SHIP OPERATION IN WINTER AND IN ICE CONDITIONS

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Contents

Summary

This chapter describes the navigation of a ship in an environment with air temperatures around and below zero degrees Celsius. Under these conditions the following have to be expected: water with ice coverage, snowfall, icing on deck and the freezing of water, condensate and other liquids on board of the ship. The vessel's classification starts with no ice class for very easy winter conditions and ends up with ice class for the high Arctic. Therefore the ship's handling varies over a wide range and must be adapted to the actual ice conditions and to the ice class of the vessel.

National and international rules regulate the quality of ships and equipment, qualification of the crew and the seasons when high latitude areas can be entered. Rules and regulations are changing quickly and are not part of this chapter.

1. Ship Operation in Cold Air Temperature

With the planning of a voyage to areas with winter conditions it is necessary to check first the environmental conditions (air temperature, ice conditions, danger of icing to the ship etc.) and the capabilities and classification of the vessel for those conditions (see. *Ship-Ice Interaction in Ship Design: Theory and Practice*, Tables 2 to 5).

It is self-evident that the vessel has to fulfil the international and national rules and regulations. These include the International Safety Management Code ISM (IMO). Furthermore in some areas the vessel needs permission from the authorities before entering.

Additionally the master should prepare a checklist for his ship in preparation for sailing in cold temperatures and in ice covered waters. The checklist should cover the areas of Rules and regulations and also operational aspects including the effect of ice and snow on deck and icing to everything above the water level. The vessel must be completely operational under such conditions (see *Ship-Ice Interaction in Ship Design: Theory and Practice*) for Winterization Aspects.

1.1. Easy Winter Conditions

Any vessel may navigate in easy winter conditions where no ice class is required. Nevertheless the ship and crew must be prepared for winter navigation. For this it is common for ships sailing in cold regions to have some suitable equipment on board, for example:
- Winter clothes and winter shoes for the crew,
- Snow shovels,
- Salt and sand to prepare a safe way over the deck.

All pipes above the waterline and on deck which are filled with water must be drained but also ready for use (fire fighting system e.g.). The water level in the ballast tanks must be reduced so that no water is in the sounding pipe or the air ventilation pipes above the waterline. Ballast tanks above the waterline should be filled to only about 90% with salt water and the water should be discharged as soon as possible. With time the ballast water will freeze on the outer shell inside the tank. The bridge window washer system should be empty or filled with antifreeze.

Cold air should not be allowed to penetrate into the ship. Windows and doors should be closed. If the temperature in some compartments of the ship sinks below 0°C make sure that no liquid can freeze. Otherwise heat is required in the room (e.g. cooling water of emergency diesel engines). Pay attention to all pipes in areas of air intake for the engines. Protect them with insulation material in order to reduce the danger of freezing liquids. Its expansion will crack the pipe.

Ice will form in salt water if the water temperature is below freezing. The freezing temperature of salt water depends on its salinity, the higher the salinity the lower the freezing temperature. For example, at 35 psu (e.g. 3.5% by weight of NaCl salt water) the freezing temperature is –1.9 °C. Figure 1 shows the river Elbe and the port of Hamburg with drifting brash ice and multi layered ice blocks. In these ice conditions the ship's resistance is slightly higher. Usually all ocean going vessels have enough power to sail under these ice conditions. The ice floats on the water surface but small pieces of ice follow the water flow around the hull. The suction of water from the sea chest takes in the small ice pieces which may with time plug up the water intake. The bottom sea chest takes less ice. Free the sea chest from ice with either water or air when necessary, otherwise a total blackout is possible.

Figure 1. River Elbe with brash ice Feb. 2012 (Photo HSVA, Rupp)

1.2. Winter Conditions

Ships with ice class are designed for operating in ice and in cold air (Winterization), see *Design of Icebreaking Ships*.

Rules and regulations define the required ice class (see *Ship-Ice Interaction in Ship Design: Theory and Practice*) for the operation area during an ice season. In some areas the crew need special qualification and / or an ice pilot for the passage. The differences between ice classed ships are large. The class ranges from an ice strengthened ship for easy ice conditions (following an icebreaker) to an icebreaker for all heavy ice conditions in extreme cold air (e.g. –40°C). The material for the ship, the design and the equipment is adapted to the defined operation area. Therefore, a well maintained ice classed ship is the right vessel for winter navigation.

The protective measures against freezing of liquids described in the previous section are also valid for ice classed ships. However the ice classed ships are designed for such low temperatures. Attention must also be paid that the quality of the bunker fuel fulfils the regulations for the area. Furthermore, the fuel for the ship must be adapted to the expected temperature and the technical installation of the fuel tank since its viscosity is sensitive to the temperature. In the following section some special items are described.

1.3. Icing

When sailing in open water in cold air below 0°C, with water temperatures around 0°C and with wind and waves, the spray will freeze on the ship and the deck cargo. Refer here also to: *Ship-ice interaction in ship design: Theory and practice*, Figure 6. This section describes how ships operate under such conditions. When sailing against the wind and waves, spray flies over the ship and the spray water will freeze. The superstructure, masts, deck, railing, cargo and basically everything is covered with ice.

Icing has the following effect:
- Reduced metacentric height (stability) due to the additional weight of the ice on top of the ship (potentially extreme danger, risk of capsizing)
- Small ships have a higher risk of capsizing than larger ships. Therefore smaller ships should seek shelter or stay in port.
- All ship equipment which is not sheltered is not in working order (e.g. windlass, crane, manifold etc.)
- All safety equipment such as lifeboats and fire fighting systems are not operable or only limitedly operable
- Bridge windows are closed by spray ice
- Ice may drop from cranes, masts or the superstructure and injure the crew or passengers
- The deck is icy and therefore very slippery
- A container deck cargo is frozen to a block. Cargo hatches are not operable when reaching port
- Production tankers with stringers or frames on deck may collect considerable ice if the tank heating cannot melt it

In order to reduce icing when the ship is at sea and also in order to keep the vessel as operable as possible a speed reduction and a course change to reduce or avoid the spray is the right choice. Defensive sailing should be started immediately when icing starts. By taking such action the ship will be at sea longer but when entering port will have less ice on deck. The result is that it will be ready for loading or discharging cargo earlier and the lost time at sea is paid back in port.

For the mechanical removal of spray ice a wooden hammer or club could be used. In some cases water steam or other heater may be useful.

1.4. Cargo Hold and Cargo

The temperature of sea water with ice coverage is around -1.9°C on the surface (freezing point of salt water at 35 psu). With increasing water depth the temperature increases. This 'warm' water in way of the underwater hull, in comparison to the much colder air, heats the cargo hold. When the hatch covers of the cargo holds are open the cold air penetrates into the hold. All inner surfaces of the hold are exposed to cold air, and any water in contact with these surfaces may freeze.

Cargo which is stored outside of a heated shelter in a cold climate may have a temperature far below 0°C. Dry bulk cargo may also contain snow and ice. Liquid cargo can be heated up before loading but bulk cargo cools the cargo hold down. Water around the cargo hold will freeze and the viscosity of bunker oil will increase. Even the sea water along the outer shell of the ship will freeze. Ice floes will freeze to the ship causing an increase in draft and resistance.

When bulk cargo is transported from very cold areas to warm areas, areas of ice and snow between the bulk cargos will melt. The water content of the bulk cargo increases and may reach limiting values for transportation (the cargo may shift).

All cargo which is transported to or from very cold regions must withstand the low temperatures without damage. If necessary the shipper must take precautions.

In the following sections the handling of a ship in different ice conditions and situations is described.

2. Operation in Ice Covered Water

Both the ice conditions and the ships sailing in them are very different. Therefore the statements are relative. Each navigator has to find out for himself what a difficult ice situation for his ship is. For example: Ship 1 is at its limit and stops in level ice of 0.30 m. Ship 2 is sailing at high speed in 0.30 m thick level ice and is breaking the ice with the bow wave.

It is recommended to use local information from ice maps and also ice training courses which are published by Baltic Icebreaking Management (www.baltice.org) for the Baltic Sea. The Canadian Coast Guard provides information about their Icebreaker Service (www.ccg-gcc.gc.ca) and information for the Northern Sea Route NSW is published by the Northern Sea Route Information Office (www.arctic-lio.com).

Concerning ice breaking see: *Ice breaking and Ship Modeling*, *Ship-Ice Interaction in Ship Design: Theory and Practice* and *Design of Ice Breaking Ships*.

2.1. Planning of a Voyage

Ship and crew must fulfil the national and international rules for sailing in the area during the defined season (Guidelines for Ship Operation in Arctic Ice Covered Waters, IMO 2002, and Guidelines for Ship Operation in Polar Water, IMO, 2010). All necessary paperwork must be completed before entering the area. The rules determine the ice class and sometimes also define the ice breaking performance of a vessel. For example, the Finnish Swedish ice class rules 1A to 1C are for ships following an icebreaker in defined brash ice thickness. Care must be taken that the vessel is able to operate alone or with icebreaker assistance in that ice covered water.

A vessel which intends to operate alone but is just able to break the expected level ice is the wrong vessel for that area. This is because the vessel would only be able to sail at a speed of around 2 knots with maximum power when operating alone. However the ice is usually not homogeneous and therefore such a vessel stops soon in easy ridges or rubble ice and the daily distance travelled could be in the range of only a few miles. Behind an icebreaker the resistance of the following ship is higher than it is in open water (more fuel required per mile) and due to stops, starts, backing and other manoeuvres the fuel consumption increases additionally.

Having up to date ice charts, satellite images and ice routing advice service is helpful and time saving.

Depending on the area in which a ship is sailing, it should be well equipped with fuel and supplies to survive even a prolonged difficult situation.

The planning effort of a voyage increases with increasing latitude, difficult ice conditions, distance from the service location and the season. For an extreme voyage unscheduled overwinter survival should be carefully planned in advance.

2.2. Seaway in Ice Covered Water

Wind induced waves and swell are able to penetrate into ice covered water. A seaway will break the ice, and wind may press the ice together. The motion damping effect of the ice is smaller with low ice coverage. The ship will also roll and pitch in the swell. The main ice strengthening of a ship is limited to an area just above and below the defined ice waterlines. In the seaway and with the motion of the ship, ice will also contact the ship outside of the strengthened area of the hull. If the ice is thick and / or hard, for instance with growlers, multiyear ice floe, bergy bit etc., damage to the ship is probable. Single ice floes are difficult to see in a seaway and they are much more difficult or even impossible to detect with ship's radar.

In order to reduce the risk of severe damage to the hull and to avoid collision with the ice, the propeller revolutions should be reduced so that a safe course can just be held against the swell. Keeping the ship in an area with thin ice, brash ice or small ice cake would be preferable.

2.3. Navigation Chart

In high latitudes the navigation charts can have less accuracy than is usual for other areas. Even the grid may not be comparable to GPS. Therefore, follow the sounding lines in the chart using traditional cross bearings or similar methods and compare the water depth with the measured echo sounder signal. Note the GPS position for the way back or for the next voyage. Extreme attention and strongly reduced speed should be used when sailing in areas without soundings. The ship may beach on unknown shallows or rocks. In coastal areas, drifting ice may beach on the ground and then push sediments to a new shallow (scoring by grounded ice).

2.4. Safe Speed of the Ship in Ice

The safe speed of a ship in ice is the speed which can be achieved without damage to the ship from the impact between the ice and the ship. On the one side is the strength of the ship's structure (ice class) and the mass of the ship, on the other side the mass and strength of the ice (parameters: season, area). The strength of the ice differs according to the location and the season. In the Baltic Sea there is only first year ice. In the Baffin Bay between Greenland and Canada there is first year ice of higher thickness than in the Baltic Sea and also very hard, strong and thick ice such as multiyear ice, icebergs and parts of icebergs (bergybit, growler). The hard ice has hardness comparable to "Floating steel-reinforced concrete" (Ice Seamanship). In order to avoid damage to the ship the safe speed in the Baffin Bay is therefore lower than in the Baltic Sea.

The ice navigator must distinguish between different types of ice. A useful book for learning this is the pictorial guide: Transport Canada, Arctic Ice Regime Shipping System.

When the water is completely covered with "thick" ice the ship's speed will be reduced in spite of full engine power due to the higher resistance in ice. When the ice concentration is only about 5/10 (surface of the sea: 50% ice, 50% water) the ship is able to sail at about its open water speed. The navigator must steer the ship around thick ice floes. If the navigator cannot filter out hard or thick ice due to lack of experience, darkness, fog or a seaway the danger of a collision with ice is probable. Reducing the speed to less than 5 knots can avoid severe damage to the ship. Even stopping and waiting for improved visibility is a normal procedure. The navigator must visually identify the ice ahead of the ship before he sails through it. Figure 3 shows a small iceberg observed from the bridge which is very difficult to see. The radar signal (Figure 4) is difficult to interpret. When using radar in ice the radar must have a 3 cm radar wave length, 1.5 nm range and the tuning is most important. On the radar, no signal could mean an open lead, thin flat level ice, thick level ice or a thick multiyear ice floe. The reflection of the ice on radar says nothing about the thickness of the drifting ice. Capsized icebergs have no or only very little reflexion on the radar screen. For near field navigation the searchlight is of help, see *Ship-Ice Interaction in Ship Design-Theory and Practice*, (Figure 7).

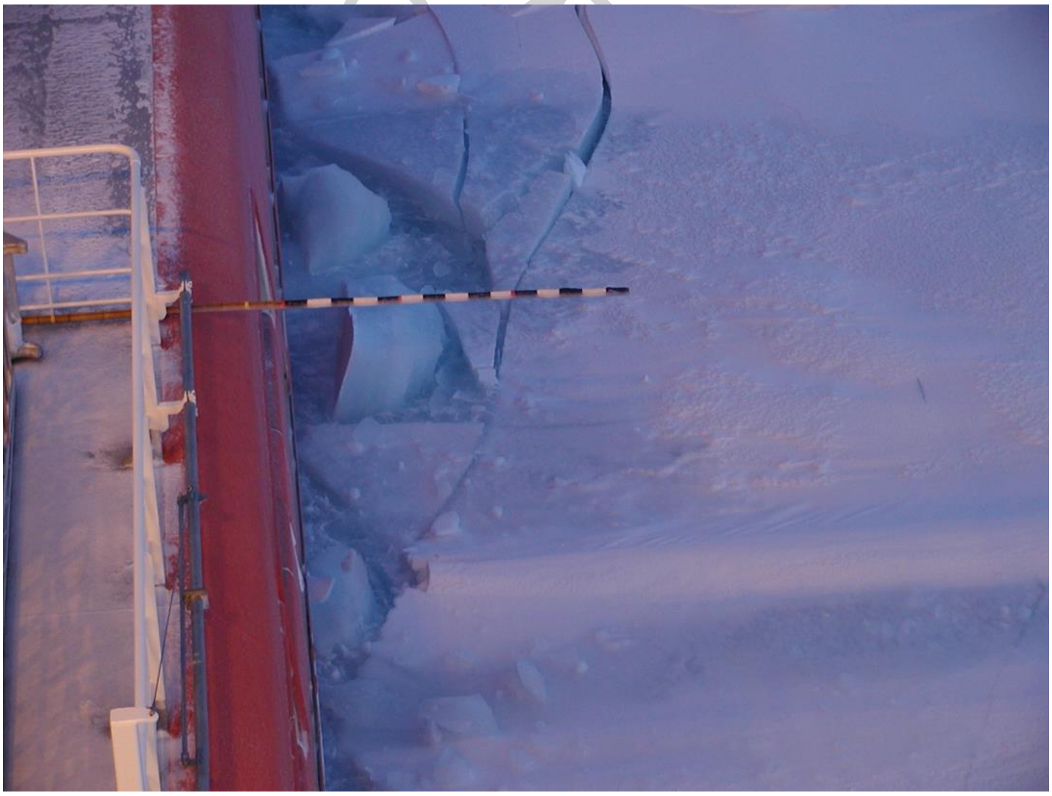

Figure 2. Level stick for estimating the ice thickness from the bridge (Photo HSVA)

"A good ice navigator is one who knows how to combine safety of operations in ice with passages that are also made speedily and in good time" (Ice Seamanship)

When sailing in ice a marked level stick attached on deck is helpful for estimating the ice thickness. The distance between the marks must be adapted to the location of the stick above the waterline and the observer's position on the bridge.

Figure 3. Capsized iceberg (East of Svalbard), seen from the bridge (Photo HSVA)

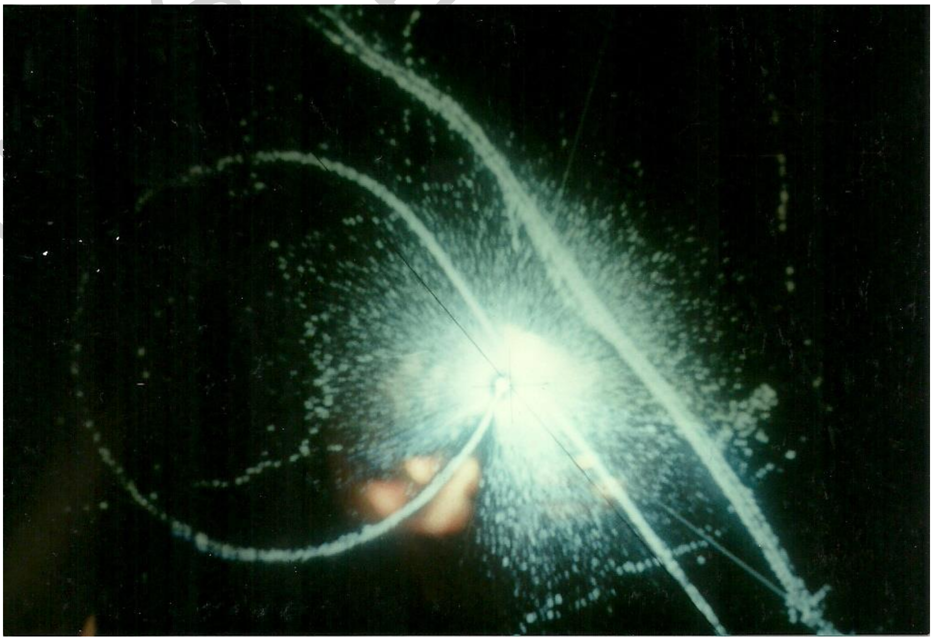

Figure 4. Radar image in smooth thick land fast ice (no reflection), with an old ice channel and just sailed a turning circle (Photo HSVA)

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Biographical Sketch

Karl-Heinz Rupp started his seafaring carreer in 1964. He visited the Nautical Academy from 1968 to 1971 and received the German master's licence for all ships. He studied naval Architecture at the University of Hannover and Hamburg (certificated engineer (Dipl. Ing.)) and graduated as Dr.-Ing. 1984 from the University of Hannover.

From 1984 to 2012 he worked as a research engineer at the Hamburg Ship Model Basin (HSVA) as Project leader for developing and model testing of:
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Icebreaking transportation vessels
Icebreaking inshore vessels for shallow draft and
Drilling vessels in ice

Participant, observer, project and task leader in several full scale trials and voyages in arctic and other ice covered regions.