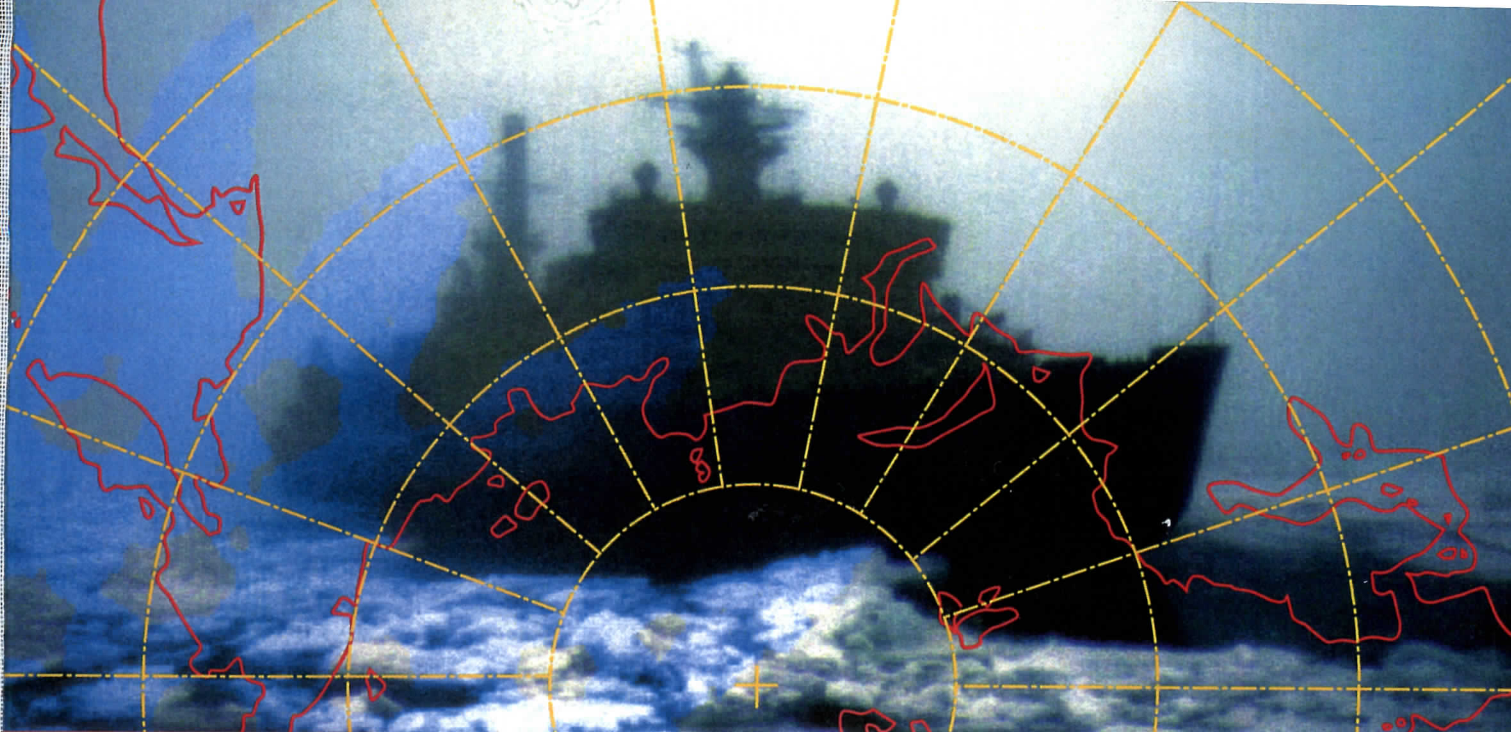

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Operational Aspects
Volume 2 - 1994 project work

Alexander Baskin, Arkady Buzuyev and Evgeny Yakshevich et al.

INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship and Ocean Foundation, Japan

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Title:	**Operational Aspects** **Volume 2 - 1994 project work**
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What is an INSROP Working Paper and how to handle it:

This publication forms part of a Working Paper series from the **International Northern Sea Route Programme - INSROP**. This Working Paper has been evaluated by a reviewer and can be circulated for comments both within and outside the INSROP team, as well as be published in parallel by the researching institution. A Working Paper will in some cases be the final documentation of a technical part of a project, and it can also sometimes be published as part of a more comprehensive INSROP Report. For any comments, please contact the authors of this Working Paper.

FOREWORD - INSROP WORKING PAPER

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

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

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

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

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- Norwegian Polar Research Institute
- Norwegian School of Economics and Business Administration
- SINTEF (Foundation for Scientific and Industrial Research - Civil and Environmental Engineering), Norway.

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GENERAL

This project consists of two parts. The first part has been prepared by CNIIMF as a continuation of the 1993-1994 investigations on operational aspects of sailing the NSR - regulations, navigation and communications, safety of sailing etc. Emphasis was placed on ways to improve techniques currently employed for support of sailing in the Russian Arctic.

The first part is composed of seven sections, each supplied with summary and key words.

The second part has been prepared by AARI and deals with hydrometeorological problems in the context of operational aspects.

PART I

PREPARED BY CNIIMF

PART I
PREPARED BY CNIIMF

CONTENTS

[1]During the report preparation the data on infrastructure for 1994 ran significantly out of date. New data are presented in the report for 1995.

I.1.2.1 LEGAL SUPPORT

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SUMMARY

Performed within the 1994 budget this work was intended to treat the legal and normative acts of the Russian Federation regulating the Arctic navigation.

Legal support to the Arctic navigation was under consideration with due regard for IMO Resolution A.680(17) "IMO Guidelines for the management and safe operation of ships and for pollution prevention" that had come into effect in Russia by the time of planning this work.

However, the above Resolution was revoked by subsequent IMO Resolution A.741 (18) of November 4, 1993, with the International management code for the safe navigation of ships and for pollution prevention (International safety management (ISM) Code) being adopted herewith.

Since the ISM Code was adopted as Chapter IX of the International Convention SOLAS-74 whereupon its provisions became mandatory; the order of the Minister of Transport of the Russian Federation of July 26, 1994 #63 "On measures to improve the safety of navigation" was issued to bring the provisions into effect.

Accordingly, this work has been performed to bring any changes and updating of the legal base of merchant shipping of Russia into line with the requirements of the ISM Code.

KEY WORDS

Guidelines, IMO Resolution, Document of Compliance, Regulations.

1 MAIN INTERNATIONAL CONVENTIONS AND NAVIGATION GUIDELINES

In spite of the fact that most of international tools on safety of navigation were ratified by Russia, there was no practice of their direct implementation. The rules of international conventions were transformed into national legislation and normative acts, legal borders of which were essentially different from those accepted worldwide. CNIIMF has conducted special research work, giving a foundation for direct application of international legal regulations in Russia, but arguments offered by the institute were ignored by the government.

Therefore, after coming into force, the 1993 order of the Minister of Transport on implementation of IMO Resolution A.680(17) in Russia acquired special significance. The point is that Appendix 2 to this Resolution contains the list of main international conventions and recommendations relating to navigation. Thus this documents have become a basis of the Russian marine legislation.

The main international conventions are:

SOLAS-74 (International Convention for the Safety of Life at Sea, 1974) as amended, lays down a comprehensive range of minimum standards for the safe construction of ships and for the basic safety-oriented equipment.

MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto) as amended, contains measures designed to prevent pollution caused both accidentally and in the course of routine operations.

COLREG (Convention on the International Regulations for Preventing Collisions at Sea, 1972), as amended, lays down the basic "rules of the road".

INTERNATIONAL CONVENTION ON LOAD LINES, 1966 sets the minimum permissible freeboard and standards of watertight integrity.

ILO Convention 147 (Merchant Shipping (Minimum Standards) Convention 1976) requires Administrations to have effective legislation on safe manning standards.

STCW (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978) lays down training, certification and qualification requirements.

IMO Resolution A.481(XII) recommends to provide each ship with a document specifying the minimum number and qualification of personnel.

IMO Resolution A.443(XI) recommends some necessary steps to be taken to safeguard shipmaster in the proper discharge of his responsibilities in regard to maritime safety and marine environmental protection.

2 CIVIL CODE OF RUSSIA AND NAVIGATION

As it was mentioned above the legislative and normative acts of the USSR, continue to be in force in those parts that do not contradict the legislation of Russia. One of the most odious national documents is the Code of Merchant Shipping of the USSR, 1968. According to this Code, all shipping companies, ports, vessels, infrastructure and supporting systems could be only of state ownership. The NSR pilotage, in particular, should be executed "exclusively by state marine pilots".

The new version of the Code of Merchant Shipping has been submitted to the State Duma (Parliament) and now is passing the examination at state law institutes. The State Duma however is unlikely to save time for careful consideration of the Code within a year or two.

Under such conditions, the adoption by the Duma, on October 21, 1994, of the first parts of the new Civil Code is a saving remedy. Pursuant to the federal law of the Russian Federation, signed by President Boris Yeltzin on November 30, 1994, N 52-F3, the first part of the Civil Code has been enacted since January 1, 1995. The new law permits the activity of organizations of any form of ownership providing that they are registered according to an established procedure. This law abrogates the old legislative and normative laws of the USSR, in particular the Code of Merchant Shipping, in those parts, which contradict the new Civil Code.

The Civil Code establishes, that "some kinds of activity, the list of which is determined by law, may be engaged by juridical persons only on the basis of special allowance (license)". The marine carriages of freights and passengers, pilotage, seafarers training on simulators, i.e. the kinds of activity, connected with safety of navigation and prevention of environment pollution, are referred to such kinds of activity.

The licensing of sea transportation and forwarding activity in Russia is executed on the basis of Decree of the Council of Ministers of the Government of the Russian Federation # 840, as adopted on August 23, 1993 (published in the Assembly of Acts of the President and Government of the Russian Federation # 35 of August 30, 1993) and on the basis of the Rule of Licensing. This Rule states, that the licensing "...is produced with the purpose of maintenance of safety of navigation and observance of established ecological norms at operation of marine and internal water transport, normal functioning of the market of transport services, as well as for protection of interests of consumers of these services..."

According to the Statute of the Ministry of Transport of Russia, authorized by Government Decree N 457 of May 18, 1993, the Ministry "...organizes and in prescribed manner executes licensing...". Accordingly, the Minister of Transport of Russia by order # 98 of November 5, 1993, introduced the series of organizational measures, aimed at realizations of the Decree of the Government of Russia on licensing, and then the order of July 25, 1994, enacted the Instruction on licensing transportation and other activity, related to transport process in the marine transport in Russia.

The similar object is pursued by periodic check of knowledge (certification) of the executive chiefs and executives of transport enterprises, irrespective of forms of ownership, who are involved in maintenance of safety of navigation, with masters of sea-going ships being checked also. This certification is established by Decree of the Council of Ministers Government of Russia # 876 of August 30, 1993. This Decree states that persons can be appointed at certain posts only after special training and check on their skill and knowledge.

The above Decree was developed by joint Order of the Transport and Labor Ministries # 13/11 of March 11, 1994, that established the Regulations of certification, which came into force since July 01, 1994. These Regulations define the suitability of persons to maintain safe transport operations. Accordingly, the tasks of certification are: the check on the knowledge of legislation on the safety of navigation and on the skill to apply it in work; the formation of well-experienced structure of executive chiefs and executives, including shipmasters, who are able to ensure safe operation of transport. Purposes and tasks of certifications completely meet the ISM Code requirements.

In organizing international navigation along the NSR, when the transportation process is executed by different shipping companies, registered in Russia, the licensing of activity of such companies pursuant to the legislation of Russia will be a compulsory initial stage.

3 GENERAL RULES OF NAVIGATION AND MOORING AND RULES OF ICE BREAKER'S PILOTAGE

In accordance with the task set by State bodies, CNIIMF developed "The General Rules of ships' navigation and mooring in seaports of the Russian Federation and on approaches to them", which really make a generalization of local rules. Such Rules are directly stipulated by Rule 1 of COLREG-72 Convention. The General Rules entered into force on July 1, 1993 by joint decision of DMT and Russian Fishery Committee. They were published in "The Marine Legislation of the Russian Federation." Book II. The edition of HDNO (Head Department of Navigation and Oceanography of the Ministry of Defense), admiralty # 9055.2, St.Petersburg, 1994.

As far as regulations of the General Rules act in the territorial waters of Russia, they are also valid to regulate the navigation along the NSR. Thus, they are also in force for foreign vessels (article 1.2). The Rules are obligatory for all ships irrespective of their flag (art.1.5). The General Rules regulate the use of COLREG-72 in Russian waters, when local rules do not state otherwise (art.1.7).

The General Rules include common requirements relating to conditions of navigation and mooring of ships. In each port they are supplemented with compulsory port rules, reflecting a local specific character, including the features of navigational conditions in an appropriate area of VTS coverage.

The section "Rules of navigation" of the General Rules regulates: the order of navigation in regions of established routes;

traffic separation schemes in river water ways; lights and shapes to inform about restrictions - impossibility of give-way action and about constraints by the draught; rules of keeping out of the way of ships engaged in special or dredging work in narrow channels; speed of *ships;* anchoring; towing and pushing operations.

The section "Ships traffic regulation" of the General Rules regulates the order, conditions and rules of using a VTS. Allocated priorities for ships, functions of VTS services, relations between VTS operators and shipmasters are mentioned in this section. According to our reckoning, the following regulations are major ones:

"2.2.8. VTS instructions concerning: sequence of movement; route and speeds of movements; anchorages; action to avoid direct danger.

The vessel shall repeat the VTS instructions relating to it, and, when it is impossible to follow them - inform of the reasons and its further intentions".

Thus, on the one hand, VTS has the power, which, taking into consideration VTS knowledge of the situation, permits the vessel to avoid emergencies. On the other hand, as far as the VTS instructions are based on incomplete information, in particular, on radar-tracking information, and these instructions limit to some degree the freedom of navigation, the right to final decision rests with the shipmaster. But he is obliged to inform the VTS.

The other sections of the General Rules bear no relation to INSROP project.

Appendix 2 to the General Rules contains "the Rules of escorting ships by ice breakers". Pursuant to these Rules, on approaches to ports and in port waters the control of ships' ice convoy, as well as of all ice breakers and tugboats operations are executed by harbor master or by ice operations chief.

The harbor master informs shipmasters about ice conditions in approaches to port, the point of meeting with ice breaker and sequence of escorting (item 2). The requests for all kinds of icebreaker support are sent in 48, 24, 12 and 4 hours before the ship approach to ice edge, if other terms are not established by local port rules (item 4). The ships, following ice breakers in ice channel, should not overtake one another (item 6). The series of regulations are devoted to instruction on traffic priority, order of use of rudder and propelling machinery and engine orders (items 7-9), as well as to mutual relations between the masters of vessels under escort and the master of icebreaker (items 8-11).

Pursuant to the Rules, neither the ice breaker, nor the owner of the icebreaker, nor the charters do not bear the responsibility for likely damage and other harm done to a ship proceeding under escort or in results of manoeuvring connected with this escort.

The table of international signals for communication between ice breakers and ships, transmitted by sound and other devices, including radio is appended to the Rules. It suggests, that any signal, except signal "Stand by to make fast (to let go) the tug," sent by ice breaker or other vessel, is to be repeated by each ship following after.

4 PILOTAGE REGULATIONS

The above book referred to as "Marine legislation of Russian Federation" contains the chapter "Marine pilots of Russia"; the provisions of this chapter came into force on December 1, 1993. If in the USSR, the pilotage service could be rendered "exclusively by the state marine pilots," word "state" in the new document is intentionally omitted. Instead of it the following new interpretation of state function of pilotage is given: "the Pilotage services (organizations) in the Russian Federation irrespective of their legal status are integral part of state system of maintenance of safety of navigation. In their work they are guided by normative documents and acts issued by state bodies, in those parts, which concern the safety of navigation. All pilots are licensed and they are supervised by bodies of state supervision - harbor masters" (item 1.1).

Pursuant to the Civil Code, the Regulations state that "the Marine pilots can be united in pilotage services of ports and hydro-bases, as well as in independent pilotage organizations (item 1.2).

It is specially emphasized, that "the activity of ice pilots on the NSR and pilots in the open sea is regulated by proper rules."

The project of rules of ice pilotage on the NSR, which establishes the important requirements is now worked out. First of all, pilotage service (organization) should have a certificate of activity, issued by a body, exercising state supervision over merchant shipping navigation - the Main State Marine Inspection of DMT. In case of gross infringements of the rules of safety by pilots this certificate may be withdrawn.

The major provision of the rules is to rule out the rivalry of pilotage service, which, if any, always results in impairment of safety: "the work of two or more pilotage services (organizations) in one region of pilotage is not permitted".

The tariffs for pilotage are to be elaborated and established by pilotage organizations and should be coordinated by the Ministry of Transport of Russia.

The ice pilots should be the persons, with special navigational education and in the rank of captain. The assignment of initial qualifying category of the 2-nd class pilot is produced after training in pilotage service for a period not less than 6 months, with skill level having been determined and examination been passed in the presence of qualifying commission under the chairmanship of harbor master with participation not less than three experienced pilots. The maximum qualifying category of the I-class pilot may be obtained by the II-class pilot only after trouble-free operation for a period not less than five years and renewal examination.

The pilotage organization, is responsible for emergency cases occurred through pilot's fault, while piloting the ship. Pilot's liability lies within ten dues.

Pilots must execute the state functions of supervision over ships in relation to the rules of pollution prevention and sanitary rules to be observed, and show all indentified infringements of rules of navigation to the shipmasters and require elimination of these infringements.

5 INTERNATIONAL SAFETY MANAGEMENT CODE

IMO Resolution A.741(18) of November 4, 1993 adopted "International management code for the safe operation of ships and for pollution prevention (International safety management (ISM) code)".

Taking into consideration the fact that the ISM Code should be accepted as Chapter IX of SOLAS-74 International Convention, which makes its rules compulsory, the order of the Minister of Transport of the Russian Federation of July 26, 1994 # 63 "On measures to improve the safety of navigation" was issued to enact the ISM Code. The Department of Marine Transport is responsible for realization of measures, connected with enactment of the ISM Code.
As a Contracting Government (Party) to all International Conventions, concerned with the safety of navigation and protection of marine environment, the Government of Russia has pledged to execute the requirements of these conventions, including the requirement that in Russian ports the rules of appropriate international agreements shall be complied with by all ships, irrespective to their flag.

Pursuant to the regulations of SOLAS-74 Chapter IX, the actions of any shipping companies and methods of ship operation should be executed on the base of a Safety Management System (SMS) approved by the Administration. An SMS of company and SMS of vessel are assumed to complete the legal and normative base of flag state and are part of the national SMS.

The elaboration of series national documents, ensuring the ISM Code introduction in Russia, is entrusted to CNIIMF. The first of these documents - the "Regulations on Safety Navigation Management System of Russia (SMS of Russia)" has been worked out. The world practice has not the analogue of creation of such national level documents, containing the philosophical reinterpretation and integration of national policy in the field of navigational safety maintenance.

The document contains the following sections: General provisions, Structure and components of SMS of Russia, Competent state bodies, Legal base, Research and design organizations, Authorized organizations and experts, acting on behalf of Administrations, SMS of shipping companies, SMS of marine vessels, Data Base, System of information support, Applicants.

It is defined, that the objectives of SMS of Russia are to ensure safety at sea, prevention of human injuries and loss of life, and avoidance of damage to the environment and property. SMS of Russia provides the achievement of such objectives by management of national legal and normative base (new normative documents are duly available and obsolete documents are promptly removed) by establishing of national legislation at least as rigid as international, by organization of state supervision for legislation.

The requirements of SMS of Russia are applied to all companies, carrying out their shipping in the regions of the Russian Federation, to all ships under Russian flag, as well as to foreign ships visiting the ports of Russia, according to international requirements.

The structure of SMS of Russia includes: the competent state bodies, research, design and other organizations and experts, acting on behalf of administrations, shipping and other organizations, activity of which is connected with navigation, shipmasters and crews.

The components of SMS of Russia are: the legal base of navigation, system of information support, SMS of shipping companies, SMS of marine ships, database.

In particular, DMT implementing the state functions in a national SMS, forms and pursues the uniform state policy in the field of safe ship operations and pollution prevention, works out the projects of legal acts necessary for SMS of Russia functioning, submits them for approval to appropriate authorities, works out and issues the necessary normative documents within its purview, maintains and updates the legal base of SMS of Russia, regulates the activity of bodies of state port supervision, collects statistics on marine accidents in Russia, develops measures to prevent marine accidents, authorizes organizations and experts to certify shipping companies and ships in conformity with SMS of Russia requirements and to issue the documents of compliance etc.

Accordingly the state functions of ports marine administrations and harbor masters, of Shipping Register, of HDNO and of other state organizations are listed.

The legal base of SMS of Russia includes the documents, regulating questions of safety management and protection of marine environment in Russia, on international sea routes, in waters of other states, in ports of call of Russian ships. The legal bases of recognized organizations, shipping companies and ships include also the normative documents issued within the authority delegated to each organization.

The authority delegated by the Administration to organizations and experts for surveys of ships and shipping companies on conformity with the ISM requirements and with the rules of SMS of Russia for maintenance of uniformity of inspections and established standards, is executed by formal written agreement between the Administration and organization/experts. This agreement determines the responsibilities of parties and the instructions detailing actions to be followed if the ship is found not fit to proceed to sea.

The data base of SMS of Russia includes the legal bases - common base and bases of system subjects; the registers of shipping companies, recognized organizations and experts; the international database with information about vessels (ISID); the data about emergency cases, pollution of environment, any failures of equipment and technical facilities, connected with vessels of Russian companies or under Russian flag; the information about ship crews and shore based personnel; the data about crew members' faults connected with emergency cases or pollution of environment; remarks of port state inspection surveyors; contracts on research and design work; program of training of marine experts in educational establishments of

Russia; program of training on simulators; the mathematical models of types of Russian ships and software enabling to simulate ship's manoeuvring; the catalogues of navigational charts and books, navigational charts and manuals covering all the world; the collection of electronic charts and hardware-software complex to display them; the world sea weather forecast and data about actual weather. The SMS database of subjects contains relevant parts of SMS of Russia database and its own data (about vessels, crews, diplomas etc.).

The system of information support, as a part of SMS of Russia, is intended to maintain its base on an up-to-date level.

The following document, ensuring ISM Code introduction in Russia, is "Rules of survey of shipping companies with conformity to requirements of SMS of Russia (on conformity with requirements of SOLAS-74 Chapter IX)." The creation of such Rules was stipulated by scientific technological program of DMT "Management system of safe ships' operation and prevention of pollution from ships involved in national shipping." This program provides the availability of :

- Regulations on recognized (accredited) organizations and recognized (accredited) experts, carrying out on behalf of Administration the survey of shipping companies or ships on conformity with requirements of SMS of Russia;
- Form of the document concerning conformity of SMS of shipping company with requirements of SMS of Russia (Document of Compliance);
- Form of the document about conformity of SMS of the ship with the requirements of SMS of Russia (Safety Management Certificate);
- Form of the document of compliance of recognized (accredited) organization, carrying out the survey of shipping companies or ships on behalf of Administration on conformity with requirements of SMS of Russia (Document of Compliance).

The document, in accordance with international practice, realizes the recommendations of IMO Resolution A.739(18) "Guidelines for the authorization of organizations acting on behalf of the Administration", as adopted by of 18-th sessions of IMO Assembly on November 04, 1993.

The Rules of the survey of shipping companies establish:

- Mutual relations between competent bodies of the Administration, recognized organizations (experts) and shipping companies in regard to implementation of the requirements of SMS of Russia (ISM Code);
- The limits of powers of recognized organizations (experts), carrying out on behalf of the Administration the survey of shipping companies and ships on conformity with the requirements of SMS of Russia (ISM Code);
- The order of state supervision for conformity of activity of shipping companies and recognized organizations, holding Documents of Compliance, with requirements of SMS of Russia (ISM Code).

The last document, which may referred to as "Guidelines on survey of Safety Management System of shipping company (SMS of company) and of Safety Management System of ship

(SMS of ship) on conformity with the requirements of SMS of Russia (on conformity with requirements of SOLAS-74 Chapter IX).

The Guidelines establish:

- The applicable International Conventions, national legal acts, state and branch standards, managing documents, rules, manuals and instructions, setting requirements to shipping companies and their staff, to sea merchant ships under Russian flag, their masters and crews, which make the legal base of surveys of shipping companies and ships on conformity with requirements of SMS of Russia (ISM Code);
- Procedure of surveying;
- Basis for refusal to issue (renew)the Document of Compliance of shipping company;
- Basis for refusal to issue (renew) the Safety Management Certificate of the ship;
- Basis for prohibition of surveyed ship to sail;
- Relevant ethical norms.

It is obvious, that the ISM Code in force in Russia is a new decisive step in maintenance of maritime safety and pollution prevention.

The most important result of the implementation of the ISM Code is to be expected on the NSR, where the probability of marine accidents, and therefore of environment pollution is higher than in non-freezing seas, and the aftermath for sensitive nature of the Extreme North is much more dangerous.

CONCLUSION

The absolute majority of new legal and normative acts of the Russian Federation regulating merchant shipping, including the Russian Arctic seas, mentioned in the project, are the drafts of documents. The consideration and adoption of these documents are planned to be made in the second half of 1995.

In the following reports, the official texts of new documents will be considered and the evaluation of regulations covering the Arctic navigation and its international aspects will be carried out.

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I.1.2.2 ROUTE PLANNING
CARTOGRAPHICAL SUPPORT OF ROUTE PLANNING

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SUMMARY

The provision of Russian nautical charts for mariners has drastically changed. This report describes these changes and tries to show the tendencies involved.

KEY WORDS

Marine charts, Catalogue of charts, Notices to Mariners.

INTRODUCTION

The problem of route planning for navigation in the Arctic Seas is one of major problems of merchant shipping both in terms safety of navigation, and in terms of commerce. The optimization of planning routes of navigation is determined by quantity and quality of available information. This is why the previous report concerning 1993 was devoted to various aspects of information support, starting with general classification of information. Simultaneously, the analysis of condition of hydrometeorological, navigational hydrographic, pilotage and icebreaker support to navigation on the NSR was made.

It was assumed, that in 1994 and in the following years the way of improving the existing system of information support to the Arctic navigation should be developed in order to supply operators and ships of different countries with necessary information displayed so as to be readily understood.

The research has brought to light the crucial point of route planning: the cartographical support to the Arctic navigation. The report is devoted, first of all, to this problem.

1. SYSTEM OF CARTOGRAPHICAL SUPPORT TO ARCTIC NAVIGATION IN THE USSR

The cartographical support to merchant shipping in the Soviet Union was based on the concept of military counterbalance of two world systems. Accordingly, with few exceptions, the collection of navigational charts and books on the seas of the Soviet Union published by the Head Department of Navigation and Oceanography of the Ministry of Defence (HDNO) had the restrictive stamps "Secret" or "For internal use". The above mainly related to the Arctic seas, which were considered as strategically important for the national defence.

The information on all navigational HDNO publications intended for foreign seafarers, was shown in the one-volume Catalogue of charts and books, admiralty # 7007. This Catalogue did not contain any charts on the NSR for all of them had restrictive stamps.

The information on navigational HDNO publications, intended for Russian merchant shipping, was shown in the Catalogue of charts and books, consisting of seven parts. Part I of the Catalogue included the charts and books published for the Arctic Ocean region. The parts of the Catalogue contained two sections: "Charts" and "Books". The section "Charts" consisted of two chapters: the first one - with information on navigational charts, the second - with information on auxiliary charts and diagrams.

The navigational charts, placed in chapter I of the Catalogue, were divided into collections. Each collection consisted of a chart index and the text attached. In the textual part of the collection, the charts were arranged in increasing order of their numbers. The collection of general charts included the charts of scale 1:700 000 and smaller. The charts of scale 1:500 000 were allocated in a separate collection.

The collection of general charts on the whole Arctic Ocean consisted of about twenty charts with scales from 1:700 000 to 1:5 000 000. Among them there were 11 charts of the Soviet Arctic seas. The number of charts varied, therefore the above data define an average size of the collections. The information on confidential charts is not given in the report.

There were 13 charts of scale 1:500 000 on the Barentz Sea.

There were charts and plans of scale 1:200 000 and larger: on the Barentz Sea - about 80 items; on the Kara Sea, Ob and Yenisey rivers - more than 50; on the White Sea - more than 70; on the Hatanga and Anabar gulfs, Hatanga and Kolyma rivers - about 30.

The supply with charts and updating materials was made by base chambers of shipping companies and by hydro-bases in Murmansk, Arkhangelsk, Dikson, Igarka, Hatanga, Tiksi, Pevek, and Providenya.

2. SYSTEM OF CARTOGRAPHICAL SUPPORT TO ARCTIC NAVIGATION IN RUSSIA BEFORE 1993

After the liquidation of the USSR, the system of cartographical support to merchant shipping did not undergo significant changes. HDNO remained to be the publisher of charts. The information about navigational publications, intended for foreign seafarers, i.e. permitted to be published openly, was shown in one-volume Catalogue of charts and books, adm.# 7007, consisting of one part. The construction of this Catalogue was completely identical to the described above. At the same time, the Catalogue gave information on navigational charts in two languages - Russian and English. Another innovation was the issue only of radio navigational charts on some regions, obviously for economical reasons. Prior to that time, the borders and admiralty numbers of navigational and radio navigational charts had been the same.

Moreover, to meet the requirements of Russian seafarers and scientists, HDNO began to work in order to review restrictions imposed on the information concerning navigational charts (CNIIMF executed the special work at this problem for the Ministry of the Merchant Fleet). Catalogue # 7007 was intended to contain all charts and books, permitted for open publication. There was about five thousand of admiralty numbers in total. Therefore Catalogue # 7007 was considered be published in two parts. Part 1 (adm.# 7007.1) on the Arctic and Atlantic oceans and Parts 2 (adm.# 7007.2) on the Indian and Pacific oceans. Such Catalogue was issued in 1992. It contained the information updated prior to December 21, 1991.

3. SYSTEM OF CARTOGRAPHICAL SUPPORT TO ARCTIC NAVIGATION IN RUSSIA AFTER 1993

The termination of military tension of NATO and Warsaw Treaty countries was reflected in the Russian system of cartographical support to merchant shipping. The system became to lose its military character onerous for Russian seafarers as well. First of all, for restrictive stamps to be removed from navigational charts, a good deal of effort was undertaken.

At first that process went on slowly, but then began to pick up speed. The moment came when the Catalogue was overloaded by updatings. HDNO was forced to issue on March 1994 an Addition to Catalogue 7007.1 (adm.# 7007.1d), with charts, permitted for open publications after September 25, 1993. After issuing the Addition, necessary corrections were prepared both for the Catalogue, and for the Addition.

The INSROP program, backed up for various reasons by many Russian prominent politic and scientific persons, positively affected the process of taking the confidentiality off Russian navigational charts. In any case, it was managed to overcome the prejudice of Russian servicemen and to receive their consent to support the international navigation on the NSR by modern charts and publications.

As a result of the work, carried out by Russia, by the end of May 1994, the international navigation along the NSR from the Kola Peninsula to the Bering Strait was supplied, in addition to existing 12 general charts of scales 1:700 000-1:750 000 (on the Vil'kitskogo Strait - 1:200 000), with more than one hundred of navigational charts of scales 1:500 000 and lager. This collection completely supports the passage of foreign ships through the NSR in the navigation of 1994 already. Seafarers received 47 charts of scales 1:5000 - 1:200 000 covering a vast region from the Yamal Peninsula to the Vil'kitskogo Strait. This number does not include the charts of river entries.

All charts newly provided for international navigation were included in the above Addition to the Catalogue of Charts and Books, part 1, the Arctic and Atlantic oceans, adm.# 7007.d, 1994, which was sent to the Fridtjof Nansen Institute. The limits and coverage schemes of 1:500 000 charts for the NSR issued before June 01, 1994, scheduled to be published in 1994 and in 1995 were sent to the Norwegian party by telefax. Then the coverage of charts of scales 1:200 000 and larger, issued in 1994, scheduled to be published in 1994 and in 1995 were also sent by telefax. Later the Nansen Institute received from CNIIMF the total collection of modern charts on the NSR.

The fact, that formerly classified Russian navigational charts became available for all the mariners concerned, was the reason of radical changes made by HDNO in the catalogues system. The decision to create a uniform system from five parts of the Catalogue was taken as follows: parts 1-4 - one for each ocean, the fifth part - to group all special charts and publications. The first of the catalogues of new system "Catalogue of charts and books. Arctic Ocean" (admiralty number 7107), which replaced all previously published materials on this matter, was issued. In it, there was all information about charts and publications for the region of the Arctic Ocean and its seas. The issue of this Catalogue was announced by Notices to Mariners (NM) on February 18, 1995 (issue 8).

The information in the Catalogue was given for the state up to March 12, 1994. In connection with the significant changes relating to nautical publications, many corrections to the Catalogue were received and the largest part of them was related to the NSR.

The data on changes in the Catalogue were published in every fourth issue of NM HDNO. The following two examples allow us to form a certain notion of volume of the corrections applied. NM issue 8 of February 18, 1995 contains 104 corrections (97 - for charts, 7 - for books). NM issue 12 of March 18, 1995 contains 48 corrections (40 - for charts, 8 - for books).

On publishing charts and books of new edition, their copies of previous years were announced unserviceable for navigational purposes. The charts were issued in new edition in following cases: first, when use was made of new cartographical materials, requiring new charts creation, secondly, when there was a great amount of corrections to be made according to Notices to Mariners.

The following data allow us to form a notion of growing rate of cartographical support to international navigation on the NSR. Before 1992 there were only 26 open charts for region from Murmansk to the Bering Strait, in 1993 - 106 charts, at the end of 1994 the number of charts was totally 229. Until April 01, 1995 there were issued:
General charts - scales 1:2 000 000/1:500 000 - 27 (fig.1);

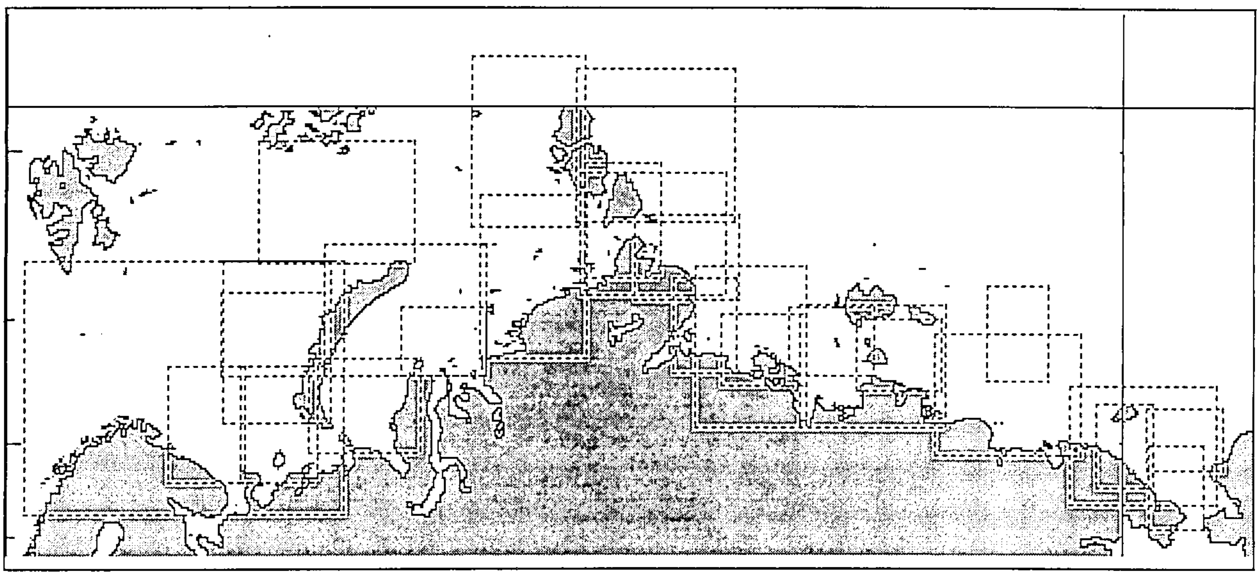

Figure 1
General charts for the NSR

Trail charts and plans - scales 1:250 000 / 1:1 000 - 129 (for region from the strait of Novaya Zemlya to the Bering Strait. fig.2-4).

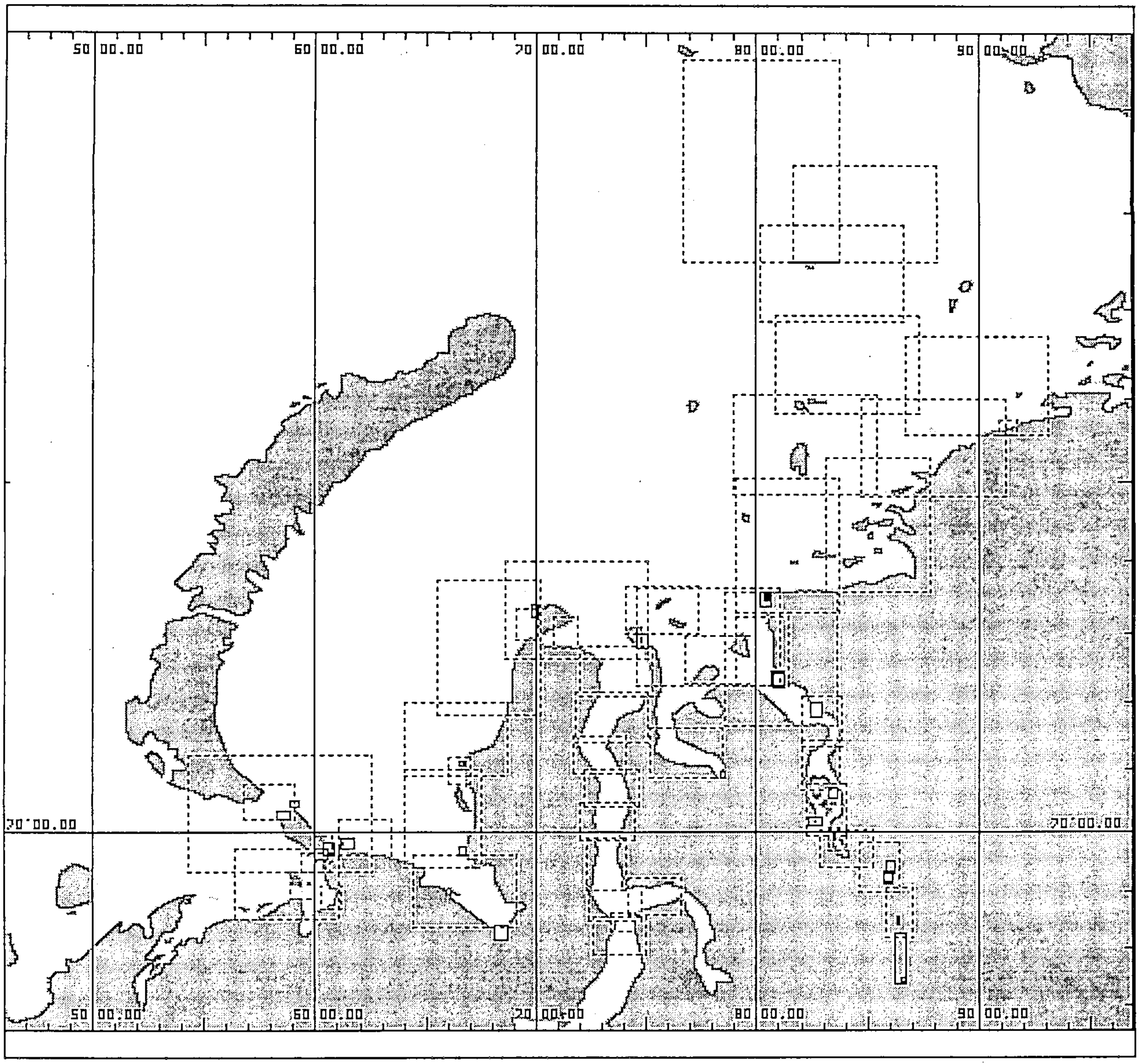

Figure 2
Trail charts and plans for the Kara Sea

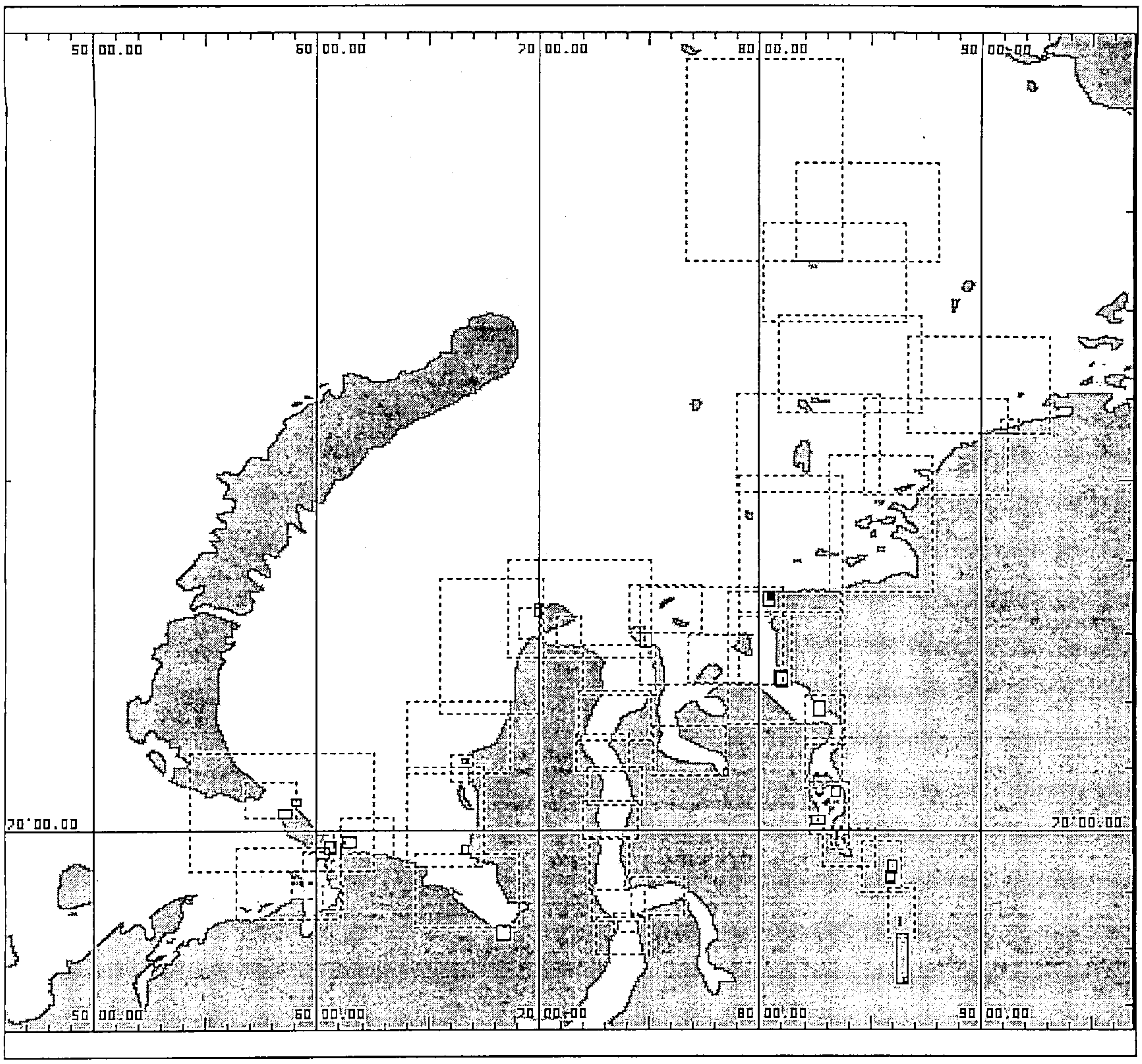

Figure 3
Trail charts and plans for the Kara Sea

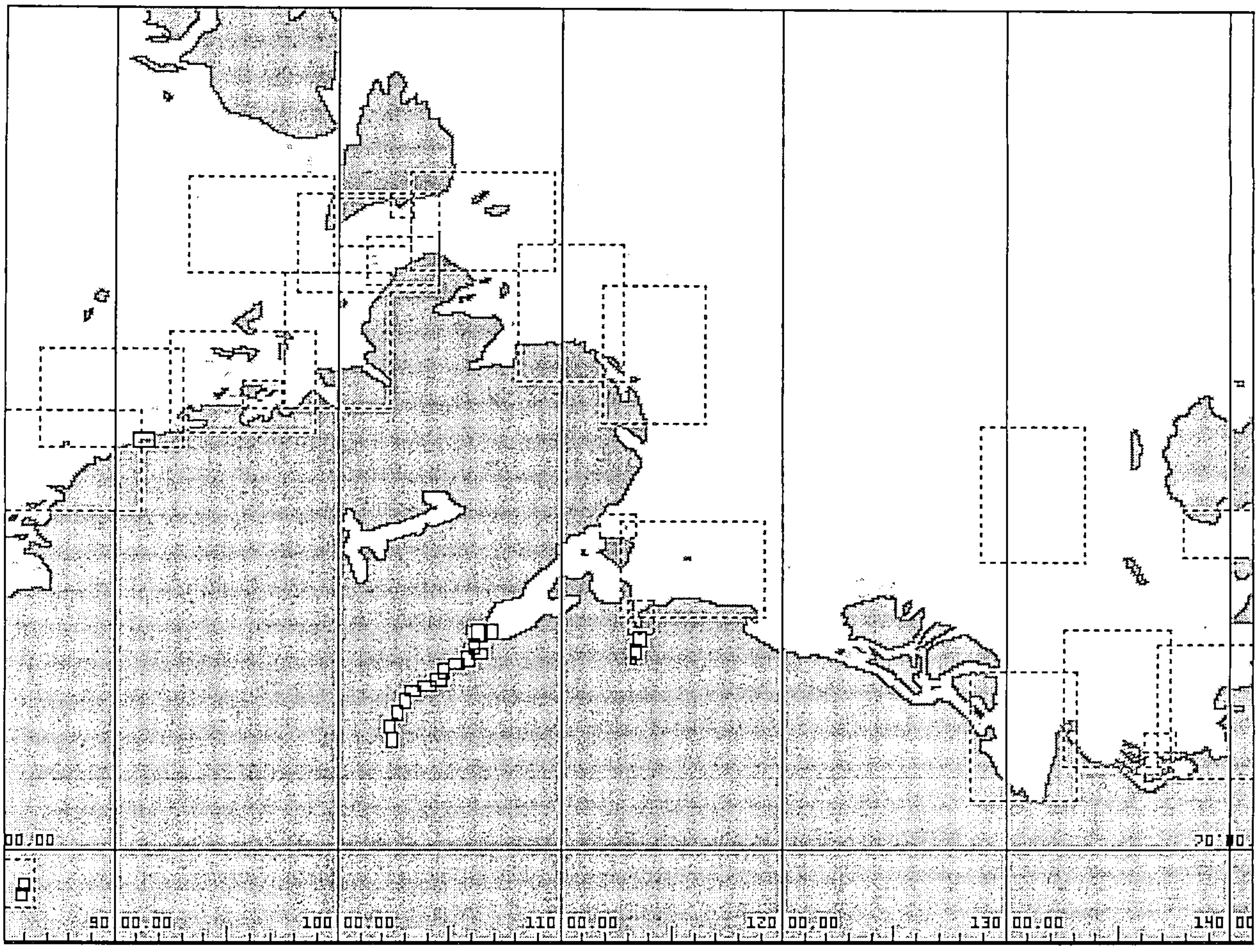

Figure 4
Trail charts and plans for the Laptev sea

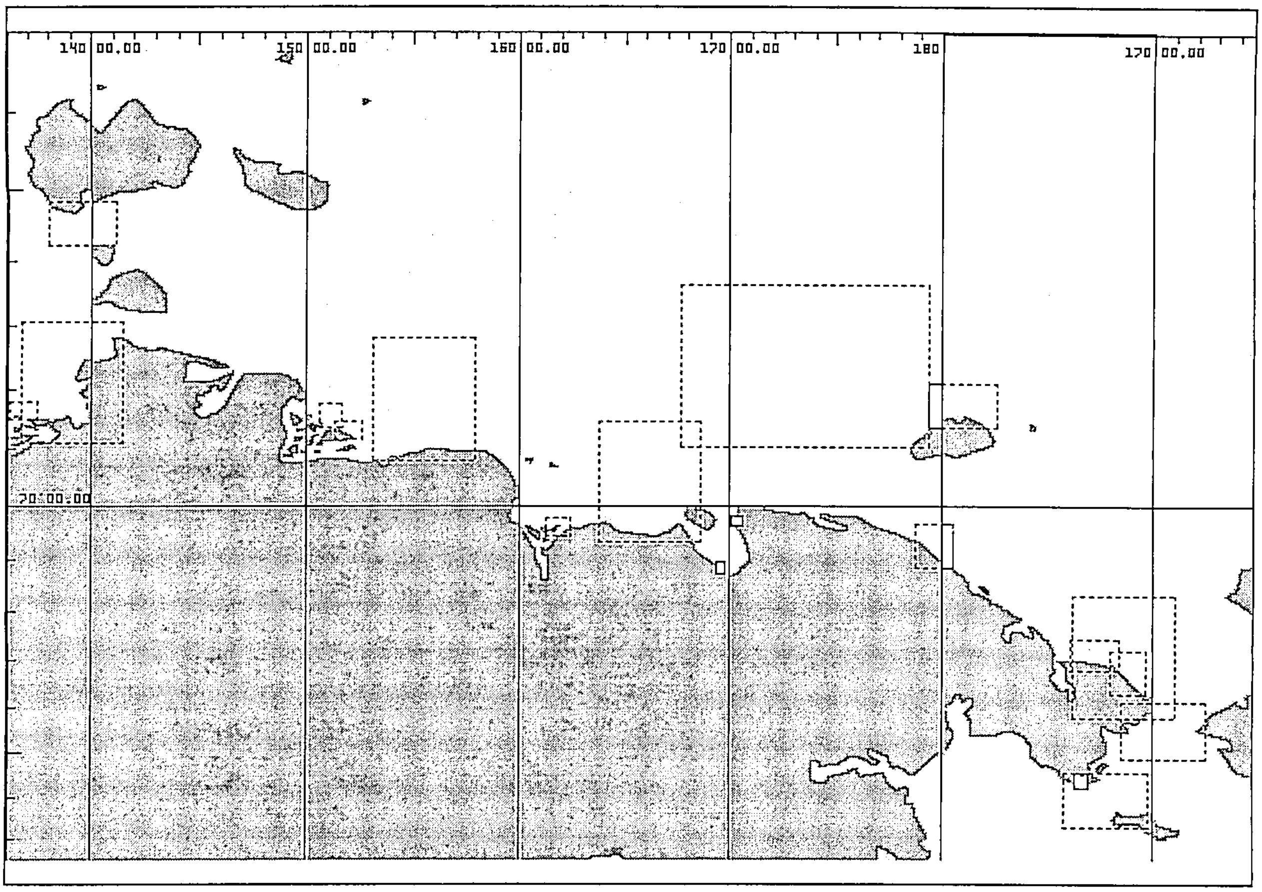

Figure 5
Trail charts and plans for the East Siberian and Chukchi seas

The total number of charts includes:
The charts, the edition of which is terminated, however they are suitable for navigational purposes - 8;

The bilingual charts in Russian and English languages - 17;
The charts classified by year of issue (a year from which all subsequent circulations of this chart are suitable for navigational use):
Till 1992 - 40;
Till 1993 - 41;
Till 1994 - 56;
Till 1995 - 19.

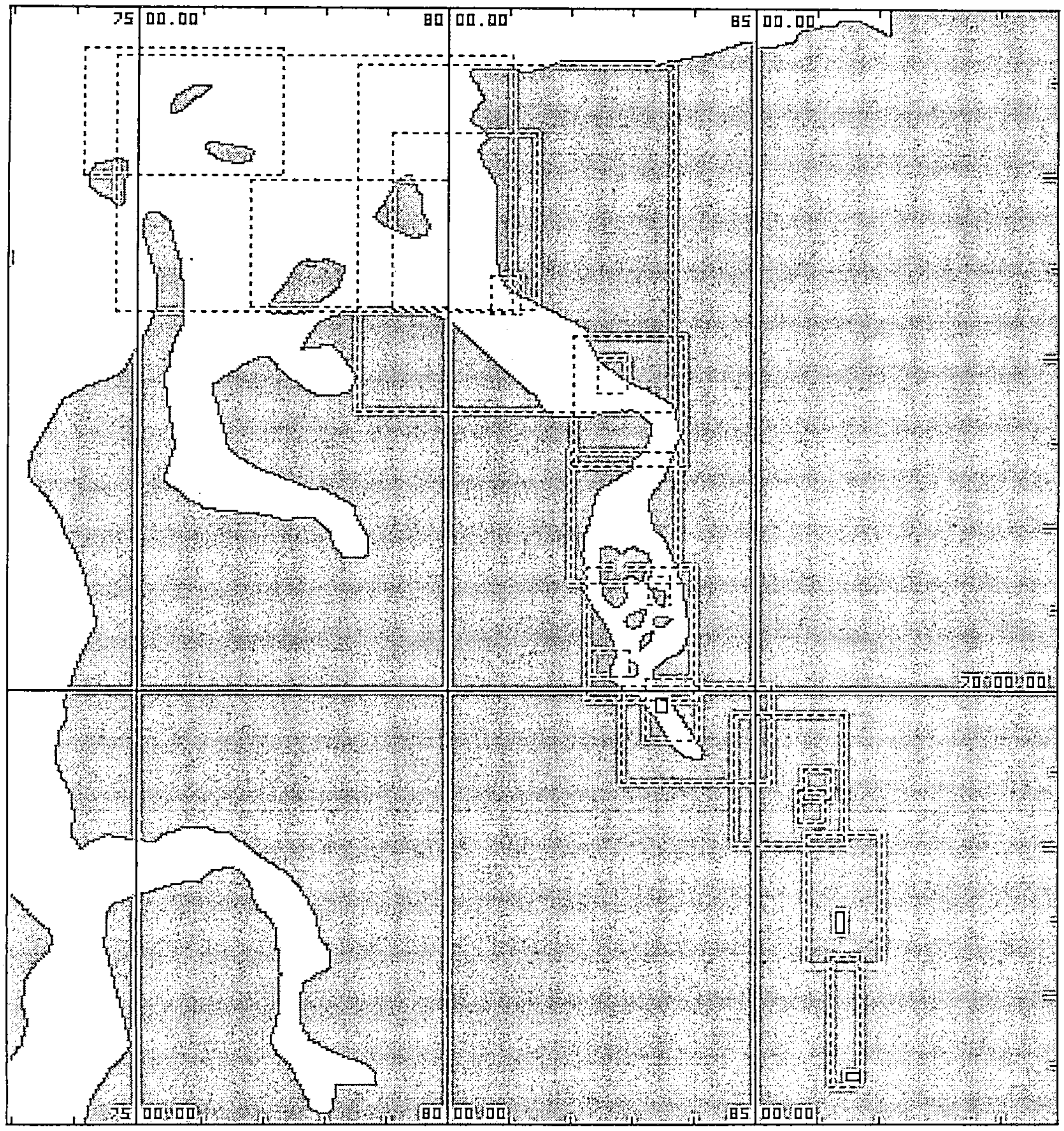

Figure 6

Trail charts and plans for the Yenisey River region

Figure 6 shows the coverage by navigational charts the route to the port of Igarka: the Yenisey Gulf - 6 charts (scales 1:25 000 - 1:200 000), the Yenisey River - 15 charts (scales 1:10 000 - 1:100 000), the port of Igarka with approaches - 1 chart (scale 1:10 000).

In 1995 it was planned to issue more 52 charts for the NSR.

The information about changes of navigational conditions on the seas of the Arctic Ocean was published in NM.

4 OPTIMIZATION OF SHIP CHART COLLECTIONS FOR THE NSR NAVIGATION

When planning the volume of ship collections for the NSR passage, the following should be taken into consideration. The inspection of Russian ships, made within the "Review of problem of supplying ships with navigational publications" program, has shown, that work on maintenance of ships' collections of Russian charts and books on the up-to-date level are distributed as follows:

The ordering - 10.7%, onboard updating - 47.0%, writing off and destruction of charts - 13.1%, storage and use - 11.4%, record-keeping -10.7%. The system used for supplying ships with charts and publications without placing any orders saves almost a quarter of expenses. On the average 43.0% of charts of ship collection are used in voyage and 40.0% are never used. In 11.3% of voyages the problem of the missing charts to be received arose because of changes made in the sailing plan including a new destination. The changes of sailing plan in 8.0% of voyages result in the urgent problem of mass updating of charts being out of use for a long time.

In planning of Arctic voyages it is necessary to make the ship collections meet the following criteria.

While completing this work the Catalogues of Russia, Great Britain, USA etc. were analysed. As it turned out, in Russia the basic scale (with reference to the number) is between 1:100 000 and 1:200 000, while in England - 1:300 000. This fact gives the tripled number of charts in HDNO catalogues in comparison with British Catalogue of Admiralty Charts for the same aquatorium.

The question resolves itself into selection of a basic scale of trail charts , on the one hand, in order to reduce the ship collections of charts for the Arctic seas of Russia, and, on the other hand, not to lose the quality of cartographical support.

The criteria of equal reliability of hardware and of cartographical support to navigation, permit us to make the following conclusion. The average accuracy of position fixing methods (2 cables) and the accuracy of graphic elements on navigational charts of order of 2 mm permit us to take the basic scale of charts equal to 2 cables in 2 mm i.e. 1:200 000. In this case the errors of position fixing and errors of chartering will be of the same order.

Thus all trail charts of scale 1:200 000 are worthwhile to remain in collections. It does not mean, that the charts of other scales should be mechanically withdrawn. Each chart should be included in collection only after separate examination.

The analysis shows, that British Hydrographic Department, as a rule, provides the approach of ship from sea to port waters with three kind of charts: the high sea - scales 1:350 000; the approaches to restricted water areas - scales - 1:75 000; port waters - scales of order 1:15 000. As a result, the number of charts and plans to be issued has been reduced to a minimum.

In HDNO publications the number of scales while passing from sea to restricted waters, as a rule, comes up to four - six: sea - 1:500 000 and then 1:200 000; approaches - 1:100 000 and then 1:50 000; port waters - 1:25 000 and then 1:5 000. This fact explains the increased number of Russian charts and plans for narrow passages, approaches to ports and port waters.

The unfounded enlarging of chart scales seems to proceed in many cases from the increase of quantity of charts and plans, and is a result of action of HDNO of the Ministry of Defence of Russia taken in its own interests, first of all with a view to preserve personnel and financing level whatever the detriment of seafarers may be.

5 GEODETIC DATUM OF RUSSIAN NAVIGATIONAL CHARTS FOR THE NSR

As it is pointed out in the last report, shallow waters, numerous dangers to navigation, the necessity to convoy ships in narrow ice lanes in order to avoid collisions with ice - all these features of navigation in the Russian Arctic seas have brought about the more exacting requirements to accuracy of ships position fixing.

The chartering of satnav observations on marine charts is performed with the use of geodetic systems of chart and SNS which may differ. In particular, since January 1987, SNS TRANSIT and GPS NAVSTAR have operated in the coordinates system WGS-84. The RNS "LORAN-C", used by vessels in the East Arctic, also operates in this system. At the same time, Russian charts on Arctic waters make use of the coordinate system of 1942 (Pulkovo-42) as a geodetic datum. The coordinate system of 1942 is determined by parameters of the ellipsoid of A. F. Krasovsky and the value of displacement of its centre with reference to the Earth centre of gravity. This coordinate system is fixed by station of the top grade - the Pulkovo observatory (St.-Petersburg).

Pursuant to the decision of the International Hydrographic Organization (IHO) of 1983, the Russian marine charts of scales 1:500 000 and larger have the geodetic system of chart and the values of corrections for conversion from WGS to the geodetic system of chart printed by publishers. If the corrections are insignificant, the case shall be indicated on charts as well.

The differences in geographical coordinates of the same points in the Arctic regions of Russia, referred to various geodetic systems, can reach 0.7 cbl, i.e. have the order of accuracy of positioning by GPS. Hence the values should be taken into account while laying out the course, especially in restricted waters. To exclude this influence, it is necessary to match the system of coordinates of chart with the system of coordinates of ship positioning equipment. The above also holds true when making use of the Electronic Charts Display Information Systems (ECDIS) and video plotters of various types for navigational purposes.

6. PREPARATION FOR SEA

While preparing to navigate along the NSR, with due regard for all specific features of navigation in the Arctic connected with ice conditions, character of operation of navigational aids, specific hydrometeorological conditions, one shall pass the following traditional stages:

selection of charts, sailing directions and other hydrographic publications for forthcoming sailing and their updating;

preparation of navigational devices;

reception of information on hydrometeorological conditions;

study of region of navigation, selection of route and completion of preliminary plotting, entering information on way points as well as other navigational information into SNS and RNS receivers and into ECDIS.

The full study of regions of navigation should be done by navigators before the first sailing is made along a selected route. The study is done with the use of selected and updated charts and other publications taking account the recommendations of the Marine Operations Headquarters.

The specific character of HDNO editions must be taken into consideration. The general charts of HDNO shows navigational dangers only in the open parts of the sea. Near to coast they are shown partially, only for navigational characteristic of the region. The navigational dangers in coastal zones, from shore line to 20 m depth contour (in steep regions to 50 m depth contour, in shallow regions - to 10 m depth contour), are not shown on these charts. The coastal part of general charts, covered by trail charts of larger scales, does not contain information on wrecks, vigias and dangers to navigation with designations "As reported".

After study of region of navigation using general charts, a route should be chosen. The route is divided into legs subject to hydrometeorological and others conditions.

However, to select a general way does not mean that the navigation will proceed as it was planned. The route, for instance can be changed owing to changes in ice conditions.
Therefore the variants of navigation along chosen legs should be considered.

A preliminary plotting along each leg is executed on trail charts of scale the most convenient for particular region. The information of charts and plans of the most large scale, which can contain important navigational data, is used.

HDNO plans to issue in the current year the "Guide for navigation through the NSR", which includes the directions for sailing along the main routes. This navigational publication will considerably facilitate the study of conditions of navigation along the NSR, analysis and selection of best variant of routes in relation to particular conditions of navigation.

The route planning in the Arctic is not limited by routine selection of routes, preliminary plotting, selection of havens and safe anchorages, analysis of weather forecast etc. In addition to usual stages of planning, navigator should analyse also the data of ice patrols to choose optimum way. While in convoy, the task of selection of a route is a prerogative of the convoy leader.

The responsibility for selecting and following the optimum route is generally imposed on ice captains, operative services of the Marine Operations Headquarters of the West and East sectors of the NSR and pilots as well.

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I.1.2.3 NAVIGATION AND POSITIONING

TECHNICAL AIDS TO POSITIONING FOR PROVIDING THE ACCURACY AND RELIABILITY OF POSITION DETERMINATION IN THE RUSSIAN ARCTIC

KEY PERSONNEL

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SUMMARY

Considered in this Section are two problems of positioning in the Russian Arctic. One is the introduction of a differential GPS service in order to provide the positioning accuracy needed for sailing the NSR safely. The proposed configuration of the DGPS sub-system is described. The second problem concerns the practical use of highly accurate position fixes produced by DGPS, i.e plotting the fixes on local nautical charts. Recommendations on mathematical methods for relating a position in one datum to coordinates in another are given.

KEY WORDS

POSITION FIXING, POSITIONING ACCURACY, NAVIGATION ACCURACY STANDARDS, DIFFERENTIAL GPS, REFERENCE DATUM, DATUM SHIFT.

INTRODUCTION

Reliable and accurate position fixing through the NSR is very important for the safety and efficiency of fleet operation in this area, especially in coastal waters, narrows, at port approaches and river estuaries. Complicated navigational conditions are characteristic of most areas in the Arctic region where sea and river vessels are practically the only transportation facilities available.

The positioning accuracy is a key parameter in performance of aids to positioning. A thorough review of positioning facilities currently employed on the NSR was given in Report 1.1.2-93. It has been concluded that as far as positioning accuracy requirements in the Arctic are concerned, the US Navstar and Russian Glonass systems hold much promise for the foreseeable future. As of now, both systems have found wide use in marine navigation.

In December 1993, the US Department of Defence announced officially the Navstar initial operational capability made available for civil use. The system was declared to be fully reliable and to provide an accuracy of 100 metres (P=0.95). The procedures for the Glonass non-military use are prescribed in the Decree of the Russian Government of March 7, 1995. Fully operative Glonass will comprise 24 satellites and is expected to have a position accuracy of 80 metres (P=0.95). The system is scheduled to be placed in full-scale service in late 1995.

A substantial improvement in positioning capability was brought about in recent years by applying differential GPS (DGPS) techniques. The actual positioning accuracy obtainable with this equipment is not worse than 5-10 m, that being quite sufficient for navigation in congested areas as well as for specialized activities, such as hydrographic exploration, researches, search operations, etc. Potentially, a higher degree of accuracy is attainable with DGPS.

To gain the operational advantages from the positioning accuracy achievable with currently available technology, it is important that the position fixes provided by satnav aids be adequately plotted on local nautical charts, i.e. that proper methods be employed when transferring coordinates from the reference system operated by the satellite navigation system involved to the coordinate system used in on-board position presentation facilities - in paper and electronic navigational charts.

Basic problems connected with technical and methodological aspects of positioning on the NSR are described below.

REQUIREMENTS TO NAVIGATION ACCURACY

The international standards of navigation accuracy currently in force were adopted by IMO at its thirteen Assembly in 1983 (resolution A-529/13). In the IMO document, phases of the voyage are divided into (1) harbour entrances and approaches and waters in which the freedom to manoeuvre is limited, and (2) other waters. In the first phase, accuracy requirements depend on local circumstances. In the second phase the error in the position fix should not exceed 4% of distance from danger with a maximum of 4 nautical miles, the probability being 95%. A navigational danger is considered to be both any natural feature - banks, rocks, drilling rigs, and conventional lines - isobaths, prohibited area boundaries, etc. The accuracy standards now in force are formulated unambiguously only for open sea navigation and for coastal sailing well away from navigational dangers. National Administrations have the right to set up navigation accuracy requirements to apply in congested waters of their jurisdiction.

The peculiarities of navigational and hydrographic conditions in the Russian Arctic require that specific circumstances be taken into account when formulating the accuracy standards for the area.

When looking at NSR route between the Karskiye Vorota Strait and Chukchi Peninsula, it can be seen that at least the half of the route runs through restricted waters - fairways, coastal and dangerous areas, where the freedom to manoeuvre is limited. To this must be added the ice fields, one further restriction on manoeuvrability. As stated in Report I.1.2.3 - 93, a peculiarity of NSR navigation is that the course cannot be planned and actual sailing accomplished within one selected narrow line. In response to changes in the ice situation, a ship may be forced to deviate from the intended track and may find herself being in close proximity to navigational hazards. With all things considered, the high-accuracy positioning is required to sail the NSR safely.

At this time there are no officially adopted accuracy standards for navigation in the Russian Arctic. This matter is being under consideration, and relevant normative documents are being prepared by authorized national organizations. It is assumed that the use of Navstar or Glonass receivers will provide sufficient accuracy for sailing NSR "other waters", in terms of IMO classification referred to above. Having in mind the IMO accuracy standards for open sea navigation (4% of distance from danger), the accuracy of the position fix given by both systems allows safe sailing at a distance not less than one mile from danger:

$1852 \text{ m} * 0.04 = 74 \text{ m}.$

As for sailing NSR waters in which the freedom to manoeuvre is limited, DGPS is at this time the only means capable to provide the accuracy required.

In view of the importance of the DGPS mode for the Arctic, it seems appropriate to give a brief review of the requirements to DGPS adopted through the world.

REQUIREMENTS TO DIFFERENTIAL GPS

Because of drastic improvement in accuracy performance achievable with DGPS (up to units of metres for mobiles and up to centimetres for fixed units), the interest in the use of this new technology for various applications is growing at a remarkable rate worldwide.

Special Committee SC-104 of the US Radio Technical Commission for Maritime Services with participation of representatives from other countries has formulated requirements to the DGPS accuracy performance. These are:

- 8-20 metres (95% probability) for radionavigation support of general navigation (harbour approaches, fairways and narrows);
- 1-5 metres (95% probability) for special-purpose services (hydrography, sweeping, mining, etc.).

The Committee has also prepared the SC-104 standard for transmission of DGPS corrections. This standard was approved by IMO and other international organizations.

CCIR Working Group 8C has developed technical characteristics for broadcasting DGPS corrections by the network of marine radio beacons. A decision to use radio beacons for transmitting the corrections was taken by the US Coast Guard.

The International Association of Lighthouse Authorities has prepared a program for creating a DR GPS single radionavigation field embracing all waters of the European north-west, from Spain to Russia, with the use of radio beacon service for transmission of DGPS corrections.

In Russia, general requirements to position-fixing systems employed for support of sailing in congested areas have been formulated and agreed upon by the organizations responsible for maritime safety in national waters: SE "Morsviazsputnik", the NSR Administration, CNIIMF, the State Hydrographic Office. A position-fixing system should meet the following requirements:

- ship position information should be available in real time continuously or at 510 s intervals;
- error in the position fix should not exceed 10-15 metres (95% probability);
- information provided to the navigator should be unambiguous and should determine the ship position relative to the midchannel for the entire run, without a need for additional calculations of any parameter;
- quantitative assessment of ship's offset from the midchannel should be presented together with the motion parameters the longitudinal component of velocity vector and the heading error about the midchannel;
- results of calculation of the route coordinates distance to waypoint, time to waypoint, lateral displacement from the midchannel, heading angle should be displayed on the user receiver;
- the costs of system deployment and operation should be minimal.

DGPS IN THE RUSSIAN ARCTIC

The projected introduction of DGPS in the Russian Arctic in the coming years will make it possible to have a single high-precision radionavigation field extending from Novaya

Zemlya to the Bering Strait, and to improve significantly the safety of navigation in this area.

In addition to general navigation applications, the DGPS sub-system will be used to aid:

- hydrographic survey
- buoyage operation
- pilotage
- establishing the state and production geodetic networks
- special marine researches (hydrological, gravimetric, etc.)
- prospecting on shelf and in open sea
- engineering survey at sea and in coastal areas (construction of ports, gas pipes, drilling platforms, etc.)
- control of aerial photography and plate axes synchronization with ship navigation systems.

There are two alternatives of the DGPS sub-system configuration in the Arctic, one employing the existing radio beacons with an effective range of 150 miles, and another using 300-mile beacons. In the former case, it will be required that 13 reference stations and 2 monitoring stations be deployed through the NSR. With the 300-mile beacons employed, 7 reference stations and 2 monitoring stations will be needed. It is believed that the second alternative is advantageous from both the operational and economic standpoints. The costs of refitting the existing beacons will be well offset by the reduction of the number of beacons required, the latter factor being of particular importance because of the known problems with maintenance of remote equipment in the Arctic. Results of DGPS pilot operation in the Arctic regions of Canada and Iceland have shown the operational and cost benefits of applying 300-mile beacons for transmitting DGPS corrections.

The projected locations of the DGPS reference stations through the NSR and the operating areas of the 150-mile and 300-mile beacons are shown in Figure 3-1.

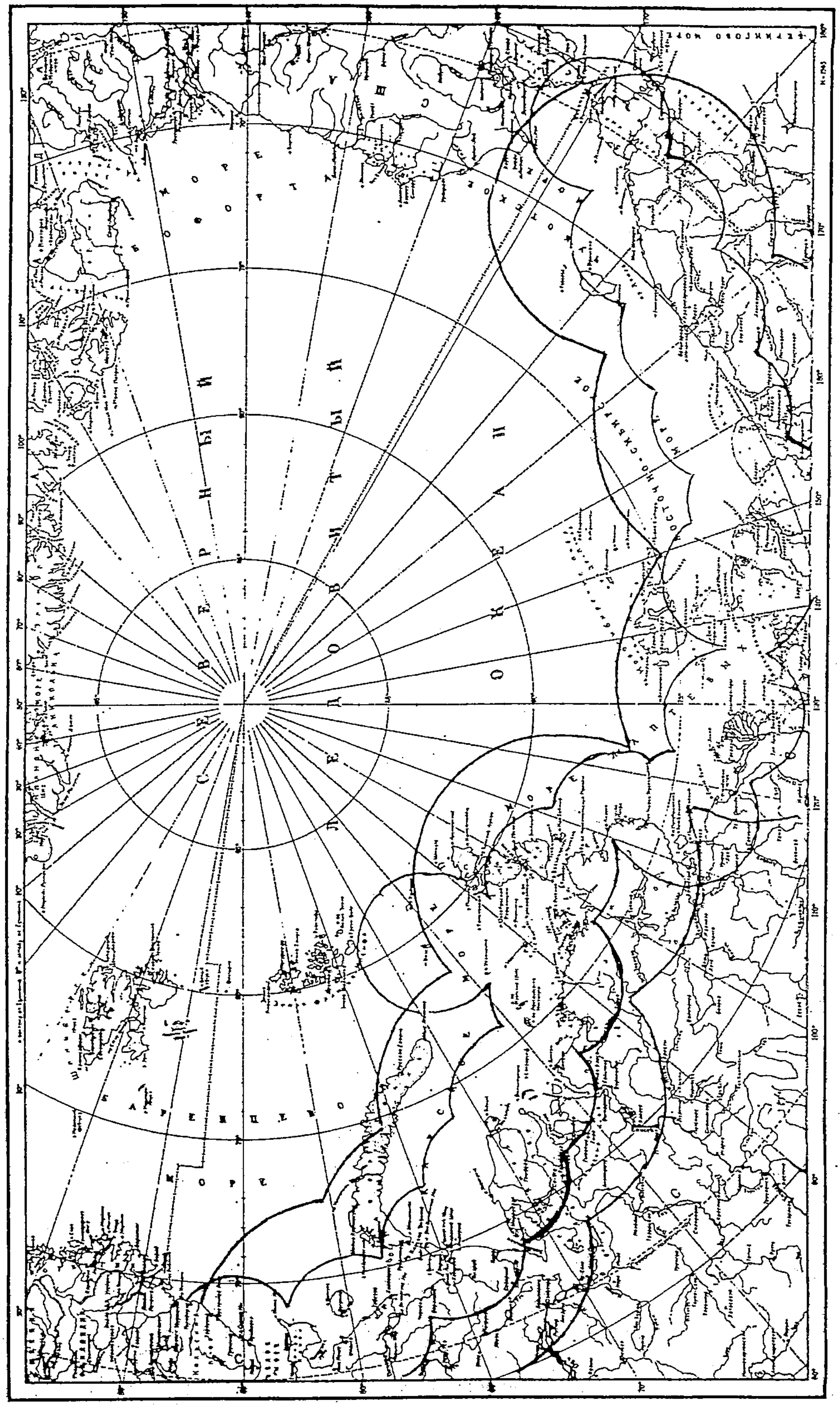

Figure 3-1 Coverage of DGPS Two Alternatives in the Arctic

The first phase DGPS will cover the eastern Arctic - from Karskiye Vorota Strait to Dikson, including the Yenisei estuary with the port of Igarka - where the needed technical facilities are planned to place in service in the shortest time.

REFERENCE DATUM

The highly accurate position fixes provided by currently available positioning equipment should be used to best advantage for ship operation.

It is known that maps are drawn and positions are defined with respect to a reference datum, and the same reference marker will have a different set of latitude and longitude coordinates in each reference datum [1]. There are several tens of reference datums, mainly of national origin, currently used through the world [2-3]. The reference datums used by satellite systems differ from the datums of local nautical charts, since satellite navigation requires a datum which is a "best fit" to the entire earth, whereas local datums have been developed to fit limited areas of interest.

The geodetic datum of Russian navigational charts for the NSR is described in Section I.1.2.2 of this Project. Here, attention will be focused on the relationship between various datums and on the coordinate transformation techniques.

The geodetic coordinate system is determined by two factors: the size and shape of spheroid (defined by the semi-major axis and by the flattening coefficient) and the spheroid's location in the body of the earth. Parameters of the most-used spheroids together with datum shifts to WGS-84, the system currently operated by the most of satnav aids, are given in Table 3-1 [3-6].

Table 3-1 Spheroid Parameters and Local Datum Shifts to WGS-84 (WGS-84 minus local datum)

Datum	*Spheroid*			*Shift to WGS-84 (m)*		
	Name	*Semi-Major Axis (m)*	*Reciprocal Flattening*	*X*	*Y*	*Z*
RUSSIA 1942	KRASOVSKY ELLIPSOID	6378245	298.3	-25	+141	+80
NAD 1927	CLARKE 1866	6378206	294.98	+8	-160	-176
NAD 1983	GRS 80	6378137	298.26	0	0	0
EUROPEAN 1950	INTERNATIONAL	6378388	297.00	+87	+98	+121
TOKYO	BESSEL	6377397	299.15	+128	-481	-664

Datum	Spheroid			Shift to WGS-84 (m)		
	Name	*Semi-Major Axis (m)*	*Reciprocal Flattening*	*X*	*Y*	*Z*
ORDNANCE SURVEY OF GREAT BRITAIN 1936	AIRY	6377563	299.32	-375	+111	-431
WGS-72	WGS-72	6378135	298.26	-	-	-
WGS-84	WGS-84	6378137	298.257	-	-	-

The absolute values of shifts to relate positions in the Russian 1942 system and in WGS-84 are shown in Figure 3-2.

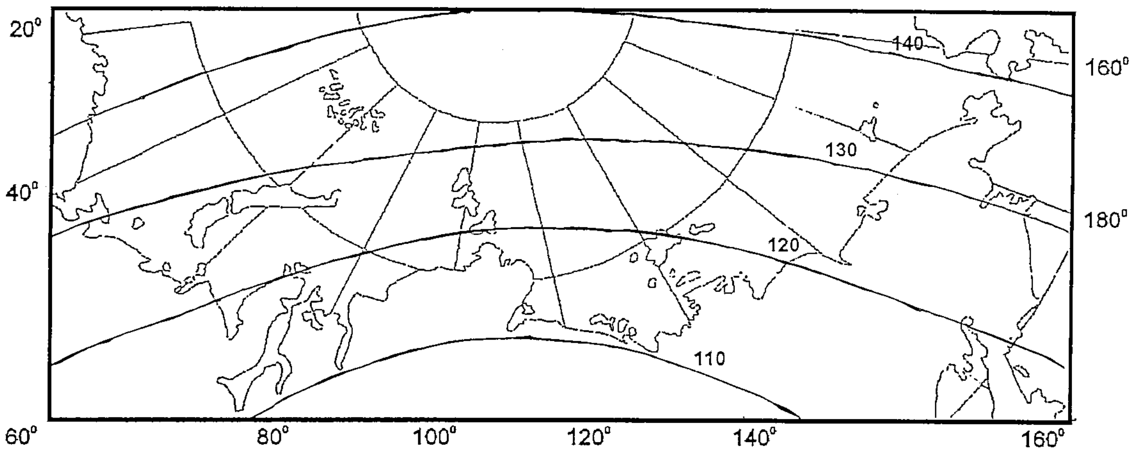

Figure 3-2 **Position Differences Between the Russian 1942 System and WGS-84**

Transforming coordinates from one reference system to another may be effected by:

- applying the shift constants specified on the chart,
  or
- datum shift calculation by formulas.

The use of the shift constants placed on charts is the most easy and reliable method of relating a position in one datum to coordinates in another. However, shift constants are indicated for the limited number of reference datums, thus restricting the applicability of this method.

The datum shift calculation is a universal method, allowing to transfer coordinates from any system to the system required.

To transform coordinates from one reference system to another, the Molodensky formulae are most often used. The abridged Molodensky formulae are:

$\Delta\varphi'' = K_1 \sin 2\varphi + K_2 \sin\varphi \cos\lambda + K_3 \sin\varphi \sin\lambda + K_4 \cos\varphi$
$\Delta\lambda'' = (K_2 \sin\lambda - K_3 \cos\lambda) / \cos\varphi$

$K_1 = (a\Delta f + f\Delta a)/30.8$
$K_2 = \Delta x/30.8$
$K_3 = \Delta y/30.8$
$K_4 = \Delta z/30.8$

30.8 = R sin 1" - length of one second

where:

φ, λ	geographic coordinates (degrees, minutes, seconds and fractions thereof) in the old geodetic system;
$\Delta\varphi$, $\Delta\lambda$	corrections to transform the coordinates from the old geodetic system to the new one (angular minutes);
Δx, Δy, Δz	shifts between ellipsoid centers of the new geodetic system and the old geodetic system;
a	semi-major axis of the old ellipsoid
f	flattening of the old ellipsoid
Δa, Δf	differences between the parameters of the old new ellipsoid and the new ellipsoid

The calculated values of K_i for the most-used local geodetic systems are shown in Table 3-2.

Table 3.2 Datum Corrections for Conversion from WGS-84 to Local Reference Systems (WGS-84 minus local system)

Datum	*Spheroid*	*Coordinates*			
		K_1	K_2	K_3	K_4
RUSSIA 1942	KRASOVSKY ELLIPSOID	+0.09	-0.81	+4.58	-2.60
NAD 1927	CLARKE 1866	+7.72	-0.26	+5.19	-5.71
NAD 1983	GRS 80	0	0	0	0
EUROPEAN 1950	INTERNATIONAL	+2.81	-2.82	-3.18	+3.93
TOKYO	BESSEL	-2.16	-4.16	+15.62	-21.56
ORDNANCE SURVEY OF GREAT BRITAIN 1936	AIRY	-2.54	+12.18	-3.60	-13.99

The characteristics of WGS-72 and of WGS-84 are closely similar, as the differences between the parameters of spheroids of these two systems are slight. The maximum values of the calculated datum corrections are as small as 0.145" (4.5 m) by latitude (on the Equator) and 0.554" (17 m) by longitude (on the Equator). Thus, the two systems may be considered identical as far as navigational applications are concerned. The same is true for WGS-84 and the Russian system of 1990 (operated by Glonass and Tsikada), since the differences between the parameters of their spheroids are even smaller, that resulting in the datum corrections not exceeding two meters.

CONCLUSION

A prerequisite for support of safe sailing along the NSR is the availability of aids to and means for determination of ship's current position to a sufficient accuracy. A high degree of navigational accuracy may be required under certain circumstances in most areas of the Russian Arctic.

The differential GPS sub-system is believed to exhibit the most promise for providing the needed accuracy of positioning on the NSR. The basic concepts of the DGPS project in the Russian Arctic as described in this Section have been approved by the national organizations concerned. It is worth noting that several foreign companies have taken an interest in technical support of the project. The US Trimbl Company has supplied its equipment for the 1994 autumn tests of the sub-system on Dikson and Yenisei. An interest in the project has been expressed by the Norwegian Konsberg and the Russian-American Ashtek Companies.

The advent of DGPS in the Russian Arctic is logically predetermined. The manner and time of the introduction of this service will depend to a large extent on the availability of adequate financing, including possible foreign investments, and on the interest from Russian and foreign transportation companies in improving the safety and efficiency of fleet operation on the NSR.

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I.1.2.4 COMMUNICATIONS
DEVELOPMENT CONCEPT OF COMMUNICATION SYSTEM IN THE RUSSIAN ARCTIC

KEY PERSONNEL

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Dr. L.Malakhov, CNIIMF
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Transl. O.Andreyeva

SUMMARY

In this Section, consideration is being given to the development concept of communication system for support of marine transportation in the Arctic basin of Russia.

Requirements to the communication system are formulated. The system structure and functional principles are proposed having regard to peculiarities of the Arctic region.

Organization of distress and safety communications to comply with the GMDSS requirements is discussed. Recommendations on composition of radio equipment are made.

KEY WORDS

REQUIREMENTS, STRUCTURE, SATCOM SERVICE, SYSTEM FUNCTIONING, PROVISION OF SAFETY, RECOMMENDED EQUIPMENT.

INTRODUCTION

The growing intensity of marine transportation in the Russian Arctic, the provision of navigational safety, the exploitation of seabed resources and continental shelf require that a highly reliable and efficient communication system be available in the area.

As it was stated in the previous Report (1.1.2.4 -93), drawbacks of the existing communication system are:
- great number of bands used;
- multistage operation;
- multi-departmentalism;
- diversity of types of equipment in use;
- use of obsolete equipment;
- low antijam capability.

As a result, delays in establishing contact when using traditional communications aids may be as long as 2 hours under normal propagation conditions, to say nothing of extremely unfavourable conditions that occur in the Arctic. Introduction of advanced communications services, such as data transmission or E-mail, on the basis of traditional aids shows no promise.

Specific features of the Arctic areas are the sparseness and remoteness of settlements, the poorly developed infrastructure, and the low density of the population. In certain areas, satcom service is the only means available for reception and transmission of information.

In accordance with the Decision of the Russian Government of June 19, 1994, "On Measures to Improve NSR Management" a federal programme for the development of communications aids in the Russian Arctic and a programme for equipping NSR radio centres with communications facilities were prepared. Following these programmes, satcom aids based on geostationary and high elliptic orbiting satellites will be widely introduced. A coast earth station to operate in the INMARSAT and MARAPHON systems will be built in the European part of Russia. Land communication system will be modified. To provide automatic data transfer between radio centres and extension to national and international communications and data networks, a complex of modern digital and radio relay stations will be implemented. The existing radio centres and radio stations in port points will be fitted with the additional satcom and traditional radiocommunications equipment and computing aids.

4.1 PURPOSE OF THE FUTURE COMMUNICATION SYSTEM

The purpose of the communication system is to make provision for improved maritime communications facilities, thereby assisting in improving distress and safety of life at sea communications, efficiency and management of ships, maritime public correspondence services.

The communication system should be capable of providing the following:

1. Maritime distress and safety communications in accordance with the SOLAS 1974/1988 Convention and GMDSS requirements (IMO Resolutions A.704(17) - A.706(17):
- reception of ship-to-shore distress alerting;
- transmission of shore-to-ship distress alerting;
- transmission and reception of search and rescue coordinating communications;
- transmission and reception of navigational and meteorological warnings and urgent information.

2. Exchange of navigational information with ships, including that within VTS systems.

3. Transmissions of hydrometeorological information and ice reconnaissance data between ships, icebreakers, ice patrol aircraft and coast radio stations.

4. Exchange of operational and commercial information between ships, coast services and subscribers with extension to the land telephone and telegraph public networks and international communications networks.

4.2 SYSTEM STRUCTURE

The communication system will consist of the following elements:

- radiotelex communications service;
- satcom service;
- VHF communications service;
- NAVTEX service;
- interport communications service.

4.2.1 RADIOTELEX SERVICE provides reception/transmission of operational information of the Marine Operations Headquarters, ice reconnaissance data, weather maps, NAVIMs, NAVIPs.

Radiotelex communications are effected through a complex of zone coast radio centres. Layout of the centres is shown in the previous Report (1.1.2.4-93).

There are three groups of communications channels employed: with ships, between ports, and with land networks' subscribers.

Communications with ships are effected via VHF, MF and HF channels. Communications between ports and with land networks' subscribers are provided via wire and radio relay communications channels as well as through HF trunk radio lines.

4.2.2 SATCOM SERVICE provides global communication of ships with shipowners, coast radio centres and subscribers of national and international land communications networks.

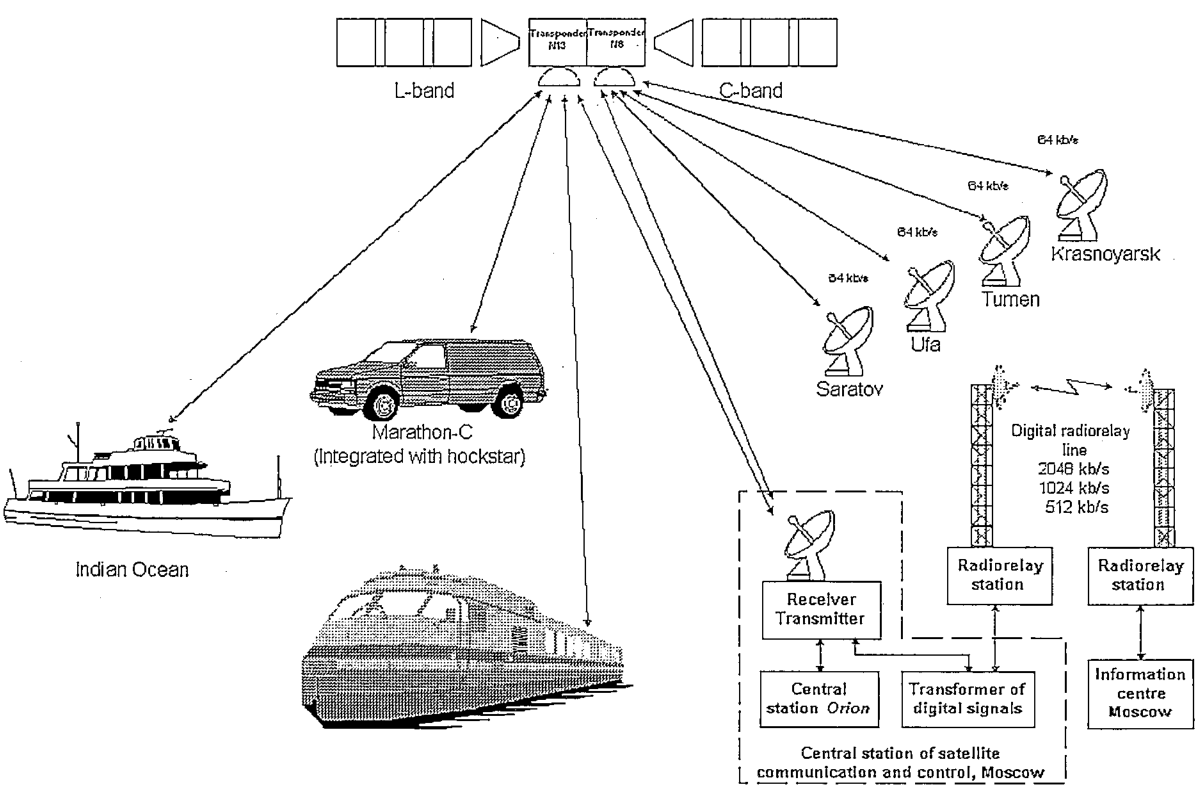
At present communications via satellite channels are provided throught the international INMARSAT system and the Russian OCEAN system. Peculiarities of operation of these systems in the Russian Arctic are described in Report 1.1.2.4 - 93.

It is expected that the Russian mobile satcom system MARAPHON will be used in the Arctic as soon as new generation satellites be launched to provide voice, fax, telegraph communications and data transmissions for mobiles or remote users. The system will provide:
- low speed (600 bit/s) data transmission with switching, retransmission and storage;
- interrogation and polling of user stations in individual, group and area modes;
- high-quality digital duplex telephony, facsimile and data transmission (2400 bit/s);
- digital data transmission at a rate of 16 Kbit/s.

The MARAPHON system's capabilities for organization of communications and service offerrings are based on the application of the operational procedures and standards adopted in the INMARSAT system.

The system will include the sub-systems capable of providing operation of Standards A, C, M, B, Aero, and a distress alerting and rescue sub-system.

The MARAPHON system configuration is shown in Fig.4.1.



Fugure 4-1 MARAPHON system configuration

The system will comprise four Arcos satellites in geostationary orbits and two Mayak satellites in high elliptical orbits. Their characteristics may be briefly described as follows:

Mayak satellites:
- orbital locations: 14 deg.E, 145 deg.E;
- orbit inclination: 63 deg.
- rotation period: 12 hours;
- coverage: as shown in Fig.4.2;
- operating frequency range: 1.5/4 GHz;
- EIRP: 41 dBW in the 1.5 GHz range,
  33 dBW in the 4 GHz range.

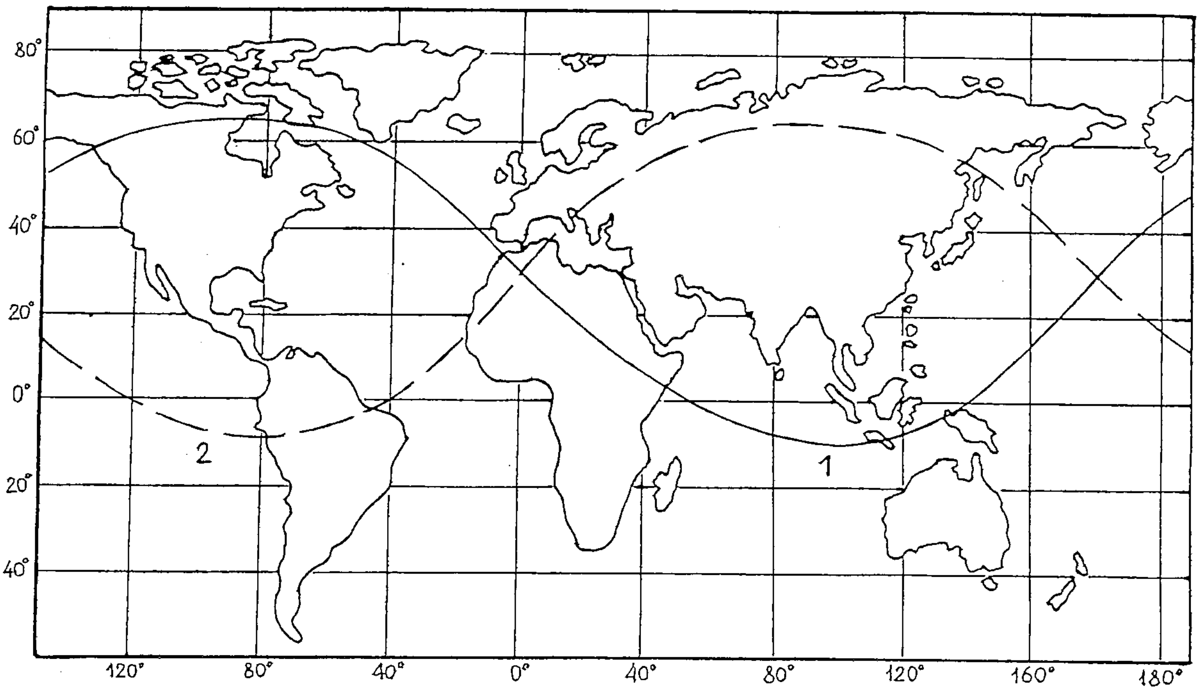


Figure 4-2 Mayak satellites coverage

Arcos satellites:
- orbital locations: 27 deg.W, 40 deg.E, 110 deg.E, 170 deg.E;
- coverage: as shown in Fig.4.3;
- operating frequency range: 1.6/6 GHz;
- EIRP: 35/43 dBW in the 1.6 GHz range,
  31.5 dBW in the 6 GHz range.

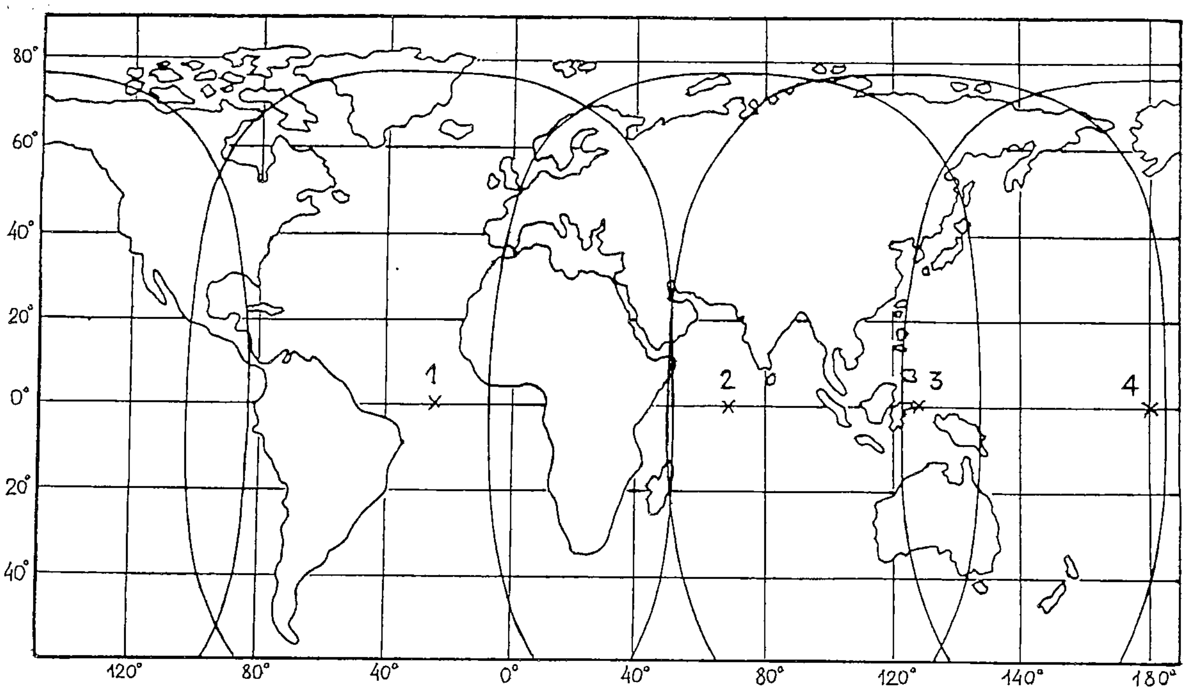


Figure 4-3 Arcos satellites coverage

The Standards A,C,M,B Aero will be used as user stations. It is expected that there will be about 2000 users employing 0.9 m antennas.

The launch of the Arkos first spacecraft is scheduled for the fourth quarter of 1995. The system will be placed into service in 1996 and is expected to be fully operative in 1997-1998.

4.2.3 VHF SERVICE provides interconvoy communications, communications with coast radio stations, and inside port production radiocommunications. Future VHF service will employ the same procedures and frequencies as these used in the present system and described in detail in the previous Report.

4.2.4 NAVTEX SERVICE

Following a common practice and in accordance with the IMO requirements, NAVTEX service radio stations are assigned the responsibility areas within 250-400 n.m. from a nearest radio station. Since MF propagation conditions in the Arctic are very complicated, it is reasonable that NAVTEX radio stations therein be assigned the responsibility areas within a range not exceeding 250 nm.

The expected locations of NAVTEX transmitting radio stations are shown in Fig.4.4.

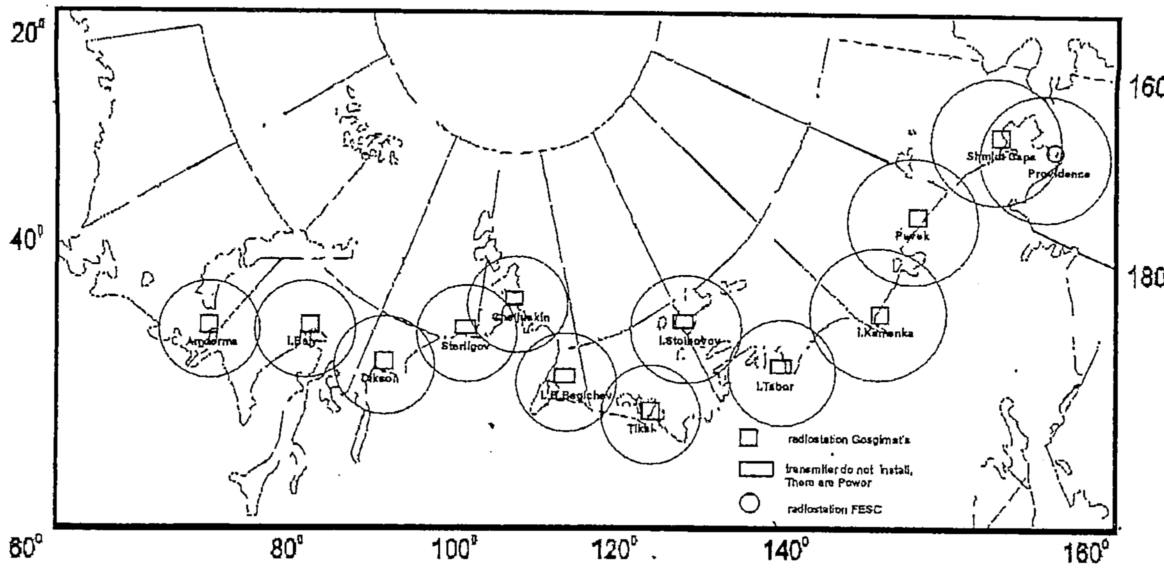


Figure 4-4 The expected locations of NAVTEX transmitting radio stations

In addition to the existing radio stations at Anderma, Dikson, Chelyuskin, Tiksi, Shmidta, Provideniya, it is planned to install stations at Belyi, Sterlingov, Begichev, Stolbovoy, Tabor, Kamenka.

Functions of the coordinator responsible for preparation and transmission of navigational warnings and meteorological messages are performed by the Marine Operations Headquarters of the Western and Eastern Sectors.

Preparation of initial data and delivery of the data to the coordinators for compiling NAVTEX formats are accomplished by the national hydrographic and hydrometeorological services.

4.2.5. INTERPORT COMMUNICATIONS SERVICE on the NSR provides transmission of all types of information between ports of the Arctic basin. To this end, radio relay lines (including tropospheric communications lines), satcom channels, cable communications lines, ADS channels between ROSGIDROMET coast radio stations will be employed.

4.3. ORGANIZATION OF RADIOCOMMUNICATIONS ON THE NSR

Traffic management on NSR seaways is provided by the West Marine Operations Headquarter at the port of Dikson and the East Marine Operation Headquarter at the port of Pevek, which serve the Western and Eastern Regions, respectively. Coordination of activities through the entire area is accomplished by the NSR Administration (Department of Maritime Transport, Moscow).

During the Arctic navigational season, the functions of operational management for provision of radiotelephone and radiotelegraph communications with ships, aircraft, various organizations are performed by the heads of ADS service of the Hydrometeoservice Management Office at Amderma, Dikson, Tiksi and Pevek. The heads of the ADS service at Dikson and Pevek are the assistants of the Chief of maritime Arctic operations on communications of the Western and Eastern areas of the Arctic, respectively. Their instructions are mandatory for all ship and shore radio stations participating in the Arctic navigation. The assistant solves all the problems relating to the organization of radiocommunications with aircraft and civil airports, with the heads of departments of radiotechnical equipment operation and communications of the Civil Aviation Department.

Service telephone radiocommunications between transport ships, icebreakers, ice patrol aircraft, helicopters and coast radio stations are accomplished in accordance with the provisions of the annually issued Instructions for Communications on the Seaways of the Northern Sea Route over the Arctic Navigational Season. When engaged in telephone rediocommunications, ships use their names or international telegraph call signs as their call signs and operate the permitted frequencies.

4.4. DISTRESS AND SAFETY COMMUNICATIONS

Distress and safety communications through the NSR are based on using the following components:
- VHF communications;
- MF communications;
- Watch on MF and HF DSC frequencies:
- INMARSAT with EGC receiver;
- NAVTEX service.

In sea area A1 (up to 25-30 miles), coast radio stations at ports maintain a continuous watch on the distress VHF frequencies 156.525 MHz (DSC channel 70) and 156.8 MHz (channel 16).

In sea area A2 , coast radio stations maintain a continuous watch on the distress MF frequencies 2 182 kHz and 2 187.5 kHz.

Having in mind the peculiarities of communications in the Arctic basin, arrangements should be made at coast radio stations for maintaining a continuous watch on the DCS frequencies in the MF band.

In sea area A3, ship-to-shore distress alerts are transmitted via satellite channels of the INMARSAT A/C system (with EGC receiver).

In sea area A.4, outside the INMARSAT coverage, the HF DSC equipment is expected to be used as a main shipborne aid to distress communications.

However, since A4 area covers the Arctic regions where reliability of HF communications is extremely low, long-range communications on HF will be poorly efficient for distress and safety purposes. Incorporation of high elliptic orbit satellites of the MARAPHON system into the distress and safety communications service in the area will provide retransmission of distress and safety messages from ship stations and emergency radio beacons, so that reliability and operativeness of distress message transfer will be the same as in areas A1, A2 and A3.

Distress alerts are transmitted to other ships and/or RCC. Communications with the RCC are established via a coast radio station or a CES. The RCC establishes communications with ships in the vicinity of the distress scene and, if necessary, sends planes and helicopters to the area.

Depending upon its location and equipment available, a ship may use the following means to transmit ship-to-shore distress alerts:
- satellite communications of the maritime mobile-satellite service,
- VHF DSC channel 70,
- MF DSC frequency 2 187.5 kHz,
- HF DSC frequencies 4 207.5; 6 312.0; 8 484.5; 12 577.0; 16 804.5 kHz,
- COSPAS-SARSAT and INMARSAT emergency beacons.

Ship-to-ship distress traffic at the distress scene is effected on the MF frequency 2 182 kHz and on VHF channel 16. The frequencies 2 182 kHz, 3 023 kHz, 4 125 kHz, 5 680 kHz or VHF channel 16 are employed for ship-aircraft communications in the area of distress.

Exchange between ships and shore object is provided:
- via INMARSAT (or MARAPHON);
- using radiotelephony on the frequencies 2 182 kHz, 3 023 kHz, 4 125 kHz, 5 680 kHz, 6 215 kHz, 8 291 kHz, 12 290 kHz, 16 420 kHz, or 156.8 MHz (near coast);
- using direct printing on the frequencies 2 174.5 kHz, 4 177.5 kHz, 6 268 kHz, 8 376.5 kHz, 12 520 kHz. 16 695 kHz.

4.5 RECOMMENDED SET OF SHIPBORNE RADIOCOMMUNICATIONS EQUIPMENT

All ships sailing the NSR should carry conventional radiocommunications equipment. In addition to this equipment, the ships should be fitted with:
- a ship earth satcom station;
- equipment for sound recording and reception of facsimile, including means for reception of weather maps;
- a VHF radio station operating 122.5 MHz for communication with air planes, helicopters, and ships in convoy.

All shipborne radiocommunications equipment should conform to appropriate performance standards prescribed in the international Conventions and in the Regulations of the Russian

Register of Shipping and should be suitable for conditions of Arctic sailing. Operational and maintenance guidances should be provided to enable the equipment to be properly operated and maintained. There should be available adequate spare parts and tools to enable the equipment to be maintained.

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I.1.2.5 INFRASTRUCTURE

During the Report preparation the data on infrastructure for 1994 ran significantly out of date. New data are presented in Report for 1995.

I.1.2.6 CREW TRAINING

TECHNIQUES FOR SIMULATION TRAINING OF MASTERS, CHIEF MATES, AND PILOTS IN MANEUVERING AND SHIP HANDLING UNDER CONDITIONS OF ICE NAVIGATION

KEY PERSONNEL

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Dr.A.Baskin, CNIIMF
Dipl.eng.S.Samonenko, CNIIMF

SUMMARY

The basic form of the simulation training is practical work on the navigation bridge; the trainees are arranged on the bridge in accordance with their functional duties imposed on the watch on duty, i.e. on the master, chief mate, pilot, and watchman; the course of training is completed with individual check-up exercises.

KEY WORDS

GREW TRAINING, SIMULATOR, EXERCISES, SCHEDULE FOR TRAINING.

Techniques for simulation training cover the following major phases: theoretical studies (lectures) in the lecture-hall, practical exercises on the simulator, and home work. The basic form of such training is practical work on the navigating bridge. Each exercise offers the trainees opportunity to work out a specific topic or complex of tasks for a number of topics. Before beginning of the exercise a brief theoretical account of the given topic is given, as well as examples of typical accidents at sea and of distinctive errors made in the course of maneuvering. At the end of the studies the trainees are provided with references on each topic.

Before the beginning of the exercises the trainees are given recommendations for precise distribution of duties among the watchmen on the bridge, as well as for organization of well-coordinated activities while working. The trainees are asked to work professionally as if they kept watch on the bridge of the real ship. They are arranged on the bridge in accordance with their functional duties imposed on the watch on duty, i.e. on the master, chief mate, pilot, and assistant watchman.

During the subsequent exercises the trainees change their duties.

In the course of each exercise an instructor exerts a continuos control over the actions initiated by the trainees. He can make changes in hydrometeorological and hydrological conditions by reducing visibility, strengthening or changing wind direction, verifying movement of targets and visibility range, and limiting new targets. Imitation of failure of instruments, devices and ship handling means can also be made.

During the exercise the instructor renders direct assistance to the trainees while they are adapting for performance of their duties on the bridge. He also establishes control over:

- organization of the look-out;
- proper use of technical aids;
- making audiosignals in due time;
- safe use of VHF means of communication;
- the trainees' decision-making;
- precision and effectiveness of commands;
- general organization of the watch.

Each exercise is followed by comments within the group on the actions undertaken by each participant of the discussion. The trainees are offered to exchange their views about the results achieved and give their own versions of the situation which, if necessary, can be reproduced on the simulator. The instructor sums up the results of the discussion, noting drawbacks and positive sides of the trainees activities, pointing out alternatives and optimal variants of the problems solution. He also has a general discussion with the whole group about reasons of the mistakes made encouraging the trainees to offer their own ideas and justify their choices.

Throughout the training course the instructor makes every effort to stimulate the trainees' activities and willingness to share their knowledge of good marine practice.

Every time before the end of each exercise the trainees are given educational aids and assignments to study the material independently or to prepare themselves for the following topic. If necessary, a supplementary assignment is given.

It is recommended that preparations for, and studies of, the topic be made with the help of such teaching aids as plane-tables, placards, schemes, film-strips with diagrams and drawings, educational films, magnetic class boards, small ship models on the magnetic basis, film-strip projector, etc.

The course is completed with individual check-up exercises in the course of which the instructor determines the level of skills and habits of the mariner in maneuvering and ship handling.

While doing the check-up exercises every person on duty undertakes in sequence his own portion of the task as the master. If he fails to do his duties properly he is given another opportunity for successful fulfilment of the task. As an alternative, supplementary exercises can be given.

"Schedule for Training at MSRC of Masters, Chief Mates and Pilots in Maneuvering and Ship Handling under Ice Navigation Conditions" is presented in the Appendix to the above text. The main aspects of the Schedule were considered and approved by International Marine Simulator Forum.

Appendix

SCHEDULE
FOR TRAINING AT MSRC MASTERS, CHIEF MATES AND PILOTS
IN MANEUVERING AND SHIP HANDLING UNDER ICE NAVIGATION CONDITIONS

(60-hours course)

Subject	Total number of hours	Lectures	Group exercises	Home work
1	2	3	4	5
1.Introduction. Objectives and tasks of the course. Features of large capacity ship handling under ice navigation conditions. Acquaintanceship with the bridge equipment. Mastering the surveillance, control and ship handling facilities.	3	1	2	-
2.Maneuvering characteristics of the ship. Acquaintanceship with the ship models maneuvering characteristics. Application of the ship maneuvering characteristics in performing tasks of navigation in the Northern Sea Route.	7	1	4	2
3. The surveillance and control facilities. The principle of relative and true motion. Methods of application of radar aids and ARPA to secure safety of navigation in the Northern Sea Route. Methods of radar navigation.	9	3	4	2
4. Maneuvering in narrow passage water areas. Forces and moments used by navigator during ship handling. Ship handling during manoeuvring in narrow passage	9	1	6	2

water areas.

Subject	Total number of hours	Lectures	Group exercises	Home work
1	2	3	4	5
5. Influence of external factors on manoeuvrability (Wind, current, wave resistance, narrows, channel and ice effects, hydrodynamical interaction of the ships). Taking account of the external factors during ship handling.	3	1	2	-
6. Handling of the ship in rivers, waterways and narrow channels. Sailing on line lights, approaching or leaving port procedures. Handling of large ships coming to, or weighing anchor.	14	1	12	1
7. Passage scheduling. Organization of watch in open sea, shallow water, on ice, under conditions of restricted visibility.	10	1	3	6
8. Handling of the ship on taking the pilot and sending the pilot. Relationship between the master and pilot under conditions of ice navigation. Specific accidents at sea during pilotage under conditions of ice navigation.	5	1	4	-
9. Executing manoeuvre at "Man overboard" alarm. Making arrangements for search and rescue under conditions of ice navigation.	6	1	3	2
10. Sailing in train under ice-breaker assisted	8	1	6	1

pilotage.

11.Summary. Evaluating of the training results.	2	2	-	-

Subject	Total number of hours	Lectures	Group exercises	Home work
1	2	3	4	5
Total amount of hours	76	14	46	16
Total amount of studies hours			60	

Note: The number of hours on each subject listed in the table is approximate and may vary depending on the students' qualification.

I.1.2.7 VESSEL PERFORMANCE

Development of Identification Tables of the Comparison for Ice Classes of Ships to Practice Use for the Assessment of Feasibility of Sailing Along the NSR

KEY PERSONNEL

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Dipl.eng. Yuri V.Glebko, scientist

SUMMARY

The main purpose of the second stage of the work on theme I.1.2.7 is to prepare, on the basis of comparative calculations, proposals for the identification tables of Arctic classes of the running Rules of the Russian Marine Register of Shipping (MRS) and of leading foreign classification societies.

The proposals for the identification tables have been developed by the comparison of the Rules requirements to elements of the ice belt with due regard to the analysis of the results obtained at the first stage of the work.

Principal results are shown in tables.

KEY WORDS

CLASSIFICATION SOCIETIES, FRAME DIMENSION, SHELL PLATING, FRAMING, THICKNESS, ICE BELT, RULE REQUIREMENTS, SPACE, SPAN, HULL, ARCTIC FLEET, ICE LOADING.

INTRODUCTION

In the performance of the first stage of works on theme I.1.2.7 "Comparison of ice classes of ships built according to requirements of different classification societies" the comparison of the classification requirements was made under the assumption that design values of ice loads upon the shell plating and framing are equal, on the basis of the formal use of relations by which the national Rules define the sizes of ice belt members.

The analysis of the results obtained at this stage has brought to light the necessity for a more precise approach to comparative calculations taking into account the effect of plasticity, differences in the values of loads on the shell plating and framing laid down in a number of Rules, as well as classification restrictions concerning shaft power.

An attempt was made in the present report to take fuller account of the characteristic properties of the national Rules regulation of ice strengthenings while drawing up identification tables of Arctic ice classes.

METHODOLOGICAL PROVISIONS

Correct solution of the problem of the development of identification tables for the establishment of compliance between ice classes of various classification societies involves for the ships to be compared fairly close values of the following characteristics:

- purpose of ship,
- characteristic of ice conditions,
- parameters of ship's hull and machinery (displacement, hull form, shaft power),
- hull strength characteristics in the zone of ice loading impact.

Individual salient features of the national Rules make difficult to directly use the results of calculations for the comparison of classes.

When comparing the Rules requirements of leading classification societies there are the following main obstacles to be taken into consideration:

1. Different density of the Rules classification net as well as relevant consideration of the purpose of ships of classes to be compared.

2. Differences in the composition of classification criteria:
    - thickness of ice broken through in continuous motion,
    - thickness of ice in which a ship is able to operate,
    - power,
    - speed,
    - mode of operation in ice (independently or following a higher ice class ship and also season and area of navigation in the Arctic).

3. Different structure of the design relationships. Formulas for the determination of design loads and contact zone sizes contain various combinations of:
    - shaft power,
    - displacement,
    - ice thickness,
    - frame inclination angles.

    In the Det Norske Veritas (DNV) and Germanischer Lloyd (GL) Rules for arctic classes the formulas do not take into account shaft power, ship's displacement and frame inclination angles.

4. Non-uniformity of normalized parameters. The American Bureau of Shipping (ABS), GL and CASPPR'72 Rules do not regulate the shear strength of the wall of ordinary frames, while in the draft of new CASPPR the elastic section modulus of frames is regulated.

5. There are differences in calculation processes sometimes reflected in formulas. In the ABS Rules formula the installation of a side stringer automatically leads to the two times reduction of an ordinary frame. For the correctness of the results obtained by these Rules the design span should be doubled.

Adopted methodic provisions:

1. Purpose of ship was taken into account:
   - for transport ships it is admissible to disregard differences in requirements to the hull afterbody[1],
   - sign of identity for icebreakers is the conformity of requirements in all ice belt areas.

2. The real shaft power ranges within which the comparison of classes is to be made were selected on the basis of the Marine Register of Shipping (MRS) Rules. In the present work, for the running Rules, use is made of a range of icebreaker powers regulated by the MRS Rules.

3. Similarity of ship's form is provided, in particular, of the frame inclination angles according to the recommendations of MRS Rules is provided.

4. Number of compared parameters was restricted by ice belt members, as this area is the main region of loading impact.

5. The section areas of the walls of ordinary frames **f** were excluded from consideration, bearing in mind that in a number of Rules of leading classification societies (ABS, GL, CASPPR'72) there is no regulation of this parameter.

Principles and advisability of regulation of this parameter **f** is a subject of additional discussion. It is possible to replace it by requirements to the stability of framing walls at local ice loads. The analysis of ice damages of Russian ships in the Arctic speaks in favour of such regulation.

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1 fore- and midbody hull areas of arctic transport ships are most subject to ice damages

DRAWING UP OF IDENTIFICATION TABLES

The following Rules were selected for the comparison:

- Marine Register of Shipping,
- Lloyd Register (LR),
- Det Norske Veritas,
- Germanischer Lloyd,
- American Bureau of Shipping,
- CASPPR.

Type of dry cargo ship was selected similar to ships of *Norilsk* type (displacement **D** - 25000 t, ULA class, length - 159.6 m, breadth - 24.5 m, draft - 9 m. Since 1982 the ship of this type has carried out the bulk of cargo transportation along the NSR, its operation has been well investigated.

In the comparative calculation for icebreaking classes LL3, LL2, LL1 and foreign classes of the similar purpose, the shaft power was taken equal to values specified by the MRS; frame inclination angles were corrected accordingly (up to 50⩩).

While making the comparison - a number of individual salient features of the national Rules were brought to light which made difficult to directly use the results of calculations for the comparison of classes. This features were taken into account in the analysis. Results of the analysis are presented in dimensionless form in comparative Tables 7-1, 7-2, 7-3 and 7-4.

In a separate Table 7-7 we have indicated the highest classes of a number of Rules as having so far no prototypes.

In the assessment of results the comparison is assumed to be made within sub-groups divided by power as it was done in Tables 7-5, 7- 6 and 7-7.

Such a division by power ranges or groups has created more favourable conditions for the comparison of results. In each group there is a satisfactory agreement just between those classes in the requirements to which the experience of operation in ice of real representative ships was well reflected.

In these tables the requirements for main parameters to the Russian Register ULA class structures were taken as basis of comparison - 1 ; spacing - 400 mm; frame span - 2 m (for ABS - 4 m); yield limit - 320 MPa; dimensionless parameters: **P** - design ice loading; **W** - section modulus of frame; **f** - shear area of frame; **t** - thickness of shell plating.

While using tables 7-8, 7-9 and 7-10 for the identification of ice classes it was assumed that the stability of the framing and diaphragm walls may be ensured by structural measures.

Table 7-1

Comparison of thickness and frame scantlings as required by MRS and ABS Rules

Ice class	D = 25000 t											
	Bow area				Middle area				Stern area			
	P	W	f	t	P	W	f	t	P	W	f	t
MRS (power and angles for icebreaker classes)									Frame span - 2 m			
UL	0.51	0.45	0.44	0.71	0.51	0.65	0.54	0.71	0.36	0.46	0.39	0.6
ULA	1	1	1	1	1	1	1	1	1	1	1	1
LL4	1.33	1.27	1.66	1.15	1.6	2.45	2.05	1.26	1.43	2.1	2.33	1.19
LL3	1.93	2.22	1.44	1.39	2.31	4.58	2.49	1.52	2.06	3.69	2.53	1.44
LL2	2.56	3.23	1.72	1.6	3.07	7.13	4.31	1.75	2.74	5.36	3.03	1.66
LL1	2.71	3.42	1.83	1.65	3.25	7.01	5.43	1.8	2.9	5.68	3.21	1.7
ABS Power 12000 kW									Frame span - 4 m			
C0	0.19	0.4	-	0.55	0.08	0.3	-	0.42	0.03	0.1	-	0.26
B0	0.23	0.5	-	0.6	0.16	0.6	-	0.54	0.07	0.2	-	0.36
A0	0.31	0.7	-	0.68	0.28	1.1	-	0.67	0.15	0.5	-	0.49
A1	0.42	0.9	-	0.81	0.42	1.6	-	0.83	0.3	1	-	0.68
A2	0.71	1.6	-	1.05	0.78	2.8	-	1.12	0.61	2.1	-	0.95
A3	1.05	2.4	-	1.27	1.21	4.4	-	1.38	0.97	3.4	-	1.18
A4	1.43	3.3	-	1.45	1.71	6.2	-	1.59	1.43	5.1	-	1.4
A5	1.72	4	-	1.57	2.06	7.5	-	1.72	1.84	6.6	-	1.57
Power 22000 kW												
C0	0.19	0.4	-	0.55	0.08	0.3	-	0.42	0.03	0.1	-	0.26
B0	0.23	0.5	-	0.6	0.16	0.6	-	0.54	0.07	0.2	-	0.36
A0	0.31	0.7	-	0.68	0.28	1.1	-	0.67	0.15	0.5	-	0.49
A1	0.47	1.1	-	0.85	0.47	1.8	-	0.87	0.34	1.2	-	0.71
A2	0.8	1.9	-	1.1	0.88	3.2	-	1.17	0.69	2.4	-	1
A3	1.18	2.8	-	1.34	1.37	5	-	1.45	1.1	4	-	1.25
A4	1.61	3.8	-	1.52	1.93	7.1	-	1.68	1.61	5.9	-	1.48
A5	1.94	4.6	-	1.65	2.32	8.6	-	1.82	2.08	7.6	-	1.65
Power 47500 kW												
C0	0.19	0.4	-	0.55	0.08	0.3	-	0.42	0.03	0.1	-	0.26
B0	0.23	0.5	-	0.6	0.16	0.6	-	0.54	0.07	0.2	-	0.36
A0	0.31	0.7	-	0.68	0.28	1.1	-	0.67	0.15	0.5	-	0.49
A1	0.55	1.3	-	0.91	0.55	2.2	-	0.93	0.39	1.4	-	0.76
A2	0.94	2.2	-	1.18	1.03	3.8	-	1.25	0.8	2.9	-	1.06
A3	1.38	3.3	-	1.43	1.6	6	-	1.55	1.28	4.8	-	1.33
A4	1.88	4.6	-	1.63	2.26	8.5	-	1.79	1.88	7.1	-	1.58
A5	2.26	5.6	-	1.77	2.71	10.3	-	1.94	2.42	9.2	-	1.77

Table 7-2

Comparison of thickness and frame scantlings as required by MRS and DNV Rules

Ice class	D = 25000 t											
	Bow area				Middle area				Stern area			
	P	W	f	t	P	W	f	t	P	W	f	t
MRS (power and angles for icebreaker classes)									Frame span - 2 m			
UL	0.51	0.4	0.44	0.71	0.51	0.7	0.54	0.71	0.36	0.5	0.39	0.6
ULA	1	1	1	1	1	1	1	1	1	1	1	1
LL4	1.33	1.3	1.66	1.15	1.6	2.4	2.05	1.26	1.43	2.1	2.33	1.19
LL3	1.93	2.2	1.44	1.39	2.31	4.6	2.49	1.52	2.06	3.7	2.53	1.44
LL2	2.56	3.2	1.73	1.6	3.07	7.1	4.31	1.75	2.74	5.4	3.03	1.66
LL1	2.71	3.4	1.83	1.65	3.25	7	5.43	1.8	2.9	5.7	3.21	1.7
DET NORSKE VERITAS Power 12000 kW									Frame span - 2 m			
1C	0.57	-	-	0.71	0.3	-	-	0.56	0.11	-	-	0.36
(*)	0.76	0.6	-	-	0.39	0.5	-	-	0.14	0.2	-	-
1B	0.57	-	-	0.74	0.41	-	-	0.67	0.19	-	-	0.47
(*)	0.76	0.7	-	-	0.55	0.8	-	-	0.25	0.4	-	-
1A' F	0.57	-	-	0.81	0.59	-	-	0.85	0.32	-	-	0.63
(*)	0.76	0.9	-	-	0.79	1.5	-	-	0.42	0.8	-	-
Power 22000 kW												
1C	0.61	-	-	0.73	0.31	-	-	0.57	0.11	-	-	0.37
(*)	0.81	0.7	-	-	0.41	0.5	-	-	0.15	0.2	-	-
1B	0.61	-	-	0.76	0.43	-	-	0.68	0.2	-	-	0.48
(*)	0.81	0.7	-	-	0.57	0.8	-	-	0.26	0.4	-	-
1A' F	0.61	-	-	0.83	0.61	-	-	0.86	0.33		-	0.64
(*)	0.81	1	-	-	0.82	1.6	-	-	0.44	0.8	-	-
Power 47500 kW												
1C	0.67	-	-	0.76	0.33	-	-	0.58	0.12	-	-	0.37
(*)	0.89	0.7	-	-	0.44	0.5	-	-	0.16	0.2	-	-
1B	0.67	-	-	0.79	0.46	-	-	0.7	0.21	-	-	0.49
(*)	0.89	0.8	-	-	0.61	0.9	-	-	0.28	0.4	-	-
1A' F	0.67	-	-	0.86	0.66	-	-	0.89	0.35		-	0.66
(*)	0.89	1.1	-	-	0.87	1.7	-	-	0.47	0.9	-	-
Power 12000 kW, 22000 kW, 47500 kW												
ICE 05	0.92	1.37	0.52	1.05	1.11	2.54	1.02	1.18	0.79	1.82	0.73	0.99
ICE 10	1.23	2.39	0.95	1.24	1.48	4.44	1.86	1.38	1.05	3.17	1.33	1.17
ICE 15	1.54	2.99	1.19	1.38	1.85	5.55	2.33	1.54	1.32	3.96	1.66	1.3
Polar10	1.54	2.99	1.19	1.38	1.85	5.55	2.33	1.54	1.32	3.96	1.66	1.3
Polar20	1.87	3.63	1.44	1.51	2.24	6.74	2.83	1.68	1.6	4.81	2.02	1.42
Polar30	2.2	4.27	1.69	1.64	2.64	7.93	3.33	1.82	1.88	5.66	2.38	1.53

Note to tables 7-2, 7-3 and 7-4:

(*) - design loads on the framing and corresponding values of the frame section modulus,

(**) - values of plastic section modulus of frames for each of Arc and CAC classes are indicated in the upper lines, while corresponding elastic values are shown in the lower lines.

Table 7-3

Comparison of thickness and frame scantlings as required by MRS and GL Rules

Ice class	D = 25000 t											
	Bow area				Middle area				Stern area			
	P	W	f	t	P	W	f	t	P	W	f	t
MRS (power and angles for icebreaker classes)									Frame span - 2 m			
UL	0.51	0.4	0.44	0.71	0.51	0.7	0.54	0.71	0.36	0.5	0.39	0.6
ULA	1	1	1	1	1	1	1	1	1	1	1	1
LL4	1.33	1.3	1.66	1.15	1.6	2.4	2.05	1.26	1.43	2.1	2.33	1.19
LL3	1.93	2.2	1.44	1.39	2.31	4.6	2.49	1.52	2.06	3.7	2.53	1.44
LL2	2.56	3.2	1.73	1.6	3.07	7.1	4.31	1.75	2.74	5.4	3.03	1.66
LL1	2.71	3.4	1.83	1.65	3.25	7	5.43	1.8	2.9	5.7	3.21	1.7
GERMANISCHER LLOYD Power 12000 kW									Frame span - 2 m			
E3	0.57	-	-	0.77	0.5	-	-	0.76	0.27	-	-	0.57
(*)	0.76	0.8	-	-	0.67	1.1	-	-	0.37	0.6	-	-
E4	0.57	-	-	0.8	0.59	-	-	0.85	0.32	-	-	0.63
(*)	0.76	0.9	-	-	0.79	1.5	-	-	0.42	0.8	-	-
Power 22000 kW												
E3	0.61	-	-	0.79	0.52	-	-	0.77	0.28	-	-	0.58
(*)	0.81	0.9	-	-	0.7	1.1	-	-	0.37	0.6	-	-
E4	0.61	-	-	0.83	0.61	-	-	0.86	0.33		-	0.64
(*)	0.81	1	-	-	0.82	1.5	-	-	0.42	0.8	-	-
Power 12000 kW, 22000 kW, 47500 kW												
Arc1	0.83	1.9	-	1.05	1.1	3.8	-	1.2	0.94	3.3	-	1.11
(**)	-	1.3	-	-	-	2.7	-	-	-	2.3	-	-
Arc2	1.23	4.3	-	1.27	1.67	9.1	-	1.48	1.38	7.5	-	1.35
(**)	-	3.1	-	-	-	6.5	-	-	-	5.4	-	-
Arc3	1.86	7.4	-	1.56	2.41	14.9	-	1.78	2.04	12.6	-	1.64
(**)	-	5.3	-	-	-	10.7	-	-	-	9	-	-
Arc4	2.3	9.2	-	1.74	2.85	17.6	-	1.94	2.66	16.5	-	1.87
(**)	-	6.6	-	-	-	12.6	-	-	-	11.8	-	-
LLOYD REGISTER Power 12000 , 22000 kW									Frame span - 2 m			
1A	0.99	0.8	-	0.76	0.95	1.2	-	0.77	0.49	0.6	-	0.57
1AS	1.03	0.9	-	0.77	1.16	1.5	-	0.84	0.66	0.8	-	0.65
AC1	1.29	2.1	-	1.15	1.65	4.3	-	1.13	1.49	3.4	-	1.05
AC1.5	2.03	3.4	-	1.43	2.61	6.8	-	1.41	2.28	5.4	-	1.29
AC2	2.76	3.7	-	1.67	3.53	7.5	-	1.64	3.23	6	-	1.53
AC3	3.79	4.1	-	1.98	4.97	8.1	-	1.98	4.43	6.5	-	1.83
Power 47500 kW												
1A	0.99	0.8	-	0.76	0.95	1.2	-	0.77	0.49	0.6	-	0.57
1AS	1.03	0.9	-	0.77	1.16	1.5	-	0.84	0.66	0.8	-	0.65
AC1	1.29	2.1	-	1.13	1.65	4.1	-	1.1	1.49	3.3	-	1.02
AC1.5	2.03	3.3	-	1.4	2.61	6.5	-	1.37	2.28	5.2	-	1.25
AC2	2.76	3.7	-	1.63	3.53	7.2	-	1.59	3.23	5.7	-	1.48
AC3	3.79	4	-	1.94	4.97	7.8	-	1.92	4.43	6.3	-	1.77

Table 7-4

Comparison of thickness and frame scantlings as required by MRS, CASPPR and CASPPR'72 Rules

Ice class	D = 25000 t											
	Bow area				Middle area				Stern area			
	P	W	f	t	P	W	f	t	P	W	f	t
MRS (power and angles for icebreaker classes)									Frame span - 2 m			
UL	0.51	0.4	0.44	0.71	0.51	0.7	0.54	0.71	0.36	0.5	0.39	0.6
ULA	1	1	1	1	1	1	1	1	1	1	1	1
LL4	1.33	1.3	1.66	1.15	1.6	2.4	2.05	1.26	1.43	2.1	2.33	1.19
LL3	1.93	2.2	1.44	1.39	2.31	4.6	2.49	1.52	2.06	3.7	2.53	1.44
LL2	2.56	3.2	1.73	1.6	3.07	7.1	4.31	1.75	2.74	5.4	3.03	1.66
LL1	2.71	3.4	1.83	1.65	3.25	7	5.43	1.8	2.9	5.7	3.21	1.7
CASPPR '72 Power 12000 kW, 22000 kW, 47500 kW									Frame span - 2 m			
C	0.58	0.63	-	0.71	0.3	0.5	-	0.56	0.11	0.18	-	0.36
B	0.58	0.71	-	0.74	0.42	0.78	-	0.67	0.19	0.36	-	0.47
A	0.58	0.83	-	0.78	0.51	1.12	-	0.76	0.28	0.61	-	0.57
1	0.39	0.88	-	0.71	0.31	1.09	-	0.64	0.22	0.78	-	0.54
1A	0.63	1.41	-	0.9	0.82	2.84	-	1.03	0.73	2.53	-	0.97
2	0.94	2.12	-	1.1	1.26	4.36	-	1.27	1.12	3.9	-	1.2
3	1.26	2.82	-	1.27	1.67	5.78	-	1.47	1.48	5.14	-	1.38
4	1.57	3.53	-	1.42	2.08	7.2	-	1.64	1.84	6.39	-	1.54
6	1.89	4.23	-	1.56	2.36	8.18	-	1.74	2.11	7.32	-	1.65
7	2.2	4.94	-	1.69	2.68	9.27	-	1.86	2.36	8.18	-	1.74
8	2.37	5.3	-	1.75	2.99	10.4	-	1.96	2.7	9.35	-	1.86
CASPPR Power 12000 kW									Frame span - 2 m			
CAC4	1.48	2.5	1.01	0.9	1.97	3.9	1.66	1.05	1.41	2.8	1.18	0.88
(*)	-	1.7	-	-	-	2.7	-	-	-	1.9	-	-
CAC3	2.22	3.8	1.51	1.11	2.52	5.8	2.48	1.18	1.8	4.2	1.78	1
(*)	-	0.9	-	-	-	4	-	-	-	2.9	-	-
CAC2	2.96	5	2.02	1.28	2.96	7.8	3.31	1.28	2.11	5.6	2.37	1.08
(*)	-	0.9	-	-	-	5.4	-	-	-	3.8	-	-
CAC1	3.7	6.3	2.52	1.43	3.7	9.7	4.14	1.43	2.64	6.9	2.96	1.21
(*)	-	0.9	-	-	-	6.7	-	-	-	4.8	-	-
Power 22000 kW												
CAC4	1.5	2.6	1.06	0.91	1.97	4.1	1.73	1.05	1.41	2.9	1.24	0.88
(*)	-	1.8	-	-	-	2.8	-	-	-	2	-	-
CAC3	2.25	3.9	1.58	1.12	2.52	6.1	2.6	1.18	1.8	4.4	1.86	1
(*)	-	2.7	-	-	-	4.2	-	-	-	3	-	-
CAC2	3.01	5.2	2.11	1.29	3.01	8.1	3.46	1.29	2.15	5.8	2.47	1.09
(*)	-	3.6	-	-	-	5.6	-	-	-	4	-	-
CAC1	3.76	6.6	2.64	1.44	3.76	10.2	4.33	1.44	2.68	7.3	3.09	1.22
(*)	-	4.5	-	-	-	7	-	-	-	5	-	-
Power 47500 kW												
CAC4	1.54	2.8	1.12	0.92	1.97	4.3	1.84	1.05	1.41	3.1	1.31	0.86
(*)	-	1.9	-	-	-	3	-	-	-	2.1	-	-
CAC3	2.31	4.2	1.68	1.13	2.52	6.5	2.75	1.18	1.8	4.6	1.97	1
(*)	-	2.9	-	-	-	4.5	-	-	-	3.2	-	-
CAC2	3.08	5.5	2.24	1.31	3.08	8.6	3.67	1.31	2.2	6.1	2.62	1.1
(*)	-	3.8	-	-	-	5.9	-	-	-	4.2	-	-
CAC1	3.85	6.9	2.8	1.46	3.65	10.8	4.59	1.46	2.75	7.7	3.28	1.23
(*)	-	4.8	-	-	-	7.4	-	-	-	5.3	-	-

Table 7-5

Comparison of ice belt thickness in dimensionless form

Society	Ice class	Hull area			Shaft power, kW	Ice thickness (ramming), m
		Bow	Middle	Stern		
MRS	ULA	1	1	1	12000	≤ 1
CASPPR	CAC4	0.9	1.05	0.88	12000	≈ 1.2 (up to 1.8)
MRS	LL4	1.15	1.26	1.19	12000	≈ 1 (up to 2.5)
CASPPR	CAC3	1.11	1.18	1	12000	≤ 2 (up to 2.4)
	CAC2	1.28	1.28	1.08	12000	≤ 2 (up to 2.4)
CASPPR'72	2	1.09	1.3	1.22	-	-
GL	Arc1	1.05	1.2	1.11	-	≈ 1
ABS	A2	1.05	1.12	0.95	12000	> 1
	A3	1.27	1.38	1.18	12000	> 1
LR	AC1	1.16	1.14	1.05	12000	≥ 1.5
DNV	ICE 05	1.05	1.18	0.99	12000	≥ 0.5
	ICE 10	1.24	1.38	1.17	12000	≥ 1
MRS	LL3	1.39	1.52	1.44	22000	≈ 1.5 (up to 3)
LR	AC1	1.44	1.41	1.29	22000	≥ 1.5
DNV	ICE 15	1.38	1.53	1.3	22000	≥ 1.5
	Polar10	1.38	1.53	1.3	22000	> 1
ABS	A3	1.34	1.45	1.25	22000	> 1
CASPPR	CAC2	1.29	1.29	1.09	22000	≤ 2
	CAC1	1.44	1.44	1.22	22000	≥ 3
CASPPR'72	4	1.41	1.6	1.56	-	-
GL	Arc2	1.27	1.48	1.35	-	≈ 1.5
MRS	LL2	1.6	1.75	1.66	47500	≈ 2 (up to 3.5)
LR	AC2	1.63	1.59	1.48	47500	≈ 2
ABS	A4	1.63	1.79	1.58	47500	> 1
GL	Arc3	1.56	1.78	1.64	-	≈ 2
DNV	Polar20	1.51	1.68	1.42	47500	≥ 2
	Polar30	1.63	1.81	1.53	47500	≥ 3
CASPPR	CAC1	1.46	1.46	1.23	47500	≥ 3
CASPPR'72	6	1.55	1.7	1.66	-	-
MRS	LL1	1.65	1.8	1.7	47500	≈ 2.4 (up to 4-5)
LR	AC2	1.63	1.59	1.48	47500	≈ 2
	AC3	1.94	1.92	1.77	47500	≈ 3
ABS	A5	1.77	1.94	1.77	47500	> 1
GL	Arc4	1.74	1.94	1.87	-	≈ 3
CASPPR'72	6	1.55	1.7	1.66	-	-
DNV	Polar30	1.63	1.81	1.53	47500	≥ 3

Table 7-6

Comparison of the dimensionless values of the frame scantlings

Society	Ice class	Hull area						Shaft power, kW	Ice thickness (ramming), m
		Bow		Middle		Stern			
		W	f	W	f	W	f		
MRS	ULA	1	1	1	1	1	1	12000	≤ 1
ABS	A1	0.9	-	1.6	-	1	-	12000	> 1
MRS	LL4	1.27	1.67	2.45	2.06	2.11	2.35	12000	≈ 1 (up to 2.5)
GL	Arc1	1.34	-	2.73	-	2.34	-	-	≈ 1
DNV	ICE 05	1.37	0.52	2.54	1.02	1.82	0.73	-	≥ 0.5
ABS	A2	1.6	-	2.8	-	2.1	-	12000	> 1
CASPPR'72	1A	1.41	-	2.84	-	2.53	-	-	-
CASPPR	CAC4	1.73	1.01	2.68	1.66	1.92	1.18	12000	≈ 1.2 (up to 1.8)
MRS	LL3	2.23	1.45	4.59	2.49	3.7	2.55	22000	≈ 1.5 (up to 3)
LR	AC1	2.15	0.92	4.28	1.93	3.44	1.55	22000	≥ 1.5
DNV	ICE 10	2.38	0.95	4.44	1.86	3.17	1.33	-	≥ 1
CASPPR'72	2	2.11	-	4.36	-	3.9	-	-	-
CASPPR'	CAC3	2.71	1.58	4.21	2.6	3	1.86	22000	≤ 2
ABS	A3	2.78	-	5.01	-	3.79	-	22000	>1
MRS	LL2	3.24	1.74	7.15	4.32	5.38	3.06	47500	≈ 2 (up to 3.5)
LR	AC1.5	3.32	1.6	6.51	3.32	5.22	2.67	47500	≈ 1.5
	AC2	3.65	1.76	7.16	3.65	5.75	2.93	47500	≈ 2
GL	Arc2	3.08	-	6.48	-	5.36	-	-	≈ 1.5
ABS	A3	3.33	-	5.96	-	4.76	-	47500	>1
DNV	Polar20	3.62	1.44	6.74	2.83	4.81	2.02	-	≥ 2
CASPPR'72	4	3.52	-	7.2	-	6.39	-	-	-
CASPPR	CAC2	3.83	2.24	5.93	3.67	4.24	2.62	47500	≈ 2.4
	CAC1	4.58	2.8	7.42	4.59	5.3	3.28	47500	≥ 3
MRS	LL1	3.43	1.84	6.91	5.56	5.7	3.24	47500	≈ 2.4 (up to 4-5)
ABS	A3	3.33	-	5.96	-	4.76	-	47500	> 1
GL	Arc2	3.08	-	6.48	-	5.36	-	-	≈ 1.5
LR	AC2	3.65	1.76	7.16	3.65	5.75	2.93	47500	≈ 2
	AC3	3.98	1.92	7.81	3.98	6.27	3.2	47500	≈ 3
CASPPR	CAC2	3.83	2.24	5.93	3.67	4.24	2.62	47500	≈ 2.4
	CAC1	4.58	2.8	7.42	4.59	5.3	3.28	47500	≥ 3
CASPPR'72	4	3.52	-	7.2	-	6.39	-	-	-

Table 7-7

Maximum values dimensionles parameters **W** and **f**

Society	Ice class	Hull area						Shaft power, kW	Ice thickness (ramming), m
		Bow		Middle		Stern			
		W	f	W	f	W	f		
MRS	ULA	1	1	1	1	1	1	12000	≤ 1
MRS	LL4	1.27	1.67	2.45	2.06	2.11	2.35	12000	≈ 1 (up to 2.5)
CASPPR	CAC4	1.73	1.01	2.68	1.66	1.92	1.18	12000	≈ 1.2 (up to 1.8)
LR	AC1	2.15	0.92	4.28	1.93	3.44	1.55	12000	≥ 1.5
MRS	LL3	2.23	1.45	4.59	2.49	3.7	2.55	22000	≈ 1.5 (up to 3)
ABS	A3	2.78	-	5.01	-	3.79	-	22000	>1
DNV	ICE 15	2.98	1.19	5.55	2.33	3.96	1.66	-	≥ 1.5
MRS	LL2	3.24	1.74	7.15	4.32	5.38	3.06	47500	≈ 2 (up to 3.5)
CASPPR	CAC2	3.83	2.24	5.93	3.67	4.24	2.62	47500	≈ 2.4
LR	AC3	3.98	1.92	7.81	3.98	6.27	3.2	47500	≈ 3
MRS	LL1	3.43	1.84	6.91	5.56	5.7	3.24	47500	≈ 2.4 (up to 4-5)
LR	AC3	3.98	1.92	7.81	3.98	6.27	3.2	47500	≈ 3
DNV	Polar30	4.26	1.69	7.93	3.33	5.66	2.38	-	≥ 3
CASPPR	CAC1	4.78	2.8	7.42	4.59	5.3	3.28	47500	≥ 3
ABS	A4	4.6	-	8.5	-	7.1	-	47500	> 1
	A5	5.3	-	10.3	-	9.2	-	47500	> 1
GL	Arc3	5.3	-	10.7	-	9	-	-	≈ 2

Table 7-8

Bow area

Classification society		Ice class					
Marine Register of Shipping	Framing	UL	ULA	LL4	LL3	LL2	LL1
	Shell plating	UL	ULA	LL4	LL3	LL2	LL1
Germanischer Lloyd	Framing	E1	E4	Arc1	-	Arc2	Arc2
	Shell plating	E1	Arc1	Arc1	Arc2	Arc3	Arc4
Det Norske Veritas	Framing	1C	1A*F	Ice05	Ice10	Ice15	Polar20
	Shell plating	1C	Ice05	Ice05 Ice10	Ice 15	Polar30	Polar30
American Bureau of Shipping	Framing	C0 B0	A1	A2	A2	A3	A3
	Shell plating	A0	A2	A2 A3	A3	A4	A4
CASPPR	Framing	-	1	1A	2	4	4
	Shell plating	C	1A 2	2	4	6	7
CASPPR, project	Framing	-	-	CAC4	CAC3	CAC3	CAC2
	Shell plating	-	CAC4	CAC3	CAC1	CAC1	CAC1
Lloyd Register	Framing	-	1AS	-	AC1	AC1.5	AC2
	Shell plating	1A	AC1	AC1	AC1.5	AC2	AC2
Deviation	< 5 %	< 10 %		< 20 %		< 30 %	> 30 %

Note to tables 7-8, 7-9 and 7-10:

Extent of the conformity between classes:

< 5 % - practically complete;
< 10 % - good;
< 20 % - satisfactory;
< 30 % - very approximate;
> 30 % - no corresponding analogue.

Table 7-9

Middle area

Classification society		Ice class					
Marine Register of Shipping	Framing	UL	ULA	LL4	LL3	LL2	LL1
	Shell plating	UL	ULA	LL4	LL3	LL2	LL1
Germanischer Lloyd	Framing	E1	E3	Arc1	-	Arc2	Arc2
	Shell plating	E2 E3	E4	Arc1	Arc2	Arc3	Arc3
Det Norske Veritas	Framing	1C 1B	-	Ice05	Ice 10	Polar20	Polar20
	Shell plating	1B	Ice 05	Ice05 Ice10	Ice 15	Polar20 Polar30	Polar30
American Bureau of Shipping	Framing	B0	A0	A2	A3	A3	A3 A4
	Shell plating	A0	A1 A2	A2 A3	A3	A4	A5
CASPPR	Framing	C	1	1A	2	4	4
	Shell plating	B	1A	2	3	6	6 7
CASPPR, project	Framing	-	-	CAC4	CAC3	CAC2	CAC1
	Shell plating	-	CAC4	CAC3	CAC1	CAC1	-
Lloyd Register	Framing	-	1A	-	AC1	AC1.5	AC2
	Shell plating	1A	AC1	AC1	AC1.5	AC2	AC3
Deviation	< 5 %	< 10 %		< 20 %		< 30 %	> 30 %

Table 7-10

Stern area

Classification society		Ice class					
Marine Register of Shipping	Framing	L	LA	LL4	LL3	LL2	LL1
	Shell plating	L	LA	LL4	LL3	LL2	LL1
Germanischer Lloyd	Framing	E2 E3	E4	Arc1	-	Arc2	Arc2
	Shell plating	E3	Arc1	Arc1	Arc2	Arc3	Arc4
Det Norske Veritas	Framing	1B	1A*F	Ice05	Polar10 Ice15	Polar30	Polar30
	Shell plating	1A* 1A*F	Ice 05	Ice10	Polar20	Polar30	Polar30
American Bureau of Shipping	Framing	A0	A1	A2	A3	A3	A3
	Shell plating	A1	A2	A3	A4	A4	A5
CASPPR	Framing	B A	1	1A	2	3	4
	Shell plating	A	1A	2	3	6	6 7
CASPPR, project	Framing	-	-	CAC4	CAC2	CAC1	CAC1
	Shell plating	-	CAC3	CAC1	CAC1	-	CAC1
Lloyd Register	Framing	-	1AS	-	AC1	AC1.5 AC2	AC2
	Shell plating	1A	AC1	AC1.5	AC2	AC3	AC3
Deviation	< 5 %	< 10 %		< 20 %		< 30 %	> 30 %

CONCLUSION

Analysis shows that for the correctness of ice classes identification it is necessary to make the comparison of the requirements within groups of ships with similar purposes: cargo vessels for independent sailing in ice, port icebreakers, linear icebreakers, as well as within subgroups of similar shaft power.

As it is shown in the work, the level of requirements for bow framing of the highest ice classes in the certain foreign Rules (classes CAC1, Arc3, A4, A5, Polar 30) is considerable higher in comparison with those for LL1 class of the MRS Rules, what corresponds to the most powerful Russian arctic icebreakers.

Evidently the sharp increase of bow framing requirements in foreign Rules is an aspiration for the development of a classification niche for new types of future ships - transports-icebreakers. Apparently such ships will have a displacement about 50 000 - 100 000 t and shaft power up to 40 000 - 50 000 kW and over.

As there is no experience of ice operation of ships with a displacement of 50 000 - 100000 t and shaft power exceeding 50 000 kW it is necessary in the development of a new classification range for these ships to ensure its close relation with the classification drawn up for ships now in operation.

The comparability of results is significantly influenced by the density of classification nets (inter-classes range).

The requirements of certain ice classes (for example LL1, LL2) are very similar, therefore sometimes two Russian classes correspond to a foreign one, and vice versa.

Taking into account the above it seems advisable to increase density of the classification net (part of which should be associated with modern fleet) relative to that of the new Rules of GL, ABS and CASPPR.

The gap in GL, ABS and CASPPR between highest classes as well as the level of their requirements and the strength of the most powerful arctic icebreakers seems to be excessive. In the higher class group it is apparently advisable to have more closely spaced net well adapted (for the lightest classes of this group) to the operating ships. As one can see from the tables in GL, ABS, CASPPR'72 and DNV Rules, even for ships with traditional dimension and power it is not always possible to find a satisfactory analogue to the highest classes of the MRS.

Bearing in mind the fact that in a number of Rules of leading classification societies (ABS, GL, CASPPR'72) there is no regulation of the section areas of the walls of ordinary frames **f** , it is advisable to exclude this parameter from the consideration at this stage of work.

Taking into account the provisions stated, it seems well-grounded to identify classes in the following way: in the forebody by the requirements for shell plating and in the middle and afterbody by relative sizes of framing ice strengthening, because the analysis of ice damages and accidents shows that framing damages during the ice compression are most dangerous in these areas

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I.1.2.8 MARINE CASUALTY

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SUMMARY

Pursuant to the plan of this work performed within the 1994 budget, the actual data on ship accidents during the shipping season in the Russian Arctic Seas, and data on ice accident rate have been submitted in the first place.

KEY WORDS

MARINE ACCIDENTS, SHIPWRECKS, ICE DAMAGES

INTRODUCTION

According to the Russian legislation, the investigation of ship accidents is the duty of the harbour master of trading and fishing port, who is at the same time the first deputy director of the Port Marine Administrations - new state bodies, created to supervise the safety of navigation and to administer state property of merchant sea ports.

The investigation of ship accidents is executed in conformity with the "The Rules of classification, investigations and registration of ship accidents", which is submitted in the previous paper. Insignificant changes have been introduced in this Rules.

The statistics on ice accident rate are assembled and processed by NSRA. These data are presented to the Main State Marine Inspection (MSMI) of Department of Marine Transport, which communicates them to CNIIMF for general analysis, development of preventive measures and provision of necessary information for all the organizations concerned.

Thus, the present work shows the data on ice accident rate against the background of accident rate features of the Russian merchant fleet.

1 GENERAL ACCIDENT RATE IN RUSSIA

1.1 INITIAL MATERIALS

The present section submits the statistical analysis of 1994 accident rate of the marine sea fleet of Russia controllable by the Department of Marine Transport and in comparison with the period of 1991-1993. The statistical analysis is based only on the materials furnished by MSMI and is not complete.

1.2 ACCIDENT RATE PARAMETERS

The absolute parameters of accident rate for the 1991- 1994 period:

Category of emergency cases	Quantity of cases/ years			
	1991	1992	1993	1994
Shipwrecks	-	1	2	3
Emergency cases	46	33	39	29
People lost	3	2	30	2

This table shows that in 1991 there were no cases of shipwreck, in 1992 one vessel was lost, and in 1993 - 2 vessels, in 1994 already 3 shipwrecks occurred. Thus, there is a tendency for serious accidents to grow.
At the same time, shipwrecks remain to be solitary cases in the Russian merchant shipping.

In 1994, there were 32 emergency cases. It is a quarter less than the average for the last three years (39 emergency cases).

In 1994, 2 human lives were lost in marine accidents.

As to ship's owners, the distribution of accidents shows, that the largest ship's owners of Russia - marine shipping companies - in 1994 had the number of accidents on the level of previous years. They contribute to 81% of total number of emergency cases in 1994. The share of all other ship's owners was accordingly 19%. For the previous three years the share of marine shipping companies was 79% of emergency cases, the share of other ship's owners came up to 21%.

The accident rate of shipping companies, which ships were operated in the Arctic, is not above (as might be supposed) but below the average rate.

So, in the Arctic Shipping Company (Tiksi) for 1991-1994, one emergency case was registered, while in the Far Eastern Shipping Company, for example, - 26 cases, in the Novorossiysk Shipping Company - 19. But in the Murmansk Shipping Company 14 cases were registered.

The analysis of distribution of emergency cases made in compliance with the Russian Rules for classification of investigation and registration of emergency cases, shows, that in 1994, of the total - 67% emergency cases were navigational accidents, 24% were technical accidents and 9% were connected with fires and explosions. Average values for 1991-1993: navigational accidents - 59%, technical accidents - 31%, fires and explosions - 10%.

In 1994, groundings accounted for 41% of total navigational accidents and contact cases; 36% of navigational accidents were of serious character . The considerable part of cases refers to the loss of ship's stability and floatability -14%.

The fact of absence in 1994 of cases of ship collisions is worth mentioning.

The distribution of navigational emergency cases of 1994 in comparison with an average level of 1991-1993 (the average data are given in brackets) is as follows:
taking the grounds- 45% (41%), collisions - 13% (-), contacts - 28% (36%), loss of stability/floatability - 6% (14%), damages caused by stormy weather - 3% (-), ice damages - (4%).

The high rate of grounding in 1994 and in previous years, may be explained by insufficient supplying of Russian ships with modern radio navigational receivers, in the first place - with

satnav receivers, as well as by a great number of dangers to navigation in Russian coastal waters, especially in the Arctic seas. At the same time, attention should be paid to the high rate of contacts. The rate of ships contacts in the good old times of the USSR Marine Merchant Fleet was far below. By the way, at present this parameter is very low in comparison with the relevant world fleet parameter.
The technical types of emergency cases in 1994 were distributed practically at regular intervals. For the whole period of 1991-1994 the maximal frequency of cases is connected with damages of ship devices (mainly - loss of anchors and of anchor chains in 1991 and in 1992). The frequency of fires and explosions in 1994 though became lower in comparison with previous years, however remains high.

The analysis of emergency cases in terms of their causes offers an opportunity to ascertain, that in 1994, the share of emergency cases, occurred through crews faults made up 66%, objective causes account for - 16%. In 13% of cases, the causes of emergency events were not revealed by the time of analysis. The dynamics of emergency cases caused by "human factor" (as was already mentioned, the role of "human factor" is established rather subjectively) are as follows: 1991 - 57%, 1992 - 62%, 1993 - 68%, 1994 - 66%, an average for the period of 1991-1994 - 63%.

Traditionally, the parameters of navigational accidents depend on the season of navigation. Adverse hydrometeorological conditions typical for the autumn - winter periods, considerably worsen ship control conditions. As a result, the potential opportunity of crew errors increases. The distribution of navigational emergency cases by seasons of year confirms this rule. In 1994, 60% of navigational accidents took place during the autumn and winter. Groundings prove to be accounted for many of these accidents.

The analysis of accident rate in relation to the age of ships shows, that in 1994 58% of all emergency cases occurred with ships, the age of which was over 15. Concerning all emergency cases for the 1991-1994 period, it will be noted, that the 40% of them relate to vessels over the age of 20 , 38% - to the ships of average age (10-20 years) and about 16% - to ships "younger" than 10 (age of 5% emergency ships is unknown). It is also worthwile to note, that technical and navigational types of emergency cases were included in this summarized distribution. This is also true for fires/explosions - 42% of these cases relates to the ships over the age of 20.

These data confirm the well-known correlation between accident rate and age of ships, which is characteristic for accident rate of world merchant shipping, and, on the other hand, to some degree objectively reflect the age structure of the merchant fleet of Russia and the process of its aging.

2 ICE ACCIDENT RATE

2.1 ICE DAMAGES TO SHIPS IN 1992

We could not include the data on ice accident rate of 1992 in the previous report, because the information was not processed by then. The ice damages to ships and ice breakers on the NSR in 1992 are characterized by the following table:

Characteristics		Damaged ships %
Region of sailing	West	86
	East	14
Period of sailing	Summer	28
	Autumn-winter	72
Damage legend	Posting by leader	28
	Close tuggage	28
	Contacts	28
	Free sailing	14
Damage type	Propellers, blades	14
	Dents, corrugations, breaks	
	Dents with cracks	43
		43
Age of ship, years	Up to 3	28
	4-17	14
	8-12	43
	17 and more	14
Ice class	LL1	28
	LL2	14
	ULA	14
	UL	43

2.2 ICE CONDITIONS IN 1993

The hydrometeorological process in the Arctic seas in the winter of 1992/1993 developed ambiguously. In the Kara and Laptev seas the winter was colder than usual. In this connection, the development of ice here went heavily and in the early spring of 1993 the thickness of ice ledge on both seas exceeded the normal by 15-20 cm. In the north-east part of the Kara Sea, including the Vilkitzkogo Strait, and in the western part of Laptev Sea the residual ice was observed in 50 % of areas under observation.

In the East Siberian and Chukchi seas winter-grade hydrometeorological processes were slightly different from the normal, and the thickness of ice ledge in early spring was less than the average. The border of residual ice in these seas was situated 50-60 miles north of the border which was calculated on the basis of several years records.

Thus the ice distribution in the Arctic early in May of 1993, is possible to characterize as adverse in the north-east part of the Kara Sea and in the western part of the Laptev Sea, and as close to normal in the East Siberian and Chukchi seas and in the eastern part of the Laptev Sea.

In May and June of 1993, the warm air carried into the Arctic seas of Russia was accompanied by prevailing winds from coast. In June in the south regions of the Arctic seas, the ice melted to a considerable degree and was destroyed. In July the warm air was carried again into the East Siberian and Chukchi seas, and into the south-western part of the Kara Sea. At the same time in the western part of the Laptev Sea July was cold. Here the ice was destroyed slowly.

Despite low air temperatures, in the north-east part of the Kara Sea the vast zone of sparse ice and clean water was formed under wind influence in July. To the West of the Laptevs Sea the adverse pressing winds were prevailing, therefore the ice with a closeness of 9-10 numbers was pressed to the coast of Taymyr.

In August, and in September there were no changes in ice distributions on the NSR. By the end of August along all NSR line, the sailing was made without assistance of ice breakers, except the region in the western part of the Laptev Sea between the Vilkitzkogo Strait and Hatanga Bay, which was sailed through by ships with assistance of ice breakers.

In the third ten-day interval of September, in connection with sharp fall of temperature, the young ice appeared in the north-east part of the Kara Sea and further to the East of the entry of the Indigirka River. In October and November intensive fall of temperature occured along all NSR line. Already by the end of October on clean waters almost of all seas (except for the south part of the Chukchi Sea) the young grey and grey-white ice was observed, that in November turned into the thin one-year ice, which is usual phenomenon for the Arctic seas in this period of year. Just like during the all navigation, in October and November in the western part of the Laptev Sea the difficult ice conditions were lasting, and about 70% of residual ice remained for winter.

Summarizing, it may be noted, that the ice conditions in the navigation of 1993, almost in all the Arctic seas of Russia were easy, except for the western part of the Laptev Sea, where the floating 9-10 numbers ice was pressed to the coast of Taymyr during the all shipping season, hindering the approaches to the Vilkitzkogo Strait from the East.

2.3 ARCTIC NAVIGATION IN 1993

In the navigation of 1993, the transit passages of ships in the both directions were executed. The cruise to the North Pole of the nuclear ice breaker *Yamal* with foreign tourists on board became traditional. The ships of the Murmansk, Far-Eastern, Sakhalin, Pimorskoye, Baltic, Kamchatka and Arctic Shipping Companies participated in the NSR navigation.

For the first time, the German oil tankers *Ledastern* and *Jadestern* and one Finnish oil tanker *Lunni* participated in Arctic carriages of petroleum from Arkhangelsk to the bar of the Yana River. The first two oil tankers made two trips, and the third one - three trips. The German ships have ice belts to meet the requirements of the Register of Shipping for class L1, and Finnish - for Ul class.

The German ship's owner did not announced any ice damages of their ships, and the Finnish tanker got a dent with a crack in the bow section of the hull.

The German research ice breaker *Polarstern* has successfully conducted the expedition works in the Laptev Sea.

2.4 ICE DAMAGES IN 1993

In 1993 on the NSR 86% cases of ice damages to ships took place in the West region of NSR, 14% cases - in the East region.

In comparison with 1992, the occurrences of ice accidents with ships in the Arctic,decreased by 66%. It was explained by easy ice conditions along all the NSR line, except for the western part of the Laptev Sea.

The table of ice accident rate in the Arctic in relation to the ice class of ships in 1993.

Ice class	Damages of ships, %		Including with water inflow , %		Total,%
	West	East	West	East	
LL1	29	-	-	-	29
LL2	-	14	-	-	14
ULA	14	-	14	-	14
UL	43	-	29	-	43
Total	86	14	43	-	100

The table of kinds of damages to ships in relation to the category of ice strengthening.

Damage	Ice class distribution, %					Total, %
	LL1	LL2	ULA	UL	L1	
Propellers, blades	14	-	-	-	-	14
Dents, corrugations, plating						-
breaks	14	14	-	14	-	43
Dents with cracks	-	-	14	29	-	43
Total	29	14	14	43	-	100

The table of kinds of damages to ships in the Arctic in relation to the age of ships.

Damage	Ship's age, years					Total Ships
	up to 3	4-7	8-12	13-16	more	
Propellers, blades	14	-	-	-	-	14
Dents, corrugations, plating						-
breaks	14	-	14	-	14	43
Dents with cracks	-	14	29	-	-	43
Total	29	14	43	-	14	100

The damages such as holes, dents with corrugations and cracks are the most frequent damages irrespective of age.

The table of distribution of ice damages in the Arctic by months of year.

Month	Damage ships, % of total		Total %
	West	East	
May	14	-	14
August	29	-	29
October	29	-	29
November	14	-	14
December	-	14	14

CONCLUSION

The collected data on general and ice accident rate of the merchant fleet of Russia show, that the country maintains sufficiently high level of the safety of navigation, keeping up with the advanced maritime nations.

At the same time, the aging of the Russian merchant fleet, existence of numerous poorly controllable shipping companies with low level of organization of service aboard, reduction of infrastructure that provides support to the safety of navigation, and deterioration of its quality, will render in the future a negative influence on the parameters of accident rate, if effective preventive measures have not been taken by then.

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PREPARED BY AARI

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INTRODUCTION

The main directions of the studies of the project under consideration at the second stage (April 1, 1994 - March 30, 1995) are presented in formal documents of the Program (Project Catalogue, 1994). A wide range of problems connected with the use of the NSR also include questions of hydrometeorological support. Taking into account their specific features and that they are administered by the Federal Service where its own standard schemes and provisions are in force, the sections on provision of hydrometeorological information to navigation (including international) should be presented as separate sections. Such variant was proposed during the preparation of the report for the I stage of the Project (March 1993-April 1994). This subdivison was not made in the final form and in our opinion it makes difficult to gain an impression of the role and place of hydrometeorological support when addressing the problems of the use of the NSR. Thus, along with the planned studies of the second stage (Project Catalogue, 1994) the Report includes some evidence on the works of the first stage.

1 FEATURES OF OBTAINING DATA ON INFORMATION CONDITIONS AT A NORMATIVE- LEGAL REGULATION OF SHIPPING ALONG THE NSR

First of all, it should be noted that serious changes have taken place in the structure of the Federal Service of Russia for Hydrometeorology (Instruction, 1995). From May 1, 1995 the Arctic Administrations at Amderma, Dikson, Tiksi and Pevek will be abolished. Polar stations are practically continuously being reduced in number, the functions related to organizing hydrometeorological support for shipping along the NSR are being transferred to the AARI. The questions of concluding agreements with the users of hydrometeorological information will be addressed by the Territorial Administrations. Undoubtedly, these changes will also affect a normative-legal regulation during the preparation and provision of hydrometeorological information for navigation. However, independently of these reorganizations the hydrometeorological support to shipping along the NSR will be provided by the Federal Service of Russia for Hydrometeorology and Environmental Monitoring (Rosgidromet).

This type of activities of Rosgidromet is regulated by normative-legal documents (WMO, 1981; Operational activity, 1990; Order for the use, 1990, etc.).

The majority amount of data on natural conditions in the NSR zone aim to meet the requests of marine branches and according to international (WMO, 1981) and national (Interaction principles, 1994) documents these data are specialized. Composition of such data, dates and ways of delivering them to the users are governed by agreements between shipping companies, the NSR Administration on the one hand, and Rosgidromet institutions on the other hand (Interaction principles, 1994).

One may hope that potential users of international shipping along the NSR will find useful information on the features of natural navigation conditions in the Guidebook for Navigation to be published in 1995.

However, not all questions governed by specific features of ice navigation have been elaborated up to the level of normative documents. In this connection, the AARI has conducted studies within the framework of this INSROP Project and these results are given below.

2 REGIONING OF THE NSR ZONE BY THE DIFFICULTY AND SAFETY OF NAVIGATION

The Northern Sea Route is usually subdivided into two regions: western and eastern. The boundary between them passes along 125°E (Guide-book, 1995). within these regions the segments are identified where natural conditions for navigation of ships differ quite significantly. This fact caused a more detailed regioning of the NSR zone by the difficulty and safety of navigation (Buzuyev, 1981). The regioning is based on:

1. Location of the main ports (points) involved in shipping activity.

2. Possible navigation variants subject to natural conditions in each region (Fig. 1).

3. Calculated, using an empirical model (Busuyev, Fedyakov, (1983)) time for navigating along a route setup by the variant most favourable in terms of ice conditions during each 10-day period of navigation.

4. Calculated, using a model (Kurdyumov, Kheisin, 1974, 1976)) probabilities of damages for ships of different type and state (operating time).

Thus, unlike the Canadian approach (Coast Guard Northern, 1994) our work on regioning takes into account seasonal and interannual changes in ice conditions and difficulties of navigation directly on shipping routes within each of the regions. Also, diverse ice conditions and navigation features are divided into types. This division is based on the following:

1. Length of the route in close ice, as well as in fast ice (for example, see Table 1).

2. Calculated operating indicators for icebreakers and typical convoys; let us remind that such indicators include velocity in ice (V_{ion}) and time to come through it (ΣT_i); for example, see Table 2.

3. Duration of unescorted navigation of ships of specific ice categories, an example is shown in Fig. 2.

In addition to operating indicators for ships a probabilistic risk estimate is also given, see Table 3.

The studies related to a detailed description of each of the NSR regions (see Fig.1.) in terms of safety and dificulty of navigation are being continued. However, we hope the approach developed by the AARI has been clearly presented. Also, additional works whose results are used for improving the regioning are of interest. These works will be discussed below.

In order to take into account background ice conditions under which marine operations are carried out the division of ice conditions into types in the seas of the Siberian shelf along the western and eastern NSR segments was updated.

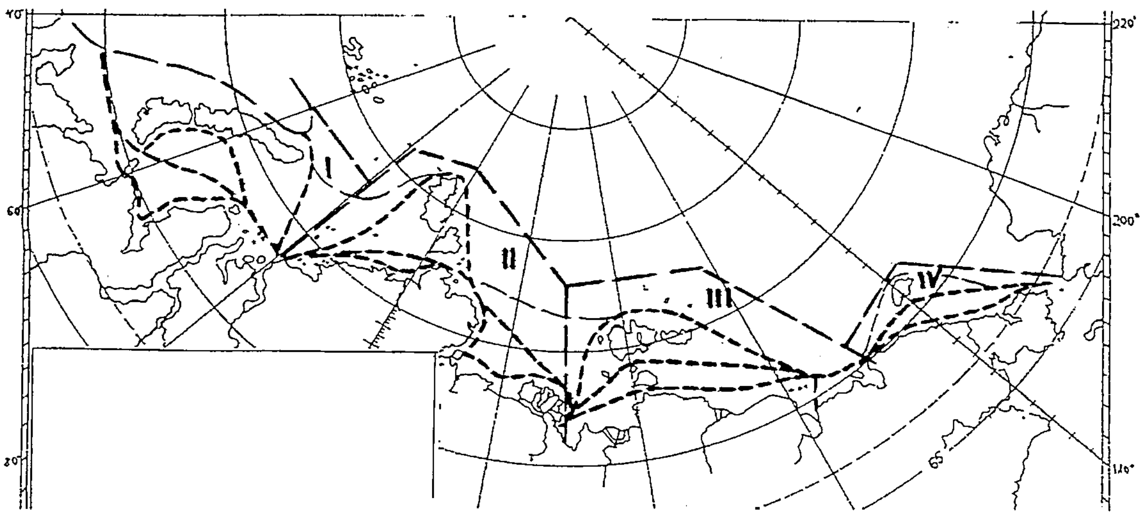

Fig. 1. Main regions of sea navigation in the NSR zone; possible navigation variants

I - ice edge - Dikson island
II - Dikson island - Tiksi intel
III - Tiksi intel - Shelagsky care
IV - Shelagsky care - Bering strait

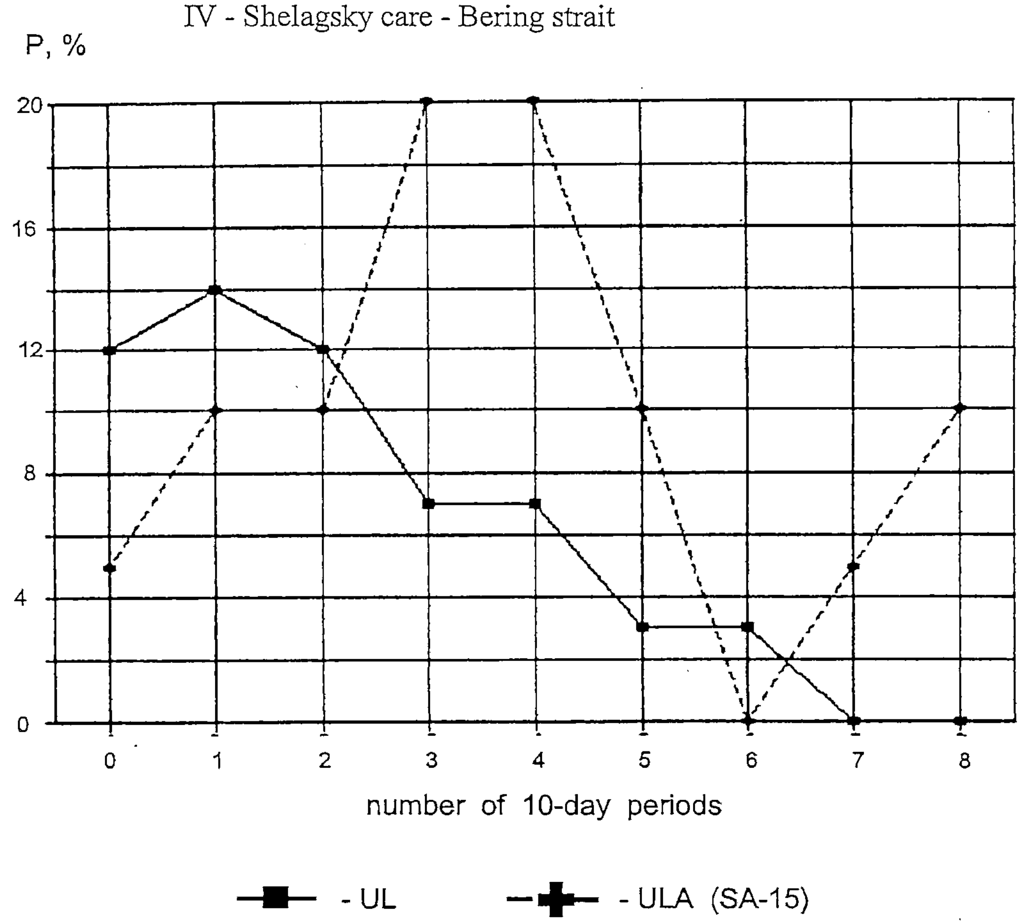

Fig. 2. Possible duration of unaided navigation due to natural conditions on the segment Barents Sea - Bering strait of the UL and SA-15 ships (1970-1988)

Table 1. Change in the route length in different ice conditions in % of the total length of the most favourable navigation variant (for example, Region II, see Fig.1, navigation period)

Months	Characteristics of navigation conditions											
	A				B				C			
	Fast ice	Drifting ice		Open water	Fast ice	Drifting ice		Open water	Fast ice	Drifting ice		Open water
		7/10-10/10	1/10-6/10			7/10-10/10	1/10-6/10			7/10-10/10	1/10-6/10	
June	30	15	10	45	38	33	4	25	40	43	4	13
July	9	12	26	53	16	24	12	48	22	43	11	24
Sept.	0	14	17	69	0	15	22	63	0	25	23	52
Oct.	0	11	10	79	0	59	9	32	0	89	4	6

Note: A, B, C - favourable, mean and unfavourable types of ice distribution along the navigation route.

Table 2. Calculated ice operating velocities (V_{ion}) and times to overcome ice zones (τ, h) for icebreakers of different power at different types of natural conditions along the NSR

Indicators of navigation difficulty	Icebreaker's power								
	May			August			October		
	75	41	22	75	41	22	75	41	22
Easy conditions									
V_{ion} knots	10.2	7.0	3.8	17.2	15.5	12.9	16.5	14.5	13.5
τ (days)	12	17	33	1	1	1	1	2	2
Medium conditions									
V_{ion} knots	7.5	3.4	imp.	15.4	12.4	11.0	16.4	13.8	11.0
τ (days)	17	33	imp.	3	4	4	4	5	7
Heavy conditions									
V_{ion} knots	5.8	2.2	imp.	13.1	8.2	4.4	13.6	10.5	7.3
τ (days)	23	68	imp.	6	10	19	7	9	14

Note: imp. - navigation impossible.

Table 3. Probability of accumulating damages (P_1) and receiving damages (P_2) by ships of SA-15 type depending on the ship's speed in ice (for example, region IV, see Fig.1)

Speed V_{ion}, knots	June		August		Note
	P_1	P_2	P_1	P_2	
16.0	0.0051	0.5049	0.0420	0.0605	Mean values of ice cover characteristics are used for each month
12.0	0.0153	0.4896	0.0132	0.0428	
8.0	0.2074	0.2431	0.0131	0.0303	
4.0	0.1870	0.1037	0.0129	0.0015	

The ice distribution type is represented by an averaged field of zones of prevailing multiyear ice, zones of multiyear ice inclusions with prevailing first-year ice, zones of prevailing first-year and young ice, fast ice and open water that are groupped by uniformity of the geographical position.

The following criteria were used as additional indications for combining ice distribution fields into a type: equal areas of ice of one age category, orientation of multiyear ice branches of oceanic massif extending to the seas of the Siberian shelf, similar configuration of the boundaries of zones of ice of different age categories, fast ice and ice edge, as well as a restriction of their deviation from its typical limit $\alpha \pm 30$-60 km in width and 60-70% in length of the boudaries.

A variety of spatial distribution and temporal variability of ice cover characteristics in the eastern region (for which a division into types has been completed) are combined into 6 types (Fig. 3, 4, 5).

As to the western region, the studies for specifying and making each component detailed in the annual cycle of the ice cover existence are still under way.

Each of the types is characterized by its seasonal and interannual occurrence, probability of persistence or transition to another type. In particular, type IV (0.68), as well as types V and VI (0.47) have increased occurrence in the eastern NSR region in the annual cycle.

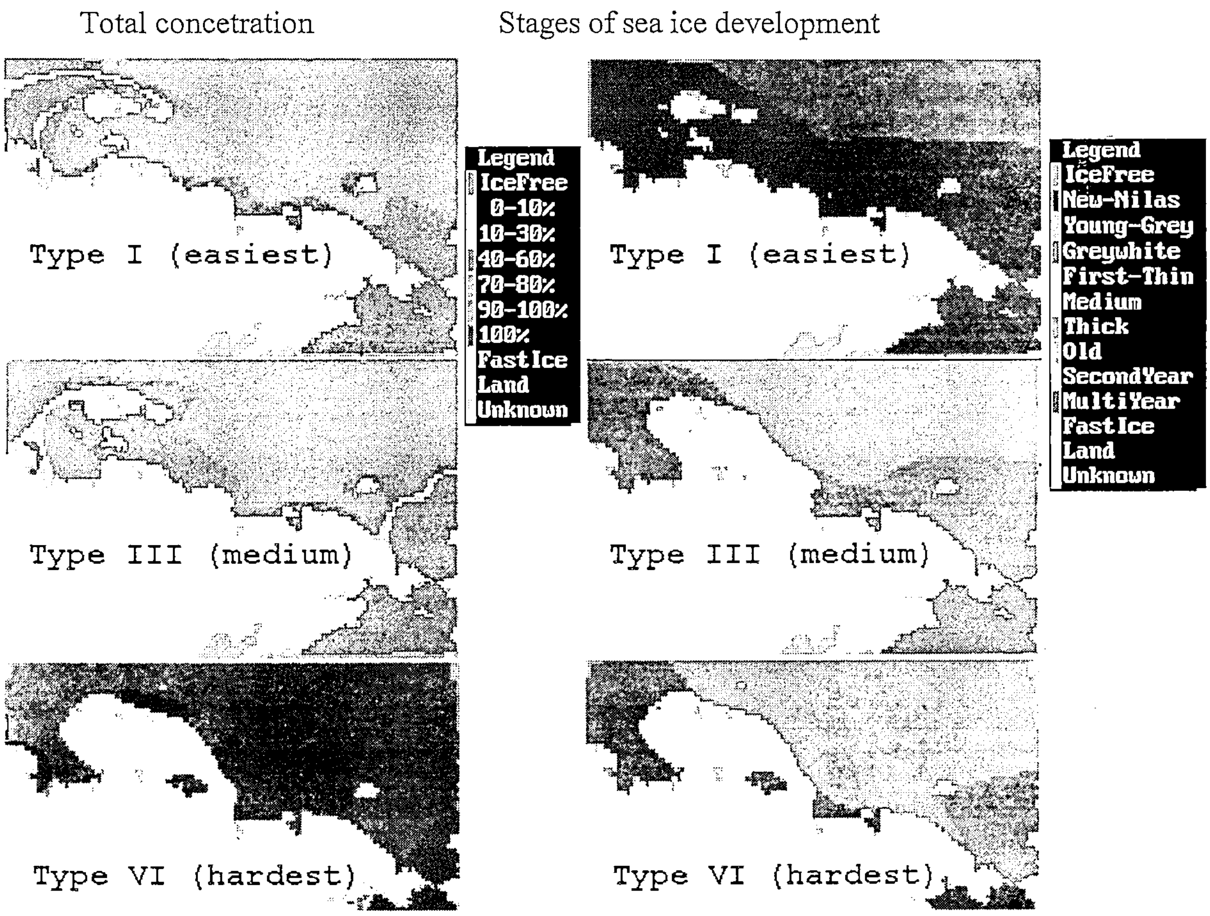

Fig. 3. Typical sea ice conditions for the 2-nd 10-days period of July for the Eastern sector of the Northern Sea Route

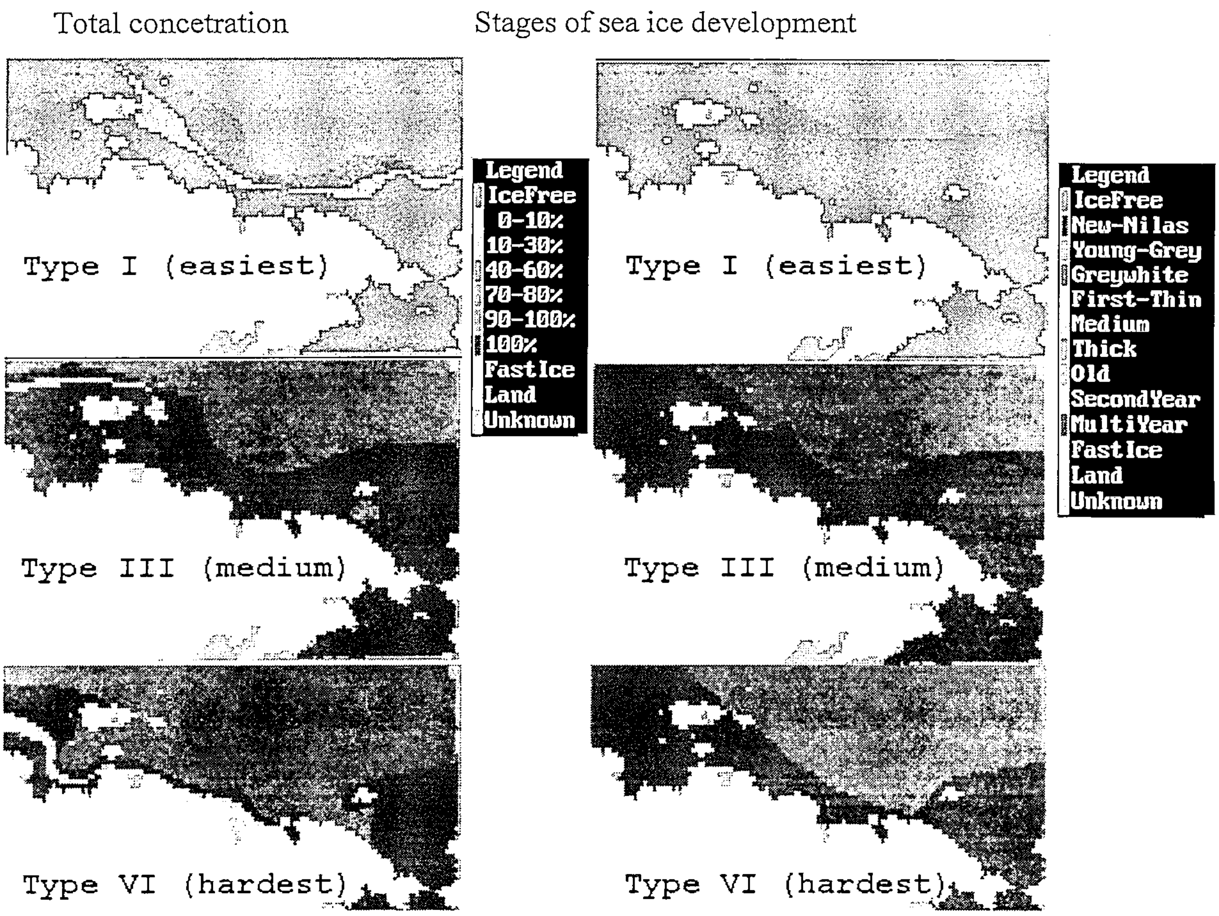

Fig. 4. Typical sea ice conditions for the 2-nd 10-days period of August for the Eastern sector of the Northern Sea Route

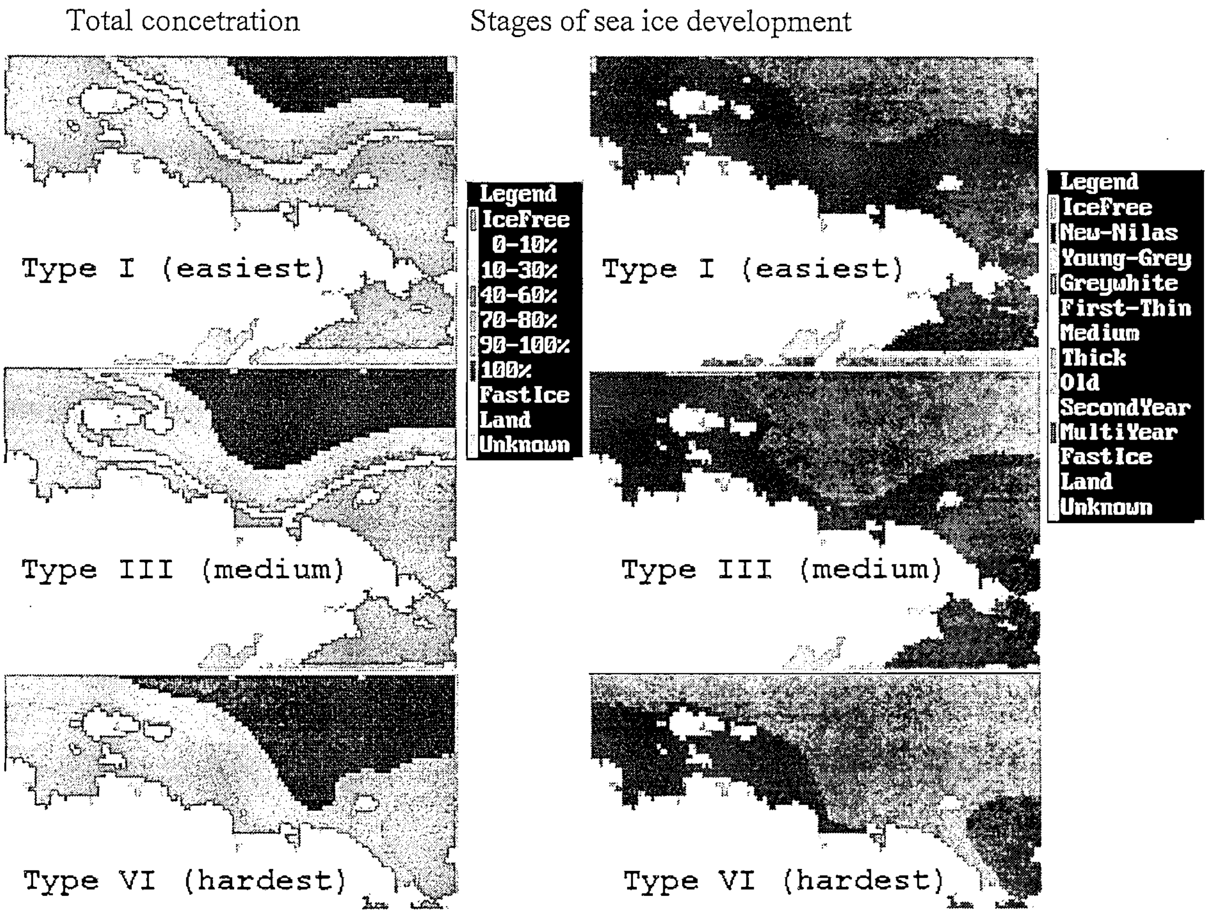

Fig. 5. Typical sea ice conditions for the 2-nd 10-days period of September for the Eastern sector of the Northern Sea Route

As has been mentioned, the ice cover distribution type reflects only a background against which marine operations are conducted. Some features, quite important for shipping (presence of flaw leads and polynyas, discontinuities, "inclusions" of younger ice, etc.), are not taken into account. As a result, the distribution type (see Fig. 1) is consistent with the type of navigation conditions only with a definite probability (Table 9). Still, similar generalized information can be useful for addressing the issues of using the NSR. But more significant, probably, is to take into account natural factors that directly influence the safety of navigation both in some regions and on the whole, along the NSR. The most objective indicator in this case may be generalized information on the regions with the largest occurrence of ice accidents (IA). An analysis of these data indicates that many of the damages (>50%) were a result of ice pressure, particularly of hummocked ice ≥ 200 cm thick. In the fall-winter in addition to pressures, the processes of ice adhesion to the hull in the form of a snow-ice "cushion", "ice river" phenomenon in narrow places or near capes play a definite role.

Table 4. Probability (%) of the ice distribution type in the eastern region coinciding with the type of navigation conditions on the segment Pevek-Bering strait

Type of ice distribution and its characteristics	Type of navigation conditions								
	easy			medium			heavy		
	VII_2	$VIII_2$	IX_2	VII_2	$VIII_2$	IX_2	VII_2	$VIII_2$	IX_2
1 (Most easy)	100	90	75	0	10	25	-	-	-
III (Medium)	50	13	32	40	67	15	10	20	33
VI (Most heavy)	5	0	0	55	50	12	40	50	88

Note: VII_2, $VIII_2$, IX_2 - second 10-day periods of July, August and September, respectively.

The regions of increased occurrence of ice accidents are the Kara Gate strait and a segment of the route from the Bely island to Yenisey Bay; B. Vil'kitsky strait and a route segment from the New-Siberian Islands to the exit from the Long strait (Fig. 6). At the same time ice accidents are almost not observed in the south-westernmost Kara Sea and along the eastern Chukotka coast at the approaches to the Bering strait (see Fig. 6). As expected, occurrence of ice accidents is sufficiently closely related to ice distribution types. In the most general way this dependency indicates that more than half of ice accidents fall on unfavourable types of ice distribution (Table 5).

Table 5. Distribution of occurrence of ice accidents (%) in the NSR zone at different ice distribution types

	Generalized characteristics of ice distribution type		
Characteristics	favourable	medium	unfavourable
Occurrence, %	12	35	53

Probably, it is worth recalling that earlier (INSROP, project 1.1.2, 1994) general typical features in the distribution of ice accidents along the western (segments I, II) and eastern (segments III, IV, see Fig. 1) NSR regions were identified (Table 6).

Table 6. Mean number of ships with recorded ice damages (in % of the total number of ships on the route) at different types of ice navigation conditions in the western and eastern NSR regions.

Type of ice conditions	NSR region	
	Western	Eastern
Heavy	7.5-8.0	14.0-16.0
Medium	3.5-5.0	8.0-10.0
Easy	1.0-1.5	2.0-3.0

Note: the data is used up to 1975 for ships out of operation.

Another natural phenomenon, ice accretion (icing), can also negatively affect the safety of navigation.

On marginal NSR segments (zone I, IV, see Fig. 1) there is a high probability of ice accretion in the fall-winter period (Fig. 7, 8). For comparatively small vessels (displacement up to 500 t) there is a danger of losing stability, especially at a rapid ice accretion (Panov, 1976).

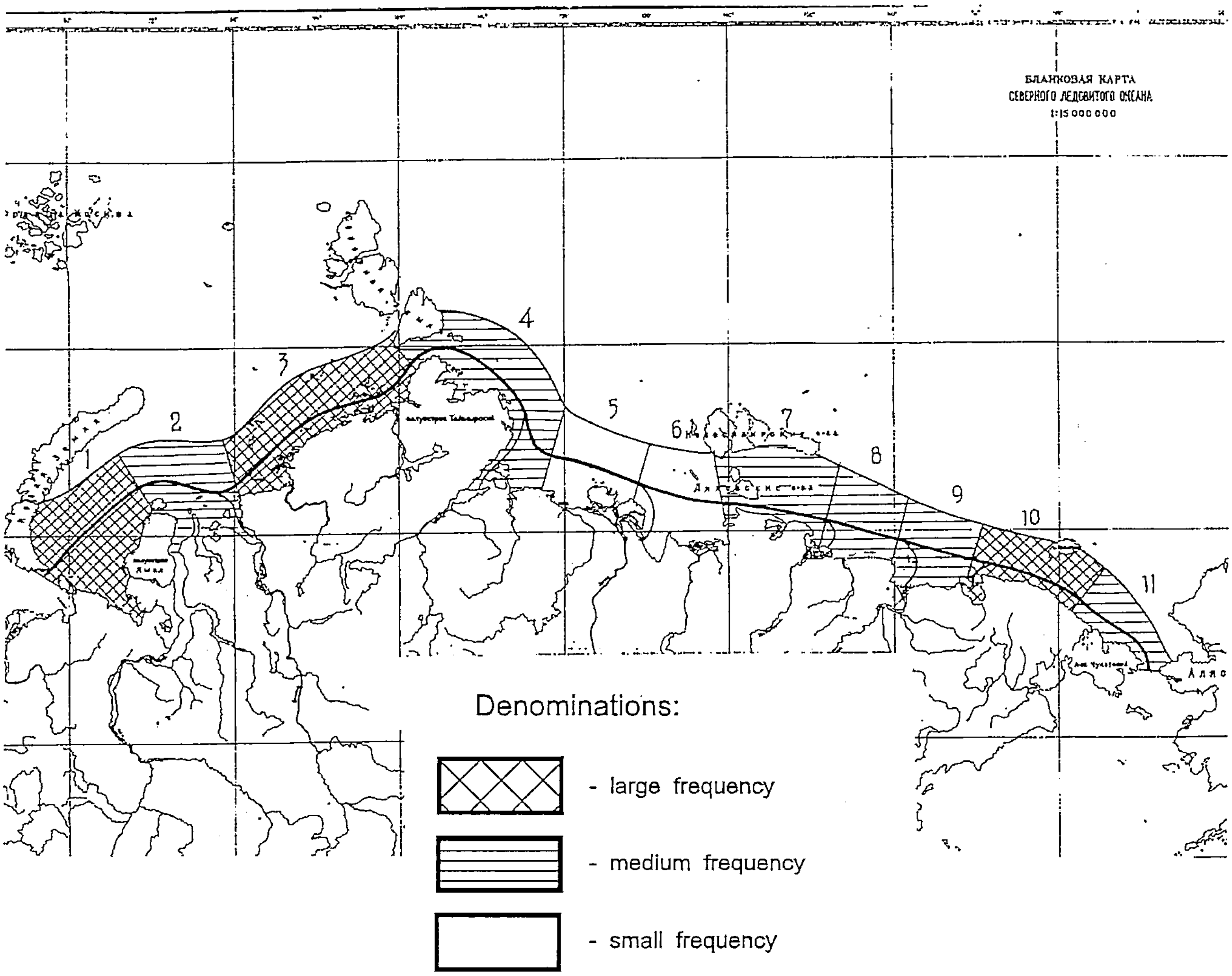

Fig. 6. Frequency of accidents along the NSR

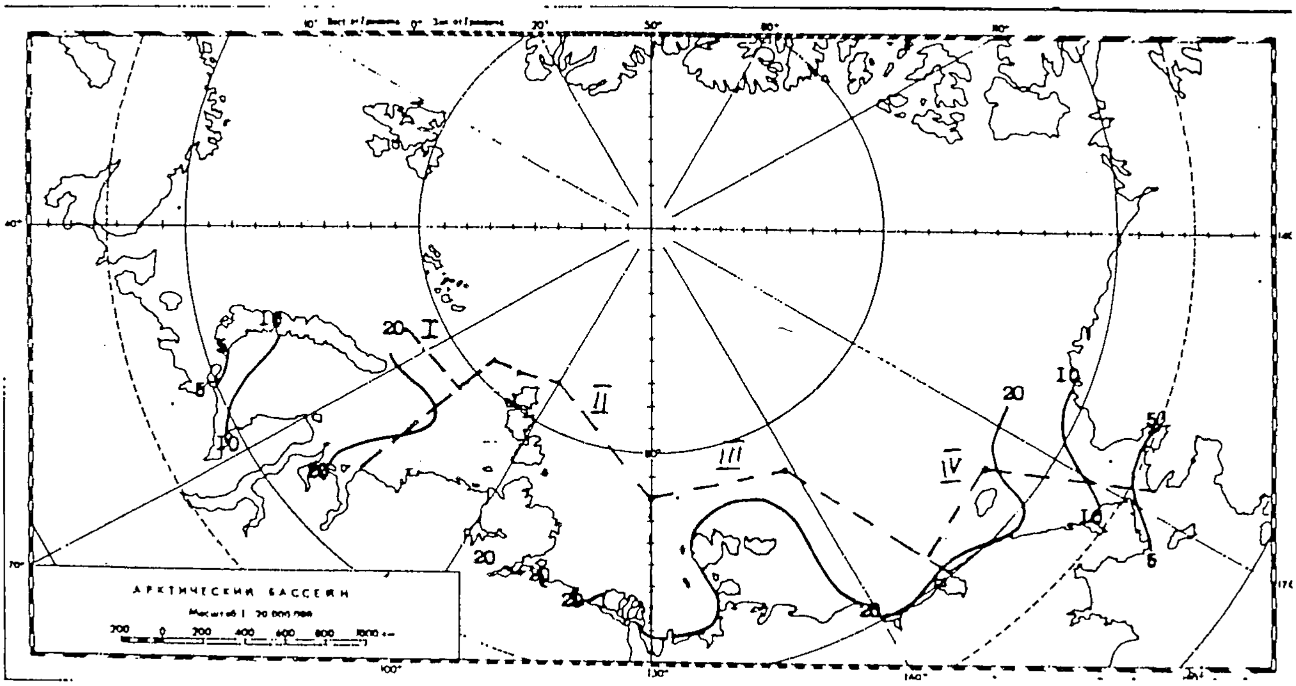

Fig. 7. The probability of fast icing of ship, % (October)

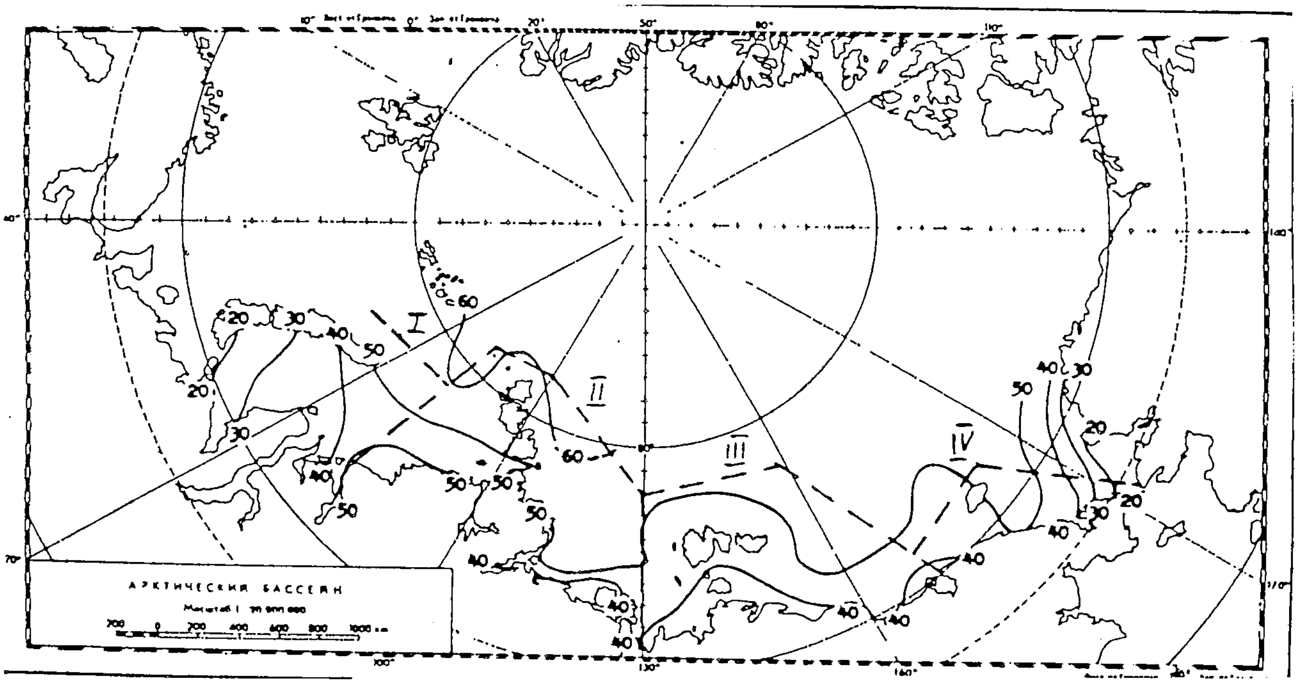

Fig. 8. The maximum value of the probability of fast icing of ship (October)

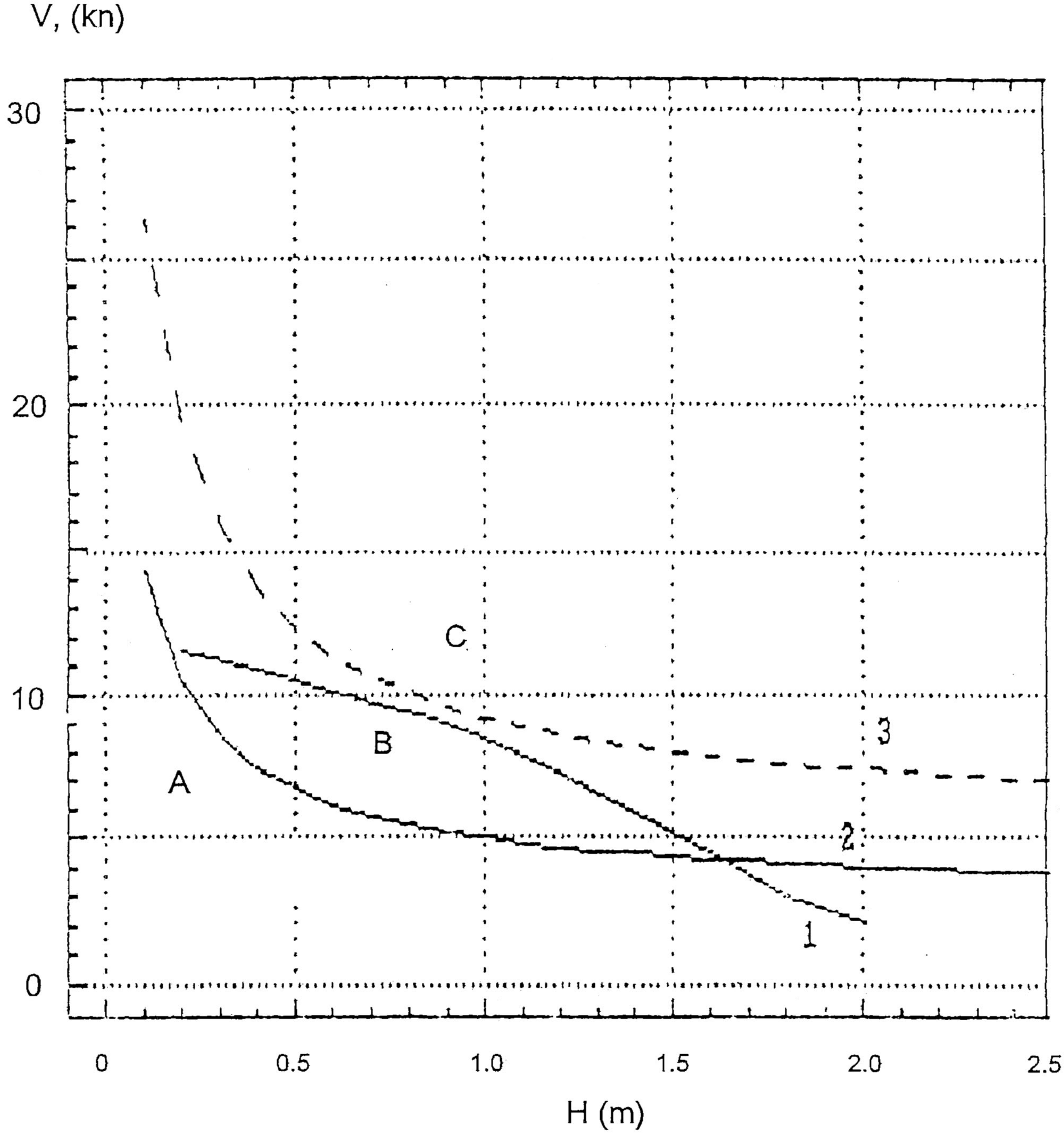

Fig. 9. Following behind icebreaker in the channel in small floe of concentration 9/10

1 - possible speed curve, A - safe zone,

2 - permissible speed curve, B - zone of possible damages,

3 - dangerous speed curve. C - dangerous zone.

As a result of the studies and generalization of full-scale observations, typical features of ice mass growth for a time unit have been found out (Table 7).

The probability values given in Fig. 7,8 refer to any ship that will be moving along the NSR, but the ice growth rate will be different (Table 7). Total ice mass that will be growing on the hull, duration of spray ice accretion being taking into account, will be rather considerable. The duration of spray ice accretion is characterized by the following data:

less than 12 h - 3.5% of all cases,
less than 24 h - 89.9% of all cases,
less than 48 h - 98.1% of all cases.

Hence, at a rapid ice accretion (see Table 7) total ice mass on the ship, for example of the "V.Bering" type can be 7 t/h·48 h=336 t.

Table 7. Ice mass forming on ships of a large tonnage at ice accretion, t/h

Type of ship	Ice mass growing on ship for 1 h at ice accretion		
	slow	rapid	very rapid
nuclear icebreaker "Lenin"	0 ... 0.6	0.6 ... 1.2	> 1.2
nuclear icebreaker "Arktika"	0 ... 0.6	0.6 ... 1.4	> 1.4
icebreaker "Ermak"	0 ... 0.5	0.5 ... 1.4	> 1.4
icebreaker "Sorokin"	0 ... 1.0	1.0 ... 1.3	> 1.3
"Noril'sk" (SA-15)	0 ... 0.6	0.6 ... 1.7	> 1.7
"Vitus Bering"	0 ... 2.8	2.8 ... 7.0	> 7.0

It should be only stressed that presence of remaining ice typical of the regions II, III, IV at the end of the navigation period, as well as intensive formation of young ice in all NSR regions in October are considered to be the main reason for a sufficiently low probability of a very rapid icing of ships over much of the NSR (see Fig. 7, 8).

So, in order to prevent ice accidents it is useful to know not only the contents of normative-reference manuals and handbooks (Guide-book, 1995), recommendations of experienced masters (Gotsky, 1961;

Chubakov, 1987; etc.), but also systematized information on the features of ice conditions of each of the navigation regions and, primarily, on a possibility of occurrence of dangerous natural phenomena and especially dangerous phenomena for shipping.

According to the results of analysing ice accidents, 48-59% of their total number fall on navigators who have experience in ice navigation for a year and less.

Hence, training of navigators for Arctic shipping is very important for avoiding accidents when navigating in ice.

3 INFLUENCE TYPE AND STATE OF SHIPS ON THE EFFICIENCY AND SAFETY OF NAVIGATION IN VARIOUS ICE CONDITIONS OF THE NSR

To enhance navigation safety on the selected route it is necessary in addition to information on natural conditions to take into account type and state of ships. Some safety level is provided by the normative-reference requirements (Rules, 1993; Requirements, 1993). However, they cannot consider all diverse conditions and modes of navigation, features of a specific ship and characteristics of ice situation.

That is why in the 60s the AARI was proposed to provide ships navigating in ice with ice passports that are being developed for each ship (or several ships of one series) that contain recommendations for choosing safe navigation speeds depending on the mode of navigation (single, in a convoy following icebreaker, etc.) and ice conditions (thickness, concentration, fracturing and other ice characteristics (Maksutov, Popov, 1981; Faddeyev et al, 1985, 1988). Since that time the methods have been carefully improved and tested in full-scale conditions along the NSR route (Likhomanov, Solostyansky, 1981) and during model tests in the ice tank of the institute. In total 15 passports were prepared, including the last one for the M/V "Mekhanik Yartsev" according to the order of the Northern Shipping Company in 1993. In the Rules for Classification and Construction of the Sea Register (the USSR Register) that are now in force the following has been stated about the use of ice passports: " it is stipulated that in the course of operations a shipowner will be guided by the requirements of an ice passport developed by an authorized institution that specifies conditions for a safe maintenance of ship in ice depending on the sign of the category of ice conditions, ice belt structures of ship and ice support" (Rules of classification, 1990, p.270).

A typical ice passport includes the following main sections:

1. Instruction for maintenance.
2. General characteristics of ship and its ice properties.
3. Diagrams for determining safe velocity at independent ship navigation in different ice conditions (solid ice, small floe, ice cake).
4. Diagrams for determining safe routing parameters when ship follows icebreaker (in various ice conditions).
5. Diagrams for estimating advisability of the routing of ship by Arctic icebreakers of different types.
6. Different Annexes.

The recommendations in the ice passport for choosing safe navigation velocities are given in the form of illustrative diagrams plotted in coordinates: V - motion speed in ice, h - ice thickness either in coordinates V and s, where s - ice concentration. The field of diagrams is divided into three zones by two boundary curves: safe and dangerous velocities. However, four types of velocities are defined: achievable, permissible, safe and dangerous.

Achievable - velocity that ship is able to develop under these ice conditions at a full capacity of a power plant. It depends on ice navigation conditions, form and particulars of ship, capacity of its power plant (i.e. it is governed by ship performance in ice).

Permissible - the largest velocity that ship can move in ice without damaging the hull. It depends on ship's mass, shape of the hull, construction strength of structures calculated in the elastic zone, i.e it is limited by the ice strength of the hull.

Safe - maximum velocity that ship is capable to develop in these ice conditions not being assuredly subjected to a risk of obtaining hull damages. It is determined in a graphic way by comparing achievable and permissible velocities.

Dangerous - velocity that when reached and especially exceeded can result in significant damages of the hull structures up to an accident. It depends on the hull strength calculated on the basis of the conditions of work of the structures in the plastic zone.

Three zones of the field of diagrams characterize different conditions for ship navigation (a degree of navigation risk). Accordingly, a safe navigation zone (zone A) is restricted by coordinate axes and by a curve of safe velocities. A transient zone (zone B) lies between the curves of safe and dangerous velocities. A dangerous zone (zone B) is located above and to the right of the curve of dangerous velocities. When navigating at velocities within the zone A, ship will not obtain any ice damages. When navigating at velocities within the zone B, ship can obtain moderate damages of the hull. Navigation at velocities within the zone B will inevitable result in serious damages that may lead to cargo damage, need for urgent repairs of ship or even its loss.

Fig. 9 below presents achievable, permissible and dangerous velocities for the M/V "Mechanik Yartsev" (ice category L1) in the case of moving in small ice floes of 9/10 in concentration escorted by icebreaker. As is evident, navigation with an achievable velocity (curve 1) is connected with a risk of being damaged (zone B, h=0, 25-1, 65 m).

Thus, the solution of the problem of choosing an optimal mode of ship's motion under specific ice conditions and making navigation more safe is facilitated and simplified by using an ice passport.

At present software for a computerized ice passport has been developed. A navigator having an ice passport onboard, can receive information for choosing a safe motion velocity, manoeuver characteristics on an operational basis in answer to the information on observed ice conditions.

As follows from the description of an ice passport, it is important to take into account ice category of ships. However, up to the present time the question of a common classification of ships of ice navigation has not yet been finally resolved.

Historically, classification and, hence, rules for designing ice ships are possible by two methods: on the basis of regulating parameters of ship performance in ice (i.e. usually, ice passage capability in continuous ice is guaranteed) and on the basis of providing the necessary strength of the hull at ice loads (i.e. safe navigation in ice conditions is guaranteed). The first method is typical of the Canadian

Rules 1972 and their interpretation in the rules of the German Lloyd and Lloyd's Rules, Finnish-Swedish Rules for the northern Baltic, Norwegian Veritas. The second method is shown in the USSR Register and American Buro of Shipping. The last draft of the Canadian Rules introduced in 1994 makes use of the second concept for the formation of design requirements.

The modern rules of the USSR Register (Rules of classification, 1985, 1990) use a hydrodynamical model of a hull impact on ice for calculating ice loads and designing ice belt structures (Popov, Kheisin, 1967) developed by the AARI and the Leningrad Shipbuilding Institute (Kurdyumov, Kheisin, 1974). Ice parameters directly involved in calculation of ice loads are as follows: σ_f - flexural ice strength, σ_c - compressive ice strength; R - floe edge radius; a_p - dynamic ice strength; h - ice thickness. The earlier published Rules used only σ_f. The USSR Register Rules in force have a different classification of ice-strengthened ships and icebreakers. This is caused by different strength criteria of the hull structures (ultimate strength and fibre yield, respectively). The calculated ice parameters h, σ_f, σ_c, a_p prescribed in approximation dependencies for ice loads are identical to the ice class of ship. Ice thickness also depends on ice category, unlike R that is assumed to be constant for all cases (R=25m).

A new concept for the ice rules of the Russian Register that is planned to be published in 1994-1995 formed by the Krylov Central Research Institute (CNII) with participation of the State Marine Technical University (Development, 1993) is based on the ice class corresponding to a permissible motion mode in ice (without the division into ships and icebreakers). In the new edition loads are calculated using specified values of σ_c and a_p (Appolonov, Nesterov, 1991) that are assumed to be dependent on ice thickness in the form:

$$a_p = a_p^0 \varphi(h) \qquad \varphi(h) = h$$

$$\alpha(h) = \frac{1}{6} + \frac{(h-1)}{12}, \qquad at \quad h>1,$$

where h - dimensionless ice thickness. Formulas for σ_c have a similar form.

However, the largest changes and additions to the rules in force (Rules of classification, 1990) are to be introduced with regard to taking into account natural conditions under which ships in the NSR zone operate. First of all, this is the use of the existing division of this route into western and eastern sectors, consideration of seasonal differences in navigation conditions (summer-autumn and winter-spring seasons). Then it is planned to differentiate navigation by types (extreme, heavy, medium, easy) and modes of ship navigation (self-contained or escorted by icebreaker).

The enumerated changes and other additions reflect an objective need for both adequate requirements to ships and conditions of their use in the NSR zone.

One of the most complicated objectives is an estimate of potentially possible damages of a specific ship in the region with prescribed ice cover characteristics in advance.

Undoubtedly, experience of navigators is of vital importance. However, in some cases it is quite useful (and sometimes necessary) to calculate potential damages.

The calculation technology has been developed at the AARI and it consists of the following stages:

1. Delineation of segments with uniform ice characteristics on the selected navigation route.
2. On the basis of known typical features of spatial-temporal changes of each of the characteristics considerably influencing ship/ice interaction forces, probabilistic distributions of these characteristics are plotted.
3. For a specific ship a probabilistic ice load distribution on the ice belt regions is calculated on the basis of a determinate model of hull/ice interaction.
4. On the basis of failure (in this section two criteria are used: fibre yield and ultimate state) the curves of the state of the ice belt structure of ship are calculated (Fig. 10).
5. The probability of a failure of the ice belt region structure is calculated on the basis of the curves of the state and load distribution.
6. The construction reliability in each of the ice belt regions is calculated using a full probability scheme.

As an example, the main calculation results for ship of the "Pavlin Vinogradov" type, UL category, operating in ice of region I in winter and region IV in summer, are given below.

The ice belt characteristics are presented in Table 8. These data are used in calculations (Fig. 11).

Calculations of the probability of damaging the outside plating of the ice belt in the bow part of ships were made for the two regons of the NSR: region I - in winter and region IV - in summer.

The result of the enumerated operations is a probability of the structure failure by a chosen criterion (Fig. 12).

Table 8. Ice belt characteristics on the level of cargo waterline of the "Pavlin Vinogradov" ship

N	x	y	α_i	β_i	t	a	σ_y
1	61.0	0.25	20	26.5	20	360	360
2	54.9	2.4	19	26.0	20	360	360
3	48.8	4.5	18	25.0	20	360	360
4	42.7	6.6	15	23.0	20	360	360
5	39.7	7.3	14	19.5	20	360	360

x,y - coordinates (m) of the waterline curve in the ship coordinate system;

α_i - angle between waterline and diametrical plane (deg.);

β_i - angle between board crossection and waterline (deg.);

t - ice belt plating thickness (mm);

a - frame spacing (mm);

σ_y - ultimate yeild of the plating material (MPa)

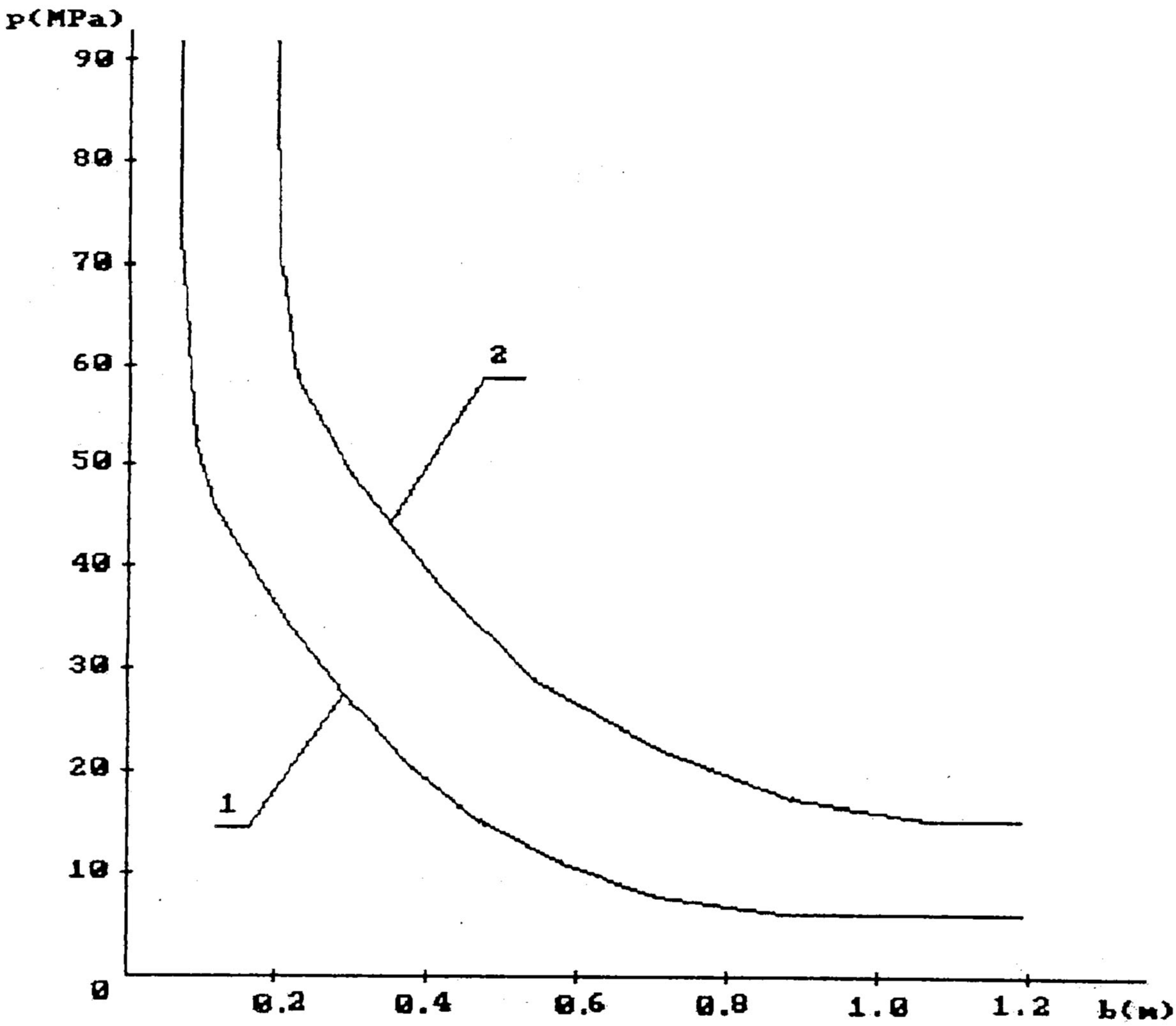

Fig. 10. Curves of the state of outside plating of the "Pavlin Vinogradov" ship, bow region;

1. Fibre yield curve.

2. Ultimate state curve.

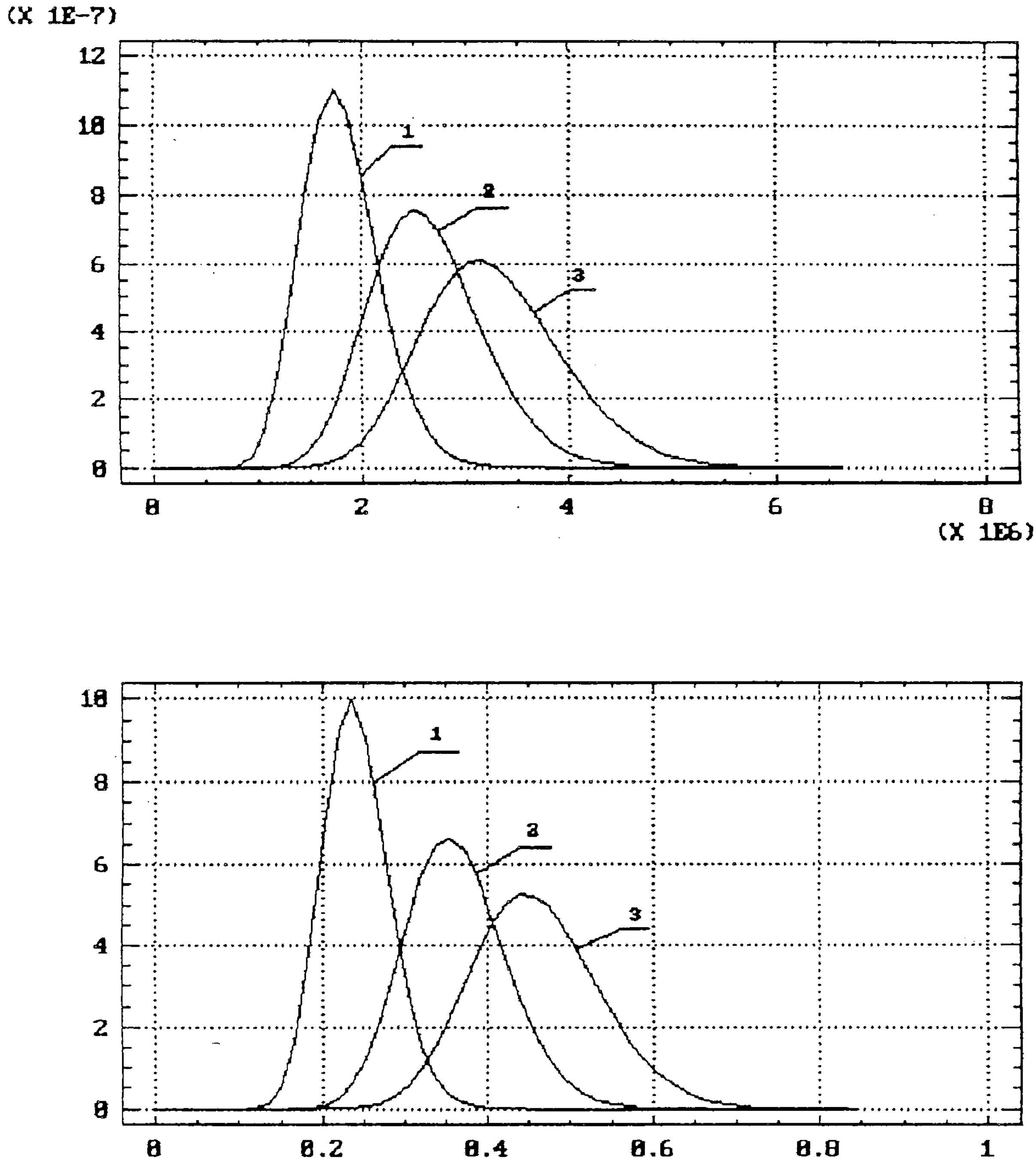

Fig. 11. Distribution of ice load parameters on the third theoretical crossection of the "Pavlin Vinogradov" for Region I. Velocity of the impact with ice:

1 - 3 knots,

2 - 6 knots,

3 - 9 knots.

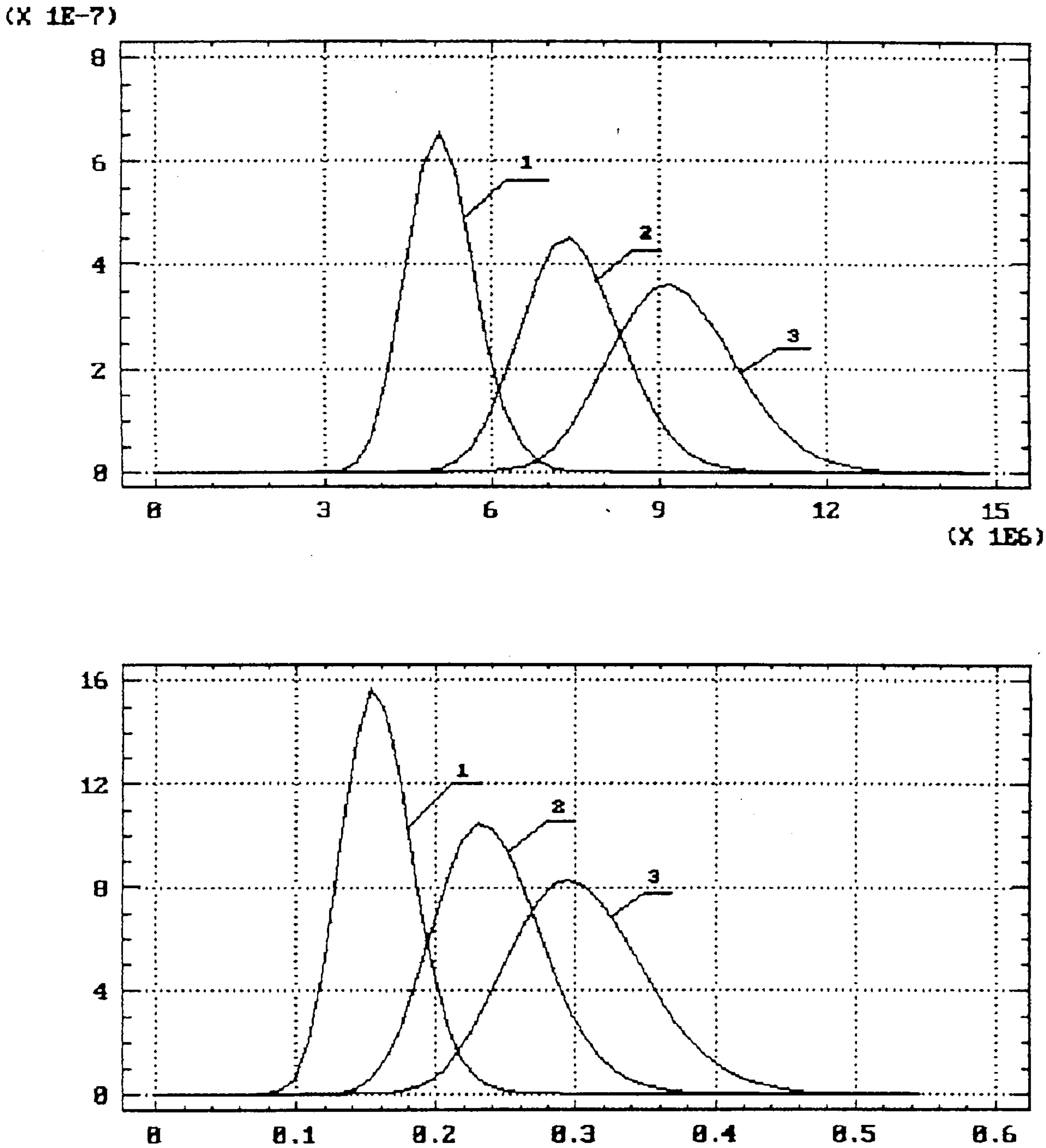

Fig. 12. Distribution of ice load parameters p (Pa) and b (m) on the third theoretical crossection of the "Pavlin Vinogradov" for region IV. Velocities of the impact with ice:

1 - 3 knots,

2 - 6 knots,

3 - 9 knots.

The generation of sampling of load parameters on the ice belt regions was performed on the basis of the dependencies of hydrodynamic impact model for three velocities of the impact with ice: 3 knots, 6 knots and 9 knots. Random values of p and b are approximated by G-distribution of a general form (Fig.11,12).

Then the probability of the structure failure is calculated by a chosen failure criterion and respective reliability. The results of calculating the reliability of the ice belt plates are given in Tables 7 and 8. These results can be interpreted as follows: for the chosen velocity of the impact with ice the reliability by fibre yield criterion means a probability of non-accumulating remaining deformations of the outside plating, the reliability by ultimate strength criterion means a probability of not receiving large one time plastic deformations for the considered ice belt region on a given NSR segment during a prescribed navigation season.

The above calculations are given only for the ice belt plating illustrating the suggested approach that has significant default reserves in the following directions:

1. Enlargement of a structural element to which ice load up to grillage with ice belt structures is applied. To take into account a non-linear structure behaviour it is necessary to calculate grillages not on the basis of a traditional beam idealization, but as a set of plates and shells. It is necessary to construct the structure state surface in six-seven-dimensional space that takes into account all parameters of loading. The state surfaces should be supplemented by a destruction criterion of the structure.

2. Taking into account a real diagram of the stress-strain material state with strengthening after the yield area.

3. A more accurate description of environmental parameters influencing the ice loads in terms of the probability theory. Obtaining of the database of such parameters.

4. Additional studies on the interaction mechanism of a solid body and ice that will allow a significant specification of dependencies for ice loads.

5. Obtaining of a correlation between damages of the ice belt and bottom structures that will allow a description of ice loads. For this purpose it is necessary to finalize the database on ice damages developed in the INSROP framework.

6. Taking into account wear of the hull for forecasting of both real and normative damage.

A practical application of the presented methods can be made in the following areas:

1. Insurance of ships and cargos for ice navigation. To this effect, it is necessary to estimate the cost of the consequences of damages both during normal operations and during accidents resulting in cargo damage and environmental pollution.

2. Establishment of a normative base of a new generation for designing ice belt structures that is based on a prescribed reliability of the structure that is, in turn, determined proceeding from the conditions of sufficiently safe ice navigation.

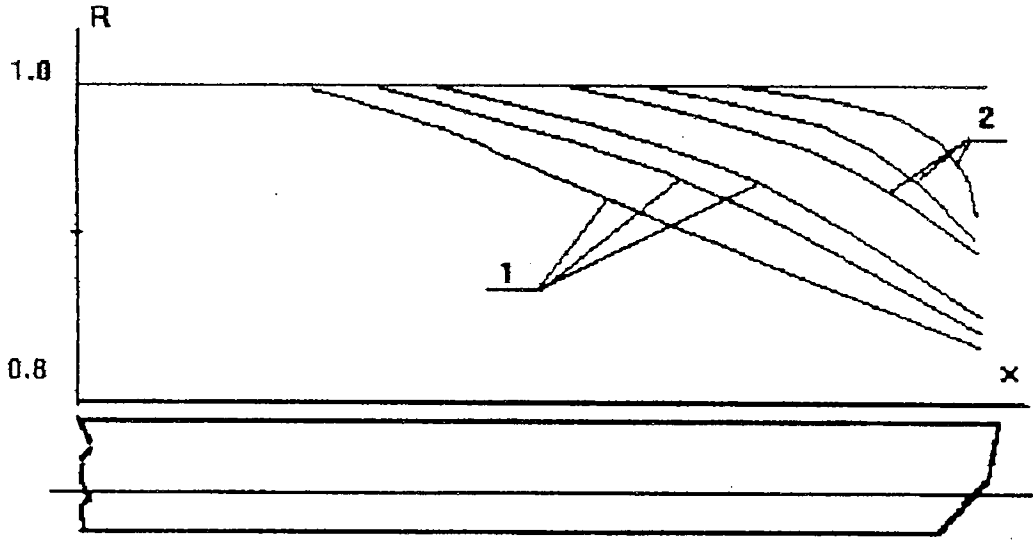

Fig. 13. Reliability of ice belt plating in Region I by a fibre yield criterion (curves 1) and by ultimate strength criterion (curves 2), x - plate position by the ship's length. The curves correspond to different ship motion velocities

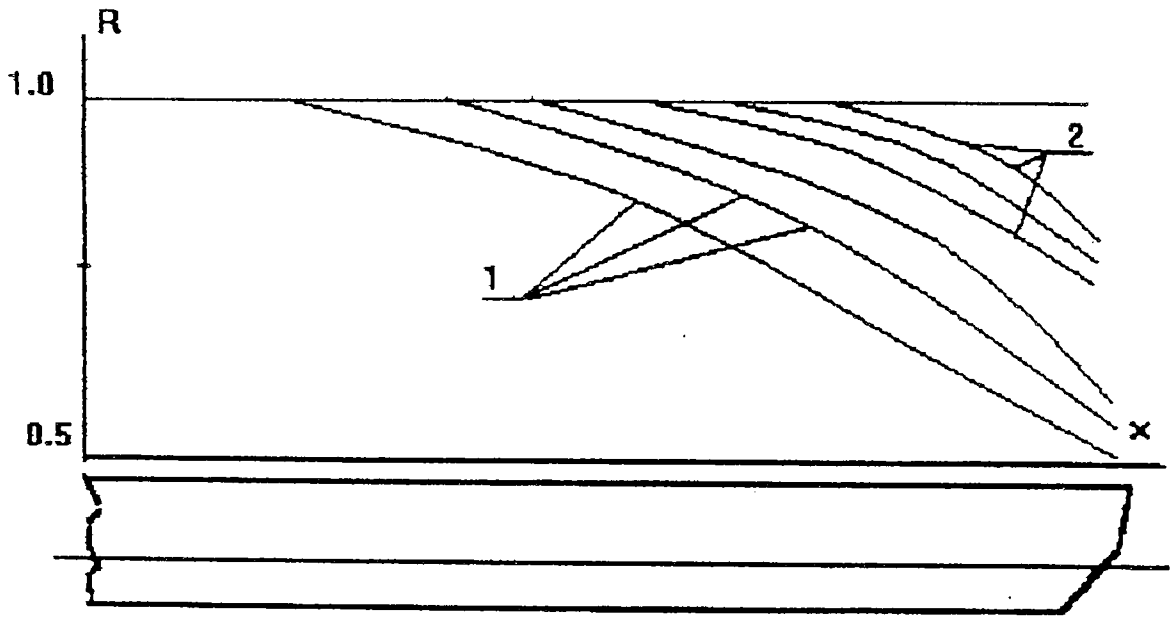

Fig. 14. Reliability of ice belt plating in Region IV by a fibre yield criterion (curves 1) and by ultimate strength criterion (curves 2), x - plate position by the ship's length. The curves correspond to different ship motion velocities.

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REVIEW of the International Northern Sea Route Programme (INSROP) Working Paper
Sub-Programme I: Natural Conditions and Ice Navigation
Project I.1.2 Operational Aspects
Volume 2 - 1994 project work and Volume 3 - 1995 project work

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This is a fine collection of work on the Northern Sea Route (NSR). The data presented is valuable and not generally known, at least in the western body of literature. It makes a valuable contribution toward understanding the operational issues of navigating the northern sea route.

The paper reviewed is presented as two volumes, the results from the work in 1994 and 1995. Each of the two volumes contain two parts, one prepared by CNIIMF and one prepared by AARI. The authors considered many operational issues on the Northern Sea Route such as legal and cartographic support, communication, vessel performance, etc. The reader is aware that each volume contains a collection of single independent reports which cover a range of somewhat unrelated topics, linked by the fact that they all relate in some manner to operation along the NSR. It is supposed that the objective of this project is an attempt to put together information about all the operational aspects connected with planning and conducting shipping on the NSR so that the most important issues can be selected for further development. If this is an intent of this research, it would be desirable to state this clearly in the introduction of each volume. The whole work may benefit by having an introduction that explains that the work was done over several years, is presented in two volumes, and combines the descriptions of the individual volume introductions.

Specific comments for individual sections of the paper are given below:

Section I.1.2.4 Communication in the Volume 3 (1995).
Taking into account that one of main elements of maintaining reliable communication on the NSR is the satcom systems, it would be useful to show in detail how reliable SES Inmarsat-A and C reception is in various modes because of the low elevations of satellites.

Section I.1.2.7 Vessel Performance of the part prepared by CNIIMF. Volume 3 (1995).
It is very hard to read the lettering on Figure 7-1.

Section 1.1 of the part prepared by AARI. Volume 3 (1995).
Figures 2 and 4 are identical.

Section 1.1 of the part prepared by AARI. Volume 3 (1995).
Three types of description of the ice conditions are considered. There is no description of the criteria for select these types. Some basis for the frequency of occurrence should be described.

Section 2.1 of the part prepared by AARI. Volume 3 (1995).
The word "remind" is used in connection with deflections and stresses. I believe the proper terms in English are permanent deflections and residual stresses for what the author is trying to describe.

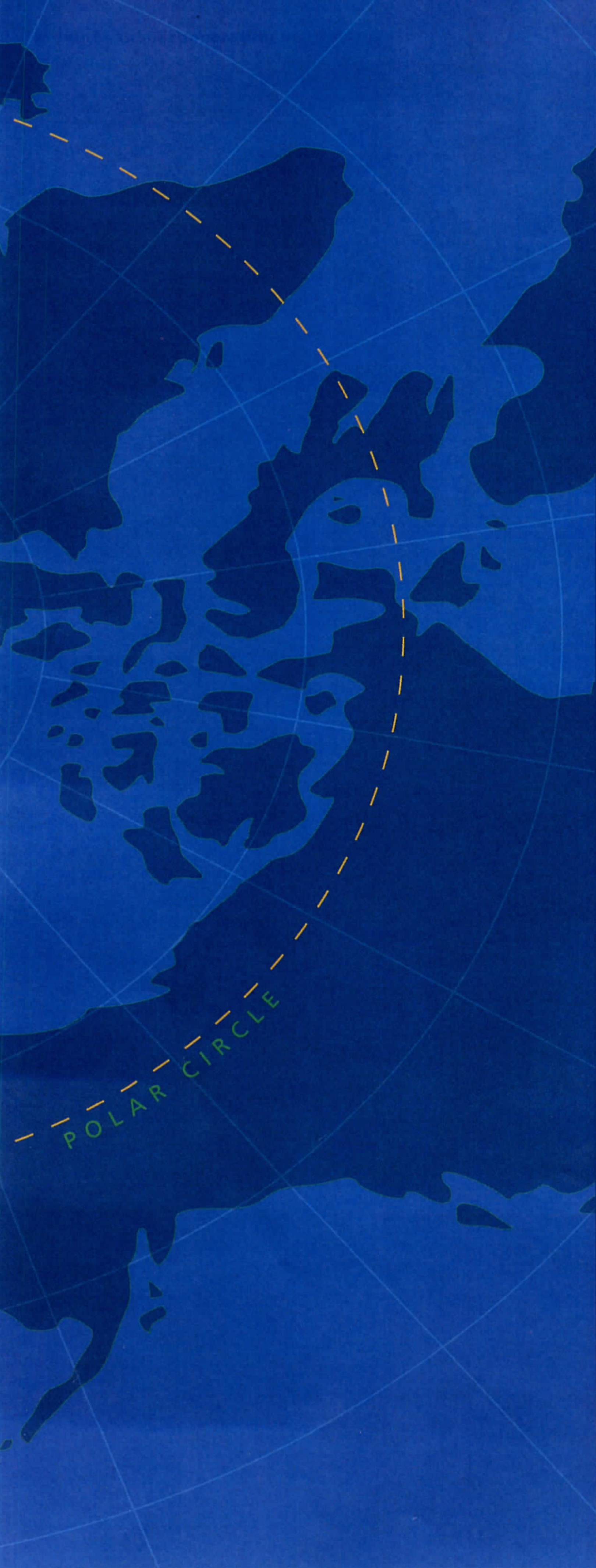
Section 2.2 of the part prepared by AARI. Volume 3 (1995).
Figure 17 is illegible and should be translated

General comments are as follows:

- Summary and key words are absent in sections I.1.2.2, I.1.2.5 and Part II;
- some sections have no conclusions;
- there aren't numbers and titles on the tables in section I.1.2.5;
- some sections do not have references.

The publication of the INSROP Discussion Papers "Operational Aspects" by Dr. A.Baskini et al. are recommended for publication after editorial changes. The reports contain the valuable technical information for Northern Sea Route shipping development. I appreciate the opportunity to provide comments on this report.

James W. St. John



The three main cooperating institutions of INSROP

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

Central Marine Research & Design Institute (CNIIMF), St. Petersburg, Russia.
CNIIMF was founded in 1929. The institute's research focus is applied and technological with four main goals: the improvment of merchant fleet efficiency; shipping safety; technical development of the merchant fleet; and design support for future fleet development. CNIIMF was a Russian state institution up to 1993, when it was converted into a stockholding company.

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