**The Hamburgische Schiffbau-Versuchsanstalt Ice Modeling Basin**
Frederking, R. M. W.



**Publisher's version / Version de l'éditeur:**
https://doi.org/10.4224/20331232
*Internal Report (National Research Council of Canada. Division of Building Research), 1977-09-01*

THE HAMBURGISCHE SCHIFFBAU-VERSUCHSANSTALT

ICE MODELING BASIN

by R. Frederking



Private copy for: Library M-20

Please note that this is a private internal report of the Division of Building Research and is sent to you for your personal use. The information in this report is not generally available and therefore the report is not to be cited as a reference in any publication.

DBR Internal Report 442

# PREFACE

The growing requirements for resource exploration and extraction from the Arctic are reflected in an increasing interest in developing facilities (ice breaking vessels, off-shore drilling structures, wharves, pipelines, etc.) that will perform safely and economically in ice covered waters. Physical modeling of the behaviour of ice covers is one area that is developing to provide information required for the rational design of these facilities.

The author of this report spent a year (May 1976 to May 1977) at the Ice Model Tank of the Hamburg Ship Testing Establishment (HSVA) studying physical modeling of ice behaviour and its application to the problem of ice action on structures. This report describes the ice tank facility and outlines the philosophy and operation of it.

Ottawa
September 1977

C.B. Crawford,
Director, DBR/NRC

## DESCRIPTION OF FACILITY

A complete description, in both German and English, of the as-built facility appears in "Schiff und Hafen", Vol. 24, No. 8, 1972, p. 549-554. The following description concentrates on the current facility and emphasizes changes or modifications.

The ice tank is 30 m long, 6 m wide and has a water depth of 1.2 m. It is constructed of concrete and has a glass fiber reinforced epoxy liner. A sketch of the tank layout is shown in Figure 1 and a visual impression is given in Figure 2. The trim tank is separated from the ice tank by insulated folding doors. The model can therefore be trimmed and attached to the towing carriage in a warm environment while ice is being grown in the tank. At the other end of the tank, also separated by insulated folding doors, is the melting basin. Water, heated with waste heat from the refrigeration system, is sprayed on the tested ice to accelerate its melting. The tank itself is cooled by finned coils which cover the entire ceiling. Air movement is only by convection.

Observation windows extend along half the length of the tank bottom. There is a passage beneath the tank so that visual and photographic observations can be made through these windows. This facility has been found useful in observing ice behaviour under ships and also around structures. An example of a photo taken through a bottom window is given in Figure 3. Ice movement around propellers, rudders and bow thrusters is becoming an area of increasing interest. The breaking pattern and ice movement under ships and around structures is often much better visualized from underwater observations. These viewing windows are indispensable in developing physical and mathematical models for ice resistance due to breaking, submerging, accelerating and friction. HSVA wishes the windows ran the entire length of the tank. There are also side viewing windows but these are much less useful than the bottom windows and are no longer used at HSVA. The required access pit has been found to lead to a thermal anomaly along that part of the tank wall.

The towing carriage is constructed of wood (framing, roof, floor and walls) but it has been found to be too flexible and now is being stiffened with steel beams. On one side the carriage has steel wheels running on a steel rail which provides traction and lateral guidance. Special provisions had to be made for the differential expansion between the steel rail and the concrete wall. The other side of the carriage has hard rubber wheels on a concrete track. The rail develops tractive forces up to about 0.5 kN but this is not adequate for testing structures, therefore a rack and pinion drive system is being installed. Motive power is from a three-phase motor with regulation, control and driving position on the carriage. Speeds from 0.5 cm/s to 2 m/s are possible. The carriage has facility for side observations of vessels or structures and also has folding platforms in front for observations of ice behaviour around the bow.

Measurements of load, displacements, accelerations and velocities are taken from the carriage via a ribbon wire system to an instrument room for recording. The data acquisition system is currently being upgraded with a computer to facilitate on-line analysis of the results. A temperature monitoring and recording system has been added to the tank. Air and ice temperatures are measured at several locations. This information is used to achieve desired ice properties.

Models used in the tank are manufactured from wood in the HSVA model shop. They are finished with a hard, wear-resistant paint that yields a friction coefficient of about 0.1. For testing at a higher coefficient of friction, abrasive materials are glued to the finish. The models are finished in red to provide maximum colour contrast for observing and photographing ice movement around the models.

In the spring of 1977, after 5 years of operation, one section of concrete in the tank wall was observed to be deteriorating. Altogether a section about 5 m long and 0.5 m deep had to be removed before sound material was reached. The remainder of the concrete in the tank appeared to be in good condition so presumably this was just one area where the quality control was not good. It was felt that the cycles of freezing and thawing (really an accelerated weathering process), rather than the salt water environment, were responsible for the deterioration.

## SIMILITUDE AND SCALING

In any modeling facility a great deal of attention must be given to the similitude conditions that are to be met. For ice modeling this is even more so the case since research and debate are still going on concerning the appropriate similitude conditions. Most modeling of ice-breaking is done on the basis of Froude similitude, i.e., the ratio of inertial and gravitational forces is identical in nature and in the model. In ice modeling it is also considered important that the coefficient of friction between the ice and the vessel be identical. Friction is a complex phenomena and HSVA has ongoing investigations of it. The modeling philosophy at HSVA also emphasizes Cauchy similitude (ratio of elastic to inertial forces) which means that the elastic modulus must also be scaled. The objective is to produce ice with an elastic modulus to strength ratio of 1500 to 2000. HSVA feels that ice that is too plastic leads to incorrect results. The crystal size and structure of the model ice is scaled with respect to that in nature.

In actual practice it is very difficult to simultaneously meet all these similitude requirements at all model scales. This is due to limitations of a physical nature. For example, it may not be possible to equally reduce strength and elastic properties of the ice to values required by the model scale. Similarly, going to too small a model may lead to increased influence of skin friction effects.

The relatively low salinity ice used at HSVA combined with their warming technique allows flexural strengths to be scaled down by a factor of about 12 while still maintaining a modulus to strength ratio greater than 1500. At this time they prefer to work with model scales in the range 10 to 20. For cases where model tests must be done at scale factors greater than 20, the philosophy at HSVA is to maintain the modulus to strength ratio even though the strength is known to be several times too great. Because of the too great strength a correction based on reducing the breaking portion of the resistance is applied.

HSVA is carrying out a basic study, funded by BMFT, (the German Federal Ministry for Science and Technology) on similitude considerations. A model of the U.S. Coast Guard Polar Star is being used to study the influence of ice strength and elastic modulus. Model test results will be compared with full scale results to be supplied by the U.S. Coast Guard. This is an example of basic research that will lead to a better understanding of the effect of ice properties on similitude considerations.

## OPERATION OF TANK

The tank is currently operated by a four-man group. It is headed by Dr. Joachim Schwarz who manages the research and test programs, prepares program proposals, analyzes research and test results and prepares reports on work undertaken. A mechanical technician has responsibility for the day-to-day operation of the tank, i.e., regulating refrigeration system, growing ice, setting up models, checking ice properties, reducing data and general maintenance. He is assisted in these tasks by another technician. The fourth member of the group is an engineering-physicist who is responsible for instrumentation application and development, data reduction procedures, analysis of results and report preparation. The group carries quite a large work load and at times works long or irregular hours quite willingly in order to carry the load. The group is also involved with field trials and is currently being expanded to undertake more basic investigations into the mechanical properties of ice.

The actual procedure for producing model ice at HSVA is as follows:

(a) Water is cooled to near equilibrium temperature for the given salinity, ~ 0.5°C for 6 per mil salinity.

(b) The air temperature is reduced to about -7 or -8°C. The relative humidity of the air is about 80 per cent. By this time a thin skin (~2 mm) of large-grained ice has formed on the water surface of the tank.

(c) The tank is then seeded. The carriage moves along the length of the tank at a speed of about 5 m/min. A board at the leading edge of the carriage is lowered to skim the large-grained ice off the water surface. A nozzle system at the rear of the carriage sprays out air and water under pressure. Cooled by the adiabatic expansion of the air the atomized water particles freeze and fall as a fine snow onto the water surface initiating the formation of a random oriented, granular ice layer about 2 mm thick. A relatively fine-grained columnar ice grows from this layer.

(d) The columnar grained ice growth is done at an air temperature of about -15°C for which a growth rate of about 1.5 mm/hr is attained. As mentioned heat exchange from the ice surface is by convection from the ceiling coolers. There is no forced air movement. This results in a very uniform ice thickness over the length of the ice tank, ± 0.5 mm variation.

(e) The warming-up process, which might take a number of hours, is started by bringing the temperature in the refrigeration coils to -1°C. At the beginning of the warming the flexural strength is about 200 kPa and the elastic modulus 500 MPa and by the end of the warming period these values are about 60 kPa and 100 MPa respectively. The ice thickness increases during this period, but at a reduced rate. Strengths are measured periodically to pinpoint the time when ice properties are optimal for running the test. The folding doors are often opened to speed up the last part of the warming process.

(f) While the foregoing operations are going on the model is being set up in the trim tank. When the ice properties are right the test is run. Usually three or four steps of increasing velocity comprise a run. Towing resistance, in some cases vertical loads, displacements and accelerations of the model and velocity of the carriage are measured and recorded in digital form. Photographs and movies of breaking action are usually made from above and below. At the end of the test run ice thicknesses are measured as are values of strength and elastic modulus.

(g) After the test the model is returned to the trim tank and the refrigerant temperature is brought above the melting point. Also the water in the tank is circulated. This all aids in warming up the ice. When the ice is sufficiently softened it is freed from the walls mechanically and then the board on the carriage is lowered and the ice is pushed into the melting basin. After the tank has been cleared of ice the temperature can be set down and the procedure for growing another tank of ice started.

## CONCLUSION

The Ice Technology Group at HSVA is actively engaged in improving its ability to deal with ice problems in the marine environment. They are carrying out fundamental studies to improve their understanding of ice modeling, actively seeking opportunities to carry out full scale field measurements to relate to their model results, and initiating work into the basic mechanical properties of ice. This is an ambitious program for a relatively small group, but their feeling is that only by being active in all these areas can they remain at the forefront of ice technology.

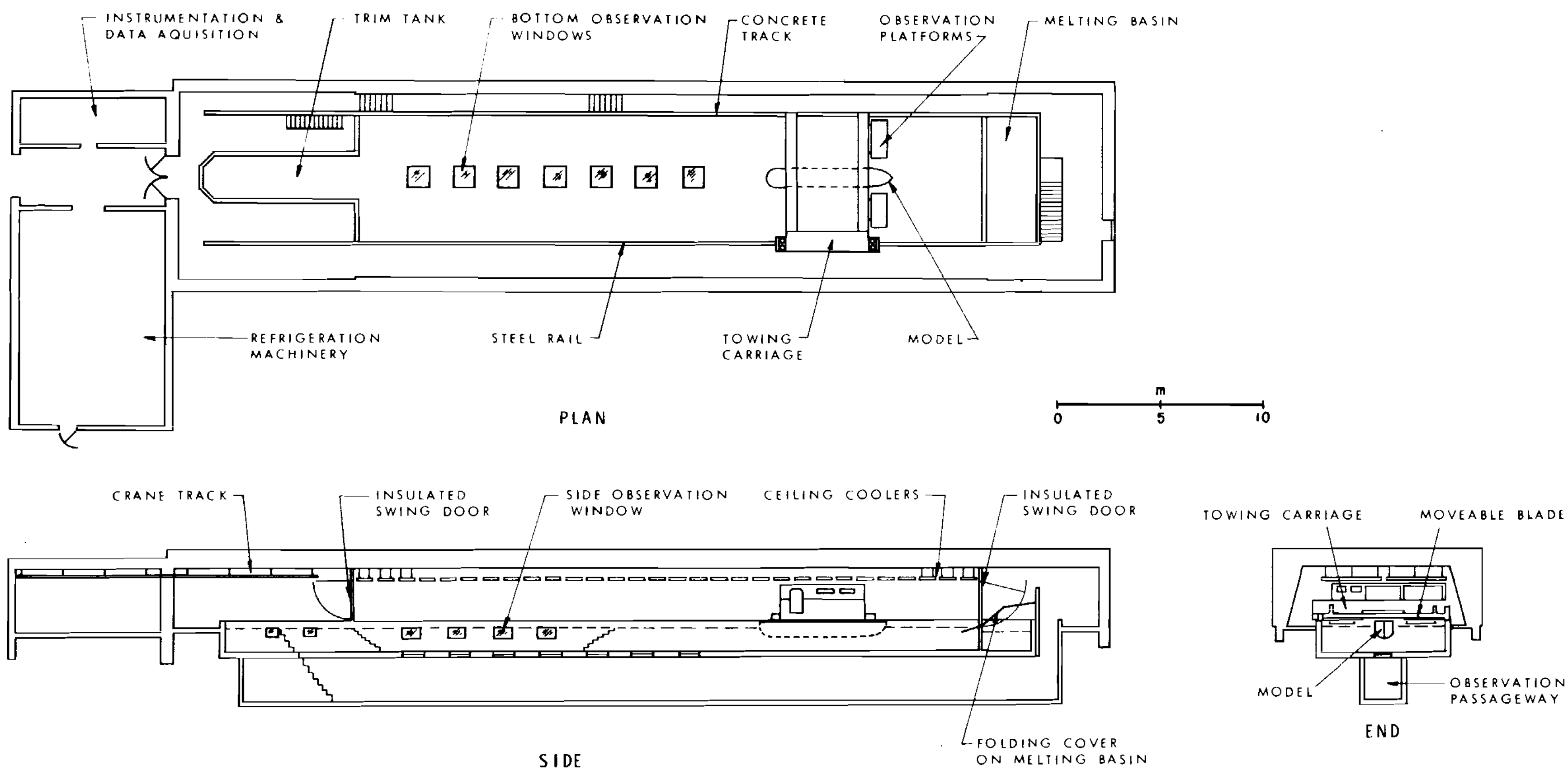
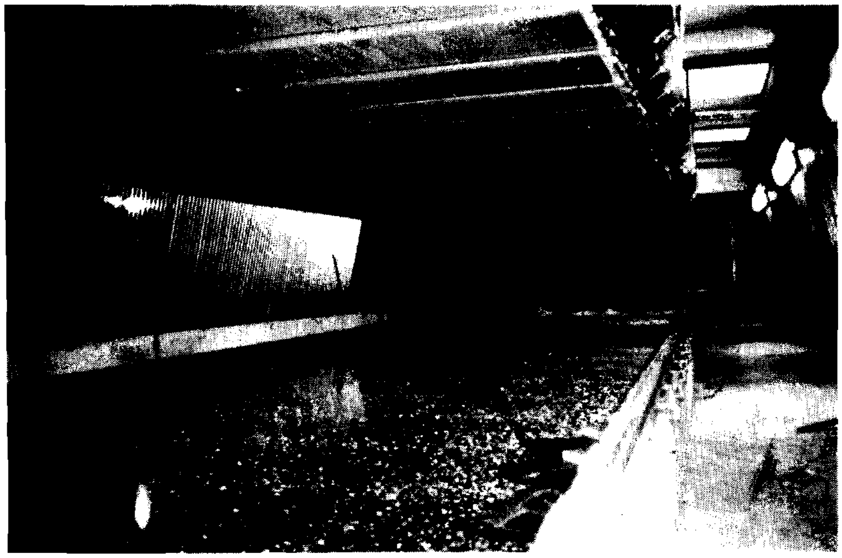
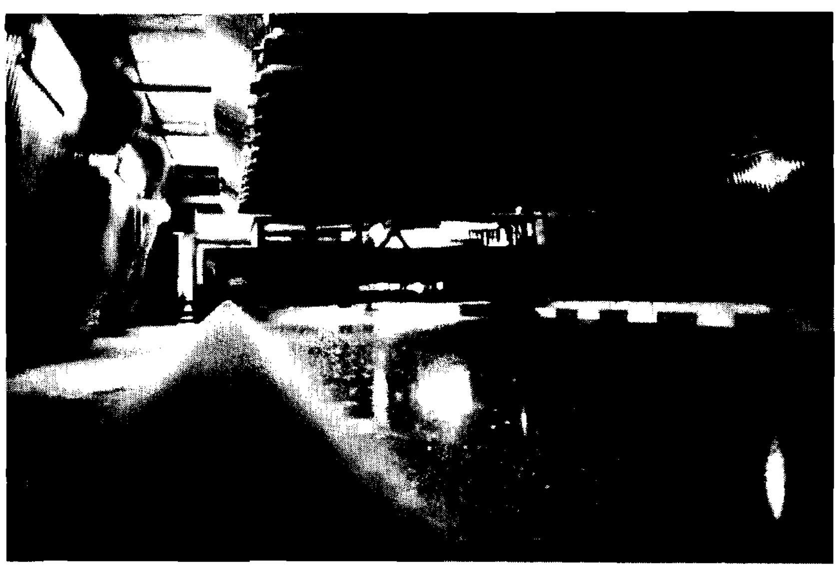



FIGURE 1 SKETCH OF H.S.V.A. ICE TANK



(a) looking towards Melting Basin



(b) looking towards Trim Tank

Figure 2

Views of Ice Tank; note convective coolers on ceiling

Figure 3

Photo taken through bottom observation window showing ice movement around stern of an icebreaker