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EXPERIENCE WITH FREEZING OUT OF VESSELS

From year to year Soviet arctic workers have been carrying on scientific research work on the study of the course of the Northern Sea Route with unflagging energy. Along with this it is necessary to emphasize that the period when navigation in the Arctic served only scientific research aims has been left behind. The Soviet Arctic Fleet, while not lessening the tempo of research operations, is ever more and more solving the problem of the economic development of the North.

At present maritime ships are able to complete the necessary freight and passenger operations and return to ports in the central and southern latitudes in the course of the short polar navigation season. Only a few of them remain to winter in the difficult conditions of the Arctic Ocean.

The number of ships visiting ports of the Arctic increases with each year. Along with this the coastwise fleet and auxiliary floating units attached to arctic ports are growing and developing. Thousands of new seamen and arctic port workers come to the Arctic. For a majority of these it is necessary to become accustomed for the first time to the peculiarities of arctic navigation and polar wintering.

Lacking suitable experience gained through practice, these people must encounter completely new working conditions, that is, follow the path travelled by their predecessors: here the same mistakes are often repeated, and consequently the date of the final mastering of the Arctic is postponed.

From these considerations we consider it necessary to share our experience borrowed from others and verified in practice, in order to facilitate and accelerate the work of new persons in the same profession. Our observations and recommended measures concern the extraordinarily important and significant question of preserving and repairing ships under arctic conditions.

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The recommended measures relate to the area of the port of Tiksi and the mouths of the Lena, Yana, Indigirka, and Kolyma rivers. In our opinion, these measures can be applied with uniform success in arctic conditions wverywhere, that is, everywhere there are low temperatures throughout a long winter.

During the wintering period of 1936-1937 we made for the first time the successful attempt at deep and complete freezing-out of the schooner Temp, having a draft of about 4 meters. An ice dock to a depth exceeding 4 meters was cut for the ship in the naturally frozen surrounding ice field which during the entire winter period was about two meters thick. Making the dock permitted us to replace the worn propellor, to repair the twisted rudder, and to make part of the lost false keel.

In the following wintering period of 1937-1938, in spite of poorer conditions, we were able to run a second test of the ice dock installation and finish full repair of the underwater part of the hull of the ship by 14 April. These operations permitted us to avoid sending the ship into repair in a port (Arkhangel'sk or Murmansk), and thus unconditionally achieve large savings in time and money.

The wide introduction into the practice of the work of arctic ports of winter repair of ships by freezing-out [illegible] the necessity of hauling the ships out onto the shore, and this is especially important for ports which are not equipped with ship-raising equipment.

The positive results achieved in this period by freezing-out and constructing a "protective ice ring" for fishing boats wintering in the strip of pack ice in the ice-navigation channel in the region of Bykov Cape permits one to raise the question of the solution of a not less important technical problem, the protection of ships wintering by chance outside of port waters. Unfortunately, our experience in this respect is still unique, and therefore we set it forth only as a suggestion.

In general, as is known, the distinguishing peculiarity of navigating in arctic waters is the presence of ice of varying thickness almost the year round. The ice is usually the reason for accidents, especially when ships are forced to winter in the open sea. The greatest damage, sometimes even causing loss of ships, is suffered by those ships which fall into the region of the so-called drifting ices, that is, the ices which periodically go into motion. Under/just such conditions were lost, for instance, the steamship Chelyuskin in 1934 and the steamship Rabochiy in 1937.

In 1938, the steamships Tovarishch Stalin and Il'men', which had wintered in drifting ice in the 1937 navigation season, were removed from the ice seriously damaged.

With the experience of the study of ice accidents, ship building engineering must try to create a special type of transport ship capable, through its durability, if not of active struggle with the ice, as an ice breaker, then in any case of resistance to ice pressure.

For operations in the coastal regions of the Arctic it is also necessary to develop a special type of coastwise and auxiliary ships. The auxiliary ships, evidently, must approximate the type of flatbottomed river ships having a draft without cargo of not more than one meter.

These ships must be equipped for navigation in broken ice and through fields of newly formed sheet ice, which usually quickly cuts through wooden hulls. All ships destined for arctic seas should have the most durable hull with a thick assembly of connections both in the lengthwise and crosswise bracings.

The cargo capacity of ships for navigation from Murmansk or Arkhangel'sk into the North Arctic Sea can be on the average about 1,000 tons. For coastwise navigation between ports of the arctic the dimensions of the ships can be considerably less, since these ships must base at those points between which it navigates.

One of the most serious shortcomings for preserving coastwise ships in the Arctic is the lack in local ports of ship-raising facilities and ship repair bases, in spite of the fact that in these ports all ships need a yearly inspection and repair of the underwater part of the hull.

For saving ships damaged by ice pressure, up to now ice navigation practice has not developed any definite rules giving always positive results. In general there is known a series of measures helpful to some degree to ships which have gotten into difficulties in the ice.

Some captains, forced to winter in the open sea, first of all try to lighten the ship by unloading it onto the ice, which reduces the draft of the ship and makes it easier for the ship to force itself out onto the ice under pressure. After the holds are unloaded, so-called ice-beams are installed in them. The ice beams are durable braces made of beams across the ship against the waterline with lengthwise padding between the ribs. These braces, which take upon themselves the force of the ice pressure, save the hull of the ship from crushing.

Finally, often in places where the ice pressure is strongest and the ice hummocks, it is blasted with ammonal or any other explosive material with the aim of breaking the large ice fragments threatening the ship.

The first two measures were used, for example, on the steamship Tovarishch Stalin, which as a result of wintering was bent severely but had not lost its navigability. After being removed from the ice it was able to move under its own power in open water.

For the almost identical steamship Rabochiy, under analagous conditions, these measures were not taken immediately, and the ship was crushed by the ice.

The enumerated measures for saving ships locked in the ice in the open sea, so far as we know, just about exhaust the possibilities which can be effected by ship's crews. When the crews have not taken these measures, they have remained in the role of passive spectators to the resulting struggle of technology with nature and witnesses either of the victory of technology or of serious damage and even loss of the ships.

In the present work, alongside the technical means and measures of protecting ships from ice damage when they are wintered in ports, we recommend one more method of protecting ships wintering outside of port waters. It is possible that this method, used independently or jointly with other measures, will be able to give under known conditions the most positive results. In any case, our method has proved itself when used for small ships in conditions of drifting shore ice.

1. Putting the Ship up for the Winter

The choice of a place for putting the ship up for wintering is one of the most difficult questions which must be decided by a polar captain. And putting the ship up for freezing-out complicates this critical problem even more, since the success of the whole operation of freezing-out and repair of the underwater part of the hull depends upon the character of the wintering place and the position of the ship.

The choice of a place for wintering is easier in closed basins where the metrorological conditions are known previously, where the depth and condition of the ice during the winter are known, and is more difficult in the little studied areas in the zone of land floe.

In the latter case it is necessary to guide oneself by the data of one's own measurings of the depths and relief of the shore and elevations. The configuration of the elevations can influence the formation of cracks in the ice, the degree of snow drifting in the wintering place, etc.

A ship put up under the protection of a high shore can be drifted to the gunwhales. Also a ship put up where the depth is shallow, can fall into the line of a so-called "tidal" crack formed by the breaking of the shore floe when the water drops; when the tide moves in water will come to the surface of the ice through this crack and flood the standing place and the prospective freezing-out place.

If an insignificant depth is left beneath the keel of the vessel, for instance, 40-50 centimeters, in the process of freezing-out it may happen that the ice forms down to the bottom and fastens on to it.

With a lack of tidal fluctuations of the level of the sea, effecting freezing-out at such a depth would be most favorable, since the solid freezing of the ice down to the bottom would remove any possibility of flooding the freezing-out from the direction of the bottom.

On the other hand, it is most dangerous to let the ship grind against the bottom, since the keel may freeze to the bottom. In freezing-out a ship it will be necessary to carry on exceptionally heavy earth works in the frozen ground. Such works must be done only in the extreme case where a ship is grounded on shore or on a sandbank.

Along the whole course of the Northern Sea Route in the coastal zone and in the mouths of rivers there are tidal or drifting fluctuations in the level of the sea of from several centimeters to a meter and more. Therefore, in permitting freezing of freezing out the bottom, it is possible to risk flooding it through the side cracks which can appear if the ice rises with a tidal wave. From these considerations it is safer to effect wintering out in a deeper place with a reserve of depth under the keel of not less than 1.5-2 meters.

The second, most important condition for putting up a ship for the winter is the choice of a correct position or course for it in relation to the prevailing direction of snowstorms. It is known that in arctic conditions snow drifts attain a depth of from 5 to 10 meters in calms. High abrupt shores become sloping after one or two snowstorms, and this permits a gently rise from the sea to the dry land, as on an inclined plane.

As has already been said, a ship put up near such a shore will be drifted in up to the superstructure.

If a ship stands in an open place with its side toward a snowstorm, it will first be drifted against along the whole windward side to a level with the superstructure or with the plank-sheer and then gradually, there will be formed in front of the ship a snowbank, and after several storms the ship will be the center of a large snow hill.

It is almost impossible to combat the snow drifts by cleaning with the ship in such a position. Snow cleaned away from the sides only all the more aids the deposition of higher and wider snowbanks with the following snowstorm. In order to avoid such drifts, it is necessary to place the ship with the narrowest part - bow or stern - in the direction of the prevailing snow-bearing winds.

Experience has shown that it is best of all to place the ship with not the bow, but the stern toward the prevailing storms.

In this, it is taken into consideration that the wider stern part of the ship, placed under the frontal attack of the storm, is not drifted with snow. With the ship in such a position, the snow drifts begin to accumulate only directly behind the bow, and this most narrow part of the ship is always more easily cleared of snow. This practice of placing a ship for wintering has already been adopted in the port of Tiksi, in the Bulunkan gulf. Port schooners and roadstead tugs are put up for wintering with the stern toward the local Stolovaya Mountain to the Southwest. At the same time barges wintering in the port continue to be placed with the bow toward the storm, and as a result a majority of them are drifted with snow and suffer damage to the rudders because of settling of the ice under the weight of the snow.

The lack of similarity in the position of ships in wintering in the Tiksi bay is explained of course by the fact that self-propelled schooners can be turned in the desired direction by their own motors, while nonself-propelled ships must be turned with the aid of a tug or by hand. On the other hand, barges have the complete facility of being turned with the stern to the wind before the freezing of the bay and without the aid of a tug; it is necessary only to transfer the anchor from the bow to the stern.

Thus it is evident that the choice of a winter position for the ship in port presents no difficulties, especially if a ship arrives at the roadstead before the beginning of ice formation.

Using the continuousness of the winds blowing at this time from the southern half of the compass (storms are brought by winds predominantly from southwest quarter), it is most simple to make a ship itself turn along the line of the wind by dropping the anchor from the stern.

Such a turn can be made also in thin young ice and in small-broken ice.

If the surface of the water has been covered with a solid layer of ice thicker than 30 centimeters, the ice around a nonself-propelled vessel must be broken with the aid of a tug or by hand enough so that the vessel's stern can be turned in the right direction.

In roadsteads, such as that, for instance, in the port of Tiksi, where tens of ships are wintering, dispersal of them to the wintering position must be done in a planned order, inasmuch as otherwise the ships placed on one line and at a short distance one/from the other, in screening one another will present a calm area for snow drifts, and therefore only the single lead ship, standing into the wind, will not be drifted up.

Knowing the prevailing direction of the winds, the planning of the disposition of many ships must be done so that one ship will not screen another. For this it would be more correct to place the ships in parallel rows with considerable intervals between the separate ships (from 100 meters to 200 meters) and with considerably larger intervals between the rows (about 200-300 meters) depending on the area of the roadstead. In such a position the ships of the second or following row should be placed in the intervals between the ships in the first row, that is, in checkerboard fashion.

When putting up for wintering ships forced to winter in the shore floe in little studied areas of the Arctic, it is necessary, taking into consideration sounding data, to consider that snowdrifts will be observed usually with southwest and westnorthwest winds; however, the westnorthwest winds will be a rare exception.

2. Cutting the Ice Around the Vessel

If insufficient attention is given to a ship wintering even in a closed basin, it can be damaged so seriously as to render it unfit for navigation without special repair. This can be most often observed with wooden barges wintering in polar ports.

Damage usually occurs at the end of the wintering period at the beginning of the summer, when the ice cover sags under the weight of the snow filled with water, and the ship, lightened after unloading, and separating from the ice, tries to rise up or float to its normal draft. At this moment the rudder fastenings, frozen into the ice, are often broken or stretched. Right behind the rudder the ski (lyzhnyy) fastenings of the stern post sometimes separate and break, and a leak appears.

To prevent these damages to a ship lightened when in a frozen condition, the process of cutting through the ice around the ship is used. (Here and in the future the term "cutting through" (okolka) will mean the continuous punching through of the ice in a section; "chipping out" (vykolka) will mean the removal of ice from the holes made in the ice field without cutting through the ice, that is, without reaching water). This measure however, does not free the hull of the ship from the harmful pressure when it strives to float in the spring.

Cutting through the ice must begin first of all with the complete freeing of the rudder from its attachment with the ice and then must be done evenly along both sides of the ship. Cutting through must be done immediately after the ship is unloaded to avoid freezing of thick ice, which will make the work more difficult and complicated.

When the ice is more than 20 centimeters thick, before beginning the cutting through it is necessary to chip out trenches along the sides. The width of the trench must be not less than 40 centimeters. The ice must be removed cautiously from the planning of the side in order not to tear calking frozen to the ice from the mortises.

It is desirable to leave the bottom of the trench not more than 8-10 centimeters thick so that it will be easier later to punch through with one blow of a bar the thin ice when it is covered with water.

To avoid premature flooding of the whole trench by a chance puncture, the trench is divided into a series of sections by crosswise links of untouched ice about 20-30 centimeters thick and about 3-5 meters apart.

The crosswise links are cut out after the whole chipping out process has been finished. If ice saws are available, it is easiest simply to saw the bottom of the trench. The chipped ice must be taken away from the side of the ship, if possible to the leeward side, and should not be left closer than 20 meters to the ship; otherwise it will act as a foundation for snow drifts. Ice thrown back into the water will promote the rapid freezing of the water and the thickening of the ice around the ship. Therefore, if after the cutting through it is planned to freeze out the ship, the ice must be thrown back into the trench. If freezing out of the vessel after the chipping out is not planned, then, in order to retard the freezing and reduce the thickness of the ice, the place where cutting through has been done must be filled with snow to a height of 0.5 meters in the form of a sloping wall with the pitch away from the side of the ship. If there is a considerable thickness of frozen ice, it is necessary to cut out the ice down to the bottom of the ship, without letting water into the trench, with the freezing out of the rudder and stern part, to avoid damage to a wooden ship when it is refloated.

If the thickness of the ice, snow drifts, or cracks in the ice or other factors do not permit the chipping out to be done correctly and do not permit the rudder to be frozen out, it will be necessary at the end of March or the beginning of April to repeat the whole cutting through and the packing of snow into the cut out area.

3. Partial Freezing Out

Partial freezing out is the best known and most widespread method encountered in practice. It is used to inspect and repair any separate underwater part of the ship. In the port of Tiksi, for instance, it has become the practice to freeze out the stern part of a schooner just enough to uncover the rudder and propeller.

In spite of the insignificant area taken up by such a freezing out (within 4-8 square meters), its results are not often successful. Very often even such an insignificant freezing out fills with water through side cracks forming in the ice, or even because of a puncture of the bottom of the frozen out hole (mayna) (in the north "mayna" means any depression or hole cut in the ice; in the future "hole" or "cut" (mayna) will indicate the whole cut-out area of the freezing out, even if it consists of many separate sections).

Cases of flooding are most often encountered in unskillfully cut deeper cuts with vertically constructed walls, shoddily maintained, littered, or filled with snow. The reason for the flooding of the freezing out is most often found in the form of the cuts made and their contents.

A narrow hole, in the form of a shaft with walls hewn vertically, does not have free circulation of cold air, and when it is fouled with rubbish and snow there is additional generation of heat. Freezing of such a cut is weak and may even stop if there are only light frosts. When the ice sheet is raised by a tidal wave, the thick walls of the out crack and fracture where they are joined with the thin layer of ice of the bottom, and water begins to seep in. The corners where the thick ice (2-3 meters) of the vertical walls of the cut connect with the thin (0.5 meter and less) ice of the bottom are the weakest. In addition, thin ice over a small area (1-3 square meters), upon joining with thick ice, is stretched in the form of a film, and because of this, loses part of its elasticity and becomes more brittle; it breaks when there are side cracks or permits a puncture in the center of the area when the water pressure is increased.

4. Complete Freezing Out of Ships

The method of freezing out, or cutting out ships frozen into the ice, has long been used in the basins of the northern rivers.

Unfortunately, we do not have definite data establishing by whom, when, and under what conditions the first attempt at complete freezing out of ships was made.

It can be assumed that the freezing out of large ships began after the experience of cutting out small sloops and generally small shallow-draft vessels frozen into ice [redacted] thicker than the draft of the vessel. This assumption can be confirmed by the fact that at present clearness is lacking in the terms "chipping out" (vykolka) and "freezing out" (vymorozka). The method, used most often, of chipping out or cutting out the ice around a ship is also called "freezing out." However, each of these terms has a definite conception and representation of the known process of working with ice.

The word "freezing out" (vymorozka) is often used as a generalizing term for the various types of operations for freeing a ship from ice. In these operations are included primarily "chipping out" (vykolka) and "cutting out" (vyrubka) the ice in the form of a trench or ditch around the vessel, and then cutting out the whole ship from the gradually freezing ice thickness.

By the word "freezing out" (vymorozka) must be understood the artificially intensified freezing of a definite thickness of ice beneath and around the ship. The freezing depends upon the gradual chipping away or removal of definite layers of ice from the top of the freezing thickness of ice.

The operation of continual freezing and depositing is repeated until the desired underwater part of the hull of the ship, isolated beneath from the water by a layer of ice of the necessary thickness, is uncovered.

In this manner "freezing out" of a ship is connected with the artificial freezing of ice beneath, while for cutting a ship out a natural thickness of ice is sufficient.

Chipping out can precede freezing out and even replace it if the natural thickness of ice exceeds considerably the depth to which the ship is frozen into the ice.

The art of freezing out consists of anticipating to a considerable degree the natural formation of ice not only as to thickness but as to time. It is based on the natural acceleration of the freezing of water under a thin layer of ice until the ice attains a great thickness, after which it is necessary to retard gradually the growth of ice beneath. Therefore when freezing out we must try by chipping out the upper layer to keep at all times as small a thickness of ice as possible, inasmuch as then the most intensive freezing of water beneath the ice will take place.

In this manner we will be able to obtain at the freezing out place, or, more correctly, at the place where the ice is removed, a thickness of ice which will be considerably lower than the surrounding ice field. In other words, we change the level horizontal ice field into a field with a hole, the bottom of which can be lower than the lower surface of the field.

Let us suppose that we must repair with the aid of freezing out the keel part of a ship having a draft of not less than three meters. For this we will have to freeze out an ice dock with a depression of

3.5 meters, and the bottom of our dock will have to have sufficient durability.

To cut out a similar dock in ice already frozen would require that one wait for a natural freezing of the ice to a thickness of not less than 4 meters, which is impracticable in the course of one wintering season even under arctic conditions. During the period of ice formation, lasting here not more than eight months (from September through May), the thickness of the newly formed ice does not exceed two meters. In such ice we would be able to cut out a dock with a depression of not more than 1.5 meters. Considering the time necessary for repairing and preparing a ship for navigation, we would not have eight months in which to effect the operations of freezing out, but a shorter period (5 to 6 months.).

In spite of the apparent impracticability of the proposed task, it can be done by menas of a correctly conducted freezing out. The planned organization of this operation permits the freezing out and repair in an ice dock with a depth exceeding by 100 percent and more the natural thickness of one-year-old ice, in a period shorter than would be necessary for the usual freezing of the ice.

The method of repair with the aid of freezing out is the cheapest, since it can be done with the facilities of the ship and the labor of the ship's crew, and the ice dock itself is built by the crew during the winter period, when the crew is free from other work.

5. Ice Pressure at Freezing Out Locations.

After the removal of a thin layer of ice, on the surface of the bottom of the hole there can be observed the appearance of small cracks distributed as if on a radius from the center of the hole. If there are old cracks in the ice, it will be noticed that they expand at the places where they intersect the outside edges of the hole. As the hole is deepened, the width of the surface cracks on the edges increases, reaching sometimes 20 centimeters and more. The small cracks on the bottom of the hole quickly fill up with brine and disappear. This phenomenon is explained by the fact that where the ice is removed from the hole the pressure on the water is reduced to the extent of the weight of the ice removed from the hole, and the pressure of the water on the bottom of the hole (from bottom to top) remains unchanged. The difference in the pressures after the cutting of the hole causes a bulging of the center of the hole, and this explains the formation of cracks on its bottom.

In order to prevent the puncture of the hole under this pressure, it is necessary to leave the bottom of the hole thick enough so that it can support the corresponding pressure of water at a given depth. The deeper the depression, the thicker the bottom of the hole.

Unfortunately, we do not have facts for detailed theoretical calculations on the basis of which we can effect freezing out operations. Therefore to decide this question it is still necessary to use only the experimental method.

The various layers of ice have different structures and qualities.

For the practical purpose of freezing out it is sufficient to consider the qualities and properties of only two layers, which differ sharply one from the other: the surface layer and the subsurface layer.

The upper layer, in opposition to the subsurface layer, is usually brittle, breaks easily, and crumbles.

The lower level of the ice preserves elasticity. With the growth of the ice to two and more meters, this layer continues to maintain an approximately constant thickness of 50-60 centimeters. Evidently its thickness is conditioned by the ability of the lower layer of ice to let water through its pores to a definite height.

In practice, this lower layer is defined by dampness, color, and by the sound it gives when struck. In contrast to the white-light tint on the surface ice, it has a darker, and in the direct proximity of the water, an almost black hue from the moisture seeping through, and when struck gives a dull sound, while the surface layer when struck gives a clear sound.

Persons experienced in freezing out use these signs in practice, and when the upper layer is being cut away do not go beyond its boundary.

The art and experience of a person engaged in freezing out consists of being able to determine by the indicated signs the upper boundary of the resilient ice and leaving it thick enough so that it will be able to support the water pressure at the given degree of depression of the hole.

The brittle upper layer of ice, having abundant cracks through it, must be regarded only as an auxiliary burden keeping the opposed water pressure in equilibrium. Let us see now what interaction is established between the ice and the ship frozen in it.

When sailing in clear water, a ship presses on the water with its weight, and the water presses with the same force on the bottom of the ship, serving as a support for it.

What changes take place in the equilibrium of these forces if the water changes from the liquid state to the solid state?

In clear water the relationships of these forces change constantly and balance themselves because of the movability of the ship in the liquid medium. We observe this phenomenon, for instance, in the change in the draft of a vessel when it is loaded or unloaded.

If the ship freezes into the ice, the ice frozen to the sides of the ship does not permit the lightened ship to raise up and the loaded ship to sink. Under such conditions the ship is suspended, so to speak, pressed from the sides, in the ice vise, and in this condition all the pressures forcing the ship to rise or sink, are transferred wholly to the sides of the ship.

We will suppose that there are no changes in the weight of the ship, but we begin to chip out ice around it. As the ice is removed from around the sides to the level of the bottom of the ship, we remove only that harmful pressure which the sides of the ship would experience if it were loaded or unloaded. When the ice around the sides is removed, the ship will be able to rise and sink through the bulging and puncture of the ice bottom of the hole, and in this manner, the ship will bear with all its weight on the bottom of the hole, and the hole, in its turn, on the water.

If we continue chipping out right under the ship, putting wooden blocks and cribs under the keel, the weight of the ship will be distributed evenly on the whole surface of the bottom of the hole, but only on the area of the blocks and cribs. In this manner in the ice bottom of the dock there appear moments of force, giving curvature: under the cribs the ice will be bent down, and in other places it will bulge upward. The greatest pressure of the ship will be beneath the keel, right in the middle of the hole, that is, where the ice will bulge upward the most. From this it is evident that, having a ship in the hole, we can allow a slighter thickness of the hole's bottom than would have been possible in an empty hole.

However, experience has shown that the thickness of the bottom of an ice dock should not be less than 30 centimeters.

6. Cases of Damage to the Hole

In observing the bottom of a hole from which the upper whitish layers has just been removed and in which a comparatively thin layer of moist dark ice has been left, it is possible to notice immediately a cupola-shaped bulging of the center of the bottom.

In order to prevent flooding of such a hole, it is necessary immediately to place a heavy load of iron objects or chunks of ice weighing about one half of the weight of the ice removed on the place of bulging. Filling up with snow and filling in with wood must be avoided, since these measures will heat the hole. It is necessary that a "weak" hole freeze as quickly as possible, for which it is useful to hang a canvas sail over it.

If the hole ruptures, and it necessary to continue the freezing out, the hole must be immediately filled as deeply and compactly as possible with chunks of dry ice with all snow removed. In order to accelerate the freezing of a flooded hole to the depth of the place of rupture, it is necessary immediately to begin chipping out a trench in the ice around the flooded place to the limit possible, depending on the natural thickness of the ice. The ridge of ice between the flooded hole and the trench must have a thickness of 40-50 centimeters. As the surface of the flooded hole freezes, layers of ice are taken from it cautiously. During this operation the isolating ridge must be preserved until the hole freezes lower than the level of the trench; then the freezing out is continued in the usual fashion.

If a small leak appears in the bottom of the hole through a crack which has formed or the puncture of a pick, the water sometimes begins to flow as a fountain, but under these circumstances the surrounding ice does not break. Such a leak can be removed quickly by packing it with oakum and tightly stopping the opening in the bottom with a sharpened wedge.

Similar cases of leaking and partial rupture of holes take place usually during freezing out operations when the ice is being removed. Therefore each person engaged in freezing out should always be provided with materials such as oakum, prepared wedges, and pegs. If a large amount of water is let into the hole, the indicated measures may cause delay and prove useless. If a puncture made in the bottom of the hole is not closed, the water, beating under pressure, begins to breaking out with the force of its movement first small, and then large chunks of ice from the sides of the crack or puncture, and breaks through the whole bottom of the hole. Therefore at the point of an insignificant puncture, which at first could be closed with a finger or a nail, in tens of seconds there can form a large hole. In such cases experienced freezing out workers, having made a rupture in the ice by a faulty blow of the heel of a pick, with the following blow drive the pick completely into the ice and leave it until all the cutting edges beneath are covered with ice.

Thanks to the plasticity of the thin lower level of ice, the surface of the hole can take various forms, departing from the horizontal levelness. At the side of the ship it takes usually a sloping form with a raised side, frozen to the ship, with an angle sometimes reaching 30 degrees and more. The raising of the frozen ice around the side of the ship is explained by the poorer freezing of the ice at the side of the ship and the bulging of the center of the freezing out; from here it follows that in freezing out the ice does not freeze in an even layer over the whole area of the bottom of the hole, but gradually gets thinner from the outside wall to the side of the ship.

For this reason in the hole one must not remove the ice strictly horizontally; one should follow a rising surface from the outside wall toward the side of the ship, determining the thickness of the layer of ice undergoing removal by its color and the sound it gives off when struck.

The slanting convex form of the ice at the side of the ship increases the surface; the surface quickly freezes through and gives the ice more elasticity when the ship is supported in the horizontal position.

7. The Harmfulness of Partial Freezing Out.

We have already spoken above of the use of cutting through around the ship, the continuous chipping out of ice around the ship, and finally, the most difficult part of ice operations, freezing out. However, it must be noted that we know of cases of damage to ships by unskillful chipping out of ice and freezing out. We will indicate the conditions under which a ship can be damaged in this work.

We have become acquainted with two types of freezing out; partial, when a small part of the surface of the underwater part of the ship is frozen out, and complete, when the whole underwater part of the ship is freed of ice. The evident expediency of complete freezing out causes no doubts, but as far as partial freezing out is concerned, it area must be limited by definite boundaries.

For an example we will imagine that we are freezing up to one-half of the hull of a ship; the other half of the ship will be left frozen in the ice with the same load with which the ship went into wintering. We will assume also that we are freezing out the first half of the hull only down to the level of the bottom. In conformance with these explanations, it is evident that the part of the ship freed from the lateral ice pressures, will try to rise under the pressure of the water bulging the bottom of the hole, At the same time the unfrozen-out half of the ship will have to remain motionless. If the hull of the ship is very strong, with the raising on the part of one of its halves the other half will burst out of the ice. A weak hull does not have sufficient strength to break its connection with the ice, and it will either break, or form a crack, or, finally, cause a sharp flexure with deformation of the lengthwise reinforcements near that place where the freezing out ends and the part not frozen out begins.

The same thing can happen on a slightly smaller scale if the ship is not frozen out by one half, but by one third or one quarter of its length. In this case the danger of damage to a long hull will be greater than to a short hull, since with the longer hull the bending moment will be larger.

In this manner, before starting partial freezing out of a ship, it is necessary to analyze carefully the situation on the spot, the condition and construction of the ship, and only after this to determine the limits beyond which such a freezing out will become dangerous.

The sinking of a barge with a load of more than 1,000 tons of coal in the Neyelov Bay in the mouth of the Lena River during the winter of 1937-38 occurred as a result of the partial freezing out or chipping out of the ice over a long distance only on the stern part, and the hull of the ship was twisted and the connections of the side sheathing were stretched. A leak appeared in the barge at the very first tide. The coal cargo got wet and began to freeze, bursting the ship from within. In addition, when the tide went out the cracks between the strips of sheathing began to widen because of water freezing in them. In the spring the ship sank altogether. This case graphically supports the expediency not of partial, but of complete chipping out of the ice around a frozen ship.

It is necessary also to indicate the possibility of similar accidents even without using freezing out. If a ship goes into winter quarters in the area of the action of tidal waves, which causes large cracks, pressure, and even hummocking of ice, as it is observed in the mouth of the Lena River, and these cracks work against the hull of the vessel, the vessel will always be threatened with the danger of fracture or deformation of the hull. It is possible to protect a ship from damage under such conditions by cutting through the ice around the ship which would permit the ship to be held level and permit some movement to the sides, in the case of a movement of the ice. Such a cut must be repeated periodically, in order to prevent the freezing of a thick layer of ice.

8. Preparing the Spot for Freezing Out a Ship.

The working area on which all operations for freezing out a ship are done is called a basin (chasha). This place must be carefully cleared of fragments of ice, snow, freight, and other objects taken from the ship.

The basin is used only during the freezing out operations for throwing ice chips out of the hole and temporary stowing of bracing and repair materials. At the end of the working day this place must be cleared of ice, snow, chips, and materials and swept clean, or otherwise these objects will serve as the foundation for snow drifts in the case of an unexpected storm. The basin is at this time a thickened zone of frozen ice around the ship, under protection of which the freezing out operations are done.

The dimensions of the basin depend first of all on the area designated for the freezing out. The difficulty of cleaning the basin after snowstorms requires that its limits be kept as small as possible. The basin is given an elipsoidal form similar to the outline of the projection of the outlines of the ship at the waterline in the plane of the ice.

This form can be determined if a definite area is traced around the ship with a template.

For a small ship, up to 50 meters in length, the distance of the outer line of the basin from the side of the ship must be taken at from 8 to 10 meters, and for larger ships, up to 100 meters in length, the size of the basin can be correspondingly increased more than 10 meters from the sides of the ship.

The wider the expanse of the basin, that is, the distance between the side of the ship and the uncleaned area on the ice, the better the ice freezes around the ship, and the wind can more easily carry snow past on a smooth sliding surface.

After the ship is established in the ice, it is necessary to wait several days in order to give weak or broken ice a chance to freeze enough so that it will be safe to walk on. After this work is begun on measurements and preparation of the basin. A thin pole marked off in meters can be used for measuring. The pole is placed on the ice with one end up to the side of the ship at right angles to it, and the planned number of meters are measured off along this line. It is best to mark the measured distances in the ice with thin pegs. When measuring the width of the basin at the stem and sternpost it is necessary to keep the same distance as at the sides of the ship. The curved form is imparted to the basin the first time that snow is swept from the marked off area. After several sweepings the area of the basin takes on a mirror-like surface and at this time the snow swept to the sides to the external boundary of the basin gives it a definite and sharply outlined form. With the passing of time, and especially after several snowstorms, the snow and ice form piles several meters high beyond the basin.

If the ship is correctly set along the line of the prevailing winds, the depositions of snow are concentrated beyond the basin, parallel to the sides of the ship, and the ship looks as if it is standing in a canal.

To assure that the snow will be carried past the ship, in no case must one make heaps of ice from the basin against the stern and bow ends of the ship. In these places it is necessary from time to time to break up natural drifts to permit the snow to pass through better and to cool the surface of the ice with drafts. Chipped ice and snow swept from the basin must be carried as far from the ship as possible, and if possible, to the leeward side, or otherwise drifts will begin to form in the basin, making extra snow removal work.

In order to prevent the appearance of cracks in the basin and in the walls of the hole, which is especially important when a floating ice dock is being constructed, it is desirable to reinforce the ring of the basin by freezing beams into the ice. This operation can be done while the ice is still thin (not more than 10-15 centimeters). The beams are placed so that their ends overlap slightly. At the connection points of the beams cuts are made in the ice through which both beams can be put under the ice, with the ends to different sides, so that they will remain in the water in the same position as was planned on the surface of the ice. The correct placing of the beams is done with the aid of boat hooks through the small cuts. The distance of the beams from the side of the ship should be about 5 meters. If there is a sufficient amount of beams or driftwood it is desirable to place timber all around the circle of the basin. If there is not enough timber, the reinforcement can be limited to the ends of the basin opposite the stem and sternpost, where it is best to place two parallel beams not less than one meter apart; it is desirable also to freeze several beams opposite both sides of the ship in the center part.

The frozen timber holds the ice of the basin together better and prevents the appearance of cracks in the walls of the hole. Usually the cracks first appear along the direction of the diametric plane of the ship, and then opposite the most expanded and depressed part of the ship; therefore the reinforcing of these places is the most desirable, so as to prevent the appearance of deep cracks and the appearance of leaks through them into the hole.

In this manner, the reinforcing of the basin of small ships can be limited, in an extreme case, to four beams at the end parts, and for larger ships, to eight to ten beams frozen into the most important end places and opposite the middle part of the ship.

9. Protecting the Basin from Snowdrifts.

As has been shown above, snow drifts are a great hindrance to freezing out operations. The snow heats the hole and under the snow the separation of brine begins; therefore it is necessary to remove the snow from the surface of the basin and hole immediately, not only in quiet periods during a storm or at the end of the storm, but during the storm itself.

Special anti-snowstorm fences and the so-called snow blowers can render considerable assistance in the struggle with snowdrifts.

The constancy of the direction of storm winds permits the successful erection of permanent fences.

In contrast to railroad fences, which cause the deposition of piles in front of the obstacle, the design of ship anti-snowstorm fences must provide for the deposition of piles behind the obstacle and away from the ship. Such fences must be turnable, like a rudder or a sail, so that the deposition of snow can be regulated by turning the fence to a definite angle.

The design of a turnable fence must also promote the tapering of the area between the fence and the side of the ship, and in the same fashion must increase the velocity of the wind so as to prevent the deposition of particles of snow in the hole.

Taking into account the great force of the winds, the repelling fences must be made lattice-like, with an area of not more than 1-2 squaremeters. The fences can be made folding or doubled, that is, fastened in pairs to one post.

When the ship is placed correctly with the stern toward the prevailing winds, the installation of fences along the sides of the ship must be done so that the snow is deposited at the bow end of the ship. From observations it is known that the deposition of snow in the hole begins approximately at the middle of the ship, and the continuous drifts begin in the area of the least formations of the bow part of the ship. Consequently, the first windward pair must be installed somewhat past the middle of the ship, nearer to the bow, and the second pair must be installed behind the least formations of the bow or in front of the stem, approximately at the first bow crosswise link of the hole. The lower edge of all the fences must be 40-50 centimeters above the level of the ice so that the intensive blowing can go beneath the fences.

The upper edge of the frame of the fence must not go beyond the plane of the main deck of a high-sided ship or exceed the bulwark of a low-sided ship.

When one fence is too short for the high side of a ship, another fence can be made and fastened to it.

To make a fence, above all it is necessary to put together a rectangular solid frame in the form of a square, with the sides about 1-2 meters, and than nail thin strips 10-12 centimeters wide spaced at intervals of 5-6 centimeters to the frame. In this manner, on a one-meter fence 5 to 7 strips will be required, since about one third of the area of the frame will be intervals.

The fence must be put in place so that the lattice-work of strips is in the vertical position. In connecting the frame one must avoid crosspieces, since they can promote the filling in of the intervals between the strips with snow and the deposition of piles in front of the fence. Wire can be used to fasten the frame together. To install the prepared fence in the ice, it is necessary beforehand to freeze two strong posts about 3 meters long and not less than 10 centimeters in diameter into the ice. To reinforce the posts it is necessary to freeze two more pieces of wood into the ice for guy wires. The guy wires can be cut out of strands of steel rope.

The posts should be frozen into the ice opposite the indicated places perpendicularly to the diametric plane of the ship and at a distance one from the other corresponding to the dimensions of the fence. The fence is hung with the aid of loops from the wire or strands of steel rope on the second post from the side of the ship at the height indicated and in such a way that the fence can revolve freely on the loops.

The second post, which is nearest to the side of the ship, will serve only to fasten the guy wires of the frame when the fence is revolved to the angle which it is necessary to establish according to the direction of the wind and the deposition of snow.

For convenience in taking in or paying out the guy wire, it is expendient to fasten a one-cycle block on the top of this post on a sling rope and beneath, a spike or eye to fasten the end of the guy wire.

To draw in the guy wire evenly, the guy wire can be taken in at the middle of a short sling, the ends of which should be embedded in the corners of the frame of the fence. [Figure 2]

The construction of the so-called "snow blowers" is not complicated. The purpose of the snowblower is to blow snow from the hole, or to blow it from a pile, with the aid of the force of the wind. The blower is installed where the action of the fence cannot be effective, and where a fresh drift of dry unpacked snow has already formed. To remove a solidly caked drift or a drift covered with a continuous hard crust the snow must first be loosened or the blower will be useless. Deposition of snow in the depths of the hole and growth of drifts takes place not only during a storm or snowfall, but also with a snow-drifting wind. In the last case deposition originates from the movement of fallen snow over the surface of the land and ice under the influence of the wind, just as sand moves in the desert.

Snow moving on the surface of the ice of land is deposited where the action of the wind on it is reduced.

Such places are calm zones under high shores, the freezing-out hole, the lee side of the hull of the ship, and in general any obstacle standing in the path of the wind.

Snow settled behind any cover causes the beginning of the formation of a drift spreading to the limits at which the influence of the obstacle blocking the wind is no longer effective.

If the wind changes its first direction and blows from the side, from behind some cover, the deposition of snow masses goes in a new direction and the places drifted with snow earlier will be completely cleared of it.

On this property of the moving of snow masses there should be based the principle of the design of the snow-blower, the task of which is to increase the velocity and change the direction of the wind in the necessary direction.

The snow-blower can be made out of light sheet iron, or, if this is lacking, out of plywood or thin strips fastened on the outside by several wooden frames.

In general this device should be a collapsible tube breaking in one, two, or three places, with a wide gate-like entrance opening for the wind to enter, and gradually tapering to the exit.

Such a blower can be made in the form of several four-sided boxes having a square cross section. The first, as a wind collector, should have a widened opening of not less than one aquare meter in area, a length of from two to three meters, and an exit opening 15-20 square centimeters in area.

The second box should be made so that the tapered part of the first box will fit into it easily, that is, it should have an entrance opening slightly wider than the exit opening of the first box.

The third box should have just such a construction for the connection with the exit end of the second box.

The dimensions of the second and third boxes can be different, from one to two and more meters, but the weight of the boxes should not make it difficult for one man to move and set them up. A sled must be made to deliver the blower to the desired location.

The sled should be of such dimensions as to permit the receiving tube to be fastened to it and also, if necessary, so that all three tubes can be carried on it. The sled can be two parallel strips set on edge and connected with cross-pieces.

If an ice anchor is fastened to the rear of the sled and attached to the ice from the windward side, it will hold the whole blower installation in the necessary place.

The blower can be used in three cases:

1. when it is necessary to increase the blowing of air along the side of the ship.

2. for blowing out the hole where the greatest drifting of snow takes place.

3. for blowing away or blowing out a swept-up pile of snow.

If the vessel is turned with its stern into the wind, in the first case we must put the receiving end of the blower behind the stern or near the stern part of the ship, turning the funnel of the receiver toward the strongest jet of wind. After connecting the second and third (if necessary) parts of the blower, it is necessary to place them so that the exit opening of the end tube will be directed along the line where there is the greatest deposition of snow because of weak natural blowing. If this line does not conform precisely with the direction of the receiver of the blower, then, possibly, it will be necessary in order to improve the action of the blower to install at the receiving opening a side shield made of plywood either to form a deflector above or to raise the whole front part with the aid of blocks under the sled. In doing this it is desirable to place the blocks so that a space is left for the snow to be blown through under the shed.

To blow out the hole the basic part of the blower is placed in line with the wind and the attached tubes are turned into the hole so as to deliver into it air by which there will be created the swirling which inevitably begins to throw the snow out.

In order to destroy a drift on the surface of the ice, the blower is set up in the wind opposite the drift. After the attached mass is destroyed, the pipes are moved until the whole mass of snow has been removed to the necessary side; the exit opening of the last tube must be laid in this direction.

It is necessary to have at least two of the described blowers on the ship. However, before starting construction of the second blower, it is necessary to test the action of the first in order to determine its shortcomings and improve the design for the second.

The expenditure of several working days at the beginning of the wintering for the construction of the described means of protection from snow drifts in the form of fences and blowers will undoubtedly save much time and labor for the crew of the vessel during the course of the wintering period.

10. The Freezing-Out Plan.

The project for the plan of freezing-out must be made up in good time, before the ship is put up for the winter. Several days before the beginning of the freezing out it should be made more precise in dependance on the conditions of the actual situation. In planning the freezing-out it is necessary to take into consideration the temperature regime of the air, the period of ice formation, the thickness of the layer of the unsolidified ice in the wintering out area, etc.

To characterize similar data we introduce table 1 of the maximum and minimum temperatures of air and water and the thickness of the ice in Tiksi Bay according to ten day periods for 1935-1936, 1937-1938, from October through July inclusive.

From this table it is evident that continuous below-freezing temperatures of air and water were observed over three years in the periods from November through May. Consequently, only in this six-month period is freezing-out possible. Judging by the temperatures, the most intensive freezing should take place from the beginning of November to the end of March.

The beginning of the intensive freezing of ice occurs about the second ten days of October, and the end is around the last days of April. Melting takes place already in May.

On the basis of the data of the table we can plan the freezing-out period for from the end of October to the middle or end of April, including in this time also repair of the underwater part of the shipshull.

Repair of the underwater part of the ship's hull must be done concurrently or right after the freezing-out in proportion to the various damages discovered after the removal of the ice. Thus, before the finish of the freezing-out of the keel we can finish repair of the sheathing, part of the bottom and the kingston valves, the rudder, and propellor.

With correct planning of freezing-out operations and repair, the end of the freezing-out should coincide with the end of the basic repair of the underwater part of the ship. Short periods left after the finishing of deep freezing out before the beginning of the thaw and the possible natural flooding of the ice dock can be used only for secondary work on the underwater part, such as, for instance, drying and painting the hull and small touching-up operations of general repair. The forcing of repair operations right after the freezing out is required also by the consideration of the possibility of a chance flooding of the hole.

By carrying out complete freezing-out of the vessel we pursue a double goal: in the first place, protection of the ship from harmful side pressures in the frozen state, and in the second place, carrying only along the way the repair possible under the technical and local conditions. Therefore, in the periods of freezing-out it is necessary to include also repair, and all the more since ice removal operations are done only periodically and take up comparatively insignificant bits of time (intervals necessary for the freezing of a new layer of ice). These intervals, lasting from 5 to 8 days, should be used for repair operations.

As will be seen below, the most limited number of persons is needed for carrying out freezing-out operations or for direct removal of ice in the hole.

In calculating the norms and periods for ice removal we will take the freezing of ice from 1 November through 1 May as 180 days. After figuring in free days, we get about 150 working days. Taking into consideration the difficulty of the work with ice and in the cold, the working day must be taken at not more than 7 hours. In order to establish a definite number of working days for ice removal, the calendar plan is thrown onto the scale of freezing.

Taking the average daily freezing of ice as three centimeters, and the period taken by us of 180 days, we can freeze a layer 540 centimeters thick.

This calculation shows that we can count on the freezing-out of a ship with a draft of up to 5 meters and leave a layer of ice under the keel of 40 centimeters.

Experience has shown that in the freezing-out period it is most expedient to remove even layers of ice at least 10 centimeters and not more than 20 centimeters at a time, with intervals of from 4-5 days to 8 days in between. With such a system of regular removal of a definite layer of ice we will achieve a regular freezing and correct calculation of the deepening of the hole.

Taking the thickness of the layer of ice removed at 20 centimeters, it is possible to calculate in advance both the number of such layers and consequently the number of benches of the future ice dock. To freeze-out a vessel with a draft of 5 meters we find: 500:20x25 benches. If it assumed that we will spend one working day on each bench, then for the whole freezing out 25 working days out of the total 180-day ice freezing period will be used.

Thus, for freezing through the hole will go 180 minus 25 equals 155 days, and there remain for repair: 150 minus 25 equals 125 days.

Table two gives a model of a calendar plan for freezing out a schooner in Tiksi Bay. The plan is made up on the basis of experience from 1937-1938.

On the basis of experience three categories of norms for ice removal in the process of deep freezing out of a ship are proposed. (table 3)

In freezing-out the qualitative side of the operations must come first, since emphasis only on the quantitative indexes, especially if a worker is inexperienced, can lead to disruption of the whole plan.

In ice removal exceptional attention, discipline, and caution are required from the workers. Practice and experience have an especial importance in this work, since they condition the above enumerated categories in the norms of ice removal.

The qualification of freezing-out workers by categories has been taken by us as follows:

First category - experienced freezing-out workers with 2-3 years experience;

second category - average experienced with 1-2 years experience.

Third category - inexperienced workers with 1-2 years experience, working under an experienced freezing-out worker.

Freezing-out workers of the first category are at the present time still an exception, although in general a sufficient number of ice cutters can be found. Most often it is necessary to carry on operations with freezing-out workers of the third category, or more correctly, teach people this work in the process of the work itself, and, consequently, making up the plan for operations, taking into account the productivity of labor, must be oriented above all on the norms for the third category.

It is necessary to name an auxiliary crew of ice gatherers for the removal of the ice from the hole to the basin and carrying it away from the side of the ship.

In order to determine the amount of ice removal for the trench of the ice dock it is necessary first to establish the volume water displacement of the ship to be frozen-out according to the formula D = LBT , where D is the water displacement of the ship, L is the length of the ship, B is the beam of the ship, T is the draft, beta (δ) is the coefficient of water displacement for the given type of ship, and gamma (γ) is the specific weight of water.

Taking the specific weight of water at 1.026 or 1.03, and the specific weight of ice at 0.90, we can derive the relation of the height of the floating part of the ice above the water level to the total thickness of the ice: 1.03 minus 0.90 equals 0.13.

In appended table 4 are given the elements for five ships of various types and the corresponding trenches of the ice docks for then.

To simplify the calculation, this coefficient of water displacement (beta) of the ice dock is taken as the same as that of the ship, and T corresponds to the deepening of the hole under the keel.

The water displacement (D) of the ice dock exceeds the water displacement of the ship by approximately 100 percent. Consequently, the quantity of ice to be removed for the trench of the ice dock matches approximately the water displacement of the ship. Therefore, for small ships it can be equal to or somewhat larger than the water displacement of the ship, and for medium-size and larger ships the quantity of ice can be less than the water displacement.

As has already been said, for the quickest freezing through, to increase the durability of the construction of the hole, and for simplicity of calculations, it is necessary to remove the ice in layers of 20-10 centimeters. the 10-centimeter -high benches should be made approaching the horizontal line of the keel line; this also keeps the removal of ice to a minumum. Under the bottom of the ship removal of ice follows closely the outlines of the ship.

In the attached chart (figure 5) are presented the cross-section dimensions of the holes for three different types of vessels having the same draft (about 4 meters).

Each of the benches has its own order number and date for ice removal. In the chart are shown the sequence of ice removal, according to the calendar plan, and the probable thickness of the ice in the place of each bench, calculated by the average probable freezing during the time of the execution of freezing-out operation.

On the basis of this data, the volume and weight quantity of ice destined for removal, it is possible to conclude that for removing the trenches of the docks of volumes of from 500 to 2,500 cubic meters, from 2 to 9 freezing-out workers are needed for a period of not more than 95 days, with an average daily removal norm of 3-4 cubic meters. From this calculation it is seen that the number of basic workers in freezing out does not exceed the composition of the deck crew of ships with a displacement of from 500 to 3,000 tons.

Thus, the actual period of ice removal lasts not more than 95-100 working days from the 150 days (the total period of ice freezing) planned according to the plan.

Thus, we have left in reserve at least 50-55 working days or about two months which can be used for repair and other ship operations. Part of this time must be set aside for bad weather, to be used for internal work on the ship. With good calm freezing weather the freezing-out operations must be pushed, being executed simultaneously with the repair of the underwater part of the hull of the ship.

Ice removal in the hole begins from either end of the ship, for instance, from the stern, and proceeds evenly along both sides until the circle of the given bench joins at the bow end.

With this it is necessary to note on the side of the ship or on the ice, and also enter in a journal, up to exactly what point in the course of each day will be removed a definite area of ice. It is necessary to know this in order to establish the times of freezing through and the thickness of the frozen layer of ice in the removed spot and to determine the period of the following removal. In removing the following bench it is necessary to hold to exactly such an order and sequence in the work. If it is assumed that with such a system we will be able to remove one bench over the whole area in the course of three days, that is, one third of the length every day, then with the finishing of the last section in the bow part the first in the stern part will already be frozen through in the course of not less than two days to a thickness of about 6 centimeters, and the middle will have frozen 3 centimeters during one day. After an interval of 4 and not more than 5 days after finishing the removal of the first bench it is possible already to begin the removal of the second bench on the first section, etc.

As the deepening progresses, the width of the benches will be gradually reduced opposite the vertical part of the hull, and consequently, the area and the volume of the removed ice will be reduced, as will be the time spent in this work. If at first it is necessary to spend three and more days per bench in removing the first layers of ice to a depth of up to one meter, in the middle part of the ship, with the same number of workers and the same norms, the removal of the regular bench can be finished in 1-1.5 days.

To avoid errors in determing the advance of the period of the regular ice removal, it is necessary to keep an accurate journal of the freezing out with specification of the date, area, and ice thickness, and also of the assumed thickness of the remaining layer.

11. The Progress of the Freezing-Out Operations.

Planning of the freezing out by a plan made up in advance should precede direct ice removal.

The plan is a schematic outline of the projection of the ship on the plan of ice to scale, with designation of the quantity, form, and dimension of the separate holes and the crosswise links between them. In accordance with the plan all holes should be numbered with paint on the side of the ship at the place of their location. Even numbers should be used to designate the holes on one side of the ship, for instance, on the right side, and odd numbers should be used for the other side.

It has been established from experience that it is more expedient to leave crosswise links opposite the diametric plane of the ship, that is, along the bow and stern, where cracks usually appear tending to split the whole freezing out in two. The presence in these spots of crosswise links will aid the reinforcing of the edges of the holes and the diversion of the cracks to the side.

Thus all holes are located symmetrically along the sides. Two opposing holes, for instance, No 1 and No 2, comprise section I of the hole, No 3 and No 4, section II, etc. Both the holes and the crosswise links in the sections should be identical in regard to areas and strictly symmetrical in location, so that the crosswise links of the holes of one side will be a continuation of the crosswise links symmetrical to them on the opposite side.

Strict planning of the holes is necessary so that the ship will have even points of support of the ship on the ice along both sides of the diametric plane.[redacted].

When the deepening of the holes in the freezing reaches the level of the lower edge of the keel, the holes of one side join with the opposite holes to form one continuous section or shaft. The freezing of ice by sections progresses more intensively and evenly than in separated holes because of the draft created or the blowing through under the keel even in a calm (because of the difference of temperatures on the opposite sides of the ship). Usually the freezing of the opposing holes goes unevenly. Holes freeze quickest which are located on the north or shady side of the ship, and freezing is slower on the sunny south side.

Division of the freezing out by crosswise links into a series of sections permits the systematic inspection and repair of specific parts of the hull and keel. However, the crosswise location of the links is a great hindrance insofar as cleaning the holes of snow is concerned, since it promotes large snow deposits in the holes and at the same time hinders the freezing of the separated holes. This negative role of the links becomes evident after their removal at the end of the freezing out, when the natural blowing of the wind goes already through the continuous united hole, along the two side corridors. In this case there are only an insignificant number of deposits and only at the bow end of the continuous hole, and freezing of the hole progresses most intensively. Unfortunately, this moment arrives only at the end of the period of ice formation, when there is only a little time left for the freezing out.

This negative peculiarity of the links of the freezing-out makes necessary a review of their importance from the point of view of their necessity so that their negative aspect can be reduced to a minimum.

As has already been showed, the links have a double purpose: protecting the whole freezing-out from flooding, incase one of the holes is flooded, and supporting the ship in a horizontal position as the ice is removed from around the hull. The supporting of the ship is important when the deepening of the holes reaches the level of the bottom of the ship; as the freezing out progresses it is necessary to transfer gradually the pressure of the weight of the ship to the ice and free the bottom of the ship from its contact first with the water and then with the ice. At this stage of the operations the links take on the function of ice supports until they are replaced by wooden supports or lumber. In this it is necessary to note that the supports are needed starting only from the [redacted] breast [redacted] formations of the ship or from the more expanded side formations. The narrow ends of the bottom, bow and stern are set on underkeel bedding.

As help for the ice supports on the sides, wooden supports are laid under the keel as the freezing out progresses. After all or part of the keel has been freed from the ice and the underkeel bedding has been installed, the ice links are gradually cut out and replaced by lumber. In this operation first four-sided, and then prepared wooden beams are installed in the cribs. They are placed solidly against the walls of the ice support and securely wedged, so that the ship will be supported on the beams, and only after this the ice support is removed, with the exception of the foundation, which serves as support to keep the beam from slipping to the side.

From the described process of operations, it is evident that the links are needed as ice supports until the end of the freezing out, in the depression near to the level of the bottom, and that the upper part of the links, down to this level, is superfluous.

Until the bottom is completely frozen out, the ship is so solidly connected with the ice that heeling of the ship is not to be feared.

To remove completely the possibility of heeling it is sufficient to install several wooden supports and beams from both sides of the ship to the benches of the hole, similar to the bracing of a ship in an ordinary dock. Installation of the side supports is not necessary, it is evident, before the beginning of the freezing out of the bottom.

From what has been said it follows that in planning freezing out we must only mark out the places for the links, but actually in the process of removing the ice do not have to begin to leave them earlier than the moment when the depression of the hole reaches the level of the surrounding side outlines in the formation of the bottom, that is, when they have become necessary for their basic function as ice supports.

From here it follows that in freezing out a ship with a draft, for instance, of about 4 meters, to preserve the stability of the ship no links have to be left until the deepening has reached 2-3 meters.

It is necessary to keep in mind, however, that the danger of flooding the freezing out remains constant in the presence of inexperienced freezing-out workers and with a lack of labor discipline and attention to the work, and also when there is insufficient account of the periods of freezing and the thickness of the freezing and removed layer of ice.

The last considerations speak in favor of leaving the links, in spite of their negative role in regard to the speed of the effecting of the whole freezing-out.

When complete freezing out of the schooner Temp was done in the 1936-1937 wintering period, the freezing out was divided into 24 holes, and 22 links. At a depth of about 2 meters one of the middle holes broke through unexpectedly. Thanks to the links the freezing out was not flooded. The moment was exceptionally serious since at this time in the stern hole the worn propellor had been frozen out and it was necessary to replace it with a new spare propellor.

If the whole freezing-out has flooded, it would have been impossible to carry out this operation; since all operations had been begun late, in the middle of December, the deepening of the stern hole, which was the deepest, had reached more than 3 meters. The links proved their function and saved the situation. The flooded mine was filled with ice and frozen out with some delay. Without the links the whole freezing out would have been delayed and it would have been necessary to start it anew.

It is impossible not to emphasize that the reason for the flooding of the hole was the lack of caution on the part of the engineers in the ship, who dropped the heavy part of the propellor shaft while they were carrying it. The shock received by the hull caused the rupture of the bottom of the hole, from which the regular layer of ice had just been taken.

This case shows that during freezing-out operations and in particular at the moment of ice removal, it is necessary to avoid all shocks in the ship; also, it is necessary to prohibit also wood splitting on board. If, however, circumstances require that operations involving heavy weights (taking on fuel, unloading etc.) be done on board, warning must be given in advance and these operation must be performed before ice removal or not less than 24 hours after ice removal, when the ice in the hole has strengthened.

A similar flooding of one of 20 holes took place in the expedition of the schooner Polyarnaya Zvezda, which had effected full freezing out in shallow water. The flooded hole was isolated and frozen out later.

At approximately the same time, all four sections of the side trenches of the partial freezing out of the neighboring schooner Leningradsovet were flooded, in spite of the links which had been left. Of the four sections flooded three were at the stern and one was along the side. An effort to pump them out with a fire pump had no success.

The reason for the flooding of the freezing out of the schooner Leningradsovet was the ring-shaped construction of the holes and the untidiness of their content.

In the 1937-38 period the attempt at full freezing out, with 26 holes and 24 links, of the schooner Temp was repeated. In spite of the numerous cracks in the edges of the holes, this freezing out was effected successfully. At the same time on the neighboring towing steamship Levanevskiy all three stern holes of a partial freezing out, having complete links, were flooded prematurely. The accident was caused by the puncture of one of the holes and the flooding of the two adjacent ones through gaps along the sides of the ship which were formed because of bulging of the freezing out. The reason for the flooding of the freezing out of the steamship Levanevskiy was the same as that of the schooner Leningradsovet - a lack of interest and attention for the freezing out.

These examples of flooding of holes show that with the schooners Temp and Polyarnaya zvezda the links proved their purpose as protection against flooding, and failed to fulfill this function in the freezing out of the schooner Leningradsovet and the steamship Levanevskiy.

On the basis of the consideration mentioned and the cases cited one can make the deduction that the links must be kept in the freezing out only until the deepening reaches one meter, after which they can be removed because of lack of necessity and even their harmfulness because of their ability to hold snow deposits.

The uselessness of the links at a depth of over one meter is illustrated by the fact that, because of the raising or bulging described above, of the freezing out, the links separate from the side of the ship a distance of about 20 centimeters.

In freezing out the schooner Temp in the 1937-1938 wintering period, there was separation of the links from the side of the ship in the form of one or several cracks with a total width of up to 72 centimeters at a depth of 3.15 meters.

For the removal of these cracks there were planned 80 man-hours for "freezing of crack links" in the plan of ship works. Lacking a special person, the captain himself did this operation. Packing the cracks was done with snow soaked in water. However, at a depth of more than one meters this operation had to be discontinued, since after each regular removal of ice deep cracks in the 24 links inevitably reappeared.

It is most expedient, after the removal of the fourth and fifth benches, that is, at a depth of 80-100 centimeters, when the independant separation of the links from the side of the ship is clearly pronounced, to cut the links away, leaving only a foundation 4-5 centimeters high so as to preserve for them a ready form and position if it should become necessary to renew them again as ice supports when the level of the bottom of the ship is reached.

As an exception to this rule, we can leave two lengthwise links - in the bow and stern part, which can be kept until the depth of the hole reaches the level of the keel. In the following the uselessness of keeping them even as ice supports will be discovered.

The bow link must be cut earlier than the stern link - if the difference of the ship is by the stern, if the ship has a cut bow or with an ice formation of the bow part. After the removal of the links the freezing out will take on the aspect of a dry dock with the concentrically placed benches of the common hole.

In regard to the question of the outlines of the ice dock, it is necessary to note that in working with ice one must avoid sharp angular connections, keeping, if possible, an oval form. With angular outlines the process of ice formation is weakened, as is the construction itself of the hole. In addition, sharply defined corners cause the appearance of cracks, since snow most often is deposited in corners, and the ice promotes the heating of local increase of temperature, which leads to the separation of salt solutions, which corrode the surface of the growing ice.

The oval form of the surface edges of the hole are most easily cleared of snow. This form of hole gives the greatest resistance to the external pressure of the water. In accordance with the outline of the hole the stepped benches of the hole must be constructed when removing ice in conformance with the outline of the hole.

Marking out the plan for the freezing out of the hole is done with a rack template, by which the dimensions of the holes and links are measured around the side of the ship. The outline of the hole can be made in the form of a rectangle. The curved form on the connection of the right angles is made approximately, with the aid of a pick, which scratches in the ice the points of the outlines of the hole. Application of the template should begin from the same end of the ship, for instance, from the stern. The outlines of the hole are marked out first from the right side, and then from the left side of the hole.

Work on the removal of the first layer of ice can begin only when the freezing out plan has been transferred from the sketch to the ice.

It is necessary to consider the beginning of the freezing out that moment when the first layer of ice 20 centimeters thick out of a total thickness of the ice field of h (hle) centimeters is removed. This layer is removed along the line of the tracings made with the template. Preliminarily, samples of the thickness of the layer of ice are taken with the aid of a long drill.

The first removal of ice to a depth of 20 centimeters, when there is an insignificant water pressure from beneath, is done strictly horizontally.

The following removals must already be calculated according to the degree more than 2 centimeters. On the basis of this calculation, the following ice removal can be done not earlier than after 3 days and to a depth of not more than 10 centimeters.

The second and third benches also are removed almost horizontally, since the raising of the freezing out is noticeably visible only at a depth of more than 0.5 meters.

12. Changing the Draft of the Vessel during the Freezing-Out Period

If one begins to freeze out an empty area in the ice to a considerable depth, with the aim, for instance, of dropping the freezing out down to the bottom, one is quickly convinced of the uselessness of the operation. In a depression approximately double the thickness of the natural layer of ice of the surrounding field, the freezing out will begin to rise in its central part, as if trying to regain a position near to the level of the horizon of the surrounding floating field.

In deepening further the freezing out of such a hole, we would be able to freeze its wall to any thickness, but we could not prevent the bulging of its center, and, consequently, we would not freeze it out down to the bottom, since this would be hindered by the opposing water pressure which is always increasing with depth. From the outside such a freezing out would have the look of a hill with a horizontal summit. The walls of such a hole would have numerous cracks, and the middle of the hole would be an ice cupola.

In order to freeze out a hole down to the bottom, it is necessary to create gradually an artificial pressure in its center equal to the weight of the ice removed or equal to the water pressure at the given level of depression.

In freezing out a ship, this water pressure causes the raising of the ship to some height, in accordance with the reduced pressure of weight on the water from the direction of the removed mass of ice.

In connection with this the draft of the ship is also always being reduced until the end of the freezing out, that is, until the moment when an equilibrium is established between the weight of the ship with the ice dock and the countering water pressure on the bottom. This raising of the ship is not even and not free, as is observed, for instance, in open water when a ship is unloaded. (The tendency of the water pressure to raise the ship up unevenly requires exceptional caution in freezing out ships with a weak lengthwise structure since in carrying out the freezing out a critical lengthwise bending moment can be set up in them.)

To be sure, a hole's own raising with a ship during freezing out is subject to the same laws as is the raising of a ship by a floating dock in clear water, that is, proportionally to the reduction of the weight of the water pumped out, and in our example proportionally to the quantity of ice removed at a given water line level.

In freezing out the schooner Temp it was possible to obtain the following results by ice removal with tools.

When the hole had been sunk to 3.15 meters the rise of the upper edge of the ice of the links was 1.12 meters above the general level of the surrounding ice field. The freezing out was planned for 4.2 meters, the vessel having a draft of 3.8 meters, with the distance of the outside edge of the hole from the side of the ship to be 2 meters. Consequently, when the width of the hole between the outside edge and the ship is 5 meters the rise of the ship should be more than 2 meters.

The observations cited show that because of the natural raising of the ice dock we are able to decrease considerably the planned deepening of the freezing out of the hole by widening it. This circumstance also permits, the freezing out of a ship with a draft exceeding considerably the artificial freezing, which is an average of 3 centimeters per day. For this it is necessary to calculate in advance the dimension of the hole in width or the volume of the ice dock capable by its water displacement of raising a ship to a definite height or to the depth accessible for the artificial freezing of ice during a definite period of ice formation.

In freezing, for instance, to 6 meters during 200 days of ice formation it can be assumed that freezing out is permissable for a ship, up to the ocean-going size, in the unloaded condition. Because of the property of the raising of the freezing out there is a reduction in the volume of ice removal as calculated for the deepening in an unmoving medium.

Taking into account the gr at ice pressure on the side of the ship, it is necessary to carry on work in this place with especial caution, leaving an even and sufficiently thick layer of ice everywhere. In addition, unexpected phenomena are most often encountered in the side ice zone. These phenomena hinder freezing through and ice removal operations. These include the appearance of large air holes, and petroleum and oil seams.

The heating action of the hull promotes the expansion of air bubbles and the increase of air pockets, which insulate the water from the ice and thus hinder ice formation.

The second cause of the appearance at the side of the ship of air bubbles, and also of petroleum and oil, is the pumping of water out of the ship. If dirty water collected inside the ship continues to be pumped over the side by machinery onto the ice area, much outside air is sucked up by the pumps and thrown under the ice, especially if the outlet pipes are located below the waterline.

Petroleum and oil get into the water through the Kingston valves, which during wintering are filled with these products to protect the pipes from bursting. To prevent this, water from the engine room and other places should be pumped to the surface of the ice and removed beyond the basin by troughs.

Air bubbles and petroleum accumulations discovered during the freezing out must be carefully removed by light puncturing or drilling of the ice and let out to the surface; the opening must be closed quickly, since water will appear right after the air or petroleum. Petroleum falling on the surface of the ice must be wiped clean with a broom.

13. The Floating Ice Dock.

So far we have observed the effecting of freezing out operations in an unmoving ice field, the border between which and the working area for the freezing out the outside line of the basin, 8-10 meters from the side of the ship, serves.

At the end of the freezing out, beyond the basin there is usually observed a piling up of cut ice and snow several meters high. This accumulation narrows the ring of the basin almost down to the outside edge of the hole and in this manner creates a calm zone and causes heating of the freezing out, and consequently the freezing of ice is retarded.

Under the weight of the ice and snow the ice bends, and deep cracks going right up to the edge of the hole, appear, water leaks through these cracks to the surface and threatens to flood the freezing out. Only immediate stuffing of the cracks with ice chips and moistened snow can prevent water from getting into the hole.

Snow saturated with water bends the ice even more, and freezing of the ice under it is reduced.

Water saturated with brine under snow does not freeze, with the exception of a thin crust which is formed on the open side of the basin and which hinders to some extend the entrance of ater to the mirror of the basin.

A raising of the edge of the hole as a result of the bulging of the freezing out also impedes the entrace of subsnow water into the hole. For this reason the basin gets a sloped surface, on which it is difficult to walk without sprinkling snow. Persons usually move along the outside area of the basin, staying beyond the snow ice pile.

It is extremely difficult to clean such a basin and hole of snow after a regular storm, since during the operations some rehandling of the snow has to be done.

It is possible to avoid a considerable part of these difficulties and inconveniences in the work by separating the basin from the surrounding ice by a circular cutting.

In this case the ice dock will be turned into something like a floating dock which will rise above the level of the surrounding ice field.

The work of cleaning the whole freezing out of ice and snow is eased considerably when the ice dock is separated.

The natural blowing away of snow deposition is better from the raised area and the necessity of removing snow and ice to the leeward side of the ship is eliminated. With a floating dock there is also eliminated the most serious danger of external flooding of the freezing out through cracks formed in the field outside, and from water on the ice when snow melts at the beginning of summer. This permits keeping the dock longer than is possible with an unmoving ice dock.

The indicated advantages of a floating dock fully justify the labor spent in cutting the basin and the trouble in keeping its sides from freezing solidly to the outside field. Clearing the cutting place of excess snow, before the end of the freezing out, is probably not necessary more than twice a month.

After each removal of ice in the hole the thin layer of ice where the ice dock is cut out will break off itself, raising together with the basin and the ship; also the edge of the ice field, laden with snow, will settle.

The raising of the basin of the floating dock should always lag somewhat behind the more intensive raising of the ship in the center of the hole. This lagging will be all the more noticeable the further the cutting out of the dock is done from the edge of the hole.

In cutting out the ice dock far from the edges of the hole, it will also be impossible to avoid the sloping or slanting of the basin toward the outside field. Thus, the wide fields of the basin will seem to sag under their own weight, creating at the same time an obstacle to the raising of the whole structure. Therefore, calculation of the distance at which cutting out of the ice dock is to be done is very important.

The most advantageous distance for the raising of the basin would be cutting in the direct proximity to the edge of the hole. However, this in its turn would create difficulties in the movement of persons around the hole during the work and the necessity of throwing the ice out of the hole, because of a lack of an area, directly into the cutting-around trench, which is not desirable, since it creates difficulties in the further removal of ice.

In view of these considerations we suggest that cutting around the ice dock be done at a distance of from 1.5 meters to 2 meters from the edge of the hole.

The determination of the time for the cutting out of the ice dock (at the beginning or end of the freezing out) is the second serious problem.

From the point of view of making the cutting easier, it would be better to do the cutting at the beginning of the freezing out, or, perhaps, before the removal of the ice in the hole, when the ice is 30-40 centimeters thick.

However, premature cutting can turn out to be inefficient in that it can freeze and attach itself anew to the outside field before the removal of ice in the hole gives the effect of raising.

At the end of the freezing out the result of the raising can be most effective. But this circumstance creates the danger of damaging the floating dock from the appearance of cracks and heeling, with the possible grazing of the edges of the dock along the edges of the field as a result of the rapid raising of the dock under great pressure.

The last considerations indicate that for cutting out the floating dock a time very near the beginning of the freezing out must be chosen.

The best moment for cutting the basin of the floating dock is the period when the freezing out of the hole has progressed to a depth of not more than one meter or after the removal of 3-4 benches to a depth of 60-80 centimeters.

The rise of the ship or of the center of the freezing out at this moment will be about 30-40 centimeters, and of the edges of the basin, about one half of this height.

The thickness of the ice of the ice field at this time should be about 70 centimeters.

The calendar period for the cutting of the floating dock can be about the last ten days of November, when the snow drifts are still slight and do not pdrsent serious impediments to the cutting operations.

The boundary of the cutting of the ice dock can be traced with a straight-edge template at a distance, as already has been said, of about 1-2 meters from the edge of the hole.

The width of the trench cut around the dock should not be narrower than 60 centimeters and not more than one meter. Until the cutting of the trench is finished, while the ice is being chipped out, it is necessary to keep links at a distance of not more than 5 meters one from the other and from 25 to 40 centimeters wide. The layer of ice left in the bottom of the trench should be not more than 10 centimeters, so that it will be easier to cut through the separate sections between the links to water. The cutting should be done in the course of 2-3 days so as not to accumulate a thick layer of ice at the cutting out spot and thus complicate the operation.

Just as in freezing out a ship, it is necessary to hold to a definite system in cutting out an ice dock. First, cutting should be begun from a definite spot, for instance, from the stern, and should be carried out symmetrically along both sides until the trenches meet opposite the bow end of the ship. Four more solid links should be left opposite the stern and bow and opposite the middle part of the ship. When the cutting around is finished, these links are removed last.

The final cutting with flooding of the sections of the trenches between the links should be done so that the sepearation of the basin from the outside ice field is done simultaneously and smoothly, without raising any edge at any place.

If there are not enough people to execute simultaneous connection of the sections, the operation must be done by methods calculated in advance. It is best to divide the whole trench ring into not less than six sections of equal length, counting from the bow and stern links, or into three symmetrical double ring cuts. The length of each such cut should occupy one third of the length of the ship.

After the distribution of the sections it is necessary to effect a corresponding distribution of people for the cutting. With a limited number of people the indicated sections are cut opposite the bow and stern ends of the ship and simultaneously from both sides, for which not less than 4 men are needed.

If there are 2-3 men, the cutting opposite the ends of the ship must be done on a diagonal, for instance, the right bow and left stern sections, then the left bow and right stern sections.

After this there remains the cutting of the two middle sections located opposite the middle of the ship. Here also, with an insufficient number of men for simultaneous cutting from both sides, it is necessary to do the operation on diagonal sections, converging toward the middle link from the bow and from the stern.

Having finished in this manner the cutting through of the whole trench, we are left with four intact links (opposite the bow and stern and two opposite the middle part of the ship).

If the ship is under strong pressure to raise itself, these links may fail to withstand the pressure and break before they are cut. The two center links must withstand the greatest pressure, and therefore it is necessary to cut them last.

If four men are available, all four links can be cut almost simultaneously, at a command or at a signal whistle. In this case the middle links should be cut slightly later than the others.

The recommended precautions derive from the consideration that the center of pressure of the basin should be at the center of the freezing out. Therefore, if one cuts, for instance, the middle of the basin first, and then the ends, by the strength of the rise the center can rise before the ends and split the basin in two. The same thing can happen if the whole basin is cut out leaving a solid connection at its ends with the outside field.

14. Installing Timbers

As has been mentioned, under-keel bedding and timbers are installed as the keel and bottom are frozen out.

The location of the timbers and under-keel bedding is determined in practice by the location of the frozen-out part and the form of the outlines of the hull of the ship.

Lumber for the timbers and bedding should be laid in advance, even if obtained from driftwood. Beams from 10 to 15 centimeters and not more than 20 centimeters through are best for this purpose.

Preparing lumber for timbers involves trimming ground beams on all four sides with an axe so as to give the beams a four-sided form, which is the most convenient when putting the supports into the cribs, and then cutting them to a more or less equal length of 1-1.5 meters. It is unnecessary to maintain great precision in the length and thickness of the beams, since when they are fitted in place it is necessary to sort, trim, and cut them to various shapes.

The lower row of the crib of timber is easily installed on the ice by clearing unevennesses or cutting slots in the ice in the form of the beams.

A more difficult task is installing the upper binding row; this is done with the aid of wedges. Before laying this row and securing it fast to the bottom of the ship with wedges it is necessary to clean this part of the bottom of the ship of ice, and it is best of all to thaw it out by heating with a burner or a blowtorch.

Ice left between the hull and the bedding can melt and cause settling and slipping of the brace to one side.

The support points of the braces are determined by the locations of the links or ice supports, which, as the freezing out progresses and as it is necessary, are replaced by the braces. It is useless to install the braces before the end of the complete freezing out, as is it useless to place any type of supports under the counter in the stern hole and under the cut of the bow in the bow hole, even if they have already been completely finished. Here under keel bedding is sufficient.

If the freezing out is going to be continued in the middle part of the ship, the ship will also continue to rise, separating from the braces and support at the ends, no matter how solidly they have been wedged. Driving pegs and even installing additional beams, after each rise of the ice, is necessary also at the end side supports.

Only the braces installed in the middle part of the ship remain solid throughout the freezing out under the keel, since the pressure and bulging of the ice is concentrated here and the ice presses against the bottom of the ship the whole time.

After the ship has been installed on braces if it is necessary to continue the freezing out deeper, the solid connection of the supports with the bottom of the ship must be maintained and when a weakening of the wedges is observed, they must be driven in, so as to maintain an even pressure of the ship on all the points of support.

In the opposite case, if the weight of the ship is transferred to a limited number of support points, the support points will be strained and either the ice will develop cracks or some support will collapse or move, threatening to destroy the whole system of supports.

If a brace is installed solidly, by the entire outer side, to the wall of the ice support, the danger of its slipping under great pressure will be removed. If a brace for some reason has to be placed in an open space in the hole, the beams of such a brace should be connected with construction brackets. The lower row of beams of the crib of such a brace should be slightly sunk in to the ice. Also it would not be superfluous to sprinkle the place where the beams are fastened into the cribs of the braces with sand or cinders in order to create more friction. This is especially important if damp frozen and slippery ice is taken for the supports.

15. Under-Keel Bedding

For the under-keel bedding one should select the most solid wooden beams at least one meter long. They should be ready at the moment of removal of ice from under the keel. Under the keel and in the center of the cross section planes of the hole, the greatest pressure is obtained, and consequently, the greatest ice compression. Therefore, as soon as there is sufficient free space under the keel, bedding should immediately be placed solidly under the lower edge of the keel. The bedding is placed with its middle across the keel. If one beam is not thick enough either two and more are installed, on the flat side one of the other, or a flat wedge is driven in, facing on the remaining area between the plane of the keel and the bedding beam.

For wide flat-bottomed ships it is necessary to place a triple-row crib under the keel: three beams along the keel and two across, so that the middle one will go under the keel. In this it is necessary, to see to it that the ice under the bedding is removed horizontally and cut and swept clean, so that the bedding will bear on the ice with its whole surface. The under-keel bedding should be placed at intervals of at most one meter and at least .5 meters. Bedding placed too close together hinders the freezing of ice and snow removal, and bedding separated too much reduces the number of points of support and creates an uneven ice compression. The ice can be pressed up in the area between the bedding and come to bear again on the keel.

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For this reason we recommend that the bedding be installed immediately after the ice is removed from under the keel and in no case should more than one meter of the keel's length be left without bedding for freezing until the next ice removal.

The following example will show how intensively the ice presses against the diametric plane of the ship. In freezing-out the schooner Temp in 1938 ice was removed from under the keel not far from the middle of the ship. The thickest underkeel bedding was prepared, but it fitted too loosely under the keel. In order to fasten it solidly to the keel, it remained to insert a thin wedge. However, this was hindered by the signal for the lunch interval. When the work was continued after an hour, it turned out that not only was the wedge not needed, but that the bedding itself, laid to one side, no longer fitted into its former place. This example shows that in installing under-keel bedding in the middle part of the ship it is not necessary, as it is for bracing, to try to achieve an especially compact joining of the bedding with the hull, and it is more important to put it in place in time, even with a gap, since the ice will compress them itself.

It should be mentioned that the freezing of ice under the bedding is decelerated. Therefore, if freezing out under the keel is continued and it is necessary to remove temporarily and regularly replace the bedding when ice is being removed, the bedding should be put in a new place, even if only at a distance equal to the width of the bedding itself, so that the whole area will freeze more evenly.

The weakening mentioned of the pressure of the ship on the braces nearer to the ends of the ships holds also for the under-keel bedding, and if a strong pressure is observed on the bedding at the middle part of the keel, it weakens as it approaches the bow and stern ends of the ship.

16. Freezing-Out the Area Under the Keel

The most difficult part of the freezing out is clearing the area under the keel, that is, the connection of the two opposite holes of one and the same section.

In the constricted area the freezing-out workers must sometimes work with a pick lying on their back. To insulate the persons from direct contact with the ice and for ease in moving in a lying position it is recommended that each freezing out worker put under himself a piece of plywood board.

The working area is limited to several meters and in any case to not more than one half of the width of the ship, since when ice is removed in sections the workers move toward one another from opposite sides.

In general it is not recommended that one side be deepened exceptionally or that ice removal be repeated on the side which freezes more quickly. It is best to effect even removal on both symmetrical holes. A considerable deepening of only one side can cause distortion of the hole and consequently in the ship.

An exception to what has been said can be permitted when the plane of the keel is approached (for a removal of not more than 20 centimeters) in order having accelerated the freezing of one side, the freezing of ice under the keel and promote the connection of the meeting holes of the same section. However, in this case one must not go beyond the line of the vertical plane of the keel or make a cut under the keel from one side. It is necessary to wait until the depressions of both holes of the section are evened up. Until this moment it is necessary to keep a ridge of ice under the keel equal in thickness to the width of the keel. This ridge will serve as an ice support under the keel for the ship until it is replaced by wooden crosswise bedding. At the moment when the depressions of the meeting holes are lower than the base of the edge of ice of the under-keel ridge, the ridge can be partially broken by circular and square cuts through it.

These cuts must not be made arbitrarily but according to a definite system and with a double purpose: firstly to accelerate the freezing of ice in places where under-keel bedding is going to be placed, and secondly to create drafts through these windows from the northern side of the hole, which freezes better, and thus to effect more even freezing of the whole section.

Preliminary cutting of the windows in the under-keel ice support should be made at intervals of 0.5 meters, that is, at the places where the under-keel bedding is going to be installed.

To produce a draft and rapid freezing of the under-keel zone, small apertures several centimeters square are sufficient at first, and then they can be gradually increased to 10-20 square centimeters, i.e., to the thickness of the underkeel beam. At this moment intensive freezing will begin.

Complete cutting of the under-keel ridge of ice begins at either end of the ship, for instance, from the stem. After the installation of the first timber, with ice removal over a distance of not more than 1 meter, an area for the second timber is prepared at a distance of 0.5 meters from the first, the ice is removed 0.5 meters further, etc. In this fashion in one section with the hole 2 meters wide and the forward link 0.5 meters thick, we must install from 3 to 5 timbers.

17. Reinforcing the Side Supports

Installing supports at the stem and the sternpost, as experience has shown, unnecessary, especially under the overhang of the stern, where, when the dock floods in the spring, the supports only hinder the ship's immediately assuming a normal floating draft and threatens to damage the sheathing.

To reinforce the ship against lengthwise movement, the usual braces, installed not closer than 2 meters and not further than 5 meters one from the other, in accordance with the curved formation of the bottom of the ship and the round outlines of the ship, are sufficient.

As a guarantee against chance heeling movements side or lateral supports can be installed as an aid to the braces. These side supports do not have to be installed more often than every 5 meters; if there is no heeling and the braces are firm, the distance can be increased up to 10 meters.

If the ship has a slight list to one side, this side must be reinforced with a large number of supports. Thus, for a small ship there are required from 3 to 5 supports on each side made up of beams 12-16 centimeters and up to 20 centimeters thick and from 5 to 9 and more meters long. In one word, the number of side supports and their dimensions will depend on the length of the ship, its type of design, and its durability. For a flat bottomed and low-sided ship the side supports may not be needed at all.

In installing the side supports it is necessary to place them at the greatest angle possible with the side of the ship, right up to 90 degrees to the diametric plane of the ship or near to the horizontal. Only in this case will the side supports serve their immediate purpose. Correct installation of the side supports is easily achieved by fastening their external ends to the upper steps or benches of the hole.

One must avoid the installation of side supports on the lower benches at a sharp angle to the side of the ship and with the support of the upper end under the rubbing stake. Such a support will hold the ship only to a slight degree against side heeling, and more from vertical movements; if the ship rises, the support will separate from the side and if the ship settles it will take upon itself great pressure and may break the rubbing stake.

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This phenomenon may take place if the ice dock floods, when the ship begins to settle to its normal draft in the water.

Installation of the side supports is done in the following manner.

After the places for the installation have been determined, the required number of beams are distributed approximately in their places. At the place of installation of a support beam a short end of thin rope, which suspends the inner end of the support, is fastened to the side of the ship. For the outer end of the support a depression sufficient to take the end of the beam is cut in the ice of the bench of the hole. Under the end of the beam adjacent to the side of the ship, there is made a solid cushioning of a short cut of wood or a thick strip with a cut in the center. The end itself of the beam is chopped off at a slight angle so as to fit snugly into the cut in the cushioning. If after the connection of the end of the support with the cushioning there appears a gap, a flat wedge is driven between it and the cushioning from the smooth side. It is not necessary to obtain exceptional tightness of the connection of the side of the ship with the supports by fastening with wedges.

If the supports are placed correctly (near to the horizontal plane) and in normal (solid) connection with the side, they will serve their purpose. If wedges are driven strongly under the supports from both sides of the ship, a crack can appear, splitting the basin along the diametric plane.

18. Drying Out the Underwater Part of the Ship

Drying out of the underwater part of the hull should be begun before completion of full freezingout.

Before the hull is dried, it should be cleaned of solidly frozen chunks of ice and then thawed. The thawing, like the drying itself, is done with blow torches and burners. The burners give the quickest results and therefore it is better to use them in working with large areas of the underwater part of the ship. We made such roasters in the form of flat tubs out of gasoline cans.

If it is necessary to make the burner out of sheet iron, the length of it can be made up to one meter and the width from 20 to 30 centimeters, with a height of 4-6 centimeters for the bent sides.

Thus there is obtained an object something like a long narrow griddle into which a thin layer of fuel - petroleum or kerosene is easily poured. In order to achieve more even burning and not too high a flame, and also so that the fuel will not spatter when being carried, the burner is first given some pitch, which is spread in an even layer on the bottom of the burner. To carry and raise the burner to various heights at the side of the ship, a flat pole or strip is fastened under the base of the burner with wire; the burner is easily raised with the extruding ends of the pole or strip by two men.

Thawing the hull with the aid of a burner proceeds from the lower to the upper frozen-out surface. So that the hull will not char and will be heated evenly, the roaster is moved constantly the whole time from below to above, to the sides, and back, until all the water from the melted snow has run off and even evaporation of the heated surface begins.

Then the same operations are repeated further until the thawing of the whole frozen-out surface is finished. In this fashion one executes the operations of drying a thawed but still damp hull. In this operation each area is heated to a temperature which can be perceived by the hand.

It is impossible, however, to heat and thaw the meeting deep seams of ice in narrow grooves, indentations under bolts, etc., with the burner. Therefore, such places are heated with the aid of a blow torch and then carefully inspected, especially with wooden ships, since water often gets into the inside of the ship through them. If ice is left in the grooves, they should not be caulked, puttied, and painted, since the insulation placed over the ice will be squeezed out by the water after the natural thawing of the ice. Some small injuries to the ice sheathing or ordinary sheathing will become noticeable only after thawing and careful inspection; these defects cannot be noticed immediately after the freezing out.

In thawing and drying the bottom of the ship in the constricted area of the under-keel part, the burner is placed on a base suitable in height and is moved with the base to the sides. It is necessary to keep in mind that the water produced in this operation falls directly into the burner and quickly fills it. One must not permit the hot water and oil to flow in the bottom of the hole, since, in addition to the melting of the ice by the hot water, the ice is even more disintegrated by the oil falling into the pores formed in the ice.

Therefore it is necessary to watch constantly the level of the liquid in the roaster and from time to time carry the roaster out to thick ice, empty it into a bucket, and empty the bucket outside the limits of the basin. To prevent the oil from dripping onto the mirror of ice of the basin and to avoid the chance splattering of fuel in general, the surface of the ice of the hole should be covered with a layer of snow opposite those places where thawing or drying of the under-water part of the hull is being carried out.

Upon completion of operations with the roaster this snow splattered with oil should be removed immediately.

Drops and traces of oil noticed on the surface of the ice should be carefully removed with a pick and the hole should be swept clean.

19. Painting the Underwater Part of the Ship

Climatic conditions in the Arctic are unfavorable for painting ships, since ships spend the greater part of the year in dampness, with sharp changes in temperature.

Relatively warm and clear days, the most suitable for painting, in the period before the beginning of the navigation season usually alternate with cold and misty days which often bring snow and rain. This period lasts usually from the middle of May until the middle of July.

The most favorable time for painting the outside surfaces is the second half of this period, that is, after the middle of June.

In the first half of this period it is also possible to choose a suitable time for painting the superstructure and gunwhales, but the ship still cannot dry out sufficiently, and the misty weather hinders the hardening and drying of the paint.

The problem of painting the underwater part of ships is much worse. A majority of ships based at polar ports are not painted for several years in a row after they leave the mechanized dock of a large port, in spite of the fact that their underwater part needs repainting every year just as much as does the above-water part.

The schooner Temp up to this time had not been in a dock since it was built in 1931. Only during the belated freezing out of the stern part during the 1935-1936 wintering period the propellor and rudder were hastily painted with red lead, but the paint was quickly washed off, since the hole was flooded in the night following the painting. At the end of the navigation season no traces of red lead were found on the propellor.

Instead of paint on the surface of the steel propellor there were discovered many traces of corrosion in the form of deep cavities, and the edges of the propellor were so thin and had so many holes in them that they could be broken off with the fingers. The described condition of the propellor confirms that the propellor was not affected by the ice and consequently, the wear on the propellor was caused primarily by the oxidation of the metal in sea water. In measuring the length of the worn blades and comparing them with the dimensions of a spare propeller of the same size, it was found that the shortening of the blades reached 8-10 centimeters. Beyond any doubt such wearing of a massive steel propellor because of a lack of insulating paint could take place to a considerable degree over a period of 5-6 years.

Traces of deep corrosion were also discovered on the surface of the steel rudder and the iron fittings of the sternpost and stem. In 1937 we gave the propellor three coats of paint (two of red lead and one of white mineral pigment (belila) and the other metal parts of the underwater part of the ship received two coats of red lead. Inspection of the ship after freezing out in 1938 showed that on the smooth surface of the propellor the paint was preserved to a small degree, but in the corroded cavities it was well preserved. The paint remained much better on the rudder and on the stern fittings, and on the ramming fitting of the stem it was completely worn off by ice.

These facts indicate that regardless of the thickness of the paint applied, on the underwater part of the hull the paint lasts for only one navigation period; consequently, the paint on the hull should be renewed every year.

Only the freezing-out period is the the time for painting operations on the underwater part of the ship, and as a result these operations must be carried out at low temperatures.

The whole process of painting consists of three basic, independent, and simultaneous operations:

1) heating the surface to be painted with burner and blow torches;

2) preparing and constantly heating the paint in a fireplace, over a kerosene lamp, or even on a primus stove (pitch is heated over a wood fire);

3) direct painting of the underwater surface.

The labor must be divided up in accordance with these types of work.

One group (not less than two persons) must constantly heat a definite area of the surface of the hull to a heat which can be perceived by touch. This group also sweeps the place to be painted with brushes, rags, or hemp fiber.

The second group prepares the paint, brings it to the heated state (but not to the boiling point), and carries it to the place of work. Paint pots which have cooled are taken away for reheating.

The third group, right after the first, does the painting with brushes. For painting operations one unfailing condition is required: absence of snowfall.

The painted surface is under the action of the positive temperature of the heated paint for an extremly short time, not more than half an hour, depending on the temperature of the air, after which rapid cooling sets in.

The short-lived action of the heat is necessary for the solid adherance of the paint with the painted surface of the ship.

In order to accelerate the process of drying the paint at freezing temperatures, periodic drying or heating of the painted places is done by the same methods used for drying the hull. In order to accelerate the drying of the painted propellor or rudder, their surfaces are heated with a blow torch without burning the paint.

Normal heating is achieved by moving the source of heat continually over the painted surface until the whole area is heated to the same positive temperature.

Usually, heated paint or pitch takes on a fresh appearance from the surface such as it had when it was being applied. It takes the same appearance under natural conditions of drying if the temperature of the air changes from below freezing to above freezing.

The more often the surface painted in freezing temperature is heated, the more rapid will be the full drying of thepaint. With the purpose of even greater acceleration of the drying of the paint, a double proportion of drying agent is mixed in the paint.

Also, here it is especially necessary to see that the layer of paint or pitch is spread as thin as possible; this is done by brushing the painted surface to a dull shade.

It is absolutely not recommended that the paint be allowed to cool or that a cold surface be painted, even with hot paint, which quickly coagulates or clots, not joining with the surface of the metal or wood. If paint so applied is heated or warmed from the outside, it begins to run off, and it is quickly washed away in water.

In caulking wooden hulls it is as difficult to achieve absolute drying of the caulking as it is to put it on in thin layers: in cold weather it cools instantly. In the sun caulking becomes liquid and the excess layer of it begins to run off. In water even undried caulking remains more solid than, for instance, red lead. In order to increase the solidity of caulking, it is useful to add animal or fish fat (beef fat, seal fat, etc) in a proportion of not more than 5 percent. Of course, before caulking, just as before any painting, it is necessary to dry the surface of the sheathing well. Caulking of a damp wooden surface is completely useless.

20. The Exit of the Ship from the Ice Dock

When we first began freezing out the schooner Temp, by means of the installation of the ice dock, there arose the danger that in the spring we would not get out of the block of frozen ice and in any case would be late with the exit to the sea at the beginning of the navigation period, since it would be necessary to wait a long time until the thickness of ice surrounding the ship increased to 5 meters. However, these dangers proved to be unfounded. Thanks to the ice dock the schooner Temp was prepared for navigation earlier and better than other ships of Tiksi port and began navigation at the same dock considerably earlier than the other ships. The basin of the ice dock not only did not hinder the immediate exit of the ship into open water, but on the other hand promoted it. The ice dock was flooded on 5 May 1937 by the natural method, as a result of a sharp thaw. Repair and painting operations on the underwater part of the ship were finished in April. Under-keel removal of ice continued until 30 April. The flooding began with the deepest stern part of the hole, at a depth of about 4.2 meters, from pitting of the surface of the ice by brine which had collected. At first the water came slowly through the pores which had formed in the ice, and then, as the openings increased, came more rapidly, and finally, when the weakened ice broke under the weight of the water, came in the form of a cupola-shaped fountain.

In the course of about $1\frac{1}{2}$ hours the ice dock filled with water to the level of the sea. The underwater part of the ship resting on the supports dropped into the water. Under the weight of the water and the ship the ice began to settle, and soon the whole basin was covered with water. Further flooding of the surrounding ice was prevented by a snow and ice ring 2 to 4 meters high formed from snow drifts and piles of ice from the holes.

The ship, which had raised itself above the level of the ice to a height of about one meter, settled. However, it did not achieve its normal draft since the braces resting on strong ice not less than one meter thick continued to hold the ship. For the normal buoyancy of the ship it was necessary that this ice melt in the water and break under the weight of the ship. This took place after 10 days. When thawing began and water appeared on the ice, we trenched the surrounding ice wall from the stern and along the bow, thus connecting with circulating canals the flooded hole of the ship with the water on the surface of the ice. The water on the surface of the ice rushed into the hole, the level of which was lower than the level of the ice.

The flow of the water on the surface of the ice continued until all the water from the surrounding ice had flowed under the ice; the braces sagged, and the ship seemed to take a normal draft.

However, in the last third of May, when the engines was tested, the ship scarcely budged. Through the action of the propellor the ice of the hole was even more disintegrated, and a majority of the timber from the braces and under-keel bedding floated to the surface. The remnants of ice on the bottom and along the sides of the hole pressed tightly against the hull of the ship and prevented it from moving forward and backward.

Only after several days, during the second tests of the engine, the ship received free movement in a small area of clear water at the place of the hole, which had turned into a lake. Navigation in the port waters with fields of friable moving ice became possible only on 10 July. The schooner Temp left the ring of the basin freely; the rings had divided trasversely opposite the diametric plane. The schooner took part in freeing ships of the barge fleet.

Approximately the same picture of flooding the hole of the ice dock and exit from it of the ship was repeated the following year (1938), with the single difference that the flooding of the freezing out took place 11 days earlier, on 24 April.

The ship, together with the ice of the basin, settled smoothly to its normal draft and no sharp movements or dangerous heeling was observed in the process.

On the basis of the given experience, all dangers in relation to removing the ship from the ice dock and immediate entrance of it into navigation are removed.

Insofar as the difference between the non-moving ice dock and the floating dock results only in a slightly larger rise of the floating dock, then, as a consequence, the flooding and subsidence of the floating dock will take place somewhat slower, but in the same order, as with the non-moving dock.

21. Freezing-Out a Vessel and Freezing Up Ice.

Freezing out of a ship is closely connected with the process of the freezing of ice.

The thinner the layer of ice, the more intensive the rate of its freezing during a definite period of time, and, conversely, ice formation is reduced if there is a thicker layer of ice and the same low temperature during the same period of time.

Freezing is also facilitated by the cleanness of the surface layer of ice, by a lack of snow in the hole, and strengthening of the natural and artificial ventilation of the freezing-out area, which is promoted by a more spacious and open construction of the hole.

Consequently, the basic condition for intensive freezing of ice is the maintainance of constant contact of the surface of the water with the most important and necessary factory of ice formation - air at a low temperature.

To illustrate what has been said, it is possible to make a simple experiment with a hollow pipe firmly closed at one end. If this end of the pipe is submerged in water to a depth of several meters, leaving the upper end open for communication with the cold air, in a short time we will notice the whole pipe is covered on the inside with ice.

It will be possible to see that as the depth increases, the layer of ice in the pipe is thinner. If several pipes of different diameters are submerged to the same depth, at the same temperature conditions and during the same length of time of freezing, the thickness of the layer of ice frozen to the walls of the pipes will be different at the same depths. It will be approximately proportional to the diameter of the pipes, that is, the larger the diameter of the pipe, the thicker and evener will be the freezing of ice in it.

We can make use of the latter condition in using the freezing out method, for instance, in the case that one of the holes is flooded.

In this hole we can submerge a small iron gasoline can or several empty iron tins, weighting them from above with some sort of load, so that the upper side is on the level of the water. By this method it is possible to achieve quicker results in freezing a flooded hole, than, for instance, filling it with ice.

If freezing out in the Arctic receives wide distribution in ship repair operations, it must be supposed that mechanization of freezing out will include manufacturing sections of standard pipes, cylinders, dismountable caissons, etc., for admitting cooled air under the hull of the ship, this all the more, since here the use of costly refrigerating machines is not required, and there would be sufficient natural cooling.

Having complete confidence in freezing out ships by means of constructing ice and floating docks for each ship separately, we are convinced that suitable mechanization of freezing out, as a measure to safeguard ships in the ice and as an auxiliary means of ship repair, can replace to a considerable degree the costly dry docks, slips, floating docks, etc. in many arctic ports. Freezing out can be used in any wintering place of a ship far from port. In mechanization of freezing-out operations the freezing-out period can be reduced by 50-67 percent, that is, instead of 4-6 months the freezing out can be finished in 2-3 months. Under such conditions it will be possible to effect not only partial and medium repair on the underwater part of the ship but also capital repair.

22. Ice Against Ice.

The idea of cutting around the ice dock occurred as a consequence of observations of our freezing out of the schooner Temp. In March as a result of the bulging of the hole, the ring of the basin took an inclined position. The links separated from the side of the ship more than 0.5 meters and assumed an angle of about 30 degrees to the horizontal plane. It became impossible to walk around the basin on the slick ice. Many short cracks, which in order to prevent water from entering the hole it was necessary to freeze up with wet snow, appeared on the edge of the hole. It was already too late to effect the cutting around of the basin under these conditions, since for this it would have been necessary to cut through ice 3 meters thick or at the beginning to remove a 2-3 meter mound of ice, so as to get at the 1.5 meter layer of ice under it.

The frequent storms and abundance of snow did not permit us to remove the snow to the lee side, further from the ship. It was necessary to throw it only out onto the basin, and thus promote even larger piles. The wet snow bent the ice, sinking together with the outside edge of the basin. The dimension of the basin narrowed from 8 meters to 4 meters, of which 2 meters was the width of the hole from the side of the ship. We could do nothing except finish the freezing out under these conditions. None the less, we were successful in carrying out the idea of cutting around the basin the same year under slightly different conditions and with a different ship.

Under orders from the port I was sent to the Bykov Cape area to examine the condition of the ships of "Rybkontora" (Fish Office) wintering there and to take measures for their protection from damage during the imminent ice movement on the Lena River.

Among the small fishing fleet of the division of "Rybkontora" on Bykov Cape there were left two schooners, Sever and Pamyat' Oktyabrya, which because of their dimensions were difficult to haul out onto the shore with the facilities available locally. The ships should have left for winter quarters in a creek on the Lena River in the area of Bulun, at a distance of about 300 kilometers from the local fishing grounds. On these transfers they lost about a month of the short navigation season and the best season for fish running, since they had to leave before the autumn ice run and freezing of the river and return after the spring ice run.

In 1937 both ships were forced to winter in the ice navigation channel, since they had delayed departing to the river until the beginning of the ice run, which threw them back into the marine gulf east of Bykov Cape. In doing this the schooner Sever was forced onto a shoal and lost its propellor, but it was possible to get the Pamyat' Oktyabrya to a deep place. The powerful spring ice movement threatened to crush the ships or throw them onto a dangerous shoal.

At first it was proposed that both ships be frozen out and hauled along the ice for several kilometers to a less dangerous place. However, this measure could be carried out only on the schooner Sever, and under it it would have been necessary to cut away frozen ground.

The freezing out of the schooner Pamyat' Oktyabrya, because of the insufficient experience of the workers was flooded through the side cracks in the hole. The suggestion of cutting a canal several kilometers long along which the ship could be carried to the shore was not practicable because of the extraordinarily large volume of work.

In regard to the schooner Sever, I proposed that the ship be put on braces moved onto a frame with runners, drawn with capstans to a point a short distance from the given place. The ship was to be left on bedding and braces on the edge of the shoal, where the water would freeze down to the bottom and the thickness of the ice would be not more than 2 meters. In this place it was suggested that repair be finished and the ship be prepared for navigation. In April, when ice freezing ended, the crew was to cut around the ship at a distance of 10-15 meters from the ship. It was suggested that in calculating the cutting, the direction of the cracks from the first movement of the ice be taken into consideration so that at the beginning of the ice movement the outer field could be separated easier under the pressure of the ice resting above and, in its turn, resting on the unmoving edge of ice on the shoal, might drift past the ship in the general movement of the ice.

In the ice movement the schooner Pamyat' Oktyabrya was to fall into the flow of the ice movement. In order to protect the ship from the ice, we proposed that a circular trench be cut around it at a distance of 10-12 meters from its sides before the beginning of the ice movement. The ship and crew at this moment were to be prepared for navigation, and perhaps, for some drifting together with the ice thrown out by the river ice movement.

The cutting of the basin in the given case was calculated on the compactness of the ice of the basin enclosing the ship.

In the general mass of the ice drifting in the current, such a chunk of ice as formed the basin, about 3 meters thick, should have remained whole and presented a serious obstacle for the thinner broken ice. If this chunk of ice were forced onto a shoal by the general drift of the ice and remained there, the hummock would begin on its edges at some distance from the ship. The hummocked ice in its turn should create an obstacle to the outside pressure of the moving mass of ice, protecting in this fashion the ship until the end of the ice movement. The ice cut out together with the ship would remain on the shoal.

Calculating the thickness of the artifically frozen ice of the block set on the shoal at not less than 3 meters when the ship has a draft of 1.6 meters, one would not have to worry about a solid settling of the ship on the shoal, since under its bottom there would be not ground, but ice 1.4 meters thick.

The proposed measures were carried out. In the thaws at the end of June the ship was already floating in its own hole, standing on the shoal with the basin just like the schooner Temp in the non-moving ice.

When the ice movement ended and an area of open water opened for navigation, the crew blasted the right side of the basin with ammonal, and the ship went into clear water.

In just this fashion the schooner Sever, according to calculations, was successfully set on the edge of the ice of a shoal during ice formation and when the 2-meter ice thawed, the ship, having a draft of 1.5 meters, floated free. Thus we were able to implement the idea of opposing a thick and compact layer of ice to a thinner and weaker layer.

The preservation of the schooner Pamyat' Oktyabrya during the period of ice movement thanks to the cut-out basin is a most positive fact. The schooner was able to move relatively smoothly with the basin in drifting ice. In this the pressure of the drifting ice did not bear directly against the side of the ship, but on the edge of the ice of the basin, which in thickness exceeded by 50-100 percent the thickness of the separate chunks of pressing ice. Thus, the basin presented for the ship something like a protective armor against the blows and pressure of the moving chunks of ice.

From the example described it follows that the ring of the basin, separated from the outside field, has great importance in regard to protecting the ship from direct outside pressures of ice, especially under conditions of ice movement.

Being in the flooded hole, the ship has some freedom of movement, which permits it, even in such restricted area, in the case of a strong flow or pressure from outside, to assume a more favorable position, giving way before a dangerous blow or pressure. A ship tightly frozen into ice which has gone into motion and can cause dangerous cracks and chipping directly at the side of the ship is in a completely different situation.

The most serious and dangerous for the ship is pressure from the sides, especially when the ship has a deep draft, and pressure against the diametric planes of the ship is less dangerous. The bow and stern fastenings of the ship and the check hull formation permits the ship either to break the ice and move to the side, or to rise onto the surface of the crushed mass of ice. Under such pressure only the rudder and propeller can be damaged. Under pressure from the sides and on the diagonal, however, the ship, not being able to turn and lean to the side, can suffer breaking, flattening, and breaking of the strips of the sheathing of the side. If the ship is lightened by unloading and the pressure bears on the rounded part of the bottom, then the ship can be forced out onto the surface of the ice. If the pressure, however, bears on the cylindrical part of the loaded ship, the whole force of the pressure from the sides should be transferred onto the cross braces of the hull assembly and if the braces are weak, they will be bent and deformed, and as a result of this, the ship will leak.

There is no doubt that the ice ring of the basin, before being destroyed under the blows of the surrounding ices, should take on itself the continual pressures of the outside medium, thus preventing damage to the ship.

A series of movements and slight changes in the position of the ring of the basin should not be reflected on the hull of the ship.

In any case, the ship in drifting ice, protected by the thickened ring of the basin, will always be in a more favorable position than would be a ship immovably pressed on from the sides.

23. Protecting a Vessel in Drifting Ice.

From the described methods and practical methods of deep freezing out of the schooner Temp in an ice dock and the cutting out of the basin of the schooner Pamyat' Oktyabrya to create a sort of floating ice dock, it is possible to assume that the method of protecting a ship in drifting ice can be based on the adaptation and development of this experience.

The technical measures for this purpose boil down to a simultaneous or partial utilization of all the above-mentioned types of working un-moving ice as a material serving, in the given case, to protect and defend the ship from the moving mass of ice.

Under conditions of moving ice we are not able, without risking preliminary flooding, to use the ice dock for the purpose of ship repair, we can all the same create here something like a floating dock to protect the ship from sudden blows and pressure by the ice.

If the drifting ship is located in a relatively large depth, where there is no danger of settling on a shoal, there is no necessity for deep freezing out.

The center of attention should be concentrated on the thickening and reinforcing of the ice of the basin or of the limited section of the ice field adjacent to the ship.

Under normal conditions of freezing out the thickening of the ring of the basin, as is known, is achieved by continuous freezing of the ice at various deepenings and gradually removing the thickened layer of ice in the hole. Under conditions of drifting ice it is necessary to freeze a protective zone several meters thick, using short periods of quiet condition of the ice, by constructing a barrier around the surface being frozen out and periodically letting water inside the snow ring.

This method permits not only the utilization of the property of the isolated thin layer of water to turn quickly into ice at low temperatures, but also the use of already prepared ice, of which an abundance can always be found on the spot, as a construction material. Under such conditions the water can be used only a a cementing material and, as a result, it is possible to achieve a solidly frozen mass which we by convention call "ice-concrete."

To turn the so-called ice concrete into a solid compact mass at the same time welded to the surface of the ice field, less time is needed than for the hardening of the ordinary construction concrete.

To achieve the greater solidity of the usual concrete structure, the hardness or resilience of its various parts and connections, various construction materials in the form of wooden and wire frames, rail beams, etc, are used.

In just this way similar materials can be used for the reinforcement of the ice-concrete structure, the basic construction materials of which are ice, water, and, partially, snow. With uniform success the necessary design calculations such as those for the general reinforcement of structures, and also those for the separate parts under pressure, blows, wrecking, etc., can be used here.

The question of similar technical calculation can be easily solved by specialists in construction technology.

Our task in the given problem is basically to direct attention of social and construction technical thought to the possibility of using the same calculation methods and materials in constructing an ice concrete structure to protect a drifting ship from damage as are used in modern engineering in concrete operations.

This problem we put forth as an expansion of the small experience, however in a somewhat different circumstance, achieved by us.

The construction of a protective ice-concrete ring will boil down basically to the following operations.

First of all it is necessary to establish the dimensions of the protective ice zone. The distance of the edge of the ice zone from the ship should serve as the basis for planning the size of the zone. It should be from 10 to 20 and more meters, depending on the condition of the surface of the ice and the hardness of the ice adjacent to the ship, and also depending on the technical facilities and personnel.

The theoretically most favorable form for the protective ring, capable of giving the maximum resistance under pressure, is ~~would be~~ the outline described by a radius from the center of the ship.

However, such a form of protective ring cannot always be carried out in practice because of the broken surface of the ice, which hinders the operations, and because of the weakening of the ice by cracks in some one of the sectors of the ring, or even because of a insufficient manpower. Therefore, instead of the desired cutting out of a large circular area, it is often necessary to restrict oneself to an even zone cut out around the ship.

In any case, independantly of the dimensions of the total area, to be cut out, in the form of a circle or contracted zone, it is necessary everywhere to keep the surface of its edges smooth. The bulging form of the edge of the ice will promote better manoeuvrability of the ice mass separated from the general field, especially in drifting among disconnected fields. The oval form of the edge of the protective ring, lacking protuberances and pits, will have the minimum number of points of contact or engaging with the outer field, and, consequently, will promote the unhindered sliding of the edge of the ring in movement.

The presence of the separate chunks of ice of several years' formation frozen in the radius of the cut out zone or even of some layers of pack ice may only promote the reinforcement of the protective ring.

The discovery of narrow cracks in the working area also cannot serve as an obstacle to the construction of the protective barrier, since the small cracks will quickly freeze when they are separated from the outer field.

After the determination of the outer border of the protective zone the preliminary trenching of the ice around the indicated edge can be begun.

With a limited amount of labor it is not always possible to effect simultaneous work on the outer cut of the zone and inside at the side of the ship. Therefore it is more expedient to finish the outside circular cutting of the ice first, and then begin operations at the side of the ship.

In cutting out the ice it is also necessary to leave links during the operation to prevent premature flooding of the trench. In this the ice thrown out of the trench is placed in a solid even wall along the whole edge of the planned zone.

Upon completion of the circular cutting of the trench, this wall must be saturated lightly with water until it turns into a solid frozen mass. This measure is necessary for the reinforming of the outer edge of the protective ring and to get rid of cracks.

Further, it is possible to start flooding the trench by cutting through. The separated edge of the protective zone should settle somewhat under the weight of the frozen ice wall.

In order to retard the freezing of the cut-around trench, it is necessary to fill it with snow.

When the ice is quiet, the operation in constructing the inner edge of the ice ring at the side of the ship can be delayed until the first ice movement.

Planning of the operations in this case must be done according to the system of full freezing out, carefully calculating it on premature flooding. Therefore it is most effective to reduce the width of the hole from one to 2 meters, keeping only a 20-centimeter graduation of the benches. For the width of the zone of the basin we also leave not more than 2 meters from the edge of the circular hole. Directly after the marked out outline of the basin we begin the piling of ice removed in the hole, in which operation we place it also in a continuous mass even in height, just as at the outer edge of the protective zone.

Upon completion of the first circular removal of ice in the hole, leaving its bottom a thin layer 15-20 centimeters thick, the circular wall of excavated ice is also moistened with water and frozen until a solid smooth ice crust is formed on it.

Thus on the surface of the protective zone we have two linked impervious ice walls, the height of which should not be less than one meter.

If the ship has powerful pumps, the free area between the walls can be filled and frozen in the course of several days.

The use of the indicated method of ice-concreting with the even distribution of prepared chunks and pieces of ice on the area planned for thickening (freezing of the ice to the required height) can be achieved considerably faster.

For the full implementation of this method with the use of reinforcing construction materials, it is necessary to place the materials first in the form of parallel and broken lines on the surface of the frozen zone between the walls, just like the frame of a house used in concreting.

The construction of the ice-concrete zone can be considered preliminarily finished if we succeed in obtaining an evenly thickened surface on the whole area of the protective zone before the ice movement.

The freezing of the ice-concrete can be done gradually, in separate sections or sectors, as the connecting materials are prepared for it.

In such a system the work must be begun on the weakest sections, such as those, for instance, damaged by cracks, or with the thinnest ice. If there is not sufficient reinforcing material it is necessary to place the material as has been recommended in reinforcing the basin of the ice floating dock, and that is, against the middle and ends of the ship.

The freezing out of the ship should be continued as long as possible, in so far as the quiet ice conditions permit, in order to also achieve some thickening of the edges of the ice by the deepening of the hole.

When signs of the beginning of ice movement are observed it is necessary first of all to cut all the links in the hole and cut out around the ship.

Under the weight of the frozen ice the protective ring should settle to the level of its normal buoyancy. If in this the normal settling of the outside edge of the ring is hindered by the frozen layer of ice after the first cutting, (the layer should be partially or completely cut again). If the freezing of ice is intensive and if snow gets into the trench as a result of the frequent settling of the thickened edge of the ring, there should not occur especially solid freezing of the outer edge of the protective ring with the outer field.

The freezing of the area of the protective ring can be continued in this manner and in the cut-out form until the lower edge of it reaches the level of the horizontal plane of the keel, which can be established by a suitable measuring of the thickness of the ice.

The basic purpose and action of the protective ring has already been described in describing the action of the cut-out rim of the basin of the schooner Pamyat' Oktyabrya. Here we have in view the examination of several peculiarities of the probable action of the thicker protective structure under more difficult conditions of drifting in heavy ice.

It is evident that the greatest effectiveness can be expected from the protective ring when it is the thickest. The greatest thickness can be achieved only by freezing a thick layer of ice exceeding the thickness of the ice of the adjacent ice field by perhaps 100-200 percent.

We consider a thickness equal to the draft of the given ship or near to this draft as a sufficient limit for the thickness of the protective zone.

The beginning of the useful action of the protective zone can be considered the moment when its lower edge sinks to the level of the surrounding outlines of the bottom under the weight of the total mass.

The protective ring under pressure of the ice may chip, break in two or into several separate pieces. Each of such separate cakes of ice of the protective zone, grinding directly against the underwater part of the ship, in the first place will be pushed under its bottom by the pressure of the surrounding ice, and this will happen even in the case that the cakes of ice of the protective zone fall under the bottom of the ship only to the level of the piece surrounding the ship.

This will also be promoted by the sliding of the edge, which we have given a beveled or wedge-shaped form because of the benched design of the hole.

Under further pressure the large cakes of ice will serve as a wedge shaped pressure or lever by means of which the ship will be pressed out onto the surface of the ice, and will not press from the side, as might be the case if ice adjacent to the ship had no definite form.

After the reduction of the pressure the ship can turn to the exit position, like the broken parts of the protective zone, if the pressure is strong, although of short duration.

TABLE 1

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MAXIMUM AND MINIMUM AIR TEMPERATURES

Months	Day	Air Temperature 1936 Max	1936 Min	1937 Max	1937 Min	1938 Max	1938 Min
October	10	- 4.1	-13.3	- 1.5	- 9.5	--	--
	20	- 3.5	-25.0	- 3.2	-14.5	--	--
	30	- 8.8	-32.9	- 7.6	-20.3	--	--
November	10	-10.2	--33.6	-9.0	-27.2	--	--
	20	-13.5	-38.1	-17.9	-25.7	--	--
	30	-12.9	-27.1	-19.3	-27.4	--	--
December	10	-10.6	-27.2	-16.9	-31.0	--	--
	20	-21.6	-31.2	-21.9	-28.6	--	--
	30	-24.1	-41.9	-24.0	-31.0	--	--
January	10	-30.2	-41.8	-27.1	-42.6	-19.2	-27.9
	20	-31.2	-41.2	-18.7	-41.5	-19.5	-28.1
	30	-28.0	-41.8	-12.1	-31.2	-20.4	-37.0
February	10	-26.5	-43.0	-17.1	-31.9	-25.3	-39.6
	20	-19.3	-40.3	-10.7	-31.4	-22.2	-39.6
	28	-26.1	-33.1	-19.8	-41.9	-26.3	-42.1
March	10	-15.4	-32.2	-21.1	-40.9	-20.6	-36.5
	20	-23.4	-38.0	-19.1	-42.9	-16.6	-33.4
	30	-11.0	-36.6	- 8.7	-33.9	-10.7	-26.5
April	10	- 8.0	-24.9	- 5.2	-31.6	- 7.1	-28.9
	20	- 9.0	-21.5	-12.6	-32.9	-15.4	-21.9
	30	- 5.8	-20.9	- 6.3	-26.6	- 3.6	-17.4
May	10	- 1.4	-17.2	7.0	-18.3	-11.0	-18.0
	20	2.5	- 8.0	4.9	-14.0	1.0	-12.4
	30	13.6	- 3.8	23.6	- 8.9	0.4	- 8.0
June	10	3.4	- 1.0	29.5	- 2.1	5.7	- 1.4
	20	5.0	0.2	10.5	- 2.0	5.8	- 0.7
	30	16.2	1.7	22.2	0.4	12.3	16.7
July	10	22.7	- 2.5	17.3	0.4	--	--
	20	8.8	1.5	12.5	1.1	--	--
	30	16.7	37.1	32.2	5.5	--	--

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MAXIMUM AND MINIMUM WATER TEMPERATURES

Months	Day	Water Temperature 1935/36 Max	1935/36 Min	1936/37 Max	1936/37 Min	1937/38 Max	1937/38 Min
October	10	2.2	-1.3	3.4	-0.6	1.2	-0.6
	20	-0.6	-0.7	-9.3	-0.7	-0.7	-0.7
	30	-0.6	-0.8	-0.1	-0.3	-0.5	-0.8
November	10	-0.7	-0.7	-0.4	-0.5	-0.7	-0.9
	20	-0.6	-0.7	-0.4	-0.4	-0.7	-0.8
	30	-0.6	-0.7	-0.4	-0.4	-0.7	-0.8
December	10	-0.7	-0.7	-0.5	-0.6	-0.7	-0.8
	20	-0.5	-0.6	-0.7	-0.8	-0.7	-0.8
	30	-0.8	-0.8	-0.5	-0.6	-0.8	-0.9
January	10	-0.8	-0.8	-0.8	-0.8	-0.9	-1.0
	20	-0.7	-0.8	-0.8	-0.8	-0.9	-1.0
	30	-0.8	-0.8	-0.8	-0.8	-0.7	-0.8
February	10	-0.7	-0.7	-0.7	-0.8	-0.6	-0.9
	20	-0.7	-0.7	-0.6	-0.8	-0.6	-0.8
	28	-0.6	-0.6	-0.7	-0.7	-0.6	-0.9
March	10	-0.6	-0.6	-0.7	-0.7	-0.8	-0.9
	20	-0.7	-0.7	-0.7	-0.8	-0.8	-0.8
	30	-0.7	-0.7	-0.7	-0.7	-0.4	-0.8
April	10	-0.7	-0.7	-0.7	-0.7	-0.4	-0.6
	20	-0.7	-0.7	-0.7	-0.7	-0.4	-0.5
	30	-0.6	-0.6	-0.7	-0.7	-0.5	-0.5
May	10	-0.6	-0.6	-0.9	-0.9	-0.5	-0.5
	20	-0.6	-0.7	-0.7	-0.8	-0.4	-0.5
	30	0.2	-0.6	--	--	--	--
June	10	-0.2	0.8	0.3	0.2	--	--
	20	0.4	0.1	1.0	0.7	--	--
	30	1.6	0.1	4.1	0.7	--	--
July	10	9.4	1.1	6.2	1.2	--	--
	20	2.6	0.6	9.8	4.9	--	--
	30	11.3	0.6	18.2	7.7	--	--

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ICE THICKNESS IN TIKSI BAY

		Thickness of Ice in Centimeters		
Months	Day	1935/36	1937	1938
October	10	8.5	1.0	1.5
	20	11	2.7	2.0
	30	54	36	41
November	10	58	46	57
	20	72	55	66
	30	80	67	80
December	10	94	77	105
	20	113	92	113
	30	120	114	136
January	10	122	125	143
	20	127	138	145
	30	135	145	153
February	10	165	156	158
	20	182	169	162
	28	187	175	177
March	10	195	178	187
	20	204	185	205
	30	213	196	209
April	10	217	197	211
	20	221	198	216
	30	222	200	217
May	10	222	202	220
	20	221	200	219
	30	218	197	216
June	10	180	120	175
	20	--	--	--
	30	60	60	65
July	10	Clear Water		
	20	" "		
	30	" "		

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Calendar Plan for the Natural Freezing and Removal of Ice When Executing Freezing-Out Operations in Tiksi Bay (in centimeters)

Period of Freezing and Removel of Ice

Days of the month	October 31 Days				November 30 Days				December 31 Days				January 31 Days			
	Natural freezing in the field	Freezing in the hole	Removal	Deepening of the hole	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole
1					43	23	20(No1)	20	82	34			137	30		
2					45	26			85	37			138	33		
3	Vo-				48	29			87	40			139	37		
4	da				48	32			90	43			140	40		
5					49	35			92	46	20(No6)	120	140.5	43		
6	Sa-				51	38			95	29			141	47		
7	lo				52	41	20(No2)	40	97	32			141.5	50	20(No11)	220
8					54	24			100	35			142	33		
9					55	27			102	38			142.5	36		
10	1				57	30			105	41			143	39		
11	2				58	33			106	44	20(No7)	140	143.5	42		
12	3				58	36			108	27			144	45		
13	4				59	39			109	30			144.5	48		
14	6				60	42	20(No3)	60	111	33			145	51	20(No12)	240
15	8				61	25			113	37			145.5	34		
16	10				62	28			114	40			146	37		
17	12				63	31			116	43			146.5	40		
18	15				64	34			117	46			147	43		
19	16				65	37			119	49	20(No8)	160	147.5	46		
20	21				66	40	20(No4)	80	120	32			148	49		
21	22				68	23			122	35			148.5	52	20(No13)	260
22	25				69	26			123	38			149	35		
23	26				70	29			125	41			150	38		
24	28				71	32			126	44			150.5	41		
25	29				73	35			128	47	20(No9)	180	151	44		
26	31				74	38			129	30			151.5	47		
27	32				76	42			131	33			152	50		
28	34				78	45	20(No5)	100	132	37			152.5	53	20(No14)	280
29	38				79	28			133	40			153	36		
30	41				80	31			133	43			153.5	39		
31	42								136	47	20(No10)		154	42		

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Calendar Plan for the Natural Freezing and Removal of Ice When Executing Freezing-Out Operations in Tiksi Bay (In centimeters)

Period of Freezing and Removal of Ice

	February 28 Days				March 31 Days				April 30 Days				May 31 Days			
Days of the month	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole	Freezing of the field	Freezing in the hole	Removal	Deepening of the hole
1	151.4	45			179	50			210.3	42			218.4	56		
2	154.8	48			181	53	20(No19)	380	210.6	44			218.6	57		
3	155.2	51			183	36			210.9	46			218.8	58		
4	155.6	54			185	39			211.2	48			219	59		
5	156	57	20(No15)	300	187	42			211.5	50	10(No24)	470	219.1	60		
6	156.4	40			189	45			211.8	42			219.2	61		
7	156.8	43			191	48			212.1	44			219.3	62		
8	157.2	47			193	51			212.4	46			219.4	63		
9	157.6	50			195	54			212.7	48			219.5	64		
10	158	53	20(No6)	320	196	47	20(No20)	400	213	50	10(No24)	480	219.6	65		
11	158.4	36			197	40			213.3	42			219.7	66		
12	158.8	39			198	43			213.6	44			219.8	67		
13	159.2	42			199	46			213.9	46			219.9	68		
14	159.6	45			200	49			214.2	48			220	69		
15	160	48			201	52			214.5	50	10(No26)	490	220	70		
16	160.4	51	20(No17)	340	202	55			214.8	42			220	70.5		
17	160.8	34			203	58	20(No21)	420	215.1	44			220	71		
18	161.2	37			204	41			215.4	46			220	71.5		
19	161.6	40			205	44			215.7	44			220	72		
20	162	43			205.5	47			216	50	10(No27)	500	220	72		
21	163	46			206	50			216.3	42						
22	163	49			206.4	53			216.6	44						
23	167	52	20(No18)	360	206.8	56			216.8	46						
24	169	35			207.2	59			217	48						
25	171	38			207.6	62	20(No22)	440	217.2	50						
26	173	41			208	45			217.4	51						
27	175	44			208.4	48			217.6	52						
28	177	47			208.8	51			217.8	53						
29	—	—			209.2	54			218	54						
30	—	—			209.6	57			218.2	55						
31					210	60	20(No23)	460								

Table 3

NORMS FOR HAND REMOVAL OF ICE WITH PICK

WHEN EFFECTING FULL FREEZING OUT OF SHIP

Deepening of Hole (in cm)	Norm for production in cubic meters per hour for each number of men						
	1	2	3	4	5	6	7
				First Category			
100-200	0.8	1.6	2.4	3.2	4.0	4.8	5.6
200-300	0.7	1.4	2.1	2.8	3.5	4.2	4.9
300-400	0.6	1.2	1.8	2.4	3.0	3.6	4.2
400-500	0.5	1.0	1.5	2.0	2.5	3.0	3.5
				Second Category			
100-200	0.7	1.4	2.1	2.8	3.5	4.2	4.9
200-300	0.6	1.2	1.8	2.4	3.0	3.6	4.2
300-400	0.5	1.0	1.5	2.0	2.5	3.0	3.5
400-500	0.4	0.8	1.2	1.6	2.0	2.4	2.8
				Third Category			
100-200	0.6	1.2	1.8	2.4	3.0	3.6	4.2
200-300	0.5	1.0	1.5	2.0	2.5	3.0	3.5
300-400	0.4	0.8	1.2	1.6	2.0	2.4	2.8
400-500	0.3	0.6	0.9	1.2	1.5	1.8	2.1

Note: Norms are given without accounting for removal of ice from working area, but including cleaning and sweeping of the hole.

Table 4

Elements of Ships and of Ice Docks for Them

$$(D=LBT\delta\gamma\ ;\ T=\frac{D}{LB\delta\gamma})$$

Type of Ship	Ship and ice dock	Length (in meters) L	Beam (in meters) B	Draft (in meters) T	Coefficient of Displacement δ	Specific gravity of water γ	Displacement (in tons) D	Difference in displacement of ship and dock $D-D_1$	Density of ice γ_1	Removal of ice (in cubic meters) V
Sail-Motor schooner	Ship	31.2	7.8	3.8	0.42	1.03	401	435	0.9	483
	Ice dock	36.2	12.8	4.2	0.42	1.03	836	—	—	—
Propellor-driven tug	Ship	45	10	3.7	0.46	1.03	782	—	—	—
	Ice dock	50	15	4.1	0.46	1.03	1,445	663	0.9	737
Icebreaker	Ship	67.5	15	5.0	0.52	1.03	2,682	—	—	—
	Ice dock	72.5	20	5.5	0.52	1.03	4,227	1,545	9.9	1,717
Medium steam freighter	Ship	70	10	4.0	0.75	1.03	2,156	—	—	—
	Ice dock	75	15	4.5	0.75	1.03	3,898	1,772	0.9	1,936
Barge	Ship	56	14	3.5	0.90	1.03	2,552	2,299	0.9	2,554
	Ice dock	61	19	4.5	0.90	1.03	4,851	—	—	—