3.3. Ice observations from the ship

3.3.1 Types of ice observations from the ship.

Large amount of material from ship expeditions has been accumulated for a long period of studying and exploring Arctic. A whole series of most essential parameters of state and evolution of ice cover can't be measured due to transition from airplane ice observations to remote sensing methods (monitoring of ice conditions using satellite). These parameters are the following: ice thickness, ice ridging, melting stage, compacting and etc. Observation materials, accumulated for previous years, and data of ship observations at present time, are the only sources of information on these parameters. Modern technology of ice cover monitoring can be based on them.

The sources of the ship data are the following:

– Special ship observations (small-scale characteristics of ice cover elements and operational indicators of ship motion);

– Navigator's observations, stored in dispatcher's report, duty log, voyage reports of captains and ship hydrologists;

– Summary ice charts of routes (sea operations), placed in expedition's reports, similar to composite ice charts by their spatial resolution;

– Ice observations, provided by foreign specialists.

3.3.2 Special ice observations from the ship.

Purpose of special ice observations from icebreaker is to obtain new natural data to detect regularities of small-scale variability of ice parameters, which significantly influence navigation efficiency, and to account ship operation characteristics during its motion in different ice formations.

Special ice observations have complex pattern, which allow to use obtained natural data for solving both practical and scientific tasks.

Main tasks of special ice observations are the following:

a) Detailed observations of ice cover characteristics' distribution along the ship route, which essentially influence efficiency, safety and reliability of ship sailing;

b) Measurement of operation indicators of ship motion in main ice formations with small discreteness;

c) Natural data obtaining about functioning of the system "ice/ship" and "ice/ convoy of ships";

In period 60s – 90s AARI specialists quite regularly conducted special ship observations of sea ice characteristics distribution along the navigation route and their effect on ship motion.

Regularities, obtained from the observations, formed the basis for ice cover description in the freezing seas as an environment for navigation, and for creating method and empirical model of quantitative accounting of ice navigation difficulty.

Further development of ice cover research, as an environment for navigation, and perception of laws of the system "ice/ship" functioning are connected with studies of influence of spatial-temporal variability of ice cover on the navigation efficiency and safety, development of risk estimations and ice navigation reliability algorithms, and verification of information from modern remote sensing facilities (ERS, RADARSAT high- resolution satellite images, and also passive microwave data from SSM/I and etc.).

In spite of significant amount of special observations, accumulated during previous years, the past capabilities of navigation equipment and technical instruments of ship motion control were not always corresponded to determination of spatial variability of ice cover elements along the navigation route, and visual ice observations were qualitative. Data, obtained in experiments, conducted during icebreakers and ship tests on special testing grounds (mostly in level fast ice), was an exception.

Modern observations are directed to obtain large, and at the same time, detailed information, using new instruments of recording ice cover parameters, and methodic principles, which are traditionally used in work by specialists of AARI. Such approach is substantiated by necessity in comparative analyze of ice and operational indicators, which were obtained during planned tests with data from previous years.

Special visual ice observations are carried out according to two connected directions:

1) estimation of standard complex of ice cover parameters on homogenous parts by both navigation region (within limits of horizontal visibility), and directly along the navigation route (along the ship route in a stripe with a width of sixfold, and with a length of threefold length of ship hull).

The following parameters are estimated in the navigation region:

- Total ice concentration;
- Relative areas, occupied by different ice types;
- Dominant forms of each ice type gradation;
- Dominant degree of ice ridging;
- Dominant ice rafting;
- Orientation types of leads relative to general course of the ship motion (channels, leads and fractures in the ice).

Practice of hydrometeorological support of navigation in the NSR in winter (period of maximum ice propagation) allowed detecting, that one of the most significant ice parameters for navigation is orientation type of leads relative to general course of icebreaker.

Five main types of leads are found:

– Type A – zone of “orientated leads”, where dominant orientation of lead system and general icebreaker course coincides or differ at most for 30°. Icebreaker moves steadily and mostly in leads, sometimes crossing joints of ice floes and rough edges of channels and fractures;

– Type B – zone of “non-orientated leads”, where lead orientation is chaotic or dominant lead orientation differs from general icebreaker course more than for 30°. Icebreaker motion there is less stable, than in zone A and combines sailing in channels with necessity to cross compact ice isthmus (big floes and ice brecchia) during transition from one lead system to another;

– Type C – “zone of higher ice crushing”, where sailing is stable and in the orientated zone, usually with prevalence of broken ice forms (WMO code 1-4);

– Type D – “zone of lead absence”, where icebreaker moves in close ice with concentration of 10/10-th and prevalence of ice floes. Icebreaker motion in this area is determined by combination of “traditional” ice parameters (thickness, ridging and etc.);

– Type E – "zone of decreased ice concentration”. In this zone clearly defined leads are absent, icebreaker moves in ice, which is homogenously distributed in water area, with concentration of 8/10-th or less. This type is typical for edge regions and sailing in spring (period of ice melting).

The following parameters are estimated during navigation:

– Total ice concentration;

– Relative area occupied by different ice types;

– Prevalent forms of each ice type;

– Range of level ice thickness for every ice type;

– Total ridging of ice cover;

– Total melting (decay) of ice cover;

– Depth of snow for every ice type;

– Occurrence and intensity of compacting in ice cover;

– Orientation of compacting axis in ice cover;

– Condition of channel, made by icebreakers (width, tortuosity, ice floes sizes in channel).

Observations are conducted according to “Instruction for ice observations from ship”, elaborated at AARI in 1975.

2) To reveal regularities of small-scale variability of ice parameters, which significantly influence navigation efficiency, in the course of expedition additional observations of the following parameters are conducted:

a) ridging:

- Maximum sail of hummocks;
- Average sail of hummocks;

b) leads:

- Average width of leads;
- Length of sailing route in leads within the limits of homogenous ice zone;
- Time of icebreaker/ship motion in leads, with a width comparable to the beam athwarthship.

c) compacting:

- Compacting type (compacting “block”, “joint”);
- Route length in compact joints of ice floes within the limits of homogenous ice zone.

These set of ice parameters is determined for homogenous ice zones. Zone is considered to be homogenous, when all ice parameters change within the limits of accuracy of usual observations.

Measurements of linear characteristics of ice cover are conducted using satellite navigation instruments of new generation (GPS) and ship radar.

3.3.3 Recording of ship motion operative indicators

Several operational characteristics, describing ice/ship system functioning, are recorded at the same time with ice parameters for every homogenous zone:

- Time and coordinates of beginning/end of homogenous ice zone to determine its length;
- Convoy warrant order (in case of steering);
- Type of autonomous ship motion (uninterruptedly, with run);
- Time of work with runs;
- Number of runs;
- Time of blocking (in case of ship blocking);
- Type of ship motion in convoy (independent, in tow);
- Time spent on ice breaking around the ship and ship towing;
- Used power of icebreaker’s power installation system;

– Scheme of control panel of icebreaker's power installation system.

Recording of geographical coordinates of ship location (GPS-data) is made on the HD of PC with small discreteness (~ 1 minute) during the entire period of sailing in the ice. This type of information allows receiving pattern of ship velocity distribution in main ice formations and homogeneous ice zones, coefficient of navigation route meandering.

3.3.4. Meteorological observations.

Meteorological observations from ship/icebreaker consist of observations of the following parameters:

– Air temperature;
– Direction and velocity of wind;
– Atmospheric pressure;
– Horizontal visibility;
– Type and nature of atmospheric phenomena.

Meteorological observations are made using automatic weather station. Data of weather station is automatically recorded on HD of PC, and also is recorded once a watch (4 hours) or when any weather parameter sharply changes. Observations of horizontal visibility are visually and constantly made.

Ship observations are conducted around the clock from the bridge (6 watches, each for 4 hours).

Change of geographical location of ship (drift) is determined every hour during icebreaker/ship station to conduct experiments on ice.

3.3.5 Navigator's ice observations.

Ice observations, conducted by navigators, consist of generalized data (for particular time interval, (usually for one watch) about main ice parameters in navigation zone with geographical coordinates and time (date) of beginning/end of navigation in this area. In case of abrupt changes in ice conditions – strong compacting, ship approaching ice edge or near edge divergence and etc., navigators record time of ice phenomena and its geographical coordinates.

Navigator's ice observations usually include information about the following ice parameters:

– Total ice concentration;
– Ice type composition;
– Dominant forms for each ice type;
– Total ridging of ice cover;

– Total degree of destruction (melting) of ice cover;

– Compacting and its intensity in the ice;

The operation factors, shown in the recording of navigator's observations, are the following:

– Time and coordinates of generalized area beginning/end;

– Convoy order (in case of steering);

– Type of autonomous ship motion (uninterruptedly, with runs**);**

– Time of blocking (in case of ship blocking in ice);

– Type of ship motion in convoy (time, spent on ice breaking around the ship, its towing and etc);

– Used power of icebreaker's power installation system;

– Scheme of control panel of icebreaker's power installation system.

Meteorological observations include observation of the following meteorological parameters:

– Air temperature;

– Direction and velocity of wind;

– Atmospheric pressure;

– Horizontal visibility;

– Type and nature of atmosphere phenomena.

These observations are obligatory recorded in the duty log, and are also included in dispatcher's reports.

3.3.6 Ice observations, made not by methodic of AARI.

Ice observations, made not by methodic of AARI, contain generalized data, for predefined time interval (normally for 1 or 3 hours), about ice parameters complex in the navigation region with geographical coordinates and time (date) of beginning/end of navigation in this zone. A set of observed ice parameters in different expeditions can significantly change. Nevertheless, it usually contains data about the most important parameters: total concentration and ice type composition in the region of ship navigation, ridging characteristics, leads and puddles, ice thickness and snow depth, compacting and etc. Apart from that, this type of observations contains data about velocity and type of ship motion, indicators of ship power installation work; meteorological data and notes.

This type of observations is more detailed analogue of navigator's observations.

3.3.7 Other data.

When ship ice observations were not conducted or observational data is not available, there is data that in some cases allows estimating difficulty of ice navigation in the Arctic Basin. Information about time and geographical coordinates of ship (with discreteness of 1-10 minutes), received from satellite navigation system of the new generation (GPS), can be referred to this data.

Regularities of spatial-temporal variability of ice cover elements, discovered in the course of ship observations, and their influence on ship motion (convoy of ships) are used for:

- Adaptation of empiric model of quantitative estimation of ship navigation difficulty in ice;
- Development of empiric-analytic model of ship motion (convoy of ships) in real ice, based on theory of ice resistance to ship motion and empirical relations;
- Development of algorithms of reliability and risk assessment for navigation of different ship types in the ice;
- Development of algorithms of computer simulation marine transport system functioning;
- Creating a real base for special meteorological support of marine navigation – choice of optimal variants of navigation, development of new methods of specialized ice forecasts and etc.;
- Verification of modern remote sensing (satellite) data about ice parameters distribution along the navigation route, especially of those that cannot be detected from satellites at present (compacting, ridging, rafting, ice thickness, decay and etc.);
- Analysis of tensometric measurements of loads distribution on tanker hull in different ice conditions.

3.3.8 Recording of observation data

Ice observation data is recorded on the following carriers:

— Observation log. It is filled during observations in accordance with a set form.

— Digital observation log. Development of digital version of observation log is carried out at the moment at AARI. This log consists of program complex, which interface allows ice expert to record ice parameters values on computer HD in real time, and hardware complex, which includes PC and receiving indicator of GPS.

— Digital tables (database)

3.3.9. Database composition (structure)

Database of ice navigation conditions was formed for storing, systematization and analysis of ice observations from ships. Database is permanently renewing and consists of results of ship observations in the Arctic and other freezing seas and in the Arctic Basin

The database consists of two blocks:

Block A – special ice observations from the ship.

- Element (line) of database is homogenous ice zone with fixed geographical coordinates and time (date) of beginning/end of sailing in it;
- Element (line) contains: ice cover parameters, separately for the sailing region, and separately directly along the sailing route, operation indicators of ship motion; notes.
- Values of characteristics (indicators) of database can be observed (measured), calculated, absent (or non-observed).

B) Ship ice observations, conducted by navigators and other specialists and carried out not by methodic of AARI.

- Element (line) of database is generalized characteristics of navigation ice conditions for particular time interval (watch, one hour and etc.), with fixed geographical coordinates and time (date) of beginning/end of sailing in this zone;
- Element (line) contains: ice cover characteristics – by zone of navigation (within limits of horizontal visibility); operation indicators of movement; meteorological conditions of navigation, notes;
- Values of characteristics (indicators) of database can be observed (measured), calculated, absent (or non-observed).