SESSION ON POWERING PERFORMANCE

Chairman: Prof. J.F. Núñez

Powering Performance Committee Memberships: J. Holtrop (Chairman) – R.L. Townsin (Secretary) – R. Bhattacharyya – G. Collatz (to January 1989) – A. García-Gómez – Y. Guo – K. Nakatake – P. Schenzle (from September 1989) – K. Varsamov.

Discussion of the Report and the Draft Recommendations of the Powering Performance Committee (cf. Proceedings, Volume 1, pp. 235–287).

I. DISCUSSIONS

PP–1

W.v.d. BERG
Maritime Research Institute Netherlands, The Netherlands

COMMENTS ON THE POWERING PERFORMANCE COMMITTEE REPORT

1. Refering to the draft recomendations to the conference (Chapter III.2) we appreciate the practical suggestions for determination of the form factor in the resistance scaling. Nevertheless the procedure involves decisions or choices to overcome uncertainty (e.g. in the case of trim and draught variation). In this respect we see an advantage in a statistical derivation of the form factor, by which further disputes in each individual case can be avoided. We would advocate to try to develope one generally accepted approximate formula for 1+k.

2. As compared to the classic extrapolation methods the modern methods should virtually cover the physical phenomena involved, such that in the ideal case no further correlation allowance would be necessary. In this regard it is somewhat disappointing that predictions for vessels at design and ballast draught should still contain further empirical corrections to match the trial results. We would recommend further effort to explain the differences in ballast and full load correlation factors.

3. The study into scaling of appendage drag is quite interesting. It might be extended to focus on some classes of appendages. In this respect the rudders may deserve a special attention, to deal with:

- treating the rudder as an appendage or as part of the propulsor;
- some rudders show excessive appendage drag, from which a part clearly originates from separation.

4. Further investigations on propeller performance with leading edge boundary layer tripping are to our opinion highly important to make progress in the elimination of scale effects in the experiments.

PP-2

K. MORI
Hiroshima University, Japan

A COMMENT TO THE REPORT OF THE POWERING PERFORMANCE COMMITTEE

My comment is to the section 10 on the review of validation.

The committee provides an example of the resistance test results with uncertainty analysis. It must be the first example of the uncertainty analysis carried out for the resistance test and it should be highly appreciated.

From the analysis the report draws a conclusion that "the results of this analysis show that by doing so an appropriate value of the form factor can not be chosen for this particular small model". The model lenght is 2.5 m

Nothing is mentioned about the procedure used for the present analysis. The procedure of the uncertainty analysis shown in our report of the validation panel has not yet been established. Therefore the discusser assumes it is not the time to draw such a definite conclusion but to discuss more on the procedures of the analysis. It is still open for the studies especially on what procedure is good for non-repeated experiments such as the resistance test.

PP-3

M. ABE
Akishima Laboratory, Mitsui, Japan

EXTRAPOLATION PRACTICE OF APPENDAGE RESISTANCE

I highly appreciate that the Committee has addressed in detail the extrapolation practice of the appendage resistance.

My point is that the extrapolation of the appendage resistance should be processed by using the relevant manner adjusted to each type, shape and location of appendages.

I agree to the application of the form factor concept to the result of the resistance test with an appended model ship, except the case of the large shaft bossings and/or brackets.

In the case of the large bossings with twin and triple screw propulsion, however, the form factor concept or the Beta factor to reduce the model appendage resistance should not be applied, but the exact extrapolation of the model appendage resistance should be processed.

Fig. 1 shows the results of the analysis of the appendage resistance, where the different sizes of the bossings both with twin and triple screws are well expressed by using the exact definition of the appended wetted-surface area. Namely, eliminating the area of the bossing root touching the surface of the hull is the key analysis on the extrapolation of the bossing resistance.

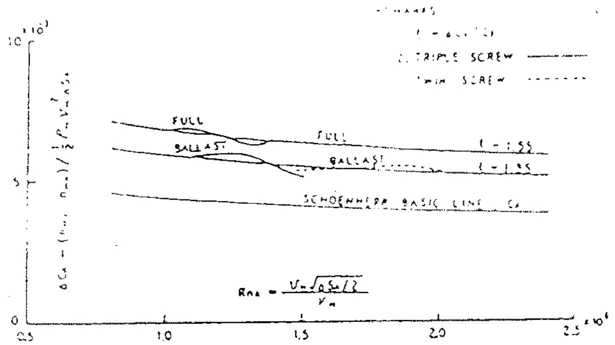

Fig. 1 Appendage Resistance

Fig. 2 demonstrates the full scale EHP curves of the different extrapolation methods. In this figure, the full line indicates the extrapolation processed as in Fig. 1 in good correspondence with the sea trial test result, whereas the chain and dotted lines show the application of the ordinary form factor concept and 50% reductions of the model appendage resistance, respectively.

The difference in the extrapolation methods is clearly shown here, and the form factor concept is not necessarily feasible in this case.

In this discussion, it is recommended that the extrapolation practice of the appendage resistance should be widely accumulated among the organization members to establish more practical powering process than in existing.

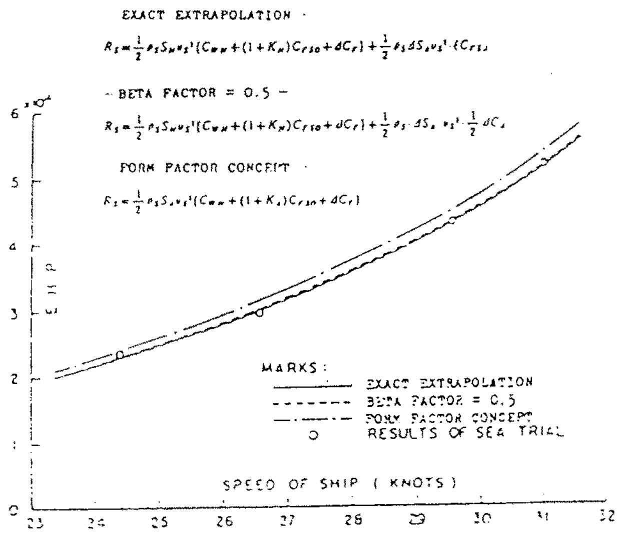

Fig. 2 Comparison of EHP Curves between Predicted and Sea Trial Results

References

[1] K. Yokoo et al.. An Investigation into the Propulsive Performance of a High Speed Container Ship with Triple Screws, J. of the Society of Naval Architects of Japan, Vol.133, 1973.

PP-4

M.A. ABKOWITZ
Massachussetts Institute of Technology, U.S.A.

FULL SCALE MEASUREMENTS OF THE RESISTANCE AND POWERING COEFFICIENTS AND THE RESULTING IMPROVEMENT IN THE EXTRAPOLATION PROCESS FROM MODEL TO SHIP

The goal of the towing tank establishments is to predict ship performance from design features (geometry/shape). Since "mathematical models" (theoretical hydrodynamics) are still very limited in their capability to satisfactorily perform this prediction, we must still rely (for quite a while yet) on scaled "physical models" tested in the towing tank. As is well known, the hydrodynamic coefficients involved in resistance and powering suffer from "scale effects" because of the inability in the model test to satisfy the viscous parameter of Reynolds' number.

In order to predict a power-speed relationship for the ship, several model tests are carried out to measure the resistance coefficient (smooth hull) (C_R), the wake fraction (w), the thrust deduction factor (t), and the propeller thrust (K_T) and torque (K_Q) coefficients in both open water and self-propelled conditions. These five coefficients are all functions of Reynolds' number and therefore suffer from "scale effects". To these a sixth coefficient in the form of roughness factor (ΔC_F) must be estimated for the ship from hydrodynamic phenomena measured at low model test Reynolds' number.

In the process of predicting ship power performance from model test, six different factors must be extrapolated from model tests or predicted from some hydrodynamic basis, all of which suffer from "scale effects".

$$\textit{predicted power} = f[(C_R + \Delta C_F),\ w,\ t,\ K_T,\ K_Q] \tag{1}$$

When measured power from ship trials are compared to that predicted from model tests,

(1) if there is an error in the prediction, then one or more of the coefficients may have been wrongly predicted.The standard culprit in the past was the roughness factor (ΔC_F) until negative roughness factors appeared when there was a significant change in ship size and fullness. In reality, the roughness factor has represented a roughness in the extrapolation process rather than specifically the ship roughness.

(2) if there is an agreement between actual ship power and that predicted from model tests, all of the coefficients may have been properly predicted or several of the coefficients may have been wrongly predicted with errors in some of the coefficients compensating for errors in other coefficients. In the latter case, one may build up confidence in a faulty prediction procedure in that compensating errors may only exist for that particular ship geometry and the agreement would be fortuitous. It probably would not work well for a different ship and/or propeller geometry.

At MIT, we have developed special procedures of system identification whereby (C_R+ΔC_F), w, t and K_T (open water) can be "measured" (identified) on the ship from simple acceleration-deceleration trials carried out during a regularly scheduled voyage using instruments normally on board. Records of the forward speed (reliably measured by Doppler or similar speed log) and the propeller RPM during the trial provide the necessary data for system identification analysis. The measurement of rudder angle and heading are made to assure that the ship is moving straight ahead with negligible rudder action. If shaft horsepower (SHP) is measured, then K_Q can also be determined.

These tests were carried out on a routine voyage between Valdez, Alaska and San Francisco and (C_R+ΔC_F), w, t and K_T of the ship were successfully identified. These trials are reported in Reference 1. More recently, similar trials on a U.S. Navy submarine were analyzed with the MIT system identification technique and the successful results are reported in Reference 2. Within a few months, these trials will be performed on one of the American President Lines' new large fast container ships on a routine voyage between Los Angeles and San Francisco.

We are now in the position to measure full scale (C_R +ΔC_F), w, t, K_T and K_Q and thereby provide a basis on which to extrapolate each of these factors from model to full scale. This should provide a marked improvement in the ability to predict ship performance in the area of ship resistance and powering. Reasonable extrapolation methods for wake fraction (w) and thrust deduction factor (t) are shown in Figures 1 through 4 using data obtained from the trials of the tanker and submarine.

In Figure 1, the model measured value and the ship identified values of w for the tanker are plotted against the plank friction coefficient C_F (inverse of log Reynolds' no.) on a background of test data from several different geosim series of models. Since C_F = 0 represents infinite Reynolds' no. (zero viscosity), potential flow calculations will give the value of w since there is no frictional wake and the trials are run below wavemaking speed. A faired curve between the values at model Reynolds' no., ship Reynolds' no. and infinite Reynolds' no. would provide a basis for the extrapolation of w for that type of ship. The model test value for w and the potential w can be obtained for a model of a new desing and a curve between these two points drawn parallel (or in a similar shape) to the faired curve previously developed would provide a predicted value for w for the ship at the Reynolds' no. at which the ship is to operate. Notice how the model test and the ship identified values of w would lie on a curve which is reasonably parallel to the geosim curves. Figure 2 shows a similar curve for the submarine. Unfortunately, the potential wakes for the tanker and the submarine have not been calculated.

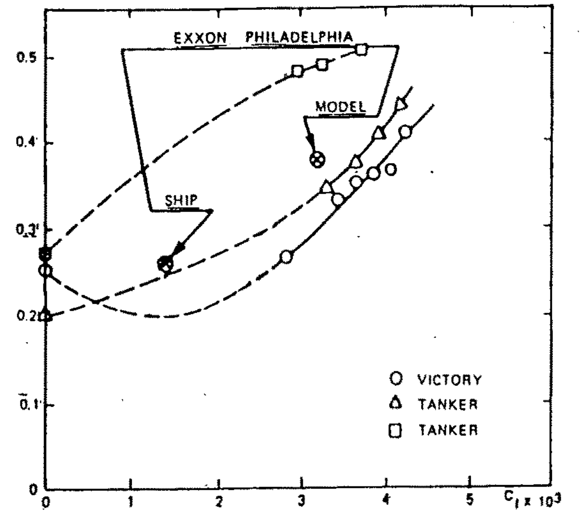

Fig. 1 Wake fraction of geosims as a function of C_f

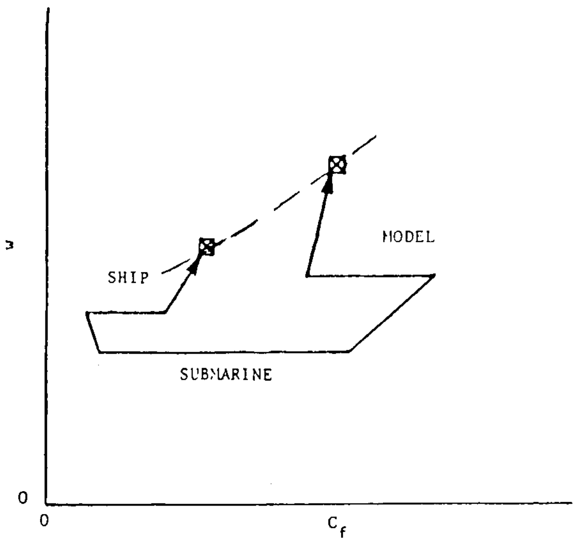

Fig. 2 Wake fraction as a function of C_f

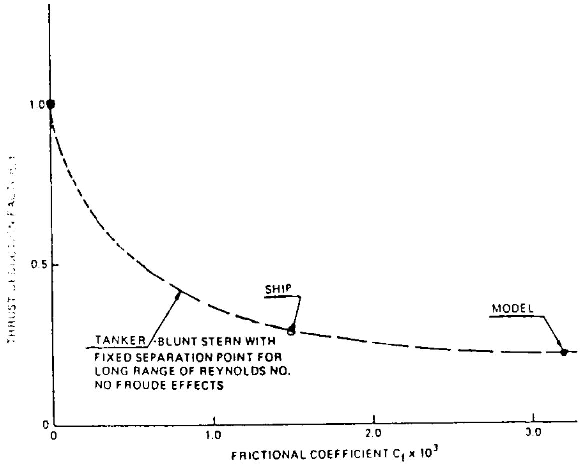

Fig. 3 Thrust deduction factor vs C_f

In Figures 3 and 4, the thrust deduction factor (t) is plotted vs. C_F for the tanker and submarine respectively. The definition of t is given by

$$\text{thrust } (1 - t) = \text{resistance}$$

At infinite Reynolds' no. ($C_F = 0$) the flow is ideal and the resistance is zero (if below wavemaking speed) according to D'Alembert's paradox. Therefore, for all ships t = 1 at infinite Reynolds' no.. In Figures 3 and 4, there are three points on which to perform the extrapolation curve for t. The extrapolation process for t would be similar to that described for w.

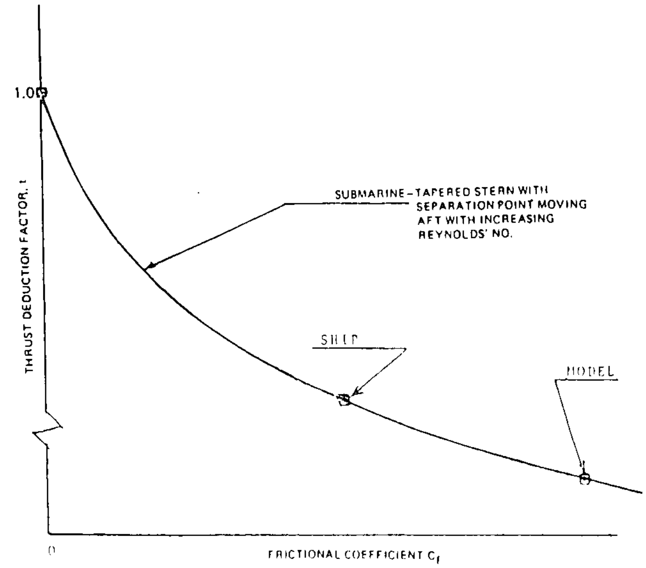

Fig. 4 Thrust deduction factor vs C_f

Since ($C_R + \Delta C_F$) for the ship is identified, we are in a much better position to improve our methods of extrapolation of model resistance to full size. The resistance coefficient for the tanker was over predicted by greater than 12% and the resistance coefficient of the submarine was over predicted by 10%. This error can be specifically attributed to the prediction of C_R and ΔC_F. We can now clearly focus our investigation of resistance scale effects on three possible contributors.

1. an inaccurate estimate of plank frictional resistance (C_F) at ship Reynolds' no. where there is no reliable data - only a lengthy extrapolation from scattered data at a much lower Reynolds' no.

2. an inaccurate method of extrapolating the eddy resistance from model to full scale.

3. an error in the estimate of the ship roughness factor, ΔC_F.

Present methods of extrapolation tend toward compensating errors in the prediction of C_F and ΔC_F.

References

[1] "Measurement of Ship Resistance, Powering and Manoeuvering Coefficients from Simple Trials During a Regular Voyage", Martin A. Abkowitz and Gengshen Liu, Transactions of Society of Naval Architects and Marine Engineers, November 1988.

[2] "Measurement of Resistance and Powering Coefficients of the Tanker EXXON PHILADELPHIA and a Navy Submarine from Simple Full-Scale Trials and Their Implications in Ship Performance Prediction from Model Tests", Martin A. Abkowitz, New England Section of SNAME, January 1990.

PP-5

K.R. SUHRBIER
Vosper Thornycroft (UK) Limited, U.K.

ON HIGH-SPEED CRAFT

I would like to congratulate the Committee to their interesting and balanced report and wish to make a few comments:

As referred to, power prediction procedures for high-speed craft are also discussed by the HSMV Committee and the conclusions and proposals of both committees seem to be largely in agreement. It may be perhaps added that it is certainly not easy, or even impossible, to define simple straight-forward procedures for all types of high-speed craft. Amongst other influences, cavitation and ventilation can considerably complicate matters; not only propeller efficiency but also thrust deduction, trim and thus resistance, etc. can be affected. Such phenomena are often difficult to allow for unless additional, more complex, investigations are carried out.

As regards scale effects on appendage resistance, obviously a subject of great importance for high-speed craft predictions, the HSMV Committed reached rather similar conclusions, namely that the β factor correction procedure or extrapolations based on a form factor method are - at present - the most practical approaches, particularly for bluff bodies, such as open inclined propeller shafts. For other appendages, corrections can usually also be based on calculations (formulae) with a reasonable degree of accuracy.

With reference to Section 6.2, I have a little difficulty with the statement about the good correlation reported between experimental and calculated results for appendage resistance. I would point out that the formula referred to (ref. [32]) and used for the calculation of the inclined propeller shaft contribution is really only valid for model Reynolds numbers and not for full scale conditions (see also discussion in HSMV Committee report).

PP-6

J.W. ENGLISH
British Maritime Technology (FM. Ltd.), Teddington, U.K.

PROPULSION TESTING

1. The Powering Performance Committee appear to be giving credence to the proposed method of propulsion testing advocated by Dr. Grigson in Refs. 15 and 16. Whilst agreeing with his comments regarding the differences between open water and behind propeller characteristics, I do not believe that he has demonstrated a superior method of calculating the towing force. An assumption on which he bases his reasoning, that the inflow to the model and ship propellers are independent of Reynolds number, is clearly in error.

2. On the subject of validation the Committee have neglected a very useful publication on the subject of repeated resistance testing by Scott formerly of the St Albans Tank, UK, and published in RINA. This reference compared repeated resistance testing in St Albans Tank and BMT No. 1 tank with and without curtains.

PP-7

M.E. DAVIES
British Maritime Technology (FM Ltd), Teddington, U.K.

EXTRAPOLATION FROM MODEL TO SHIP - ABKOWITZ DISCUSSION

The method presented relies on potential flow being an appropriate description of the total flow field, in the limit of Reynolds' no. $\rightarrow \infty$.

It is suggested that this is a fallacious argument. In the limit Re $\rightarrow \infty$, viscosity continues to be important at the solid body surface. Vortivity is still generated in the boundary layer (however, thin this becomes) and the wake is, therefore, not irrotational.

II. REPLY BY THE POWERING PERFORMANCE COMMITTEE

Reply to Mr. v.d. BERG

The Committee is grateful to Mr. v.d. Berg for his contribution. Consistency and the reduction of the risk of drawing wrong conclusions from systematic best series has led the committee to write in Chapter II.2.3 of its report that in many cases, for ordinary ships, a statistical formula for 1+k can be quite useful. A practical solution could be to use an individual form factor derived from the experiment as a basis and to determine effects of changes in trim and draught on 1+k by a suitable statistical formula to preserve consistency.

The empirical correlation coefficients needed to predict the actual trial performance originate form differences in test set ups and measurement procedures, and also, the simplicity of the extrapolation methods including the modern procedures, causes some systematic deviations to occur in the correlation coefficients, depending on the test condition and ship type. The Committee expects that through validation of the procedures followed, including the use of standard models, differences in correlation factors between institutions and test conditions will be better understood.

The Powering Performance Committee doubts if the variation of the power correlation coefficient is really substantial when laden and ballast conditions are compared, provided a modern method of analysis is used. In a recent paper, Ref. 8 of the Committee's Report, Dr. Grigson shows that the model-to-ship power correlation factor C_P is almost constant for one single ship for a wide range of draughts. Dr. Grigson used a modified version of the ITTC-1978 power prediction method.

As far as rudders are concerned we fully agree with Mr. v.d. Berg that they need special attention. Some paragraphs were devoted to the various rudder effects (scale effect on rudder drag, the stator action, the effect on the wake scaling etc.) in previous reports of the Powering Performance Committees of the ITTC. The question of whether the rudder is to be considered as an appendage or as a propulsive element, is a matter of academic appendage or as a propulsive element, is a matter of academic interest, provided the scale effects are taken into account properly and the same power and rotation rate is predicted. So, if the rudder is considered a part of the propulsor its influence on the self-propulsion factors should be evaluated instead of considering the appendage drag scale effect in combination with the scale effect on the local flow velocity. It is true that some well oriented rudders, with an unconventional length to thickness ratio show an appendage drag higher than expected from previous experience.

The effects of the separation of the flow could be studied by testing a single rudder with a propeller just upstream at various Reynolds numbers. This might indicate some Reynolds number effect on model scale, which is an important indication as regards the similarity of the flow on model and full scale. Turbulence tripping is considered important in such experiments.

The Powering Performance Committee is grateful to Mr. v.d. Berg for his support of their recommendations to encourage research on turbulence tripped propeller models.

Reply to Prof. MORI

The Powering Performance Committee thanks Prof. Mori for his contribution.

These results were obtained following the Procedure included in the Report of the Panel on Validation Procedures. We wished to determine the form factor for this relatively small model.

The Committee considers the attempts to apply the given procedure for uncertainty analysis as an exercise rather than a result disquality the determination of form factors from small models. The Next Committee should look into this matter more thouroughly and more analysis are needed to draw general conclusions, in particular in the field of non-repeated experiments.

Reply to Mr. ABE

The Committee appreciates very much the documented contribution of Mr. Abe.

His comments about the determination of the form factor of models appended with large bossings agrees with recommendation 2.3 given to the Conference. A further study of the various methods as presented is worth the next Committee's time.

The results of the form factor procedure in the presented example should be examined further to trace the origin.

The Committee considers the creation of a data bank of appendage drag data, including both model and full scale data, as very valuable. The Committee encourages all the member organisations to respond positively to enquires that may come forward in this field.

Reply to Prof. M. ABKOWITZ

The Committee thanks Prof. Abkowitz for his contribution. For reasons of available time the Powering Performance Committee is unable to respond to all the points raised. In fact, the critical review of the current state of affairs relates to many activities of ITTC, in particular the validation of prediction through model experiments. A few remarks can be made nevertheless. The Committee of ventures to doubt the accuracy of most of the basic measurements aboard the full-scale ship used as input to the analysis procedure. Since time and shaft revolution counter readings are the two most reliable measurements on board, the shaft measured power and speed through the water should always be related via the exact open water characteristics of the working propeller, as originally suggested by Telfer. A critical survey should be made in this respect.

The Committee further doubts the strong Reynolds number effect on the thrust deduction which resulted from the measurements. In particular, the limit value of t=1.0 at vanishing viscosity is doubted. We agree that higher thrust deduction are found for the full scale ship but this is rather due to the effect of the reduced propeller load of the full scale propeller, thanks to the wake scale effect. Some experts may look further into this matter because of its impact on extrapolation procedures.

Reply to Dr. K.R. SUHRBIER

The Powering Performance Committee is grateful to Dr. Suhrbier for his contribution.

We fully agree with him that the complexity of the scaling problem would require further studies and we acknowledge that deriving a suitable extrapolation procedure according to the frame work of the ITTC-1978 more attention was paid to correlation rather than to a proper modelling of the hydrodynamic phenomena involved.

As to the remark on the accuracy of current calculation procedures we agree with Dr. Suhrbier's comments. In particular for open raked shafts there is indeed a lack of consistency if variations in arrangement and Reynolds number, over a wide range, are considered. This indicates that the calculation procedures, referred to in our report, are not yet sufficiently accurate to replace either the more conventional scaling procedures or the measurement of the appendage drag.

Reply to Dr. ENGLISH

The Powering Performance Committee is grateful to Dr. English for his contribution. We agree that Dr. Grigson has not convinced the towing tank community that testing at an underloaded condition is superior to the methods currently in use. The Committee does not share Dr. English's view that Dr. Grigson's approach is based on an assumption of Reynolds number independence of the propeller inflow. This assumption is not made in Dr. Grigson's work. On the contrary, wake scale effects are recognised, although loading effects, present on the wake are difficult to transpose to the full scale ship. The Powering Performance Committee thanks Dr. English for drawing attention to the repeated resistance experiments in the UK.

Reply to Dr. DAVIES

The Powering Performance Committee thanks Dr. Davies for his contribution to the discussion with Prof. Abkowitz. It is clear that the confussion aroused by considering ultimate conditions has not yet solved the issue of scale effect on the thrust deduction, if any.

ITTC-1978 Questionnaire

During the Conference the Powering Performance Committee gave once more the opportunity that information on the use of the ITTC-1978 power prediction method could be provided by means of a brief questionnaire, now in a notice board.

Six institutions replied to this questionnaire, thus increasing the total number of respondents to 27. It appeared that 5 of the six new respondents use the method in more than 10%. The other one uses the ITTC-1978 method in 1-10% of the cases.

From the total return it appears that 10 out of 23 respondents use the method in more than 10% of the cases.

The relatively low return, of about one third, prevents that new more general conclusions are drawn.

Once more the Committee expresses its thanks to all those who responded.

III. COMMITTEE REPORT ERRATA

p. 241	Right hand column, 3rd line from bottom 2.3.3. Tests in which Flow Separation is Apparently Present.
p. 246	Right hand column, last two lines should read: water and propeller rotation rate. The heading and rudder angle are also measured to assure that the ship moves straight ahead with negligible rudder action.
p. 247	Left hand column, the first two lines should read: The testing includes running the ship with a windmilling propeller during the deceleration.
p. 247	Left hand column, 6th line from top, insert: The resistance is also independently measured from the acceleration run.
p. 258	Right hand column 6.1 Prediction of Ship Performance...
p. 258	Right hand column Line 9 As power prediction...
p. 260	Right hand column Line 13 from top number 6, should read 7, and $C_{AA}=0$ should be $C_{AA}\neq 0$
p. 260	Right hand column line 14 from top Number 7, should read 6.
p. 263	Right hand column line 7 from top, insert < to read thus: ... with $R_t(50) < 230\ \mu m$ the correlation...
p. 272	Right hand column line 12 from top should read: ... as depth decreases.