

SESSION ON PROPULSION
PERFORMANCE

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Dipl.Ing.A.Gross

Discussion of the Report and the draft Recommendations of the PERFORMANCE COMMITTEE.

I. DISCUSSIONS

G. AERTSSEN - University of Ghent, Ghent, Belgium.

Committee commented the variation of form factor with R_n . A wooden model 2m in length, of tanker REINE FABIOLA, 227m in length, block 0.80, was tested in the wind tunnel of the von Karman Institute (Belgium), and the form factor calculated on a basis of the 1957 I.T.T.C. line. The tanker being in loaded condition without bulb, the form factor decreased from 1.304 at $R_n = 7 \times 10^6$ to 1.294 at $R_n = 10^7$, 1.279 at $R_n = 1.1 \times 10^7$ until at $R_n = 1.2 \times 10^7$ this form factor appears to attain a constant value 1.27. The model tests extended to $R_n = 1.4 \times 10^7$. The reason of the decrease probably was

flow separation which was visualised at $R_n = 1.3 \times 10^7$ and from the photographs shown in Fig. 12 of the ATMA paper [1] it is clear that the area of separation is an oval of 2cm x 3 cm. Form has an effect on the viscous pressure drag, and from wind tunnel tests carried out in the Von Karman Institute it may be concluded that, at service speed, a slender ship $C_B = 0.53$ had a viscous pressure drag much lower than calculated wave resistance, whereas on a full ship $C_B = 0.80$ the measured viscous pressure drag was of the same amount as the calculated wave resistance. In both cases the viscous pressure drag was obtained deducing the calculated wave resistance from the Froude residuary

resistance obtained in the tank. Coming to Technique 3, propulsion in waves, Committee is right in stating that propulsion coefficients do change in a seaway. Perhaps even a thrust deduction coefficient may change in waves, but, assuming no change, it is not difficult, when carrying out trials at sea, speed, power and thrust being measured, to establish the effect of sea state on propulsive efficiency. It was found on the Lubumbashi that loss of propulsive efficiency increased with wave height and that in a head sea Beaufort 7 this loss of propulsive efficiency was as high as 18% [2].

The big difficulty remains, when predicting ship performance in a calm sea, to establish the hull roughness. It is quite exceptional that this roughness is measured. Encouraging ship owner to carry out this measurement, even in a crude way, would stimulate the yard to have new-built ships well painted. On the other hand it would be helpful to establish a more correct ship-model correlation.

Finally, for the first time air resistance calculation is included in the prediction calculations. My suggestion is that, whenever feasible, wind tunnel tests of the above water form of the newly-built ship be carried out. If then longitudinal and transverse forces and moments are measured, not only will air resistance be known, but more knowledge will be gained on the manoeuvring abilities of the ship in oblique seas.

REFERENCES

1. Aertssen, G., Gadd, G.E. and Colin, P.E.: "Résistance de vague et résistance visqueuse du pétrolier REINE FABIOLA avec et sans bulbe", A.T.M.A., Vol.74, Session 1974.
2. Aertssen, G.: "Further sea trials on the Lubumbashi", Trans. R.I.N.A., Vol. 99, 1957.

SHOICHI SUDO - Akashi Ship Model Basin Co., Ltd., Akashi, Japan.

Concerning the characteristics of model propellers, the Committee Report says that Tsuda et al. (Akashi Ship Model Basin) obtained improvements by the use of low-pitch propellers (on page 370). But it is regretful to say that they have corrected the conclusion; that is, the attempt at applying low-pitch propellers to self-propulsion tests seemed to be useful for the improvements of the tests at the first stage, but further investigations conducted after the preceding paper [25] did not always produce successful results.

The reason is considered as follows: The use of low-pitch propellers can raise the Reynolds number ($=ND^2/\nu$) up to the order of 5×10^5 in self-propulsion conditions (about twice as high as that for ordinary propellers). It is generally believed that the characteristics of a model propeller become stable when the Reynolds number exceeds the critical one. However, it was found by the flow-visualization tests that, concerning the low-pitch propellers as well as ordinary ones, the boundary layer on the model propeller blades was still a laminar flow, and three-dimensional laminar-flow separation clearly took place on the back side of the blades when the Reynolds number exceeded 5×10^5 .

Accordingly, the characteristics of low-pitch propellers in self-propulsion conditions might be still unstable, and the results of the self-propulsion tests with low-pitch propellers could not be consistent enough. In addition, the self-propulsion factors obtained with a low-pitch propeller happen to differ from those obtained with the ordinary propeller. Maybe the difference of the self-propulsion factors is caused by the considerable difference of the pitch between the two propellers. This is the reason why the low-pitch propeller method does not come into the practical use in Akashi Ship Model Basin.

C.P. SHENG - Shanghai Chiao-Tung University Shanghai, Peoples Republic of China.

In order to study the influence of propeller scale effect on the model-ship correlation factors (ΔC_T , $e_i = \frac{1-w_m}{1-w_s}$), my colleague, Mr. K.C. Wang analyzed the trial data of seven single-screw cargo ships (13000-25000 DWT) and the corresponding model results tested in the ship model towing tank of the Shanghai Chiao-Tung University.

The ship models are made of wood of about 4m in length. For resistance tests a 1mm dia. trip wire is fitted at $\frac{1}{20} L_{PP}$ abaft the F.P. The ship models are without bilge keels and rudders.

The screw models are made of white metal with diameter varying from 110 mm to 140 mm. For open-water tests the RPM of the screw model are increased to 2000 to get the maximum possible Reynolds number, which amounts to: $(R_N)_{0.75R} = (2.3-3.5) \times 10^5$. The model propulsive components w_m , t_m and η_{rm} are obtained by thrust identity method.

The model-ship correlation factors are analyzed by two methods. Both of these are based on the 1957 ITTC formula and on the assumptions that $t_m = t_s$, $\eta_{rm} = \eta_{rs}$.

Method 1. No propeller scale effects are introduced, i.e., the model open-water characteristics are used.

Method 2. The estimated full-scale propeller characteristics are used which are calculated by the 14th ITTC IDP4 method.

The model-ship correlation factors obtained by the use of the two kinds of propeller characteristics are given in Table 1 and Fig. 1.

Fig. 1 (or Table 1) indicates that the influence of propeller scale effect on the correlation factors tends to increase the ΔC_T and decrease the Δw . It also shows that the correlation factors are only slightly influenced by propeller

scale effect.

A detailed report is in preparation and to be published later on.

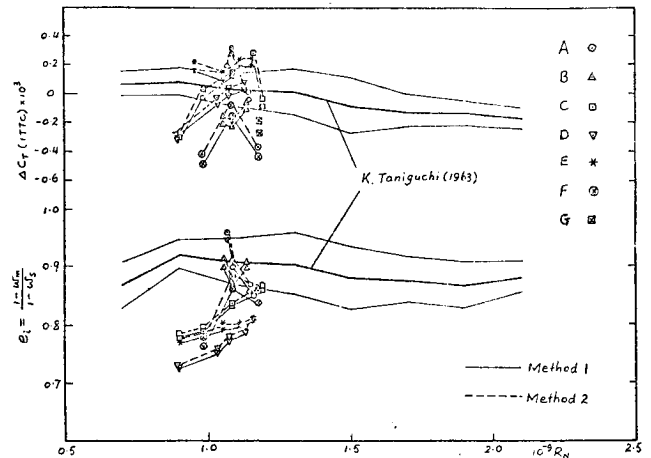


Fig. 1. Model-Ship Correlation Factors.

In its report to the conference, the performance committee mentioned that " R_{nco} must not be lower than 2.10^5 at the open-water test". It seems that the value of 2.10^5 is too low and some uncertainties might be introduced in the prediction of ship performance.

Recently, the ship model towing tank of the Shanghai Chiao-Tung University, collaborating with the Ship Scientific Research Center, has carried out a programme of experimental research on five geosim propeller models with diameters 0.103 m, 0.1187 m, 0.1395 m, 0.1691 m and 0.2146 m respectively. The prototype is a typical MA_u4-60 screw propeller with diameter 5.58 m and pitch ratio 0.788.

The models are made of white metal and carefully finished off. Each model was tested at five constant RPM. The range of the local Reynold's number at 0.75R is $(1.17-8.09) \cdot 10^5$. The experimental results are plotted in Fig. 2 and Fig. 3. It shows that the value of $3 \cdot 10^5$ might be taken as the lowest Reynold's number (R_{nco}) for open-water test.

Problems related to the propeller scale effect are rather complicated and further investigations are required. However, at the present state, I would like to suggest that, for practical purpose, the lowest R_{nco} at the open-water test to be 3.10^5 in order to obtain reasonable results in the prediction of ship performance. Incidentally, it seems that there are two misprints in the committee's report:

1. p.380, $(\Delta C_F$ and $\Delta t)$ should be $(\Delta C_F$ and $\Delta w)$.

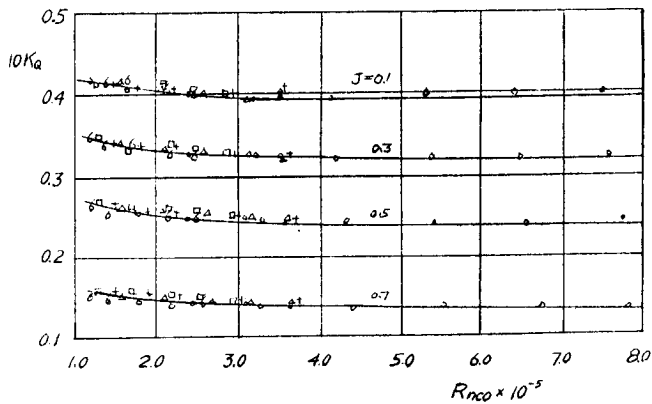
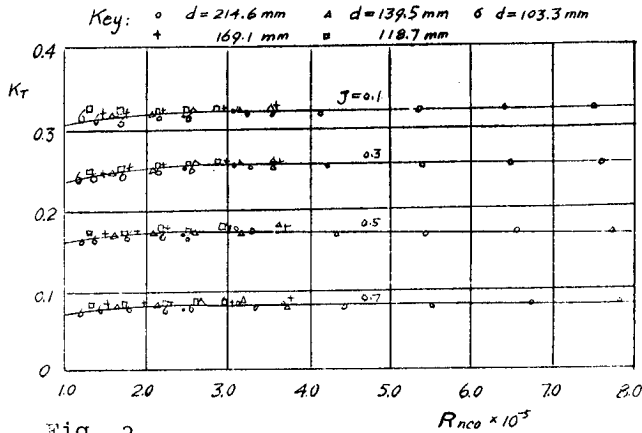
2. p.390, $R_C = \frac{(1+k)C_{FMC}+C_R}{(1+k)C_{FM}+C_R}$ should be

$$R_C = \frac{(1+k)C_{FMC}+C_{R_{R_{TM}}}}{(1+k)C_{FM}+C_R}$$

or $R_C = \frac{1}{2}\rho SV^2 | (1+k)C_{FMC}+C_R |$

Ship No.	V_s (Kts)	R_B 10^9	Method 1			Method 2		
			ΔC_T 10^{-3}	Δw	$e_1 = \frac{1-w_m}{1-w_s}$	ΔC_T 10^{-3}	Δw	$e_1 = \frac{1-w_m}{1-w_s}$
A	16.26	1.07	0.14	-0.037	0.9455	0.19	-0.026	0.9611
	16.5	1.085	0.28	-0.071	0.9012	0.32	-0.063	0.9113
	17.4	1.145	-0.04	-0.106	0.8579	0.01	-0.096	0.8695
B	15.99	1.055	-0.21	-0.037	0.8997	-0.16	-0.062	0.9135
	16.44	1.086	-0.23	-0.100	0.8691	-0.17	-0.092	0.8783
	17.25	1.138	-0.11	-0.075	0.8985	-0.06	-0.061	0.9108
C	13.36	0.9002	-0.31	-0.176	0.7788	-0.268	-0.169	0.7858
	14.61	0.985	-0.03	-0.168	0.7894	0.003	-0.161	0.7964
	16.11	1.084	0.12	-0.125	0.8355	0.14	-0.121	0.8399
	17.23	1.161	0.22	-0.111	0.8518	0.284	-0.101	0.8633
	17.71	1.194	-0.09	-0.105	0.8584	-0.035	-0.097	0.8678
D	13.51	0.895	-0.32	-0.250	0.7246	-0.29	-0.242	0.7311
	15.59	1.033	-0.07	-0.217	0.7527	-0.03	-0.208	0.7603
	16.26	1.077	-0.01	-0.195	0.7727	0.04	-0.187	0.780
	17.07	1.131	0.03	-0.178	0.7893	0.07	-0.170	0.7968
E	13.67	0.9058	0.16	-0.194	0.7723	0.22	-0.186	0.7796
	15.91	1.054	0.09	-0.171	0.7944	0.15	-0.161	0.8041
	16.83	1.115	0.19	-0.17	0.7966	0.23	-0.162	0.8043
	17.50	1.160	0.19	-0.16	0.8065	0.24	-0.152	0.8144
F	13.18	0.984	-0.493	-0.176	0.7605	-0.41	-0.160	0.7775
	14.54	1.086	-0.15	-0.089	0.8639	-0.079	-0.074	0.8842
	15.77	1.178	-0.435	-0.112	0.8386	-0.37	-0.093	0.8622
G	15.51	1.182	-0.28	-0.231	0.6627	-0.195	-0.225	0.6686

Table 1. Model-Ship Correlation Factors



Further to the above I would like to mention, that there is a contradiction between the propeller and performance committee's report !

1. p.276, right col. near the bottom.
 The propeller committee report says: "... $R_{n-} < 2.5 \times 10^5$, which supports the performance committee recommendation of a minimum R_n of from 3 to 4×10^5 ..."
2. p.390, right col. last two lines.
 the performance committee report says: "... R_{nco} must not be lower than 2×10^5 at the open-water test". It means that the minimum R_n is 2×10^5 .

It will confuse the ITTC members, so it is hoped that the performance committee makes this clear.

T. TAKAHEI and N. NAGAMATSU - Kawasaki Heavy Industries, Co. Ltd, Kobe, Japan.

The purpose of this brief note is to describe the practical technique to stabilize the flow under unstable conditions, occurring around the full ship models. Some of the resulting thrust and torque records during the self-propulsion tests are presented and compared with those observed without the artificial means. The recommendations of the 14th I.T.T.C. suggested that further studies of the flow conditions in self-propulsion tests are required. This suggestion came from the findings by Dr. Watanabe of the presence of two types of flow around the stern of full ship models. A comprehensive study of this phenomenon has been undertaken by SR 159 Committee of the Japan Shipbuilding Research Association, in which our Institute has taken part. It has been noticed by flow observations and analysis of self-propulsion test results that there are two types of flow patterns for the unstable conditions (Fig. 1). In the pattern A, the thrust

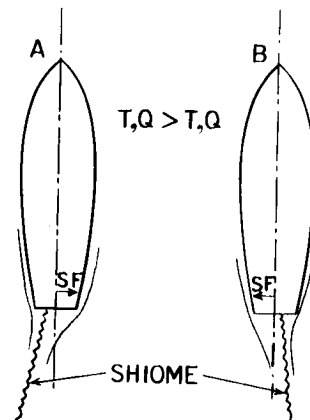


Fig. 1. Two flow patterns associated with unstable phenomenon (For right-handed propeller).

and torque are greater than in the pattern B, and a side force is delivered to the starboard side for a right-handed

turning propeller. In this case, a "shioime", a streak of disturbance due to separation, is observed on the port side of free surface around the stern. On the contrary, in the pattern B, the thrust and torque decrease and the direction of side force is towards port side. The "shioime", in this case, is observed on the starboard side. With a left-handed propeller, the fluctuations in thrust and torque and the direction of side force are reversed in relation to the side that the "shioime" occurs.

It is a matter of nuisance that the change of flow pattern occurs temporarily during the self-propulsion tests with some of full ship models. The model whose particulars and lines are given in

Model Ship	Lpp	2.0(m)
	Breadth	0.3333(m)
	L/B	6.0
	B/d (65% load)	4.1
	Cb	0.7743
Model Propeller	Dia.	60.0(mm)
	P/D	1.015
	EAR	0.8
	Number of Blades	3
	Rotating Direction	Left-Handed

Table 1. Principal particulars of model ship and propeller.

Table 1 and Fig. 2. is an example of such case. The model is 2 metres in length and fitted with the left-handed propeller.

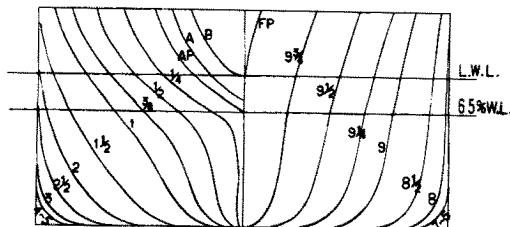


Fig. 2. Body plan.

Fig. 3 shows the record obtained in the self-propulsion test at the speed of $F_n=0.18$ and the propeller revolution at 16.8 rpm on the 65% of full-load condition.

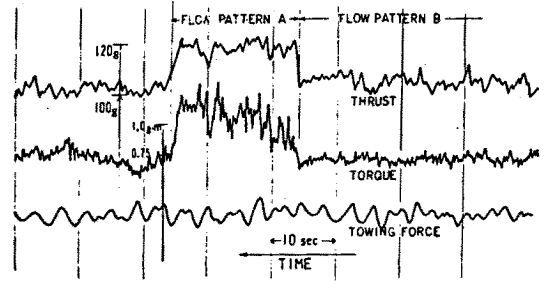


Fig. 3. Example of unstable phenomena for left-handed propeller ($F_n=0.18$ prop.rev. =16.8 rps 65% load).

Both the thrust and torque are given a step increase without a noticeable change of speed, and at the same time the "shioime" transfer from the port side to the starboard side.

Our technique used to keep the flow to either of the bistable flow condition consists of placing a template along the "shioime", as shown in Fig. 4.

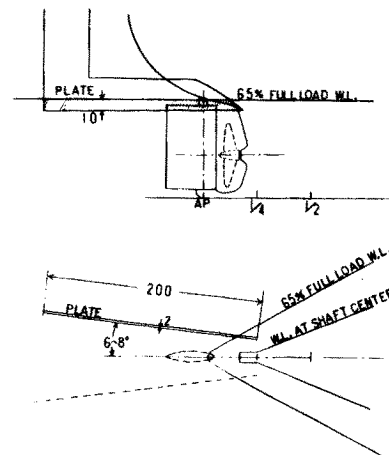


Fig. 4. Flow stabilizing template and its arrangement (2m length model, dimensions in mm).

Fig. 5 is a record taken by placing the template on the starboard/port side on the same test condition as in Fig. 3. By transferring the template, the thrust and torque are given step change in their magnitude and the flow around the stern assumed the corresponding pattern A or B. These facts were also confirmed by flow

observations employing tufts attached to the model hull.

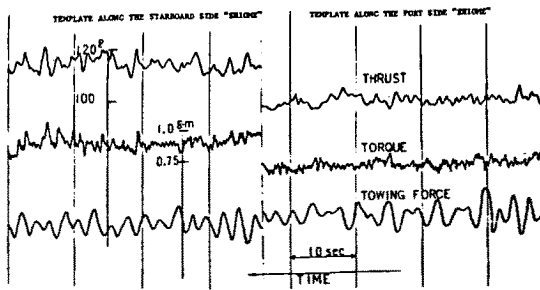


Fig. 5. Resulting records in flow stabilizing experiments for left-handed propeller ($F_n=0.18$ prop.rev. =16.8 65% load).

Our stabilizing technique is due to be tried with larger models for the next stage, and it is expected that this technique can be utilized to clarify the unstable phenomenon around the stern of full ship models.

I. TANAKA - Osaka University, Osaka, Japan.

First of all I would like to praise the Committee's tremendous work to bring up such a fine report.

I would like to say two things here. The first is about the terminology in Appendix. In the second paragraph in the introduction on p.388, we read that "the viscous and residuary resistance..." In my understanding the word "residuary" is properly used for expressing the remainder of total resistance subtracted by the frictional resistance of the corresponding plate, as proposed by Froude. In other words, it is used rather like a proper noun closely related to Froude method instead of a general, common noun. As the viscous resistance is defined and used in the report, this includes already part of residuary resistance in the original sense. Therefore, if we use the word "residuary" resistance as the remainder of total resistance to be added to viscous resistance, it may lead a

confusion of the terminology. I think it is better to use the word "residuary" only for expressing the old, original meaning, both for not introducing another complexity in terminology and for keeping the memory of Froude. How about to use "non-viscous" or "wave-related" instead of it?

Next about roughness. At the same place in Appendix, committee shows a formula of ΔC_F , roughness allowance coefficient, instead of a correlation factor. I think this is surely an improvement as compared before. In this connection, I would like to call the attention of the committee about the other researches on roughness resistance conducted in Japan about 15-20 years ago. Prof. Em. H. Sasajima of Osaka Univ. and his co-researchers published several papers about the wavy roughness like paint surface. They show partly similar and partly different results. Some of them were translated into English, but most of them seem to be unknown here. I can send their copies to the committee for a possible reference to the next I.T.T.C.

Prof. Tanaka also raised the question of a need for dividing the form resistance into its different components, i.e. pressure and frictional parts.

C.W.E. NETHERCOTE - Vickers Shipbuilding Group Limited (St. Albans and Dumbarton), St. Albans, United Kingdom.

The performance committee strongly recommends use of form factor extrapolation of model resistance; if we accept this, it is necessary to consider the means of derivation. The committee has told us how, but perhaps with too much brevity. As ship prediction is principally a commercial practice we would have to accept form factor analysis as a routine matter, yet the committee have failed to provide an explicit, clear guide to enable avoidance of differences in interpretation by different establishments.

I say this on the basis of experience, having recently faced a situation where two establishments derived importantly differing form factors for the same actual model! The differences between the two model resistance curves did not in themselves explain the difference which could only be one of interpretation. And what should we do when we have one of the extraordinary curves given by some bulbs? I understand that the committee roughness formulation implies that ship "rough" C_F values parallel "smooth" C_F values, a situation different from the classic assumption; yet in scaling propeller characteristics the classic Schlichting formulation is used. Is a fundamental difference between ship and propeller roughness effects implied by the Committee ?

D.I. MOOR - Vickers Shipbuilding Group Limited. St. Albans, United Kingdom.

Three years ago, I criticised the Performance Committee on three grounds:

- (1) for not having carried out the instructions of the 1972 conference to evaluate the changes in resistance and wake from model to full scale;
- (2) for mixing incompatible data, and ignoring the principles of scientific analysis and inference; and
- (3) for offering a method which gave less accurate predictions than a number already in existence and use.

Naturally, the committee reacted strongly to such accusations with alas a smokescreen of denials rather than evidence of rebuttal, but subsequent discussions with at least some members of the committee seem to have borne fruit in that:

- (1) the analysis programmes have been amended to read out values of δC_{Fa} and w_{sa} actually deduced from the data, thus giving the "values of the wake and resistance scale factors for statistical analysis" required by the 1972 conference.

- (2) in combining the international data, the need for an individual residual factor for each establishment has been recognized.
- (3) some comparisons have been made with the results of using the current methods of three establishments and of using the ITTC 1960 methods in conjunction with the ITTC 1972 (Scott) formulations.

It is again impossible to discuss the whole of such a wide investigation in detail in the time allowed, but in an endeavour to persuade the committee and the conference to take yet another look at the problem before adopting any proposals, I will make some remarks, based on the analysis of 607 sets of results during 169 single screw ship trials correlated at St. Albans. Of these, a sub sample of 260 sets of results during 71 trials were with virtually all-welded ships in very good weather conditions. As noted in Appendix 2 of the committee's 1975 report, the basic data were deliberately withheld from inclusion in the international sample, in accordance with the well-known policy of retaining at least one major set of data for independent tests of the results of the analysis of the main sample. Contrary to the assertion in the report, summaries of earlier analyses were supplied to the committee, but my subsequent offers to compare results across the table with representative members of the committee, and to seek reasons for differences in the findings, were firmly rejected.

Be that as it may, since receipt of the committee report, the proposed 1978 method has been tested against the St. Albans sample, and the values of \bar{C}_p and \bar{C}_N , with their standard deviations, are given in the accompanying table for the whole St. Albans sample and for the sub sample. The figures for the latter appear to be similar to those obtained from the international sample (although it is noticeable that on this occasion, unlike 1975, the committee has published practically

Sample	All Ships			All-welded ships in good trial conditions		
	1978	1978 Typical Modif.?	1960/1972	1978	1978 Typical Modif.?	1960/1972
\bar{C}_p	1.065	0.999	0.992	1.015	0.994	0.992
σ	0.107	0.074	0.061	0.074	0.074	0.066
\bar{C}_N	1.017	1.000	0.993	1.002	0.996	0.996
σ	0.034	0.024	0.015	0.032	0.024	0.017

no actual figures of their achievement), but as shown in Figures A and B, they are emphatically worse than those obtained by using the ITTC 1960 method with the 1972 coefficients, shown in the same table. It is the bottom line, demonstrating the tolerances in the prediction of RPM, which is of paramount importance to our customers.

third set of figures to compare with those quoted by the committee on page 364 for three other establishments. The committee claim that these figures show that their proposed method gives better accuracy than the 1960/1972 method; but their test is not valid in two cases, and it was long ago shown that the results from the other establishment do in fact confirm the St. Albans findings.

Clearly the proposed method can hardly be considered as satisfactory or as near the attainable limit as the committee claim, but one reason is not difficult to see, since the committee surprisingly still uses δC_{fa} as if all the difference in resistance between model and ship were frictional. Figure C shows for the St.

COMPARISON OF 1960/1972 AND 1978 METHODS
ST. ALBANS SAMPLE
ALL SHIPS

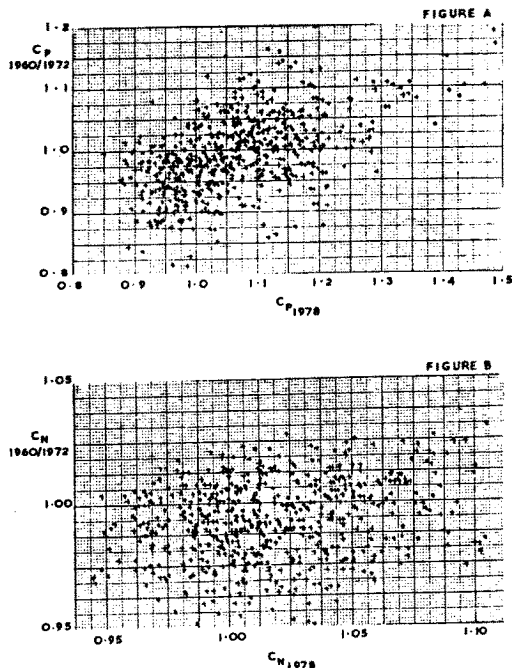
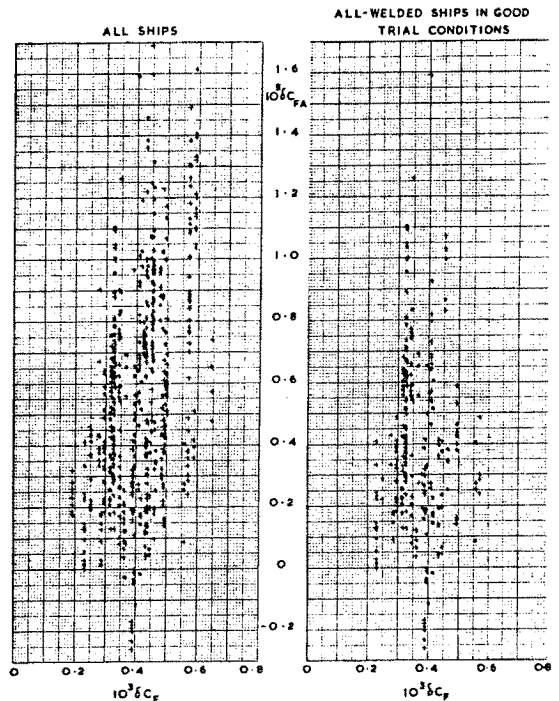


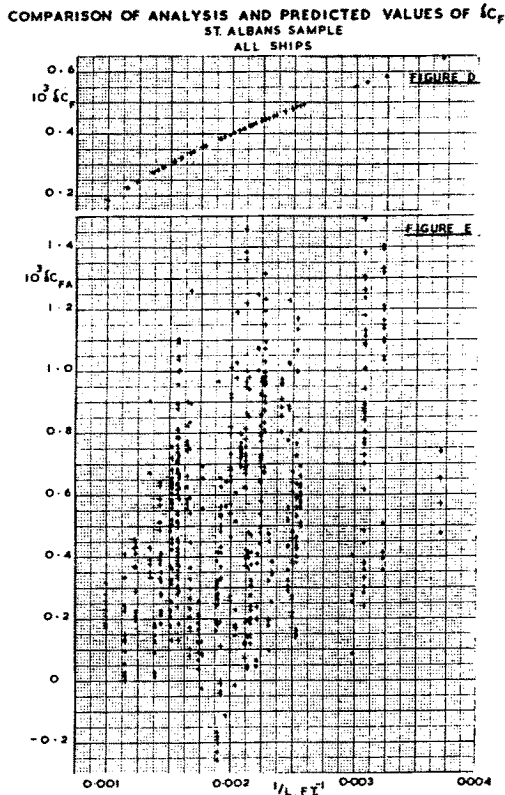
FIGURE C
COMPARISON OF ANALYSIS AND PREDICTED VALUES OF δC_f
ST. ALBANS SAMPLE



The 1960/1972 method is, of course, the one in everyday use at St. Albans and Dumbarton, so there is no need for a

Albans main and sub samples values of δC_{fa} plotted against the committee's formula values for δC_f . Obviously the latter are inadequate, even for good hull and trial conditions. The committee has assumed that δC_f is a function of

only relative roughness and with $K_S = 150 \cdot 10^{-6}$ m obtain the unique curve in Figure D. The real facts are shown in Figure E. Comment is superfluous.



Time has not permitted a full analysis of the variations of δC_{fa} and $\delta w_a = (w_m - w_{sa})$, but expressing them as a variety of simple functions of hull condition, external environment and propeller environment, while omitting form factor terms in the assumption that they have been superceded by the adoption of form factor extrapolation, and remembering that in general δw_a varies inversely with δC_{fa} , gives \bar{C}_p and \bar{C}_N virtually equal to unity with in a typical case standard deviations between the 1960/1972 and 1978 figures, for both the main and sub samples. Such results are a nominal improvement on the committee's own proposals, but as shown in the table are still not as good as obtained by the use of the 1960 methods with the 1972 coefficients.

Some critics will no doubt mistakenly

call formulations for δC_f and δw of the type I have described irrational for use within the main framework of the committee's programme, and others will scorn the introduction of empiricisms (although what else are the committee's own formulations?), but the degree of improvement possible over the committee's own proposals is so great that I can see no excuse for adopting those proposals. I most certainly do not suggest that any of my own first formulations, the only ones I have had time to try since receiving the committee's proposals a month ago, are fit to be accepted as they are, but so again urge that the committee should evaluate the changes in resistance and wake by making the statistical analysis requested by the 1972 conference of the wake and resistance scale factors, which the committee's new programme has now made available, that such evaluations should be properly tested against each of the independent samples of data available to the committee and that individual residual factors for each establishment should be determined, until we can all confidently claim that we truly have a method which will give more accurate predictions than the ITTC 1960 methods in conjunction with the 1972 factors. Only then should we consider changing.

J. HOLTROP - Netherlands Ship Model Basin, Wageningen, The Netherlands.

The general concept of the prediction method proposed can be well accepted because it more basically than any other method incorporates scale-effect corrections on resistance components and propulsion factors that are founded on theory and experiments. The use of the proposed method, however, requires the availability of resistance measurements and open-water test results as well. The proposed prediction method does not account for the lack of either the resistance test or the propeller open-water test or both.

In this contribution an outline is given of a method that utilizes the modern extrapolation technique but that does not require the additional resistance and open-water tests. This method is being developed at the NSMB for routine applications. Another aspect of this method is that the effects of the propeller loading on the propulsion factors and the form factor are taken into account automatically.

In the propulsion test the towing force F , and the propeller thrust T and torque Q are measured for a number of model speeds V and propeller revolutions n . For one or two speeds the measurements are repeated once or twice with different propeller loadings. In view of the determination of the form factor, the speed range at low Froude numbers should be included. First the coefficient

$$p = \left(\frac{\partial T}{\partial F} \right)_{V=\text{constant}}$$

is determined from the measurements in which the propeller load was varied. Next, the form factor $1+k$ is determined under the assumptions that at low speeds the Froude-dependent resistance components vanish, the flow around the model remains turbulent and that the towing force is equal to the resistance if the propeller thrust is zero:

$$1+k = \lim_{F_n \rightarrow 0} (F-T/p)/R_F$$

There are several ways to determine $1+k$, e.g. by using Prohaska's method, which employs a 6th power representation of the Froude-dependent components with the speed. Alternatively, use can be made of the regression equation:

$$F-T/p = (1+k)R_F + c \cdot \exp(mF_n^{-0.9})$$

where the coefficient m can be either determined numerically in the least-squares sense, or derived from a statistical formula.

For the model scale the following relations are established:

$$F-T/p = (1+k)R_{FM} + f_1(F_n)$$

$$K_{TM} = f_2(J_{VM}, F_n)$$

$$K_{QM} = f_3(J_{VM}, F_n)$$

Assuming the coefficient p independent of the scale, which is practically identical to the assumption that no scale effects are present on the thrust deduction, the full-size thrust can be calculated:

$$T_S = -p \{ (1+k)R_{FS} + R_A + \rho_S \lambda^3 f_1(F_n) / \rho_M \}$$

in which the model-ship correlation allowance R_A is determined from statistical data obtained from the analysis of speed trials. Apart from the scale effect on resistance, scale effects are assumed to be present on the effective wake and on the propeller characteristics.

In Fig. 1 the application of the scale effects ΔK_T , ΔK_Q and $(1-w_S)/(1-w_M)$ is illustrated. In the example given in this diagram the Froude dependency of K_T and K_Q has been neglected.

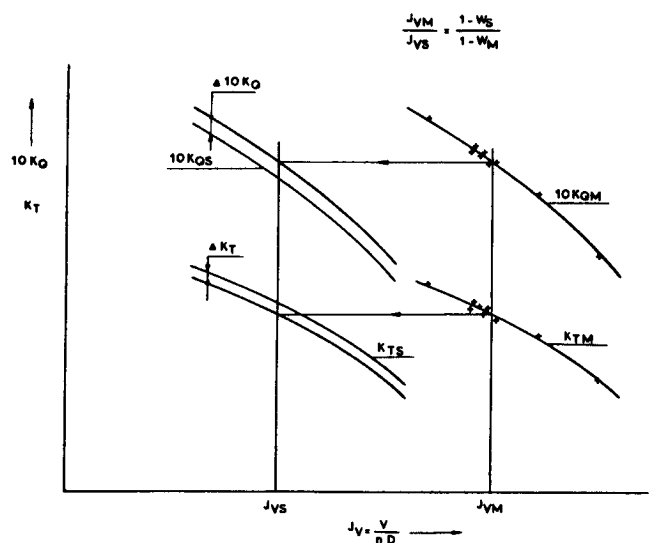


Fig. 1. K_T and K_Q as a function of the apparent advance coefficient J_V .

From the relationship between J_{VS} , K_{TS} and K_{QS} the number of revolutions and the shaft power can be obtained easily if use is made of the coefficient:

$$\frac{T_S}{\rho_S D_S^2 V_S^2} = (K_T/J_V^2)_S$$

By interpolation with $(K_T/J_V^2)_S$, J_{VS} and K_{QS} are found. The rate of revolutions now follows from:

$$n_S = V_S / (J_{VS} D_S) \text{ RPS}$$

and the shaft power from:

$$P_S = \frac{2\pi \rho_S K_{QS} n_S^3 D_S^5}{75 \eta_S} \text{ HP}$$

With respect to the consistency of the coefficient p and the determination of the resistance of a ship model with propellers fitted, the following conclusions were drawn from a survey of about 20 overload tests and resistance tests:

1. p is independent of the propeller loading
2. p is almost independent of the Froude number
3. The ratio $(F-T/p)/R$ appeared to be equal to 1.01 ± 0.01 .

G. COLLATZ - Hamburg Ship Model Basin, Hamburg, Federal Republic of Germany.

In principle I fully agree with the philosophy behind the 1978 ITTC Performance Prediction Method, but I do not agree with some of the details:

1. The method (at least the program) can only be used, if resistance and propulsion tests were done. However, in order to save money, often only self-propulsion tests will be carried out. If the method shall be a standard method, this fact has to be taken into account.
2. Some of the formulas used in the program have been selected from a series of similar formulas only for reasons of minimum standard deviation of the correlation factors. For me this seems

a little bit dangerous, because we now use formulas chosen on basis of a limited amount of data available. If the data sample would have been another one, some formulas would probably be not the same.

3. There seems to be an error in the program or at least in the example given. If a correction is made for scale effect on wake (due to the higher Reynolds number of the actual vessel), this should lead to an increase of the number of revolutions. And if allowances are made for additional resistance of bilge keels and wind, this leads to a higher propeller loading and will also cause a higher number of revolutions (on and above the increase due to the wake reduction). But obviously this is not the case with the example as stated. If the model's propeller speed (given on page 402) is converted to full scale without any correction, i.e. by

$$n_S = n_M / \sqrt{\lambda}$$

one gets about 3 p.c. higher values than calculated by the computer program (given on page 403). This means, the correction for the number of revolutions calculated with the computer program went in the wrong direction.

4. Last but not least, according to my opinion, one should make a correction of the propeller open-water characteristics before using them to determine wake and relative efficiency of the model. Mostly the propeller open-water tests are done in the same basin in which also the resistance and propulsion tests are carried out and not in a circulating water tunnel. Hence the propellers are running against still water and the inflow to the propellers is fully laminar. This is not the case during the propulsion tests where the propellers operate in the more or less turbulent wake field behind the model (at least for single screw vessels).

This should be taken into account by a proper correction from laminar to turbulent flow at the model's Reynolds number before the open-water diagram is used to determine the hull efficiencies.

A further correction (for the Reynolds number of the actual vessel, as described in the 1978 method) should then be made in order to take account for the scale effects of the propeller efficiency.

W.A. CRAGO - British Hovercraft Corporation Ltd., Isle of Wight, United Kingdom.

Form factors are fashionable. Is their use correct? Page 364 says "the introduction of the form factor philosophy leads to a better ship-model correlation". That is evidence for the adoption according to the report.

If the form factor philosophy is correct then it must be possible to demonstrate that it gives a better collapse of the data in the many geosim series available for study.

I have looked at only two such series but I persuaded myself that, in both cases, the use of a form factor method gives a poorer collapse of the data than did the old fashioned method we all normally use when a single correlation line is employed. This is a critical issue and the geosim series data which are readily available provide a critical way of assessing the rightness of the form factor philosophy in a much more direct, obvious and accurate way than that employed by the Committee. Until such direct evidence is tabled I feel we should not adopt the proposed performance prediction method.

II. REPLY OF THE PERFORMANCE COMMITTEE

In their reply the Committee will first comment on the discussions of the proposed prediction method and thereafter on the remainder of the questions raised.

Mr. Moor's comments are very wellcome and the Committee does certainly appreciate that he in principle seems to have accepted what he calls the main framework of the Committees program. Based upon studies of his own sample of trial data he claims that it is possible to reach appreciable improvements by introducing further parameters through some kind of regression analysis.

The Committee agrees with him that improvements on each individual sample are possible, although it does believe that he has overestimated them, which can be verified from Fig. 7 on page 574 of the 14th ITTC proceedings. From this figure a clear indication of the possible gain can be obtained. The Committee does not introduce this kind of empiricism in its proposal for a standard procedure but has left it open for each individual institute to add such a procedure according to its own experience and judgement.

It is impossible to make any comments on *Mr. Moors* findings as regards his own material as the Committee has not been able to analyse and compare it with its own material. Contrary to *Mr. Moor* the Committee claims that members of the Committee have several times invited him to take part in their work and they have promised him complete insight into their statistical material if he gives them the same material from St. Albans. Up to now that material has not been shown with the exception of some very summarizing tables. *Mr. Moor* seems to want to bring us back into the same position as we were three years ago.

Then, the Committee presented a number of alternative methods that had been studied and claimed that method No. 55 was the most promising. It wanted, however, to get another period for further verifications and to try to find possible improvements. The work carried out since the Ottawa Conference has proved that it is not possible to come further with the material available and that the method now proposed is the best possible that can be offered. The Committee however, is convinced that the method does not represent the final goal. We shall have to wait for the results of further work, for instance, within the Resistance and Propeller Committees and as soon as they are prepared to propose new methods the Performance Committee will be willing to check them on the available material. If such new proposals represent significant improvements they may easily be incorporated in a modified version of the present tentative standard 1978 ITTC Method. *Mr. Moor* regrets lack of detail informations in the Committee report. In answer to that remark a photograph was shown to indicate the extent of the entire material representing the Committee work. The President of the ITTC is certainly not prepared to include that material in the transactions. As a matter of fact already more space was used than permitted for the report.

In the discussions *Mr. Moor* referred to the ITTC 1972 formulations and the Committee wishes to quote from the 1972 Conference Proceedings in that respect. The Proceedings stated that "as an interim measure for single-screw ships the prediction factors described in Appendix I may be used". It will be noted that the 1972 factors were adopted as an interim measure

and the present Committee has now rejected them in favour of the ITTC 1978 Method.

It should be mentioned that several members of the present Committee were also members of the 1972 Committee.

One of the principle reasons for rejecting the 1972 Method is that it assumes there is no scale effect on propulsive efficiency. If progress is to be made in the correlation of ship and model performance, the Committee considers that the influence of scale on wake fractions and propeller efficiencies should be examined and the correlation procedure should take these effects into account, as in the ITTC 1978 Method.

Mr. Moor has emphasized that he has used the St. Albans' data as an independent test of the method proposed by the Committee. Using the St. Albans' data he has given comparisons for the 1972 and 1978 Method and has stated that the 1972 Method gives better accuracy. However, if reference is made to Appendix I of the 1972 Committee Report it will be seen that the 1972 Method was derived using the St. Albans' data and, therefore it cannot be considered as an independent control in these comparisons. The Committee has compared the two methods for three separate institutions and, in each case, the 1978 Method gave better results.

Mr. Moor has given some information in his discussion of the analysis of the St. Albans' data using the 1978 Method and the Committee would be pleased to receive further details.

In conclusion, it is pertinent to address some remarks to the Conference in general. If reference is made to page 387 of the Report it will be seen that the Committee recommends that the 1978 Method should be used as a tentative standard. It is not suggested that institutions should stop using their own methods for ship performance prediction but, simply that the 1978 Method should be used alongside the present methods and an assessment made as to whether it is satisfactory.

The Committee will be pleased to receive information on the reliability of the 1978 Method and any proposals as to how it may be improved.

Mr. Holtrop starts his contribution with supporting the Committee's proposal for a standard prediction method. The Committee is thankful for that. He further takes up the problem of how to make a prediction if no open water or resistance test results are available. Although the Committee feels, that the ITTC in its responsibility towards its clients has to try to persuade them to carry out a complete test program for a reliable prediction, the Committee understands that a situation may arise where only self propulsion test results are available and does appreciate *Mr. Holtrop's* approach and solution to that problem. The Committee, however, is not prepared to give any further comments until it has obtained an opportunity to make a more detailed check including numerical comparisons and they should appreciate very much, if *Mr. Holtrop* could report further studies on the possibility of changes in "p" due to propeller loading and Froude number on models with full stern, where flow separation may take place by the action of the propeller. Finally the Committee wishes to mention that considerable differences may occur in the wave patterns measured with and without operating propeller at the stern of high speed single screw cargo ship models, again probably giving rise to doubts about the constancy of "p" over wide Froude number ranges.

Dr. Collatz says in his first sentence that he fully agrees with the philosophy behind the 1978 ITTC Performance Prediction Method. His statement is appreciated. As regards his comment that in the program the formulae have been chosen only for reasons of minimum standard deviation is wrong. All formulae have been originally chosen for other reasons but have been verified to satisfy requirements on base of minimum standard deviations also.

With the help of all those who have taken part in the Committees work, during the years that have passed, the Committee has been aware of and has corrected a number of computer program errors. Whether or not Dr. Collatz has found another one as stated in his paragraph 3 has to be checked as soon as possible.

Dr. Collatz proposes to make a correction of the propeller open-water characteristics before using them to determine wake and η_R .

As stated in the report visualization of the flow on the blades in behind and open-water condition has several times showed that the flow may be laminar also in the behind condition and that the flow for identical R_n differed very little.

However, the extent of turbulent flow was somewhat larger in the behind condition. It should in principle be logical to apply a R_n for the open-water tests such that the ratio between the extent of turbulent and laminar flow is the same in both conditions but the Committee does not feel that it may give any advise in that direction at the moment. It would probably be better to include corrections for differences in turbulence level in some method for estimation of scale effects on η_R as proposed in the report.

The Committee agrees with *Mr. Crago* that, in principle, it should be possible to use geosim results to examine whether the form factor method of extrapolation is correct. However, in practice it is very difficult to draw any positive conclusions of this kind from geosim data because of the inaccuracies in the experimental results. The inaccuracies may occur because of the possibility of laminar flow on the smaller models, the need to apply blockage corrections to the data, and the inherent errors in model manufacture and resistance measurements.

Professor Aertssen's comments are welcomed by the Committee. As the Conference is aware he has carried out pioneering work on the performance of ships in service.

One of the Committee's recommendations is that more attention should be given to the determination of service performance margins and the Committee considers that Professor Aertssen's investigations will be invaluable in this respect.

Professor Aertssen has pointed out that propulsive efficiencies are different for performance in calm water and in waves. The Committee agrees with him and more work in this area would probably lead to an improvement in the correlation of ship and model performance. He has also referred to the influence of flow separation on form factors and, as discussed by Dr. Takahei and Dr. Nagamatsu, it may prove desirable to ensure that separation is stable on the model hull.

Professor Aertssen's information about windtunnel tests he carried out with a model of a full tanker shows a decreasing k-value with increasing R_n . A quite similar result was also reported by Gadd in his RINA paper, as is mentioned in the Committee report. In both cases, according to the authors, it can be assumed that the reason for this is a change of the extent of the separation zone, which influences the pressure drag. After the separation zone has disappeared at a certain Reynolds number a constant value of k is obtained. This endorses again the admissibility of the adoption of a constant and Reynolds number independent form factor as is presumed in the trial prediction program, until better and more detailed knowledge is available on this subject.

Finally, it is pertinent to mention, that in the present report the Committee has given rise to some confusion about the Reynolds number dependence of the form-factor, when mentioning Dr. Dyne's work on boundary layer calculations. Dr. Dyne at the time was in error, when he came to the conclusion of an increasing k-value. His work shows now that the k-value is nearly independent from R_n . The knowledge of this new finding, however, came too late to correct the respective sentences

in the Committee report.

Mr. Sudo mentioned that further investigations conducted after the original work carried out at the Akashi Ship Model Basin in order to reduce the instability in the characteristics of model propellers, did not always produce successful results and that the self-propulsion factors obtained with low-pitch propellers could differ from those obtained with ordinary propellers.

It would be interesting to know which of those results are the most relevant.

The Committee still feels that efforts similar to those made at Akashi should be continued in order to find means of stabilizing the flow on the propeller or propulsor used in the propulsion tests.

In answer to Professor Sheng, the Committee confirms to fully agree with him, that the introduction of corrections for scale effects on the propeller characteristics will lead to an increase in ΔC_F and to a decrease in Δw .

It is reasonable that the correlation factors were only slightly influenced by propeller scale effects because R_n 's up to $3.5 \cdot 10^5$ were used during the open-water tests.

The Committee agrees that the R_n on page 590 in the report should be $3 \cdot 10^5$ instead of $2 \cdot 10^5$. In Fig. 1 and on page 372 in the report it is indicated that R_n should be higher than $3 \cdot 10^5$ to be sure that low R_n number effects have been reasonably reduced. Fig. 2 indicates, however, that also the EAR/Z ratio is an important parameter in this connection. Its value must not be too low also.

In cases with low R_n and EAR/Z values one should be very careful in using the open-water diagrams for the speed prognoses or analysis of trials. In these cases the open-water results should be analysed using Lerb's method and the thrust and torque characteristics corrected for the change in drag coefficient. The thrust and torque correction applied by the Committee are semi-empirical and, as shown in

Fig. 1, they have chosen $A=5$ in the Aucher formula as an average value for the calculation of the model drag in the proposed method. This must be taken into consideration when using the program.

Though high R_n will give improvements, it is still felt that this is not enough. In the future methods will have to be introduced for scale effects on the lift coefficients of the propeller sections. These effects may be important in determining the full-size propeller characteristics, for which one is referred to the report of the 14th ITTC.

With regard to the misprints mentioned by Professor Sheng the Committee confirms that on page 390 the formula for R_c should read:

$$R_c = \frac{(1+k) \cdot C_{FMC} + C_R}{(1+k) \cdot C_{FM} + C_R} \cdot R_{TM}$$

The Committee does not agree with the suggestion that on page 380, ΔC_F and Δt should be modified into ΔC_F and Δw , since in Δw the only empirical coefficient is Δt and thus Δt should be maintained in the text.

With respect to errors it is appropriate to mention here, that except for the above error another was found by the Committee in equation No. 4.16, where the right hand side has to be multiplied by the factor P/D .

The Committee is grateful to Dr. Takahei and Mr. Nagamatsu for presenting their interesting contribution on a method to stabilize the unstable flow pattern around full ship sterns. The Performance Committee appreciates the work of SR159 of the Japan Shipbuilding Research Association very much and looks forward to receiving further information on this complicated phenomenon.

The Committee is also grateful to Professor Tanaka for his comments on roughness and would be glad to receive copies of the papers to which he refers. He has noted that equation 1.19 on page 366 used by the Committee for estimating the effects

of hull surface roughness, does not include a term for speed or Reynolds number. The equation was derived by analysing trials data which included measurements of ship thrust and surface roughness and, by assuming that the thrust deduction fractions were the same for model and ship, it was possible to estimate the resistances for the ships from the thrust measurements. When examining the ship resistance increments due to hull roughness, as derived by using this method, it was found that the data did not show a dependence on ship speed or Reynolds number. It is possible that such a dependence does exist but it is not revealed because of the inaccuracies in ship trials measurements and also because the measurement of hull roughness itself, in terms of mean apparent amplitude, is imprecise. As a reply to the question of definition of different components of resistance the Committee is of the opinion that the term residuary resistance for the remaining part is better than those suggested by Professor Tanaka, since we have subtracted the viscous part from the total resistance. The Committee finally wishes to reemphasize that in their report they have clearly expressed that a reliable form factor can only be determined if no separation occurs. It is well understood, that the form effect can be divided into two parts, i.e. frictional and pressure, but the difficulty lies in measuring these parts separate-

ly, at least in routine work. This will be without doubt an essential area for future work, since the results of such measurements are highly needed for instance for obtaining scaling laws for the extent of separation zones and their effect on pressure drag.

Mr. Nethercote has noted the fact that the Committee has used equation 1.19 to estimate the hull roughness effects whereas Nikuradse's sand roughness equation has been used when deriving the drag coefficients for ship propellers. This has been done because there is a paucity of information on the influence of roughness on propeller performance.

Mr. Nethercote further reported on model tests on one model in two towing tanks which gave practically the same resistance results. The evaluated form factors differed remarkably due to the individual interpretations of the examiners. The Committee admits that this can happen since two persons may have different ideas about fairing. To avoid this the Committee recommended in their report the determination of the best power of F_n and of the k-value by a least square approximation, which is possible by use of a computer in an unbiased way. In the case of bulbous bows the same procedure is used, however, it is necessary to extend the speed range to lower speeds to avoid wave breaking at partly submerged bulbs.

III. FINAL NOTE

During the presentation of Section 1 of the Committee Report it was mentioned, that results from calculations with the ITTC Trial Prediction Test Programme were received in April 1978 from Istituto Policattedra di Ingegneria Navale in Genova, Italy and in June 1978 from Krylov Ship Research Institute in Leningrad, Soviet Union.

Genova has delivered results from 19 trials with 5 slender ships in ballast and 6 full formed ships in full load. Corresponding figures for Leningrad are 50 trials with 35 slender ships in ballast and 18 trials with full formed ships (10 full load - 8 ballast)

Their results have been summarized in the following table:

Variable	Method	Ind mean all inst	Genova	Leningrad
$\Delta C_p/C_p$	71	0.095	0.090	0.103
	10	0.078	0.057	0.090
	55	0.072	0.040	0.082
$\Delta C_N/C_N$	71	0.033	0.021	0.042
	10	0.028	0.031	0.044
	55	0.029	0.022	0.042

As seen both Genova and Leningrad have obtained results similar to those of the other institutions. In all cases the coefficients of variation were lower for method 55 than for the other methods tested.