SESSION ON PERFORMANCE IN ICE

Chairman: Mr. W.A.Crago

Presidium of the Session

Discussions of the Report and Draft Recommendations of the Committee on Ships in Ice-Covered Waters

1. DISCUSSIONS

U.R.MILANO - Consulting Engineer, Alexandria, Virginia, USA

I have read through the report several times, and I have no substantive comments concerning the details contained in the report. I noted a number of minor points as well as certain typographical errors which you may want to take action on, and these I have listed in the attached enclosure. In overview, I feel that you have given a concise summary in your report of the current state of the art of ice model testing and this should be of real informational value to the ITTC Congress.

I wish you could have been a bit more focused and specific in your recommendations, especially as regards action items which should be undertaken and supported by the ITTC in the near term. In this regard, I would have preferred your recommendation to have been presented in two distinct categories; i.e., recommended general statements of policy and recommended near term action items or tasks to be approved and chartered by the ITTC for near-term accomplishment. In the category of general statements of policy I would include your recommendations 1, 4, 6, and 8. The remainder of your listed recommendations plus a few additional which I feel should be added, would be structured into specific tasks for review and approval by the ITTC Congress with some committment to near term accomplishment. These tasks would include:

1. Complete the expanded test program for the ITTC ice committee standard model using various established friction coefficients. Analyze the test procedures used by each participating facility and the resulting test data including correlation with full scale test data for assessment of predictive adequacy of results. Prepare report to be presented to the 17th ITTC Congress along with recommended test procedures for possible incorporation (your recommendations 2, 3, and 9).
2. Develop a program and recommended procedures for testing the effects of ice pressure and ice pressure ridges on the performance of surface ships and structures in an ice field (your recommendation 5).
3. Develop a program and recommended procedures for testing the effects of mush ice on the cold weather performance of ships and structures (new recommendation).
4. Review present procedures used by the various test facilities for the self-propelled testing of ships in an ice field. Undertake a correlation analysis of model test results with full scale operational test data where available. Prepare summary report for presentation to the 17th ITTC Congress with recommended courses of future action (your recommendation 7).
5. Analyze current analytical techniques for predicting the resistance to ship motion in ice. Undertake an in-depth correlation analysis of the results of these prediction techniques with existing model and full scale test data. Evaluate or assess the reliability and effectiveness of these analytical prediction techniques and their inherent limitations when used for early conceptual ship studies. Prepare a summary report to 17th ITTC Congress (new recommendation).

I would strongly recommend you to consider the restructuring of your recommendations into the two distinct categories discussed above. The recommendations of policy statement can be adopted as the sense of the ITTC Congress and serve to guide future broad efforts in the field of ice testing. The remaining recommendations, which are presented as specific action item tasks, should be presented for concurrence or approval and assignment for accomplishment to one or more of the member organizations. In my judgment, the presentation of your recommendations in this format is desirable in order to focus the ITTC Congress action and to act as a catalyst for specific follow-on activity.

On page 366 of the report you speak to a figure 1. Figure 1 shows a plot for 13% carbamide, the text talks to 1.3%. One of these should be corrected.

The lower curve of figure 1 implies that model test conditions come rather close to achieving an E/σ_f ratio of 2,000. I certainly do not think this is typical in any of the test tasks that I am familiar with, except perhaps HSVA.

You state that the initial ice strength is a function of C, Q, t_W and t_A. I agree with this, but is not salinity also a key parameter? Was it your intent to include salinity within the context of Dopant concentration? This point could be clarified.

There is a repetition of one of the sentences in the first paragraph under item C.

On page 368, paragraph 2 - The implication is made that the Kashtelyan method, as originally developed, can be used to estimate the resistance of icebreakers whose form differs from that of "Ermak". I really question that, and feel that the statement is somewhat misleading. The form of the Kashtelyan equation is quite general and predicated on the physical interaction at the ship/ice interface. This can certainly be applied to any ship. However, the constants which are a key part of these equations and which are required for use of these equations tend to be ship peculiar. Those that Kashtelyan developed were specifically for "Ermak" and really cannot be extended to use with other ships, unless of course they are almost identical in form to that of "Ermak". For any significant change in hull form, hull dimensions or volume distribution, the use of the constants as developed by Kashtelyan would be questionable and I feel would lead to serious prediction errors. For such extrapolative use, new constants must be developed for the hull form under consideration. It should be noted that this is not a limitation of the Kashtelyan method alone, but rather applies to all semi-empirical relationships used for these prediction purposes, of which this is only one example.

On page 369 the description of energy term E_5 makes it appear that the term involves only the effects of buoyancy. This is incorrect, and misleading. In point of fact, the buoyance contribution to this energy term is small, and as the ship speed increases, can almost be ignored. The major elements of energy term E_5 include the inertial effects of the ice pieces being upended, rotated and driven down into the water by the oncoming ship, plus the frictional effects of the ice pieces moving down and aft along the length of the hull under the influence of the flow pressure field. These resistance effects are not mentioned in your report, yet at speed in excess of about 5 feet per second, can represent the significant energy loss by the ship.

I would disagree with the last paragraph on the left hand side of page 369 concerning validation of the analytical program. The statement is too strong and in the case of particular analytical models is incorrect. For examle, I have undertaken extensive efforts to correlate my particular analytical results with whatever model scale and full scale test data that I could get my hands on. Over the years, this involved considerable correlation and validation. In the model regime this has included towed-ship tests as well as self-propelled model tests. In the full scale regime, it has included consideration of thrust data measured directly at the thrust block as well as propeller thrust computed on the basis of torque measurements and propeller characteristics. In each instance where I could get reliable data, the correlation has been good to excellent irrespective of hull form, i.e., conventional polar icebeaker, river icebreaker, or large ice breaking tanker or bulk carrier. The results of these correlation efforts were presented at "Intermaritec 80" in Hamburg. In my opinion, this particular analytical model has certainly been evaluated and validated as well as any such system can be, given the paucity of test data for such use. Certainly, more should be done, and the results published for the information of the profession, but for this purpose, test data must be made available. It was in this context that I included a recommendation in the main text of my letter to recommend that the ITTC Congress approve an action item to evaluate analytical techniques, undertake correlation with model and full scale test results, and publish the results at the 17th ITTC Congress.

J.W.LEWIS - Arctec Inc., Columbia, Maryland, USA

In general I think the report is fine and consequently I have only the following comments:

1. On page 364, last paragraph, the comment is made "In addition if a dopant or synthetic ice is used, the chemical makeup must be reported". It was my understanding that the Ice Committee decided to delete this.

2. On page 365, first paragraph on right, the comment is made "Propulsion tests are very important because the results can be compared directly to full scale". Whereas I agree that propulsion tests are very important, I do not agree with the reason stated. As we enter into the area of self-propelled model ice testing, a whole host of new ice scaling problems are created due in part to the inability of saline or urea model ice to properly scale ice compression (crushing) strength. This causes improper model propulsion efficiencies, thrust deduction factors, wake fractions, and relative rotative efficiencies and therefore they cannot be directly compared with full-scale. Even in open water model testing, correlation between model self-propelled and full-scale tests have not been satisfactorily established. As it stands now, the only way we can truly establish correlation of model and full-scale ice resistance tests is to conduct full-scale towed ice resistance tests. This would be a major undertaking, but it is feasible and something I would like to see the Ice Commettee promote. I certainly think self-propelled model resistance testing should be actively researched as I feel we can improve upon the propulsion efficiency of icebreakers.

3. On page 365, first paragraph under discussion of model ice, the comment is made "The major problem associated with synthetic materials is that they have a very high coefficient of friction compared to real ice". The synthetic material used by ARCTEC (both USA and CANADA) does not have this problem.

4. On page 366, last paragraph, the comment is made "The experiments conducted at USACRREL produced very positive results". I would like to see the phrase "positive results" expanded to include data which can be compared with Timco's original work.

5. Regarding the Melville Shipping LNG Carrier Model Experiments, I am very encouraged that the Ice Committee found that, after appropriate allowances for friction coefficient variations, results from the four ice model basins agreed to within 10 percent. This is particularly important in that three different sc le ratios ranging from 1:36 to as small as 1:100 were used. Based on these findings, I would think that the Ice Committee should reconsider their past comments about using small scale models for ice resistance testing. I also think that the full Ice Committee report regarding this project should be made available to the public particularly in view of the comments made on page seven under state-of-the-art model testing of offshore structures in ice regarding making these results and techniques public.

6. In Appendix A, the dimensionless coefficients C_I, C_{IB}, C_{II}, C_{IS}, C_{IT}, and C_{IW} are not defined.

U.I.KASHTELYAN - Arctic and Antarctic Institute, Leningrad, USSR

1. It is gratifying to note that the ITTC Ice Committee has made considerable and important efforts aimed at the standardization of model and full-scale ice ship tests. The ship-ice performance has been evaluated on the basis of the model test results. These tests are carried out

in different ice tanks, which use various techniques and procedures for the tests and different types of model ice. Hence it is of vital importance for the Ice Committee to establish standard methods. I understand that the Ice Committee has made steps in the right direction starting tests of a standard model in the ice facilities of different countries. However, this complicated, time and effort consuming task has not been completed yet. Not all of the ice facilities, that agreed to participate, have finished with the tests. The results of standard model tests and the Ice Committee's conclusions are waited for in all the ice tanks. In this respect the results of the model tests made at the request of the Melville Shipping Co. appeared to be extremely useful. They indicated once more the friction effects on ice resistance. At this stage ice friction coefficients in some ice tanks are considered to be a parameter used for the correlation of model and full-scale results. I agree with the Committee that the Melville tests will facilitate the standardization of test techniques and correlation of results. The Melville results would significantly help the Ice Committee to analyse the standard model results.

It is very encouraging that despite the difference in methods used by the participating facilities, the full-scale prediction turned out to be very close, the difference being not larger than 10 per cent, though the tests were made with models of different dimensions (from M 1:36 to M 1:100). There is another difficulty in model tests, that is how to evaluate the scaling effect, so this is one of the tests for the Ice Committee to consider in its future work.

2. The problem of the model doped ice which would fairly well satisfy the criteria of similarity has become very urgent. This is why the information in the Report on the use of urea for ice preparation is interesting. I would like to hope that the Ice Committee would make efforts to make the results of the experiments with different types of model doped ice public.

3. The Report stresses the importance of propulsion tests as they can be directly compared to the full-scale. We believe that the study of model propulsion test results in conjunction with full-scale data would contribute to the research of model ice.

Due to the difficulties of the full-scale resistance tests the use of propulsion model test results is quite promising for the correlation of model and full-scale data, though this is rather difficult at this stage. The Ice Committee should be concerned with both resistance and propulsion tests, since these are the two possible approaches to the correlation problem, contributing to each other.

4. The Ice Committee Report in general is quite adequate, covering a wide spectrum of problems; though most of them are still to be solved, the Report shows the Ice Committee to be on the right road.

E.ENKVIST - Wärtsilä, Helsinki, Finland

Generally I agree to the views put forward in the report and the chapter III recommendations of the committee, are sufficiently general to be fully accepted.

The subjects which I have selected to comment are:

1. Propulsion tests (model scale);
2. Model ice properties (icebreaking mechanism);
3. Theoretical prediction (Milano)

3.1. Propulsion model tests in ice introduce difficulties if employed for resistance predictions, reasons:

scale effect in milling model ice;
improper scaling of the inertia and torque versus RMP characteristics of the propulsion machinery.

Thus, propulsion tests may be accepted in addition to resistance tests but not as the sole method to predict the resistance.

Full-scale towing tests of small ships might be encouraged to eliminate errors in propulsion analysis.

3.2. A proper E/σ_f will not solve the most critical scaling problems in connection with the resistance components. Shearing and crushing of the edge seem to influence the breaking component radically, and are more or less non existing in presently used model ice.

The list of symbols should be completed with the dynamic coefficient of friction between surface of body and ice during crushing.

3.3. For some reason space is used in the report to describe Milano's theoretical approach, which was introduced 10 years ago and suffered from lack of elementary experimental backing. Thus, the cyclic breaking including detail analysis of the ship dynamics during a single-point-of-contact breaking cycle is non-existent in real life. Furthermore the broken ice is not just moved "aside and under the broken sheet" as Milano assumed as he had no underwater pictures to show what really happens.

The method is extremely complicated, and like any other method it may be manipulated to show acceptable predictions. Observing edge-crushing is a merit, but does not motivate further use of the whole method.

V.KOSTILAINEN - Helsinki University of Technology, Finland

In the 15th ITTC I emphasized the difficulties arising from the random nature of the properties of the ice even in laboratory conditions. For example, if resistance is measured in ice model basins, the scatter of results is large and repeatability poor. Testing in ice is expensive. Sample sizes are small and statistical methods cannot be used. I therefore propose to the committee another way to approach the problems on ships in ice-covered waters.

Randomly varying forces arise mainly from the elastic ice-breaking forces. These forces should be determined numerically in ship scale. Statistical approaches can then be used. The other components of ice resistance are of a more deterministic nature. Model testing technics in simulated broken ice can be used to determine these components. If broken ice is simulated with some material, which is permanent in room temperature and which has the same density and friction coefficient, then the scatter of test results is small and repeatability is good. These tests can be made in ordinary towing basins with certain additional equipment. Interaction of the elastic ice-breaking forces and other forces is disregarded in this approach and this is a drawback. Validity of this approach can however be cleared by comparison with full scale results or with results in ice model basins.

To demonstrate the experimental benefits of this approach some test results obtained last week in our laboratory is given in Fig.1. It shows the measured total and net ice resistance values of 3 m and 7 m long geosims of a twin-screw passenger and car ferry. Tests were run in broken ice channel conditions. Broken ice was simulated with plastic peaces having the same size distribution as the ice fragments in a typical old broken channel in the Northern Baltic. The net friction coefficient and density of this material is the same as of wet ice.

Scatter of the results is satisfactory and repeatability was checked to be good.

Even these first results obtained in two days testing show some interesting features such as:

- Net resistance in this case is nearly independent of speed;
- Ratio of the resistance of the two model sizes is proportional to the square of scale ratios.

We can not yet draw any final conclusions from these results because we don't know if these features are connected to this particular hull form or this particular testing configuration. However in the continuation it is very easy and cheap to study the effects as some parameters.

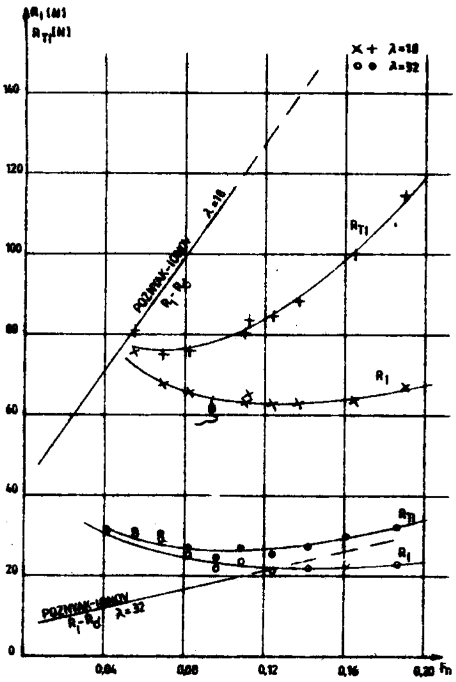

Fig.1 Resistance in broken ice channel conditions of two geosim models of a twin-screw car and passenger ferry.

The results of these very first tests were compared with the values obtained with Poznyak-Ionov formula which was presented in the SNAME Ottawa meeting last summer. The results show satisfactory agreement in the case of smaller model. Differences are large in larger model.

B.JOHNSON - U.S. Naval Academy Annapolis, Maryland, USA

ON THE RECOMMENDED LIST OF SYMBOLS FOR RESISTANCE AND PROPULSION TESTS IN ICE

Speaking as a member of the Information Committee (but not for it) I should like to offer the following comments on the proposed symbol list. The Information Committee greatly appreciates the effort made by the Committee on Ships in Ice covered waters in preparing Appendix A to their report.

Before our committee can recommend approval of the proposed symbols, however, definitions of the more significant symbols such as C_{IT}, C_{IW}, R_{IS}, etc should be included since it is not possible to understand the symbols without definitions. I would also suggest that R_{IW}, n_{IW}, Q_{IW}, T_{IW}, and any other symbols that indicate measurements without ice be stricken from the list to be replaced by the standard ITTC symbols used for still water testing.

Y.N.ALEKSEYEV - Krylov Shipbuilding Research Institute, USSR

In accordance with the 15 ITTC recommendations the Committee on ships in ice-covered waters has prepared a list of symbols on the performance of ships in ice-covered waters. We shall not consider here the whole list of symbols as it is included in the Committee Report as an Appendix. We should like however to give consideration only to that part of it referring to propulsion tests.

In developing this part of the list the Committee made following assumptions:

- When running in some ice conditions the propeller of an icebreaker or of an ice-strengthened ship is operating (part of the time) in the water and part of the time is in direct interaction with ice blocks of various sizes;
- During the propeller-ice interaction there is a pronounced change in hydrodynamic forces at the propeller blades, and also large mechanical interaction forces are added to them, sometimes exceeding the hydrodynamic forces many times;
- The duration of this mechanical contact can be characterized by the relative time of propeller-ice interaction.

On the basis of these assumptions, it is suggested to introduce the following symbols into the list:

a) T_{IW}, Q_{IW}, n_{IW} - thrust, torque and number of revolutions, respectively, for the conditions without propeller-ice interaction:

b) T_I, Q_I, n_I - mean value of thrust, torque and number of revolutions, respectively, for the time of propeller-ice interaction;

c) C_{TI} - relative time of propeller-ice interaction;

d) T_{AI}, Q_{AI}, n_A - thrust, torque and number of revolutions, respectively, averaged for the time of observations.

Quantities under item "a" significantly depend upon the hydrodynamic velocity field in the propeller disc for a ship operating in given ice conditions.

Quantities under item "b", besides, depend upon the geometry of the propeller and ice blocks, upon their position against one another and ice strength properties. The relative time of propeller-ice interaction for one ship characterizes the degree of severity of ice conditions,while for comparison of several ships operating in the same ice condition it characterizes the degree of propeller protection against ice action. If C_{TI}=0, the propeller is ideally protected, and propeller-ice interaction is eliminated. The relationship between quantities under item "b" and quantities under item "a" characterizes the degree of variation in propeller characteristics when it is interacting with ice.

Comparison of quantities under item "a", measured for a given ship in the hydrodynamic model basin and in the ice model basin will give a possibility to estimate the effect of ice upon the velocity field in the propeller disc. And comparison of data obtained in the ice model basin with those obtained in ice trial will give a possibility to determine the value of the velocity field scale effect.

At the modern state of the art not all of the strength properties of the ice simulated in the ice model basin can satisfy the similitude laws to the same degree. This can lead to the fact that the thrust T_I and the torque Q_I measured in the ice model basin and corrected to ship value will not agree with those measured during ice trials. It is suggested to characterize the degree of disagreement by using KK_T and KK_Q correlation coefficients.

By the time of this Committee Report preparation the data which give a possibility to compare icebreaker model test data obtained in the hydrodynamic basin and in the ice model basin with those obtained during full scale trials were not available to the Committee. This work will be performed for a R-class icebreaker.

II. REPLY OF THE COMMITTEE

The technical committee thanks *Dr.Milano* for his very valuable comments. The committee will consider his suggestion of restructuring the recommendations into two categories, i.e., general statements of policy and near term tasks, in the final statements. Dr.Milano's suggestion of including recommendation No.5, the testing of the effect of ice pressure in addition to pressure ridges, is not to be adopted at this time. The committee feels that would overload the near term program. Nevertheless the committee agrees that the effect of lateral ice pressure on a ship's performance in ice is important and should be addressed soon.

The committee does not feel that investigations of the effects of mush ice on the performance of ships and structures could be initiated at this time. The basic physical properties and definitions of mush ice must first be established. This work is, however, under way.

Dr.Milano's rewording of recommendation No.4 is being considered by the committee.

The lower curve in Fig.1 (saline ice) comes indeed close to an E/σ_f ratio of 2000 but only in the bending strength range of 30 to 60 KPa. For testing icebreaking ships and offshore structures ice model basins, in most cases, are required to reduce the strength to 30 KPa and lower, in order to satisfy the similarity laws. In this range the E/σ_f ratio is significantly lower.

The salinity of the model ice is being taken into account by the symbol C which is the dopant concentration.

Dr.Milano questions the applicability of the Kashtelyan method to predict the resistance of icebreakers whose form differs from that of ERMAK (1898). The committee has discussed this issue with Dr.Kashtelyan and concludes that the Kashtelyan formula was developed in order to determine approximately the resistance of icebreakers in their initial phase of design. The more accurate prediction would have to be determined through model tests. With this preface and the limits given in our report the Kashtelyan formula can also be used for typical icebreaking forms but not for icestrengthened cargo vessels. For typical icebreaking forms the shape effect is being taken into account by coefficients. How accurate these coefficients are, needs to be investigated.

Dr. Milano is correct in his statement that the inertial effects of the broken ice pieces have not been mentioned as being a major part of the energy loss E_5.

Concerning Dr.Milano's disagreement with our statement on the validation of analytical programs, the committee acknowledges his efforts to prove his theoretical predictions by comparison with model and full-scale measurements, in particular the comparisons as published by him at "Intermaritec 80". However, the committee still questions his method of correlating theoretical calculations with full scale thrust data, to determineresistance, without knowing the thrust deduction. Only model test results on resistance and self-propulsion, including thrust, can provide this needed information.

The committee appreciates Dr.Milano's contribution and fully agrees with him that efforts in evaluating analytical techniques for correlating model and full-scale test results should be increased.

The Committee consider that data, which does not include details of the chemical composition of the model ice, is of limited scientific use since it is not possible to carry out independent evaluations and further developments.

Mr. Lewis agrees that model self-propulsion experiments in ice are very important and points out some of the scaling problems when making full scale predictions.

Reasonable modelling of crushing strength is now being achieved in ice model basins.

Much more model self-propulsion and corresponding accurate full scale trial data is required to further assess the correlation problem. Such data are now becoming available and the results of the ITTC compositive ice model program and the full scale results for this form will also be most helpful.

For clear water predictions the state-of-the-art has now reached a high level, whose data for hundreds of vessels have been examined thanks to the work of various ITTC committees. For correlation purposes both model self-propulsion and resistance experiments should be carried out.

The Committee would, however, question the cost effectiveness of carrying out full scale resistance experiments in ice.

For new design development and more accurate performance predictions in ice, model self propulsion experiments in ice are now recognized by the Committee as a requirement. These experiments are the only means for an understanding of propeller/hull and propeller/ice interaction effects.

Information on synthetic model ice materials, used at room temperature, disclosed to the Committee before the 15th ITTC did indicate,they had higher friction than real model ice. The Committee would welcome the opportunity for independent investigation of any new model ice materials.

Since the original work on model ice dopants, other than sodium chloride, carried out at the National Research Council of Canada, there have been new papers published, including a paper by CRREL on their experience, published at IAHR 1981. It should be noted that the results achieved depend upon the freezing techniques used in each establishment.

On the intertank comparisons of the Melville Shipping LNG Carrier models, by correcting the results at different scales to a common friction value, using empirical methods, the results agreed to better than ten per cent. This, in itself, is not however regarded by the Committee as a justification for the use of small models. Self propulsion experiments in ice require larger models to satisfy model propeller Reynolds numbers requirements along with long established ITTC experience, apart from any ice modelling considerations.

In giving the experiment results to the Committee, Melville Shipping set various guidelines for publication. The present report is within those guidelines. It is to be expected that in the future, this company.along with others generally will release more data.

Insofar as the non-dimensional coefficients are concerned, it was felt by the Committee that, even though the means for making these physical properties non-dimensional are not defined, it was important to categorize the coefficients in a list at this time. The symbols can be used for publication purposes and individual definitions given. Standardization of the definitions is a task for the future.

The continued participation of Mr.Lewis is always welcome.

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The Ice Committee appreciates Dr. *Kashtelyan's contribution, it fully* agrees with *Dr. Kashtelyan* in his evaluation of the role of propulsion model tests in the problem of the propeller/ice interaction. We can only add that propulsion tests are very important for the study of the processes of propeller/ice interaction, for the determination of the rpm variations, as well as thrust and propeller shaft torque changes.
All the data of the experiments with model ice (urea) have been published by Dr. Timko in his papers at POAC-79 and IAHR-81.
The programme of the tests with standard R-class icebreaker model in various ice facilities is planned for several years, these tests are extremely time and labour consuming. The test results will be published after the tests are completed and results analysed.

From *Dr.Enkvist's* remarks we see that the wording in the report is somewhat misunderstood. It was not the intention of the committee to state that only self-propulsion tests are needed for determining both ice resistance and propulsion characteristics. It is the committee's opinion that in order to determine the performance of a ship in certain ice conditions self-propulsion tests give in many cases satisfactory accuracy. There are scaling difficulties as Dr. Enkvist quite right pointed out but for the time being we do not know the magnitude of possible errors due to this.

Self-propulsion tests never give proper information on ice resistance but both resistance and self-propulsion tests are needed in order to study ice resistance and propulsion characteristics in ice. In many cases the problem is time. A typical resistance test series of a model takes two weeks of the whole capacity of the laboratory and adding propulsion tests to *this more than doubles the time. Therefore* the committee has stated that in spite of errors due to scaling difficulties self-propulsion tests alone can be accepted for performance prediction purposes.

The committee agrees with Dr.Enkvist that the full scale towing test is an ideal solution to eliminate errors in propulsion analysis. There are practical difficulties to arrange this kind of test. It is difficult even in ice-free water and much more difficult in ice conditions.

Dr.Enkvist has quite right pointed out that solving the E/σ_f problem does not solve the whole problem of scaling the strength properties of natural ice. The committee realizes that shearing and crushing have to be considered in the future. But because of very limited resources in this field of research we cannot solve all problems at one time. It is unfortunately true that we do not know today too much on the importance of these parts of the breaking resistance component.

Friction coefficient during ice crushing has not been studied very much so far. We should get some verification of this and especially on the difference of the dynamic friction coefficient between the crushing case and the non-crushing case. The committee feels that the question of a separate symbol should be discussed thereafter.

The committee is fully aware of the limitations of the method by Dr.Milano and we would like to emphasize that we did not recommend that method to be used for predicting ice resistance. However, Milano's method is the only comprehensive analytical method for determining ice resistance and should be used for further development of analytical approaches. During the last decade main emphasis was put to the development of model testing techiques. The committee feels that some work should be initiated in the near future towards development of improved analytical methods.

The Committee thanks *Prof.Kostilainen* for his interesting written contribution. It is difficult, however, to agree that the determination of level ice resistance in ice model basin is in such a poor state. Ice model basins have been used for a quarter of a century. Large experience has been gained on obtaining ice fields with uniform physical properties along the basin length and with constant thickness. This provides acceptable repeatability and small error of model data. The small amount of data, however, which can be obtained per day, as well as the high cost of testing in ice are perhaps reasons to consider the proposal of Prof. Kostilainen. He has mentioned a drawback of his proposal as disregarding of the interaction of the elastic icebreaking forces and other forces and ice strength properties.

It is difficult to estimate the importance of this assumption, and the problems which might arise in the numerical determination of these forces, ice strength and interactions. Therefore primarily, model testing in non-scaled strength synthetic broken ice could only be used for the determination of the effect of ice fragment density upon resistance due to the submersion of ice and the inertial resistance. The tests proposed by Prof. Kostilainen may also be useful for the determination of the effect of ice piece size and the shape of propeller blades upon the ice forces acting upon the propeller of a ship in brash ice. Even in brash ice, the lack of scaling of internal shear stresses and cohesion forces are further limitations.

The Committee does not consider that the method proposed by Prof.Kostilainen can be used as a substitute for model testing in real model ice.

The Committee welcomes the suggestion of *Prof.Johnson* to have a more closer cooperation among Technical committees and to join efforts in finalizing the list of symbols for resistance and propulsion tests in ice.

In one of the previous replies it was mentioned that "even though the means for making these physical properties nondimensional are not defined, it is still important to categorize the coefficients in a list at this time. The symbols can be used for publication purpose and individual definitions given".

Definition of the other symbols , if possible, will be submitted to the Information Committee for approval after consideration by the new Committee.

The Ice Committee cannot agree to eliminate the symbols R_{IW}, n_{IW}, T_{IW}, Q_{IW}.

The parameters represented by these symbols are measured in ice model tests. They do not coincide with the parameters measured during model tests in hydrodynamic laboratories. They account for the influence of the ice moving along the hull.

Such motions of the ice change the boundary conditions of the water flow around the hull and the velocity field at the prepeller disk. These changes in the flow conditions are reflected by introduction of the relevant symbols.