SESSION ON HIGH-SPEED MARINE VEHICLES

Chairman: Mr. W. A. Crago

High-Speed Marine Vehicle Committee Memberships: D. Savitsky (Chairman) - P. C. Knowles (Secretary) - J. A. Alaez - B. Muller-Graf - T. Murakami - P. van Oossanen - S. D. Prokhorov - O. Rutgersson - R. A. Wilson.

Discussion of the Report and the Draft Recommendations of the High-Speed Marine Vehicle Committee. (Cf Proceedings, Volume 1, p. 335-398, and separately distributed "Bibliography and Proposed Symbols on Hydrodynamic Technology as Related to Model Tests of High-Speed Marine Vehicles", publ. as SSPA Publ. Res. Report No 101, 1984.) Also Committee Report Errata.

I. DISCUSSIONS

K. R. SUHRBIER - Vosper Thornycraft (UK) Ltd , Portsmouth, UK

ON THE REPORT OF THE HIGH-SPEED MARINE VEHICLE COMMITTEE

I would like to congratulate the Committee on their most interesting Report.

I read with interest the discussion on the wetted area estimates and would like to ask whether the Committee has perhaps an interim view on the effectiveness of thin films of water (as can be observed on the model) and their treatment in the resistance scaling procedure.

The performance prediction for craft with cavitating propellers is a matter of great interest to me and the principle effects are also discussed by the Cavitation Committee (as referred to in the Report). Perhaps it may be worth pointing out that there more emphasis is placed on the identity of the effective (horizontal) rather than that of the axial propeller thrust loading K_T/J^2 (p. 365). I fully agree that more unified approaches need to be established to allow for cavitation effects. I also hope that we can identify more clearly the propeller/hull (or propeller/wall) clearance effects referred to; see also Cavitation Committee Report.

With regard to the rudder drag (p. 370) I like to say (and I agree with a statement made later in the Report) that this component usually decreases with increased propeller loading in case of a rudder-in-slipstream arrangement (as also stated elsewhere,see also Suhrbier, Int. Ship. Prog. 1974 and Ref. 46). In the case of well faired rudders, zero drag or even a propulsive force can possibly be measured (though hardly on wedge-type rudders). I would therefore not normally recommend to use Peck's procedure referred to in Section 6.3.2, i.e. a higher (slipstream) velocity in connection with the drag formulation given.

Finally, I would be interested in the Committee's view (or recommendation) on a subject not discussed in the Report, namely the treatment of the perhaps complex aerodynamic drag of, say, a planing craft model (possibly with an open "deck") which is part of the measured model resistance. I believe that normally no allowance is made for this contribution and the full scale aerodynamic drag is added in the prediction.

E. BABA - Nagasaki Experimental Tank,
Mitsubishi Heavy Industries, Ltd.
Nagasaki, Japan

ON WETTED SURFACE ESTIMATES, AND SUGGESTIONS FOR FUTURE REVIEWS

First, I would like to point out that several establishments including Mitsubishi Nagasaki Experimental Tank are not listed in Appendix, though these establishments did reply to the questionnaire.

In the Committee Report, detailed accounts are given on the experimental methods for measurement of wetted surface area of high-speed vehicles, and mentions are made on the difficulties in diminishing the error involved in extrapolating the test results to full-scale notwithstanding rather costly measurement. The discusser would appreciate the Committee's review work on this matter, and would like to present some complementary data, which show how difficult it is to estimate the wetted surface area of a given hull form in the early design stage before conducting model tests.

Figs. 1 and 2 show the variation of wetted surface area and waterline length with respect to model speed for 20 different hull forms of semi-displacement and planing type measured by means of visual observation from outside models. Due to a large variation among different hull forms, it is hard

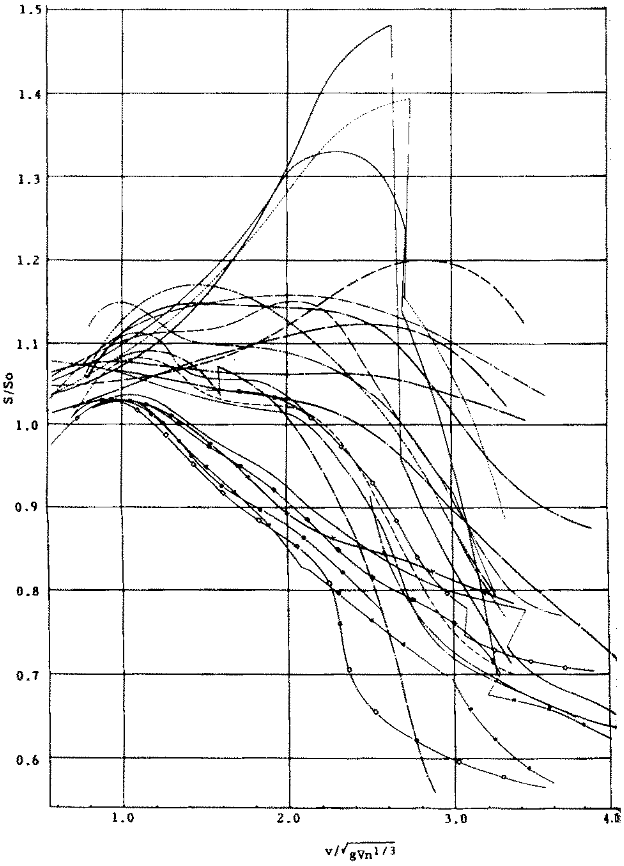

Fig. 1 Variation of Wetted Surface Area in Running Condition

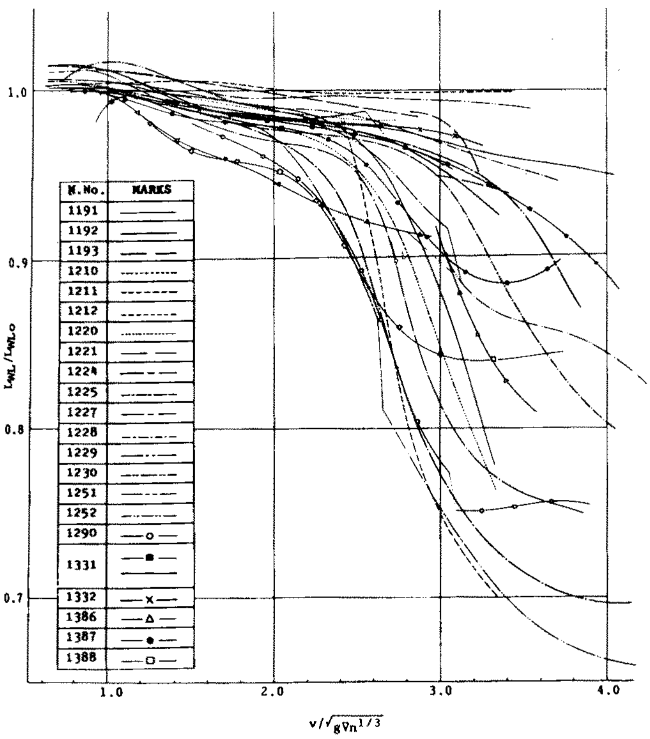

Fig. 2 Variation of Load Waterline Length in Running Condition

to see a universal trend for the estimation of wetted surface area. Therefore, accurate estimation of the wetted surface area for a given hull form in the early design stage is not expected. For the sake of convenience and considering cost effectiveness, the wetted surface area and the waterline length at rest are being used as routine practice for semi-displacement hull forms in the Nagasaki Experimental Tank. Ship model correlation factors have in this case a physical content differing somewhat from those applied to conventional displacement ships. However, when dealing with craft operating in semi-displacement conditions, it may be considered that the correlation factors roughly correspond to those for conventional ships.

Finally, the discusser would like to suggest some areas of technical survey to be considered in the Committee's future work. Due to the extension of exclusive economic zones and active work around coast and islands, diversification of missions and operational areas of HSMVs poses a variety of hydrodynamic problems, e.g. ocean going capability of light hulls of large size and operation in shallow water area on the other hand. Tank experimental techniques related to these problems are for instance:

i) Structural load measurement techniques for reliable structural design to cope with rough sea conditions.

ii) Self-propulsion test techniques to study hull-propulsor interaction when unconventional propulsor is adopted such as waterjet propulsor, which is suitable in shallow water operation.

For reference, papers related to these topics presented recently from the Nagasaki Experimental Tank are listed below:

[1] TAKAHASHI, T. and KANEKO, Y.: "Experimental study on wave loads acting on a semi-displacement type high speed craft by means of elastic backbone model", Proc. High Speed Surface Craft Conference, London, 1983.

[2] HOSHINO, T. and BABA, E.: "Self-propulsion test of a semi-displacement craft model with a waterjet propulsor", Journal of the Society of Naval Architects of Japan, Vol. 155, May 1984.

R. K. BURCHER - Admiralty Research Establishment, Haslar, Gosport, UK

ON A BRITISH COOPERATIVE TEST PROGRAM

On behalf of the British Towing Tank Panel I wish to make an oral report as a contribution to the chairman.

Over the past two years the British tanks have undertaken a cooperative test programme on the resistance and power of a high speed form. For this purpose we have used the same model which has been tested in each of our facilities.

Unfortunately, this programme had not reached a stage of completion which would have enabled us to provide a formal report to the Committee.

Briefly it is possible to report that we have all produced the resistance curve over a wide range of speed. Our agreement has been very good over the lower two thirds of the speed range. (Much better than that reported by the Resistance Committee.) At the higher end there have been some differences, but we believe that these are related to quite small differences in each of our towing and guidance arrangements. Aerodynamic effects are sufficient to give differences in the use and running trim of the model resulting in different resistance measurements.

By far the greatest difficulty we have encountered is in the measurement of wetted area in the running condition. This is largely dependent on human judgement by the experimenter/analyst, and where the dynamic waterline intersects the chine line at an almost tangential angle it is very easy to have large differences in observed wetted length resulting in considerable differences in calculated wetted area.

Swaths, of course, are especially sensitive to ballasting. Welcome the Committee Report, which predominantly deals with tankery though some specialist aspects heighten awareness of techniques in general.

R. H. ZONG - Marine Design & Research Institute of China, Shanghai, China

ON CALCULATION OF THE WAVE PROFILES OF A SIDEWALL HOVERCRAFT

This paper uses the linearized water wave theory to establish a mathematical model of a sidewall hovercraft with Kelvin sources being distributed on the pressure plane, Kelvin sources and doublets on the centerplanes of both sidewalls, and Kelvin doublets on the tailplanes of both sidewalls that extend to infinity. Using the linear characteristic of the Laplace equation and the boundary conditions, a perturbation velocity potential can be resolved into four parts, as

$$\varphi = \varphi^P + \varphi^R + \varphi^L + \varphi^M$$

where φ^P, φ^R, φ^L and φ^M are velocity potentials due to source distribution on $z=0$, $y=-bs$, $y=bs$ and doublet distribution on $y=\pm bs$ respectively. They satisfy certain equations and boundary conditions respectively. Since wave heigh h is related to $\varphi_x(x,y,0)$, it can be resolved into four parts, as

$$h = h^P + h^R + h^L + h^M$$

According to the boundary conditions satisfied by φ^P, φ^R, φ^L and φ^M, the analytical expressions for source distributions and a Fredholm integral equation of the first kind for doublet distributions are developed. Then by the discretization for the integral equation, a set of linear algebraic equations are obtained. Solving these, doublet strengths can be obtained. In terms of the complex exponential integral $E_1(\alpha)$, a double integral in a local wave is reduced to a single integral and calculation is greatly speeded up. The formulas for the perturbation velocities of a Kelvin plane doublet (rectangular and y-direction) are developed. This paper has carefully treated singular integrals such as $\int_{-\infty}^{\infty} f(\lambda)d\lambda$ and oscillating integrals such as $\int_A^B g(\lambda) \genfrac{}{}{0pt}{}{\cos u(\lambda)}{\sin u(\lambda)} d\lambda$. Monacella method, correcting Romberg method and stationary phase method are put to use.

Using this mathematical model, inside and outside wave profiles of a sidewall hovercraft are calculated. The computed results are modified by experimental values of trim angle. These results are compared with the experimental data, and it shows that the outside wave profiles agree well with the experimental data. As to the inside wave profiles, the experimental concave surface is deeper than the computed one. With regard to present sidewall hovercraft, the wave height induced by a pressure plane is the main part, and the interference between a pressure plane and a sidewall as well as between both sidewalls is very small. The results of the present study may be useful for the design of sidewall hovercraft.

D. ZHANG - China Ship Scientific Research Center

ON HIGH-SPEED WORK AT CSSRC

In our opinion, the state of art made by this Committee also includes the present state in China. Since 1959, we have been studying and testing the resistance, lateral stability, performance characteristics, seakeeping quality of self-stabilizing hydrofoil craft model. From next year, we shall be able to perform model experiments on craft with fully immersed hydrofoil and its automatic control device. We have also studied the performance characteristics of cavitating isolated foils by theoretical means as well as in cavitation tunnel.

The conclusions of this Committee agree with our previous experience, but for self-stabilizing craft with not very high speed it is difficult to satisfy the requirement of $Rn>1x10^6$. From our previous experience, when $Rn>6x10^5$, the drag coefficient will no more vary with speed.

We are now making a six-component balance to study the performance characteristics of the isolated foil and hope it will be of use very shortly.

C. KRUPPA - Institut für Schiffstechnik, Technische Universität Berlin, Berlin, F. R. G.

ON THE EFFICIENCY OF PROPELLERS IN OBLIQUE FLOW

I am always intrigued if I see diagrams being presented which show an increase in propeller efficiency in oblique flow, as is the case in Figure 28 of the Committee Report. For all I know, the propeller efficiency is always smaller on an inclined shaft as compared with open water conditions, provided of course that the thrust is properly defined and measured, as for instance demonstrated in Figure 12 of the Report of the Cavitation Committee. I therefore have to assume that in Figure 28 the efficiency η_B is calculated with the axial shaft force only, without taking into account the normal force on the propeller and deriving from those two components the correct horizontal thrust.

J. P. BRESLIN - Davidson Laboratory,
Stevens Institute of Technology,
Hoboken, N. J., U.S.A.

COMMENTS ON THE COMMITTEE REPORT

Dr. Breslin noted his long term interest in the area of pneumo/hydrodynamic coupling and the lack of atmospheric scaling and its effect on SES motions. He also noted that the equation presented in the Committee's Report has an asymtotic limit.

B. JOHNSON - United States Naval Academy,
Annapolis, Md., U.S.A.

ON THE NEED TO CONSIDER SAILING YACHT TESTING

I congratulate the Committee on an excellent Report and tutorial paper on the testing of non-conventional craft. I should like to suggest that the Committee consider including the testing of sailing yachts in the work of their Committee for the 18th ITTC. There are many special problems associated with yacht testing, but little guidance is available in the literature. Sailing yachts frequently exceed a Froude Number of 0.4 ("hull speed") while sailing off the wind so, in a sense, they qualify as "high speed marine vehicles". The tank testing program associated with the 12 meter yacht "Australia II" has renewed the interest of the yachting community in model tests of racing yacht designs. Your Committee, or a special working panel, should prepare a summary of yacht testing technique for the next ITTC.

O. BJÖRHEDEN - KaMeWa Marine Laboratory,
Kristinehamn, Sweden.

ON HIGH SPEED MARINE VEHICLES

I wish to thank the Committee for this interesting Report dealing in such a constructive way with many of the problems involved in the model testing of HSMV. The propulsion section of the Report is mainly focused on propellers and all the complications in testing related to cavitation, ventilation, propeller shaft inclination etc. It may not be necessary at all but I still wish to draw the attention of the Committee to the increased use of waterjet propulsion. On many planing and semi-planing craft water-jet propulsion in comparison with propellers offers specific advantages such as very shallow draft, improved manoeuvrability and low noise and vibration levels. The design of a water-jet propulsion unit involves the pump itself, the inlet channel and the outlet part with reversing and steering devices. The design work in itself should not be the task of the HSMV Committee but in the process of establishing reliable trial predictions for water-jet propelled craft, the available model testing techniques suffer from even more severe shortcomings than those at high speed propellers. Hence, no safe procedure for conducting self propulsion tests including measurement of the total thrust of the water-jet unit is yet available, the main complication being the fact that som of the thrust is generated by the water channel which is normally an integrated part of the hull. In order to develop water-jet propulsion further it is highly desirable to find suitable means and methods for analyses of the interaction between the water-jet unit and the ship's hull i.e. to enable the evaluation of propulsive factors such as wake, thrust deduction etc. in a way similar to that applied at propeller propulsion. Hopefully, the HSMV Committee can give this problem area some consideration in its future work.

II. REPLY BY THE HIGH-SPEED MARINE VEHICLES COMMITTEE

The Committee would like to thank *Mr. Suhrbier* for his questions and comments. In response to the first question, concerning the effectiveness of thin water-films and their treatment in the resistance scaling procedure, we have to refer to the final remarks in the topic of wetted area estimates and we have also to refer to the in-depth Report of the High Speed Marine Vehicle Panel for the 16th ITTC where under item 3.2.2.2.2.3 possible scale effects of Semi-Displacement Round Bilge Hulls are discussed. At present we have very limited informations about the velocity in the thin water-film closely behind the stem and we have also limited informations concerning a proper specific frictional resistance coefficient which can be used for this region. In addition no useful method for estimating the frictional resistance of those areas covered by a thin water-film or by spray has been developed taking into account the deviation of the local flow direction from the direction of advance. But it is known from numerous tests that, depending on model size and radius of the model stem in the waterline, the wetted area closely behind the stem on the model can become considerably larger than at the full scale vessel due to surface tension effects. This influence of the Weber Number, which is too low at the model, can be minimized by using models which should be as large as possible and by providing a stem radius at the model which should be smaller than given by correct scaling.

Concerning the performance prediction for craft with cavitating propellers the Committee is well aware of Mr. Suhrbier's interest in the question. The Committee also very much appreciates the discussions and suggestions from Mr. Suhrbier and looks forward to a future cooperation with the Cavitation Committee on these problems.

With respect to the problem cited, of the decreased drag of rudders often found in high-speed craft when situated in a propeller slipstream, the Committee agrees with Mr. Suhrbier that the formula derived by Peck, given on page 370, should not be used. In fact in that case none of the formulations given in the Report are valid. The problem of decreasing (or increasing rudder drag with increasing) speed is often associated with incorrect alignment of the rudder(s) in the slipstream, causing a lift force on the rudder with a (small) forward component, reducing (or increasing) the drag. In the Report of the Committee the problem of securing correct alignment of appendages such as stabilizer fins, struts of brackets and rudders is quoted as the cause for important increases in appendage drag and that special alignment tests are necessary to overcome this problem. Generally, the formulations given in the literature for appendage drag do not take the effect of angle-of-attack into account.

Regarding the Treatment of Aerodynamic Drag the Committee has the following comments: Normally the hull model is tested without super-structure so that the measured resistance includes the aerodynamic drag of the hull alone. The super-structure is accounted for separately by estimating its aerodynamic drag and pitching moment about the center-of-gravity and properly loading the test model to represent these effects.

The aerodynamic drag of super-structures can be estimated using the methods given in Hoerner. For speeds well in excess of 40-50 knots it is recommended that separate wind-tunnel tests be conducted as a more special means for estimating the aerodynamic forces and moments of the super-structure.

The Committee welcomes the contributions of *Dr. Baba* concerning the change of wetted area and wetted lengths of Semi-Displacement Round Bilge Hulls and Planing Hulls under way. The diagrams confirm very closely the statements of the Committee Report, that the wetted area of semi-displacement hulls can become up to 50 percent greater than at rest and that the wetted area of planing hulls can decrease up to 40 percent approximately. The diagram of the variation of wetted length in running condition shows a remarkable scatter of the reductions in wetted length. The diagrams would be very useful for further studies dealing with the influence of the hull form on the change of wetted area if Dr. Baba could give us informations about the section shape or hull form, about the length-displacement ratio, L/B ratio and LCB position for each curve of the diagram. We agree with Dr. Baba that for estimating the wetted area in an early design stage and for reducing the expenditure of tank tests curves characterizing the change of wetted area are urgently needed especially for Semi-Displacement Round Bilge Hull

The Committee does apologize for the omissions made in the list of institution which responded to the questionnaire. By mistake Institutions Nos 19-25 are missing in the first Volume of the Proceedings. A correction to the list is included in Section III.

The Committee would like to thank *Dr. Barcher* for his interesting comments regarding the comparative high speed craft model testing being carried out by the British Towing Tank Panel.

We understand that the model is likely to be re-circulated around the various Towing Tanks and further comparative tests are to be carried out in the near future. The HSMVC looks forward to receiving some published data as soon as they are available.

We also would like to make reference to Chapter IV.2 in our Report where different methods to determine the wetted area on high-speed vessels are discussed.

To the criticism of Figure 28 expressed by *Prof. Kruppa* the Committee has the following comments:

At cavitation tests of propellers behind complete ship models it is difficult to use definitions other than the axial thrust unless the total thrust deduction could also be measured.

The purpose of Figure 28 is to show the large difference in results obtained between using only the inclined flow as simulation of the working conditions and using the complete ship model. In both cases efficiency and thrust are based on the axial thrust and torque measurements. Thus the differences in efficiency are not due to corrections for normal forces but actual measurements carried out in the same way in oblique flow (without hull) and oblique flow behind the hull.

The Committee thanks *Mr. D. Zhang* for his comments and look forward to receiving the results of the performance study of the foil in due course.

The Committee wishes to thank *Dr. Rong Huan Zong* for his comments. This type of information is used indirectly by those in tankery since the use of computer codes such as this lets the SES designer narrow in on the best design for a given set of specification without the expences of testing many designs. At the David Taylor Naval Ship Research and Development Center we use codes similar to the one described in this contribution but developed by *Dr. Larry Doctors* of the University of New South Wales to predict both the cushion and sidewall wavemaking resistance and the interactions of cushion and sidewall generated waves. Since we have various combinations of sidewall and cushion length-to-beam ratio as well as variations in cushion loading and sidewall design and buoyancy contributions, analytical codes such as Dr. Rong Huan Zong's or Dr. Doctors' let us reduce the design variables and hence, reduce the cost of characterizing the performance of the SES design.

The contribution provided to the Committee by Dr. Rong Huan Zong is only a summary of his paper and we hope that he will make the paper available to others active in the SES field.

The Committee would like to thank *Mr. Björheden* for pointing out the need for developing the technique for testing water-jet arrangements. The Committee has no other opinion than Mr. Björheden and in fact water-jets were on our list already for this ITTC. However as prediction procedures for vessels with propellers are believed to be a more fundamental problem these were given priority over water-jet testing this time. One of our Recommendations to the 18th ITTC HSMV is however to examine and report on model test procedures for water-jets and this time the water-jets will be given priority.

In answer to *Prof. Johnson's* remarks about expanding the activities of the High-Speed Marine Vehicle Committee to include the problems associated with the testing of sailing yacht models the Committee feels that the sailing yacht does not constitute a high-speed marine vehicle even though at time, the Froude number of racing yacht approaches Fn=0.50. The individual members of the Committee nevertheless agree with Prof. Johnson that the testing of sailing yacht models poses unique problems to which different towing tanks have persuaded different solutions. In the light of a considerable increase in the work of this nature in some countries it would be a timely move to appoint a small ad-hoc panel or working group to report to the 18th ITTC some of the problems associated with this type of work and the solutions adopted by different Members. The 18th ITTC could then make a decision whether or not this problem area needs to be monitored continuously or only every now and then by an ad-hoc working group or panel.

The Committee wishes to thank *Dr. Breslin* for his continued interest in the SES/ACV pneumo/hydrodynamic coupling and scaling of SES/ACV model motions data.

This technical area is one which needs continued attention to determine whether cushion mass flow rate or other parameters are important in the cushion pressure dynamics in addition to the equation contained in the Committee's Report. Data contained in the HSMV Committee's Report to the 16th ITTC as well as other unpublished data show that model data adequately predict the motions of surface effect ships in the 100-200 ton size. Full scale data verifying the existence of the phenomenon were obtained on two ships of this size by driving the ride control system at the specified frequencies while in relatively calm water and recording the resulting pressure and acceleration oscillations. The heave-pressure mode natural frequency for similar craft are generally higher than the encounter frequency of most seas experienced. This, however, will not be the case for multi-thousand ton SES. The ride control system which will be on these large ships to reduce cushion pressure induced accelerations should be capable of minimizing the effects of the heave-pressure mode natural frequency but the phenomenon must be fully understood to size the ride control system and to formulate the control laws.

III. COMMITTEE REPORT ERRATA

The following corrections should be observed in reading the original Report of the 17th ITTC High-Speed Marine Vehicles Committee (Proc. Vol. 1):

Page 370, right column, formula for D:

Shall read

$$D = \tfrac{1}{2}\rho V^2 A C_F [1.25 \frac{c_m}{c_f} + \frac{S}{A} + 40 (\frac{t}{c_a})^3]$$

Page 371, right column, formula for D_R:

Shall read

$$D_R = \rho V^2 A_R C_F [1 + 2(t/c) + 60(t/c)^4] + \tfrac{1}{2}\rho V^2 S_B 0.14 \left(\frac{C_F 2A_R}{S_B}\right)^{-1/3}$$

Page 383, Fig 44 - Flow Chart for Selecting the Scale Ratio ...:

To be substituted by the Chart reproduced here on p. 160.

Page 392, APPENDIX , TABLE I - LIST OF ESTABLISHMENTS ....:

To include list Nos. 19-25 given below:

19. Krylov Shipbuilding Research Institute, Leningrad, U.S.S.R.
20. Nagasaki Experimental Tank, Japan.
21. Netherlands Maritime Institute, Wageningen, Netherlands.
22. N.M.I. Limited, Feltham, U.K.
*23. Offshore Technology Corporation, Escondido, U.S.A.
24. Seakeeping and Manoeuvring Basin, University of Tokyo, Japan.
*25. Sektion Schiffstechnik, Universität Rostock, G.D.R.

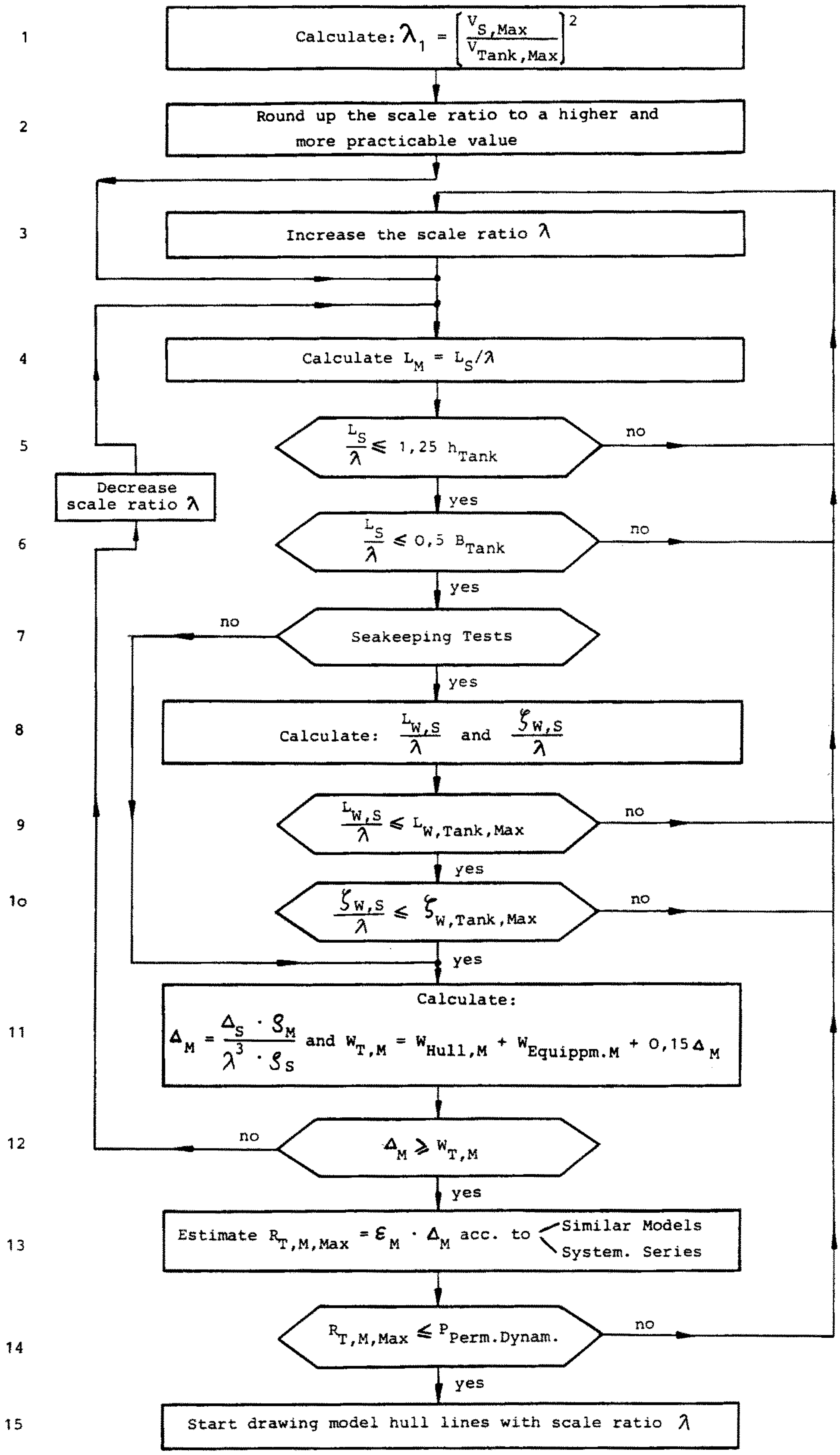

Fig. 44 - Flow Chart for Selecting the Scale Ratio of Planing Hulls and Semi-Displacement Hulls for Resistance and Seakeeping Tests