the CNIIMFs program the following work was performed *Preliminary estimation of the required ice class of tanker to ensure all the year round export of gas condensate from the Ob Gulf to European ports.*

Within the scope of this work the investigation was performed – analysis of the experience of the operation of domestic cargo ships of different classes in ice of the western area of the Russian Arctic including:

- Generalization of the statistics on the ice damageability of hulls of the ships operating in the western area of the Arctic;
- Assessment of the effect of ice class upon the efficiency to use domestic ships in the western area of the Arctic.

The following subjects were analysed:

- experience in the performance of sea operations on the delivery of goods to the Ob Gulf;
- types of domestic tankers and icebreakers to provide for the transportation of hydrocarbons from the Ob Gulf;
- • navigational conditions and average speeds of sailing in the Kara Sea and Ob Gulf from the experience of operation;
- experience in the use of ships of different classes in the western area of the Arctic.

As a result, preliminary recommendations on the selection of ice classes of prospective tankers intended for the transportation of hydrocarbons from the Ob Gulf were developed.
The essence of these recommendations is as follows:

- for all the year round mode of operation tankers of the ULA class should be used.
- for the operation during the traditional summer-autumn navigation it is envisaged to use tankers of the UL class.

Within the framework of package **WP-9** the following works are being continued:

- Calculated evaluation of anticipated ice loads on the hull taking into account areas of the shallow water on the route;
- Identification of domestic and foreign ice classes of arctic ships.

Proposals for further investigations

Bearing in mind prospects of transit navigation along the Northern Sea Route (NSR) as well as the possibility in the future to explore the shelf zone of the Laptev Sea, rich in the hydrocarbon raw material, it is suggested as an extension of works on **WP-9** to carry out some preliminary investigations on problems concerning the operation of ships in the Laptev Sea and other seas of the eastern area of the NSR, namely:

1. Generalization of the operational experience of domestic cargo ships in ice of the Laptev, East-Siberian and Chuckchee seas.
2. Analysis of the ships damageability on routes of the eastern area of the Arctic.

WP 16

3. Development of preliminary recommendations on types and ice classes of tankers intended for the export of hydrocarbons from the Laptev Sea. Consideration of the possibility to use for this purpose the tankers intended for the Ob Gulf.

WP 16

WP 11	Environmental Protection	WP-manager: K.U.Evers HSVA

Conclusions

Previous to the month-long round trip of MT UIKKU from Murmansk - Sabeta (Ob River) - Rotterdam with respect to the necessities of WP 11 Environmental Protection the NESTE representative carried out the co-ordination work for convincing the Russian authorities in order to obtain the relevant permission. For the purpose of this task very valuable support was provided by AARI and CNIIMF. Effort has been made to avoid any violation on the environment and every possible precaution measures have been considered in order to protect the environment. The environmental safe operation concerned two main aspects, i.e :

a) the environmental safe navigation through the Northern Sea Route and b) the environmental safe ship-shore cargo operation on Yamal peninsula for loading gascondensate. The successful completion of these tasks was carried out in co-operation with the Russian authorities and the Russian teams (crew and scientists) on the icebreakers and on the „loading terminal".

The facilities of the motor tanker „UIKKU" , icebreaker „Kapitan Dranitsyn", the loading terminal itself as well as the loading process of gas condensate is well documented. Recommendations concerning the improvement of the environmental safety for the ship navigation in ice and the loading procedures are summarized.

Future research is necessary with respect to the improvement of environmental protection, e.g. additional structural requirements for the ships of different Polar Classes taking into account the probability of oil spill in the event of ice damages. The Ship Oil Pollution Emergency Plan (SOPEP) should be complemented by additional sections taking into account specific cases of operational emergency spillage in various ice conditions. Prototypes of suitable oil spill recovery devices and adsorbent materials for the operation in cold climate conditions have to be developed, designed and tested in laboratories and under realistic conditions in the field.

Recommendations for Future Research

- Development of additional structural requirements for all types of ships of different Polar classes for the environmental protection taking into account the probability of oil spill in the event of ice damages
- Development of a proposal for the IMO to include additional requirements to subdivision and damage stability for all types of Polar class ships.
- Complement of the SOPEP by sections taking into account specific cases of probable operational emergency spillage in the ice conditions.

- Since there is a certain precariousness in the behavior of gas condensate / oil concerning the penetration and distribution into snow or ice detailed basic laboratory investigations for different types of hydrocarbons should be carried out.
- Prototypes of suitable oil spill recovery device for the operation in cold climate conditions have to be developed, designed and tested in laboratories.
- A feasibility study and ice model tests of various types of loading terminals for ice covered waters should be conducted.

WP-11. Environmental Protection (CNIIMFs Contribution)

I. In accordance with the Programme of works of CNIIMF within **WP-11** the following works have been done before the beginning of the expedition (ARCDEV).

A. Analysis of probable sources and extent of operational pollution of the marine environment from ships operating in ice conditions which showed that taking into account the peculiarities of construction of the ship the most likely emergency operation oil spill can occur only during cargo handling operations with the use of hoses or pipelines laid through ice. The pollution is possible in the case of the damage of hoses or leakage through joints between individual sections.

B. Additional structural and survivability requirements for tankers from the point of view of the environmental protection during the ice navigation were developed on the basis of statistical data on the parameters of side ice damages of cargo ships in their navigation under ice conditions along the Northern Sea Route and the basis of the last statistical data of IMO for parameters of the bottom damages due to stranding. The point of these requirements is that all cargo tanks as well as fuel and oil tanks should be located at a distance of not less than 0.76 m. from the outer shell plating of the ship's hull corresponding to the maximum depth of ice damages. It is allowed to use double bottom tanks within the length of the aft machinery space for the storage of fuel and lubricants the capacity of any tank not exceeding 20 m^3. In doing this, all arctic tankers should meet the damage trim and stability requirements specified by the MARPOL 73/78 after the assumed side or bottom ice damages applied anywhere in the ship's length (two compartment standard of subdivision) and additional requirements to the trim and maximum angle of heel in the case of asymmetrical flooding.

C. Recommendations to composition of the ship's equipment protecting the environment were developed. The tanker should have a set of equipment and materials for the containment of minor oil spilled over the sea surface in the polynya area and recovery and clean up of oil spilled from the ship deck and ice surface including emergency portable pump, mini - booms, sorbents, mechanical means.

D. Measures for the prevention of oil spills in the process of loading operations were developed. Special precaution measures take into account for the fact that loading of tanker involves the use of hoses connecting pipelines on ice with the ship cargo ones and include the requirements to the cargo hoses and pipelines, their joints, ship to shore means of communication, pressure control in the pipelines and hoses.

E. Supplements to “Shipboard Oil Pollution Emergency Plan” (SOPEP) by sections taking into account the peculiarity of ice navigation for different scenarios of the operational oil spill (tank overflow, pipe leakage with oil spilled upon the deck and into the polynya water at the ship’s side) were developed. To prevent oil spills a list of checks to be made prior to loading, during and after the completion of loading operations is presented.

In the case of the detection of spillage of petroleum products during cargo handling operations the actions are to be taken for the prevention and elimination of the aftereffects of oil spill in accordance with the procedures set out in the “Plan”. Besides it is necessary to inform a responsible person of the port personnel in the event of an oil pollution incident. List of the communication centres of Russian state organizations, ports and interested institutions is attached to the “Plan”.

The results of work set out in p.p 1.2-1.5 were drawn up as “Preliminary Working Paper” that have been handed over to the tanker *Uikki* and representatives of interested organizations (HSVA and Neste) before the beginning of the voyage.

II. During the expedition the representatives of CNIIMF in conjunction with HSVA and Neste kept a lookout for the peculiarity of loading operations in ice conditions and the observance of measures for the prevention of pollution. The evaluation was carried out of eventual conditions and places where operational oil spill is most likely to occur and the sufficiency of the composition of ship’s equipment for the environmental protection.

III. At present (after expedition) the analysis of the peculiarity of loading operation in ice conditions from the point of view of the prevention of pollution is being carried out proposals for the decrease of the risk pollution and the supplements to SOPEP for arctic ships are being developed. In particular, the call of oil skimmer foreseen by the “Plan” in the case when oil spillage cannot be recovered by the ship’s crew in ice conditions, in our opinion, is unrealistic. It is necessary to study the matter regarding the advisability to supply the assisting icebreaker with appropriate equipment for the environmental protection.

WP 16

Proposals for Further Investigations

Polar regions are important and especially vulnerable components of the global ecosystem where it is prohibited to discharge any oil products and other hazardous substances. The remoteness of these region as well as severe and dangerous conditions of navigation in ice make rescue or clean up operations difficult. The ships operating under ice conditions are exposed to the additional risk because of the probable hull ice damages. The sinking of any tanker or ship carrying hazardous cargo is ecological catastrophe and is inadmissible. Therefore all ships navigating in Polar waters should meet additional structural safety requirements to mitigate and possibly avoid the risk of the hull ice damages and the marine environment pollution.

The minor operation spills of oil caused by damages of hoses or leakage through joints between individual sections, tank overflow during the cargo handling and bunkering operations should be eliminated, as rule, by the ship's crew in accordance with the SOPEP taking into account the peculiarity of the ice navigation.

Bearing in mind the above, it seems necessary in the process of future investigations for ensuring the environment protection in the Arctic and Antarctic to carry out the following works:

1. Development of additional structural requirements for all types of ships of different Polar classes for the environmental protection taking into account the probability of oil spill in the event of ice damages.
2. Development of the proposals for IMO regarding the inclusion into the Polar Code of the additional requirements to subdivision and damage stability for all types of the Polar class ships and the complement of SOPEP by the sections taking into account the specific cases of probable operational emergency spillage in the ice conditions.

WP 16

WP 12	Data Management	WP-manager: NESTE

ARCDEV – Contributions from WP 10 to WP 16
from the Sight of Data and Information Management
Supplemented by Aspects of Applied Oceanography and Marine Telematics

Klaus D. Pfeiffer
HYDROMOD Scientific Consulting

revised by: Ivan Ivanov
Neste Oy / Neste Shipping

Revision 1.0 **November 19th, 1998**

Introduction

The following contributions to ARCDEV´s Work Package 16 – *Overall Evaluation of Results and Definition of Cluster for 5th Framework Programme* – summarises experiences achieved during the conduction of the ARCDEV project both along the ongoing project as well as during the Arctic Demonstration and Exploratory Voyage and therefrom derived suggestions for future research in the field of Arctic Shipping and Transportation.

The reflected aspects reveal in particular to data and information acquisition, processing, dissemination and management issues as far as presently achievable during the conduction of the project on- and offshore. These might be versatile for follow-up and spin-off activities which may result directly or indirectly from the ARCDEV project. They may be also of interest for other marine research project in particular those utilising ships of opportunities and/or platforms not especially designed for marine research and survey work.

Further, suggestions and ideas are briefly depicted which arise from the authors experiences while participating in the voyage and during the still ongoing collection, validation and merging of data and information and in view of planned dissemination and publication activities. Finally and based thereon, the authors view of application possibilities in applied oceanography and marine telematics are reflected which may stipulate future research activities in the areas of research concerned.

The ARCDEV project has already applied and implemented several of the recommendations and suggestions depicted above. DIM was assigned as a separate work package conducted in close co-operation with and assigned directly under the project management. Several new ideas in particular with respect to handling and dissemination of meta-data and other project information have been assigned and will be incorporated into ARCDEV´s final data products.

Moreover, ARCDEV has dedicated strong concerns on public relations and dissemination of project achievements and results to the public which have been incorporated into and clustered under the DIM activities. In this respect the DIM activities have been widened towards aspects of documentation and processing of results in a manner understandable and of interest for the public. Although not all ideas can be realised on the project level partially due to technical constraints and partially due to lack of resources ARCDEV and therefrom achieved DIM experiences can facilitate as a muster project which may stipulate other and future projects.

The technical constraints are likely possible to overcome in the nearest future by new methodologies becoming available in the information, telematics and computer technology sectors. Shortcomings in resources can be overcome by allocation of respective preferences to DIM as well as by further standardisation and optimisation of DIM activities as depicted and suggested below.

Improvement possibilities of data and information management issues and activities

Although data and information management (DIM) for RTD projects and thereunder clustered work is considered as a routine service to a project this topic is rather new and thus a certain activities could be further standardised both on the working as well as on the procedure and policy levels. Besides the fact that every individual project has its own specific requirements and needs and thus the DIM activities have to be tailored accordingly there exist several common properties and demands which bare chances for further standardisation and definition plus application of common DIM policies. However, the matter is so far introduced in RTD activities on different levels of acceptance. General goals and objectives of project related DIM are so far barely specified and related policies are still lacking common consensus.

Within RTD marine activities of the European Commission the Marine Science and Technology Programme (MAST) has made certain achievements in this respect resulting in a general guideline for project related DIM the *MAST Code for Data* Management which have been applied in some MAST projects already at the final phase of FP III and as a general requirement in FP IV. However, these guidelines are predominantly limited to collection, processing, quality control, dissemination and banking of field data and lacks to a certain extend detailed issues of other information in particular with respect to data documentation (the so called meta-data), handling of other project related information (like for instance reports, images, videos) and other results as achieved from simulation and modelling or from higher levels of post processing and aggregation of results. Also the guidelines elaborated in MAST are so far not expanded into other RTD programmes of the EC.

In particular with respect to FP V and the therein specified more horizontal and cross-subject approaches it is recommended to conduct complementary activities in this respect which may yield

- **general policies and guidelines for DIM within EC research projects,**
- **definition of common goals and objectives for the DIM,**
- **a higher level of standardisation in DIM approaches, techniques and methodologies,**
- **stipulation of acceptance of DIM activities, requirements and benefits.**

These should also concentrate on the following aspects:

- **improvements in data documentation,**
- **integration of other project related information,**
- **public and project-internal data and information dissemination aspects and therewith related matters of security and confidentiality (both on the policy as well as on the technical levels),**
- **utilisation of new computer and telematics technologies for project internal data exchange, data dissemination, public information and public relation aspects,**
- **issues concerning long-term safeguarding and archiving of project results and data,**
- **further possibilities of value adding of project data, information and results. In the past few years DIM activities have partially emerged from the public sector and have been conducted not only by data centres of scientific teams. They have become a versatile service for RTD projects and certain activities have been and are conducted by – usually small to very small – companies which have developed specialised services and methodologies for project related DIM. In this**

respect recommendations are given to find optimised measures how DIM as a routine service could be incorporated into RTD projects keeping in mind

- **the service character of project related DIM,**
- **the allocation of DIM as a management function with therewith related allocation of responsibility and attorney for the data manager,**
- **the assignment of sufficient resources for project related DIM (a common figure among data managers whether from the public or private sectors reveal efforts for proper and state of the art project related DIM by approximately 5% of the overall project costs).**

This may yield to optimised ways for allocation of DIM activities within a RTD project. From the sight of a specialised small company in this field the recommendation is given to programme officers and policy makers to consider and probably revise thereto complying regulations and possibilities of SME participation and involvement in DIM.

Improvement possibilities for field research, survey and on board data processing and retrieval

The central activity of the ARCDEV project comprised the exploratory and demonstration voyage with multi-disciplinary research activities conducted on three ships operating in a convoy in the Russian Arctic (Barent Sea, Southern Kara Sea and Ob Estuary) by about twenty different research teams from European Union member states and Russia. These exchanged more or less continuously data and information acquired and achieved on different processing levels already on the ship. On the ARCDEV voyage and generally on most multi-disciplinary research cruises and surveys efficient data and information exchange measures supported by electronic measures considerably enhance efficiency of work at sea. Furthermore, during the voyage certain preferences were dedicated to provide up to data information to the public by various means (i.e. by daily update of the project's web site and sporadic video conferences).

In this area the following measures for optimisation can be suggested:

- **Developments of guidelines and procedures for optimised electronically supported data and information exchange on research cruises and surveys between arbitrary research teams;**
- **development of mobile packages and transferable services for data and information exchange and retrieval including incorporation of enhanced communications devices on ships of opportunity which may comprise especially:**

- **Easy, low effort and fast set-up possibilities of a ship-internal local area network (LAN) including a central data and information server and therewith related support and access control facilities;**
- **efficient, high-speed and high-capacity ship to ship communication links (e.g. optical) improving ship-ship data and information exchange in convoy operations;**
- **utilisation of new and upcoming technologies in high-speed, high-capacity and low-cost ship to shore communication (e.g. InmarSat-B, JEP-satellites) including incorporation of ships of opportunity into wide area networks (WAN) and improvements for Internet access to support data and information exchange, retrieval and transmission (also comprising a basic requirement for other objectives like ice routing or remote service and maintenance) as well as fast dissemination and public information.**

These measures will certainly yield benefits for marine field research and surveys in general as well as for optimised utilisation of ships of opportunity therefore.

Improvement possibilities for on-shore data processing and utilisation

On the ARCDEV demonstration and exploratory voyage and within the following evaluation activities a variety of multi-disciplinary and partially very heterogeneous data and information have been acquired and produced. For most of these – despite for the standard marine status and environmental parameters – no common standards exist. For instance the Russian and the WMO‘s ice classification, discrimination and observations considerably differ from each other. Also ship performance and ship technical data are partially lacking standardisation.

In this respect the following is recommended:

- **Definition of common needs and requirements for data and information processing and consistent integration of marine (arctic) multi-disciplinary data and information in particular with respect to achievement of**
  - **higher levels in standardisation and enhanced possibilities for computer aided processing of ice condition observations and classification;**
  - **achievement of less person, research respectively observer team and methodology respectively experience dependent methods for ice condition observations (ideally independent of personnel related issues and experiences at all);**
- **development of standardised information categories and data catalogues for marine data including those parameters relevant for (arctic) shipping and transportation as well as upgrading and/or harmonisation of existing data catalogues for marine status and environmental parameters especially with respect to sea ice conditions and ice mechanical parameters;**
- **development of improved and commonly accepted parameters and/or criteria for ship performance in ice which should also suit computer aided processing and archiving;**
- **development of improved operational forecast models for all (e.g. improved local circulation and ice drift / ice evolution models, local meteorological models);**
- **development of new methodologies for integration, combination and merging of**
  - **numeric measurement data on different processing levels and in different temporal and spatial resolution;**
  - **visual observations and therefrom derived aggregated results;**
  - **images and videos and therefrom derived aggregated results;**
  - **sat- and airborne remotely sensed data and information acquired from different carriers and sensors and in different spatial and temporal resolution as well as therefrom derived results and data products;**
  - **simulation results of various categories (e.g. ship routing forecast models, ship performance models, oceanographic fore- and nowcast models (i.e. circulation, ice evolution and drift), meteorological models;**
  - **reference data and historic data and expertise.**

WP 16

Improvement for marine information services and telematics for ship routing in the Arctic

All of the above mentioned activities are coincident with and support developments of integrated marine / arctic information systems and services. These may facilitate various needs and requirements for a broad community of end-users in particular and predominately for arctic shipping, transportation and marine operations which would require rapid and quasi real-time access. In addition they are complementary for e.g. the Global Ocean Observing System (GOOS) and will give a strong support for other marine science and research in the Arctic.

At present several components required for such information systems are already available or are close-by to reach the operational level. Thus applied and practically oriented developments should concentrate on modularization and integration of existing methodologies and technologies by flexible interfaces and incorporation of modern developments in telematics and marine communications. Linking together teams and experiences from both research and industry from various countries with the end-user community is an utmost requirement for acceptance and sustainability of such systems. Teams and users from both EC member states and from Russia must closely co-operate therefore on a level of vice versa trusteeship and acknowledgement of each other experiences.

Thus the initialisation of a RTD project targeting on the construction and implementation of a pilot-version and prototype of an integrated marine information system to support arctic shipping and transportation by all or at least most relevant means is strongly recommended.

WP 16

WP 13	Trafficability	WP-manager: HSVA

Conclusions

The basic information for the work are:

- ice data
- power and
- speed (position) of the ship.

During the ARCDEV expedition, the position, speed and course was logged by HSVA every second with GPS/Glonas receiver on board of the Icebreaker Kapitan Dranitsyn (KD). The power of the three propeller motors of KD were measured (KMY) and the power of ROSSIA was noted every hour during a short period of the voyage (CNIIMF). The ice data were observed over 24 hours and listed and compared with the predicted ice data. The ice thickness was measured 5 m sideward of the ship´s side at the forebody of KD with an EM device. These measurements provide a complete set of data to calculate and calibrate programs for predicting the vessels speed in ice.

Up to the north end of Novaya Zemelja the KD was the leading icebreaker, but the ice was mainly very thin. During the voyage through the Kara Sea in weak but also in very severe ice conditions, the KD followed the leading icebreaker ROSSIA. Therefore nearly all data which were measured on board of KD are from the broken channel behind the ROSSIA. This is only one part of a trafficability model. To calculate the trafficability of KD as the leading icebreaker is therefore very restricted for the ARCDEV voyage. Due to these circumstances the calibration of the trafficability model is only partly possible. Nevertheless the data set is a first step to calibrate trafficability models.

The voyage showed that the calculation of the average speed in different legs towards the place of destination in the varies ice conditions is important. But the results scatter in a wide range. One reason for this is that the predicted ice conditions should give more detailed information about ridged and hummocked ice which is a great barrier for all vessels.

The information from satellite images of the ice conditions, the ice prediction should be developed in such a way that the information are more reliable for the use in trafficability models to improve the speed of the vessel or a convoy in ice using the easiest way.

Recommendation:

1. Improving the trafficability models for the varies ice conditions
2. Testing the trafficability model on board of a leading vessel
3. Improving the model for the use on board of icebreaking vessels

Using the model for optimizing the track through ice covered water (ice routing) using the results of satellite images

WP 16

WP 14	Navigation Simulation	WP-manager: ISSUS

Introduction

In principle, operating in ice has hidden dangers compared to navigating in open water. Faults can have serious consequences for the safety of crew, ship and cargo when operating in ice-covered areas. Further danger can be caused to the environment considering the increase of traffic with tankers in arctic waters.

If there is a greater need to navigate in ice and simulators are required for training to operate in ice, more resources must be provided for the development of such a system. Developing a suitable mathematical model is a very complex task and the efforts required to do so should not be underestimated.

Considering the traffic in the eastern Baltic Sea during the winter and the damage that occurs every year due to inexperience, it would be extremely advantageous to provide special training for captains and navigators by using simulators for training to navigate in ice.

There is a great interest in Canada, Sweden, Finland, Russia, Germany and Norway in developing the simulation of navigation in ice. The development is looking towards an increase in traffic in ice. Captains and navigators of different origins already have to prove their ability to navigate in ice. This, the sea accident statistics in ice, the unusual features of operating in ice as well as a number of other conditions prove that we seriously need to start developing the simulation of navigation in ice.

Recommended Steps for the Development of Simulation of Navigation in Ice

1. Realisation of navigation in ice floes

- Development and consequent expansion of a suitable mathematical model, taking into account the interaction between ship and ice as well as between ice floes themselves
- Development of an interface which guarantees the exchange of data between the ice simulation process and the simulator and vice versa
- Demonstration of results, including making comparisons with reality

2. Realisation of navigation in level ice

- Development and consequent expansion of a suitable mathematical model
- Development of an interface which guarantees the exchange of data between the ice simulation process and the simulator and vice versa
- Demonstration of results, including making comparisons with reality using typical operations in ice

3. Development of a suitable method or software for modelling ice for the purpose of visualisation of different ice conditions including demonstration of results

WP 16

4. Installation of full mission simulation for navigation in ice

- Integration of navigation in ice floes
- Integration of navigation in level ice
- Integration of the visualisation system
- Development of scenarios taking into account typical operations in ice
- Demonstration of full mission simulation of navigation in ice
- Comparison with reality

WP 16

III. Other Contributions:

1. H. Wierda, SHELL

Shell's contribution to the recommendations for further work based on Shell's internal views, the results of ARCDEV, on discussions with the participants and our interpretation of the current economic climate in the oil industry in Russia.

It is also based on my understanding of the Mission the ARCDEV joint industry project has set itself:
Execute joint research work with the objective to remove potential blockers for the use of the Northern Sea Route for commercial oil transport.

Many of the technical issues to be resolved have been identified and research has taken place by individual companies and institutes. The trip in May provided the opportunity for the participants to execute the relevant measurements to base new technology on and/or to test newly derived methods for ship design and navigation purposes. The results of this trip still need to be evaluated and made available before we can jointly decide what to do with it. Some of the information gathered seems to have more commercial value for one party than for the other and it is therefore important that the use of this information is agreed upon to avoid conflicts of interests between the participating parties

The obvious question arises as to how we wish to proceed with the ARCDEV joint effort.
My view is as follows:
Before the commercial use of the Northern Sea route can be effected the following issues need to be resolved:

- Technical matters such as:
  - reliable designs for ice-breaking tankers, loading and transshipment techniques for reliable use in Arctic ice conditions
  - development of techniques to enable optimum navigation in Arctic ice conditions.
  - development of technology and identification of supporting infrastructure needed to avoid accidents with the ships and damage to the environment.
- **Commercial concepts** for the ownership and operation of the shipping and navigational support facilities taking into account the interests and the availability/capability of resources of the existing Russian infra-structure.
- **Financing** issues: who is going to pay for the ships under whose (partly) ownership, for navigational infrastructure/aids necessary; for extension of the ice breaking fleet (if confirmed appropriate)
- **Economics**: how will the various commercial, ownership and financial concepts translate into a fee structure and what levels of fees can be expected
- **Politics:** who can participate; control over the Northern Russian waters; consequences for employment in the Northern Sea route harbours and NSR infrastructure

To a large extent it can be concluded that the technical feasibility of the commercial use of the NSR is effectively established (partly owing to the ARCDEV effort and prior effort of their participants) and that few major technical issues remain unresolved. The final report from all the WP managers should identify these. The remaining issues are to a large extent related to the optimisation of ship design and navigational technology and tend to be project specific. Their resolution is therefore likely to be funded by the parties directly involved. Measurements required to resolve them will therefore only be required in the event the execution of a firm project is expected in the near future. In the current climate of the Russian oil industry our view is that that situation is at least a couple of years away. In the event that specific project information should then be collected under the responsibilities of those parties directly involved in those projects (perhaps under supervision of the local authorities) and not necessarily by a Joint Industry effort.

Considering the many alternative solutions for the various issues, the solution of all the above aspects will be major effort. It should also be realized that the ARCDEV effort in its current composition cannot tackle all these issues if it is desirable at all. Nevertheless I feel that the participants, perhaps with the addition of some major Russian parties (eg. Gazprom/Lukoil) could address more of the non-technical issues such already suggested under WP 1 and 2, than currently has taken place. To identify where ARCDEV could contribute AND to limit the volume of work it is proposed to define a fictive NSR model that describes the dimensions of the organization of the NSR concepts in terms of production rate to be sustained, fictive location of say three terminals (of different nature), size of ships, hence the frequency, operational limits of projected designs and hence the requirements for ice breaking tankers etc.

Such definition will enable to review the scheme against the issues mentioned above and derive from there where ARCDEV participants can contribute and where it might be logical to invite other partners (e.g. manufacturers of navigational equipment).

To avoid the use of community money for pure commercial use (and hence the associated potential conflicts about how to use it), I feel we should concentrate on those issues where synergy is obtained between the parties involved but also on those issues which eventually will be under the responsibility of the local authorities such as navigational control, the installation of land/sea based navigational support infra-structure, the permanent collection of navigational data which is not easily obtainable by individual vessels. I.e. those areas where a multidiscipline input from the industry is essential to assist the authorities. In this context JERIS could play a role.

I also expect that the above structure may provide a clearer justification for parties to participate and a systematic approach to the priorities for further work by the (current and new) ARCDEV participants.

WP 16

2. AARI's General Recommendations for Future Research

1. Improvement of methods for forecasting of ice conditions specifically aimed at arctic navigation.

Forecasts of those parameters of ice which influence considerably on effectiveness of ice navigation along Northern Sea Route, should be analyzed. These parameters are as follows: ice concentration, age of ice, hummock coverage, ice pressure, orientation of leads. Both short-term (up to 7 days of advance) and average-term (from 7 to 15 days of advance) numerical and physically-statistical forecasts of the above-stated parameters of ice cover have to be improved. In the future research within the frame of the ARCDEV program it is considered to estimate efficiency, quantity of output information and ways for improving of forecast methodology.

2. GIS-technologies based simulation of arctic maritime transportation systems.

Modelling of operation of European Arctic Maritime Transportation System based on GIS-technologies application is proposed. This study will be aimed at development of the methodology and computer software for time-domain simulation of operational parameters of the basic components of transportation systems such as cargo vessels, icebreakers, onshore and offshore terminals and loading facilities. The simulated parameters are cargo flows, time of delivery, maintenance and operational expenses and other characteristics that are required for trafficability and economical analysis. An essential part of the simulating will be use of historical data on environmental conditions (mainly ice conditions) on the Northern Sea Route.

3. Data base on ice property measurements.

The objectives of the study are collecting of previously obtained ice properties measurements and presentation of this information in an unified format within a computer data-base. The following ice properties measured during field research in Arctic, will be included: temperature, salinity, density, uniaxial compressive strength, flexural strength and others (if available). These basic ice property data are accompanied with information on geographical location, ice floe thickness, air temperature, surface water salinity, test conditions and other data that are requires for interpreting and application of the records. A widely acknowledged license computer software for creating and managing data bases is planned to use.

4. Large-scale strength of ice features.

The study is aimed at verification and improvement of numerical models for prediction of ice loads on ship and offshore structures. It includes investigation of bending of level ice and bending and shearing of ice ridges, as well as indentation tests. The main distinguishing peculiarity of this research (in comparison with others performed previously) is comprehensive measurements of the field of stress/strain in ice cover and in indentor for further evaluation of ice rheology equations and failure criteria that may be applicable to a large/full scale. Large-scale tests are accompanied with conventional measurements of ice properties. Time-domain numerical simulation of the same processes that were investigated experimentally, with subsequent comparison of theoretical estimates with actual values of the forces, stress/strain, etc. is an essential part of the proposed study. The numerical simulation is based on application of finite element method.

5. Development of a combined model of ship motion in ice

The objective of research is developing a combined model of ship motion in ice that would have advantages of both analytical models for evaluation of ice resistance to ship motion and empirical models of ship transit based on statistical analysis of data on actual navigation of icebreakers and cargo ships along the Northern Sea Route.

6. Development of a satellite module of information system for supporting ice navigation

The main aim of research is development of a satellite module of information system for supporting ice navigation with the joint use of Russian and non-Russian satellite data. This study includes: making more precise and detecting new signs for interpretation of high resolution SAR information with the use of all accessible hydrometeorological data including the AARI's historical information and measurements on ice stations; definition of optimal combination of different satellite information to support ice navigation in definite regions and for different seasons; introduction of advanced progressive GIS- technologies for processing satellite information.

7. Telecommunications for supporting ice navigation

The objective of research is analysis and preparation of proposals for organization of telecommunications for operational transmission of all necessary information on board icebreakers / ships from shore based Ice and Weather Information Service Center and back, definition of optimal content and information formats, hardware

WP 16

3. IDEAS FOR JERIS ICE RESEARCH ACTIVITIES DURING WINTER 1999—2000

1. JERIS ACTIVITIES

1.1. METEOROLOGICAL AND HYDROMETEOROLOGICAL STUDIES

1.2. SEA BOTTOM STUDIES
- 1.2.1. Bathymetry
- 1.2.2. Sediment samples from the bottom
- 1.2.3. EM measurements of the bottom
- 1.2.4. Observations of the behaviour and movement of the bottom sediments
- 1.2.5. Scouring studies

1.3. LARGE SCALE ICE STUDIES
- 1.3.1. Satellite images
- 1.3.2. Laser profiling
- 1.3.3. Visual ice reconnaissance flights

1.4. LOCAL ICE STUDIES
- 1.4.1. General ice properties and level ice measurements
  - 1.4.1.1. Compressive ice tests
  - 1.4.1.2. In situ cantilever beam tests
  - 1.4.1.3. Structure indentation tests
  - 1.4.1.4. EM measurements of the level ice thickness
- 1.4.2. Thermal drill
- 1.4.3. Sonar
- 1.4.4. Sonars mounted to sea bottom in drifting ice area
- 1.4.5. Levelling
- 1.4.6. Stereo photographing / air photographing
- 1.4.7. Thermistors
- 1.4.8. Ice movement studies
  - 1.4.8.1. Wireline
  - 1.4.8.2. Theodolite measurements

1.5. STRUCTURE STUDIES
- 1.5.1. Structure type
- 1.5.2. Force measurements / instrumentation
- 1.5.3. Ice grounding and pile up in front of the structure

1.6. CAMCOPTER™ USAGE

2. TIME TABLE

2.1. ESTABLISHMENT OF THE BASE

2.2. LONG TERM MEASUREMENTS / FOLLOW UP

2.3. ICE MEASUREMENTS

WP 16

A short general description of each topic is presented.

1. JERIS ACTIVITIES

1.1. METEOROLOGICAL AND HYDROMETEOROLOGICAL STUDIES

Basic meteorological measurements should be measured during the whole ice period. An automatic weather station should be established, which would measure at least the following parameters:

1. Air temperature
2. Air pressure
3. Wind speed and direction

Cloudiness, visibility and precipitation could also be observed.
Hydrometeorological studies would include following studies:

1. Tide measurements
2. Current measurements
3. Sea water temperature, salinity and density
4. Ice edge location and the classification of the winter in comparison with other winters
5. General and local ice charts

1.2. SEA BOTTOM STUDIES

1.2.1. Bathymetry

Sonar scanning of the area that is to be studied during the ice studies.

1.2.2. Sediment samples from the bottom

Samples from the bottom before the ice season and also possibly during the ice season to see the bottom structure.

1.2.3. EM measurements of the bottom

This could be done during the ice season.

1.2.4. Observations of the behaviour and movement of the bottom sediments

This is to show how stable the sea bottom is and what kind of structures can be based there.

1.2.5. Scouring studies

Scouring studies should be done twice. Firs study is to be performed before the ice season in the beginning of the whole program, i.e. in September.
The second study is to be performed after the ice season in the end of the program, i.e. in July.
We may also check how the dredged channel to the Kharasevay changes during the wintertime. This means one sonar measurement before and one after the winter before the fairway is dredged again.

1.3. LARGE SCALE ICE STUDIES

1.3.1. Satellite images

Weather satellites to be used in determining the overall ice situation.
More detailed satellite data to be used to determine local ice conditions. Radar satellite data (historical and present) could be used to analyze how the cracks and leads that help ship passage are developing in the southern Kara Sea. This would give information of regularities in the pattern the leads are formed and the frequency of navigable leads in different areas of the Kara Sea.

1.3.2. Laser profiling

Laser flights to be flown in the Southern Kara Sea between Kara Gate and Kharasevey. Local area laser flights could be arranged with the CAMCOPTER™.

1.3.3. Visual ice reconnaissance flights

This would produce ice charts and produce data for the calibration of the radar satellite images.

1.4. LOCAL ICE STUDIES

Local ice studies would concentrate on the fast ice zone in the vicinity of Kharasevey. The studied area would be about 2—3 km wide area from the shore to the fast ice edge (maximum).

1.4.1General ice properties and level ice measurements

1.4.1.1. Compressive ice tests

To be performed in the area in coherence with the other ice research.

1.4.1.2. In situ cantilever beam tests

To be performed in the area in coherence with the other ice research.

1.4.1.3. Structure indentation tests

To be performed in the area in coherence with the other ice research.

1.4.1.4. EM measurements of the level ice thickness

1.4.2. Thermal drill

Three intensive drilling periods would be made in the studied area. Each period would last about 2 weeks. First in late January / early February. Second in March—April and third in June. Each time the same ridges would be drilled with a dense grid.

1.4.3. Sonar

Ridge sonaring would take place simultaneously with thermal drilling at the same site. Synchronization with co-ordinates should be done

1.4.4. Sonars mounted to sea bottom in drifting ice area

These sonars would measure the keels of the ridges that pass by. To avoid equipment and data loss, the sonars must be placed in at least 30 m deep water.

1.4.5. Levelling

Simple theodolite leveling to get common co-ordinates for the Sonar and the Thermal drill measurements.

1.4.6. Stereo photographing / air photographing

Stereo photographs to be used in determining the ice elevation of the studied area and to get information of the pile up against the studied structure.

1.4.7. Thermistors

Thermistors would be placed in selected, relatively stabile ridges to see the development of the consolidated layer.

1.4.8. Ice movement studies

1.4.8.1. Wireline

To be performed in the area in coherence with the other ice research. This would be situated near the erected structure.

1.4.8.2. Theodolite measurements

To be performed in the area in coherence with the other ice research.

WP 16

1.5. STRUCTURE STUDIES

1.5.1. Structure type

The structure would be a relatively small, simple conical or cylindrical structure. The installation of the structure should be ready well before the ice season.

1.5.2. Force measurements / instrumentation

Instrumentation would embrace force transducers that measure total ice forces. Also a time-laps camera could be used to register the ice situation in the area.

1.5.3. Ice grounding and pile up in front of the structure

This would be done in connection with the other ice studies that are performed in the area.

1.6. CAMCOPTER™ USAGE

Local area laser profiling and general ice observation.
The CAMCOPTER™ could be equipped with an infrared sensor for ice bear watching.
Ship based navigation aide

2. TIME TABLE

2.1. ESTABLISHMENT OF THE BASE

The follow-up of the development of the winter and the start up of the base should be started, when the first sea ice starts to develop in the area. This would mean late September — early October. The structure preparation could demand for even an earlier start.

2.2. LONG TERM MEASUREMENTS / FOLLOW UP

This should be started simultaneously with the establishment of the base. The measurements that are to be carried out are meteorological measurements and photographing / video shooting. Weather satellite images could also be used to see the development / movement of the ice edge.

Level ice thickness measurements can also be labeled under the long term measurement plan.

2.3. ICE MEASUREMENTS

This would be divided in three parts:

I. First intensive ice measurements would start in late January / early February.
II. Second ice measurement campaign would be in March — April
III. Last ice measurement campaign would be in June. This could include some break-up study also.

VII Summary of ARCDEV-Results and Recommendations

In April/May of last year (1998) the EU and BMBF sponsored Arctic Demonstration and Exploratory Voyage (ARCDEV) was carried out to demonstrate the technical feasibility of transporting oil/gas condensate from the Russian Arctic to Western Europe by icebreaking tanker and to evaluate the economical situation of such transport. A convoy of two ships - the icebreaking tanker UIKKO and the Russian icebreaker KAPITAN DRANITSYN - started at Murmansk for carrying gas condensate from Sabeta at the Ob-River to western Europe. The convoy made a record voyage, even though the ice conditions in the Kara Sea were severe. At the northern trip of Novaya Zemlya, where the ice conditions became too heavy for KAPITAN DRANITSYN, the most powerful atomic icebreaker ROSSIA took over the lead of the convoy.

70 scientists from seven countries in Europe - mainly from Russia, Finland and Germany - carried out investigations on the ship's performance in the Arctic ice. In spite of the overall success of the voyage a number of issues have been defined, where research would significantly improve the technical and economical performance of such a transport system.

According to the evaluation of the ARCDEV-results the following measures could improve the so far unsatisfactory economical situation of such marine transport system:

1. The size of the tanker must be at least quadruplet.
2. The average speed in ice should be improved by the development of sophisticated routing advise and of the icebreaking capability of the tanker.
3. The costs for the icebreaker assistance must be reduced. The calculation of the icebreaker costs should be based on the operation conditions of a tanker fleet at a later stage of the transport operations, i.e. when every second day a 60 000 tdw tanker leaves the Arctic and the icebreaker assists the tanker only in areas with critical ice conditions. This means, that in the starting phase of the implementation of the Arctic Tanker Transportation System the Government should reflect possibilities to cover cost deficits in order to get this new enterprise started.
4. Icebreaking tankers should be developed, which can and are allowed no navigate in moderate ice conditions without icebreaker assistance and which have also a good open water performance.

The other technical problem to be solved is the Offshore Loading Terminal. Some experts are of the opinion that the Single Point Mooring (SPM) or the Submerged Turret Loading concepts (STL) are not safe enough for Arctic ice conditions and will cause much downtime of the loading operation.

A German group of companies recommend the Double Exit Terminal (DET), which consists of two parallel barges with the harbor in between.

All these items must be addresses by research and development in the years to come. This can be on national level but also within the EU-program. The development of an competitive marine transport system for the western Russian Arctic would contribute to the development of the Russian economy as well as in the long run to commercially using the Northern Sea Route from Europe to Far East.