SESSION ON MANOEUVRABILITY

Chairman: Dr. O.P. Orlov

Manoeuvrability Committee Memberships: E.P. Nikolaev (Chairman) - I.W. Dand (Secretary) - A. Baquero - C. Coppola - S. Grochowalski - K. Kijima - L.Kobylinski - P. Oltmann - Z.Y. Sheng.

Discussion on the Report and Draft Recommendations of the Manoeuvrability Committee (Cf. Proceedings, Volume 1, pp. 379-428).

I. DISCUSSIONS

MN-1

J.P. HOOFT
Maritime Research Institute Netherlands, The Netherlands

Recommendation for future work

Recommendation No. 3 of the committee in the Proceedings refers to any method to determine (predict) the ship's manoeuvrability. I agree full heartily with this recommendation.

However, the Manoeuvrability Committee has underexposed the significance of ship handling research on a simulator for a well balanced advice about the ship's manoeuvrability to the shipping industry.

To overcome this shortcoming of the committee recommendation 3 has been changed with the addition "Progress in ship handling simulators should be reviewed".

I think that this statement might lead to a misunderstanding for the next manoeuvring committee.

Therefore, I suggest to add explicitely a 6th recommendation in which the use of simulator studies and the judgement of the results of such studies will be reviewed and commented.

Recommendation 6.6:

Extend the review of methods to consider the ship manoeuvring characteristics from a point of view of operability of the ship by taking into account the results from simulator research. An evaluation should be made of the results from experiments on ship handling simulators to study the acceptability of the manoeuvring characteristics of a particular ship in particular boundary conditions, taking into account the complete man-ship-environment system.

MN-2

K. HASEGAWA
Department of Naval Architecture and Ocean Engineering, Osaka University, Osaka, Japan

INCREASING NECESSITY OF SHIP MANOEUVRING SIMULATION INCLUDING A NAVIGATOR'S MODEL

Being needless to cite the Exxon Valdez o l spill 1989, the demand for safety assessment of ship navigation, marine traffic control system and waterway design is increasing. As such a casualty often occurs in confined and/or congested waterways, I agree with the committee recommendation describing the necessity of further researches on more accurate description of hydrodynamic forces acting on a ship in various conditions.

After the suitable mathematical model is provided, computer simulation is a powerful tool for prediction of ship's manoeuvring. However, for the total assessment of safety navigationability, we cannot neglect human factors including decision-making procedures of a navigator as described in 1.4 of the committee report.

In 1980's and still now so-called real-time full-mission simulators have contributed for these assessments, however, the increase of experiment costs is now a big obstacle.

Now we can do the same in computer simulation fully utilizing the rapid development of knowledge engineering.

From these points of view, I would like to emphasize that the importance of computer simulation including a navigator's model will increase, and to advise the committee will pay more attention in their future work.

MN-3

M. FUJINO
University of Tokyo, Japan

DISCUSSION TO MANOEUVRABILITY COMMITTEE REPORT

First of all, I would like to congratulate the Manoeuvrability Committee for splendid and comprehensive committee report.

Concerning the recommendations for the Conference as well as the recommendations for the future work of the Committee, I fully agree with the Committee's opinion.

However, I would like to emphasize the importance of paying adequate attention to the unsteadiness of hydrodynamic forces acting on the hull of a ship travelling in shallow water at a constant speed. According to my limited experience of conducting captive model tests, particularly captive model tests to clarify the hydrodynamic lateral force and turning moment caused by reverse rotation of propeller, hydrodynamic force and moment fluctuate more significantly in shallow water than in deep water. The dominant period of such fluctuation ranges from several seconds to several ten seconds in model scale.

At the present time, however, I cannot identify the correct reason for the fluctuation. A few plausible reasons can be considered; one of them is the instability of extremely confined flow beneath the ship's bottom, and another reason might be level undulations of the bottom surface of the towing tank; even a small undulation of tank bottom results in remarkable variation of botton clearance under the ship's hull.

Incidentally, free–sailing model tests of stopping manoeuvre indicate that the change of heading angle and lateral deviation at the instance when advance speed of a ship model vanishes scatter more definitely in shallow water than in deep water. The repeatability of stopping manoeuvres is fairly good in deep water, but in shallow water it is remarkably reduced. This is the reason why I would like to remind of unsteadiness of hydrodynamic forces on a ship in shallow water.

MN–4

J.P. HOOFT, G.K. KAPSENGERG, A. REM and H.J. VAN WIJHE
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NECESSITY OF TAKING ROLL MOTION INTO ACCOUNT FOR MANOEUVRING

Present day cruise liners have an increasingly high superstructure. This superstructure has an enormous windage, but also the height of the center of gravity is increasingly goind upwards. This is no concern to hydrostatic stability, since beam draft ratios of these vessels are very high, so the metacentric height is also very high. However, when such a vessel, which also has a lot of engine power so has a high speed capability, does a full rudder maoeuvre at high speed, the roll angles are considerable.

In order to give an accurate prediction of the turning circle characteristics, it is necessary to use a mathematical model which also describes the influence of the roll angle on the manoeuvring coefficients.

2. CORRELATION BETWEEN MODEL EXPERIMENTS AND FULL SCALE MANOEUVRES

The correlation between full scale manoeuvring tests and similar manoeuvres on model scale is still a point of concern. There is a constant need of accurate full scale experiments under fully documented conditions.

3. SAFETY OF SLOW SPEED VESSELS

There is a demand for economical slow speed vessesl. These vessels have a large diameter, low rpm propeller. When encountering severe environmental conditions, these vessels have a safety problem because course keeping might prove impossible. The hydrodynamical forces on the hull are not high enough to counteract the environmental forces on a given course.

MN-5

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COMMENTS ON THE MANOEUVRABILITY COMMITTEE REPORT

The appearance of the first volume of the ITTC Proceedings has always been an important event, perhaps less controversial nowadays, when the often somewhat subjective appendices of the "modular" type of report have been replaced by a largely enumerating global review of the new literature. Nevertheless, this review is of great value. My comments here will include a suggestion for a Questionnaire study on documented cases of "unusual scale effects" showing **clear** discrepancies between model and ship behaviour, a cause for a modified nomenclature concerning "regression-type models" and for their usefulness in routine prediction work, and a request for "Captain's comments" to be filed with trial data.

In addition to performing the review, the 18th ITTC asked the Committee to continue to carefully consider the subject of model/full-scale correlation (Item 5). This task has been handed over to the next Committee (new item 4). In the paragraph on correlation methods the present report discusses the well-known issue on the scale effects due to screw and rudder loadings, finding evidence in support of each argument. More serious, no doubt, is the possible existence of stern anomalies, which make the model behave different from its full-scale prototype, and which defy any pretrial prediction. (Cf. Proceedings ITTC 1966, 1972 (Material for Reports), 1978 and 1981). In view of present trends of design this problem could not warrant a Questionnaire to Member Organizations, asking for documentation on cases experienced. ITTC once issued a warning to the Member Organizations to be observed when dealing with hull forms of high "obesity products" C_b x B/L; what more do we know about the crucial stern geometry today?

The question of stern flow phenomena is closely associated with the choice of structure for a computer model. The very first mathematical models were modular models in the sense that the effect of the rudder was calculated separately as a force, which entered into the Y and N equations, just as the open-water propeller thrust was added to the resistance of a ship in the X equation. The interaction between the hull, propeller and rudder is much more complicated than that given by the simple thrust deduction factor, however, and the total-force approach was found more straight-forward. Captive tests on non-stripped models have usually been analyzed with respect to total forces, and accumulated data have been subject to regression analysis with respect to various total-force derivatives. The regression analysis technique is by no means limited to the total forces or to the use of certain main hull data as independent variables, however. It is not correct to make the distinction between "modular models" and "regression-type models" but rather between "modular" and "global" models.

Certainly the modular model offer a high degree of flexibility, but they will also place special demands for the use of interaction modules, which depend on the geometry of the control actuators as well as that of the hull. (Again, it may be worth while to recall that many authors have advocated the use of the combination of screw + rudder as the proper propelling device in the routine open-water test). Whereas the modular models are excellent for systematic studies their use may also introduce unnecessary errors in a routine manoeuvring trial prediction for a new ship.

In their Conclusions the Committee regrets the apparent lack of activity in the determination of manoeuvring criteria, mainly due to a lack of activity at IMO. It should be observed in this context that following the issue of the 1985 "Interim Guidelines for Estimating Manoeuvring Performance in Ship Design" (MSC Circ. 389) IMO left a period of five years for an evaluation of the response from the industry and the scientific community. Although industry response remained low, and although financial difficulties postponed the reunion of the IMO Working Group on Manoeuvrability until April 1990, the Group did put forward a draught proposal for quantitative criteria. The actual figures are not included in the DE Sub-Committee Report to the Maritime Safety Committee, but they were disclosed by the IMO representative at the MARSIM & ICSM 90 in Tokyo in June, which also featured a number of papers on the issue of manoeuvring standards. At the Panel Discussion at that Conference the present discusser suggested that the future evaluation of manoeuvring criteria based on trial manoeuvres could be very much enhanced if the ship's captain was required to submit the "Captain's Comments" on the performance of his ship within say six months from the formal trials.

One final remark to the review of the literature, mentioning a new concept replacing the conventional rudder and steering gear by an azimuthing thruster in counter-rotating propeller position. The idea and theory behind the original concept was described by Carl-Anders Johnsson in a paper presented before ATMA in April 1989, "Investigation of a New Type of Contra-Rotating Propellers and Other Means of Improving the Propulsive Efficiency". (Cf. Proceedings 19th ITTC, p. 151).

MN-6

V. FERDINANDE
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CONTRIBUTION TO THE REPORT OF THE MANOEUVRABILITY COMMITTEE

While appreciating very much the Report of the Committee, I would like to comment on two points:

- In the report the importance of the knowledge of ship manoeuvrability in shallow water is emphasized.

Most dangerous situations of ship navigation take place in such circumstances indeed. However, the h/T-ratio, or the keel clearance, can only be determined unmistakably if the sea bottom is of solid, hard material. However, if the solid bottom is covered with layers of soft material, viz. mud, a definition of depth, and keel clearance, is not straightforward anymore. Moreover, ship behaviour in general and manoeuvrability in particular are affected by the presence of a mud deposit.

Studies are going on in Belgium to determine the practical "nautical depth" in sea channels to the ports. On the other hand, full scale navigation and manoeuvring tests have been carried out on a suction hopper dredger [1], and a pilot-model test program was started in a small tank with ship models equipped with propeller and rudder. Several mud simulating materials have been tested, and a mixture of trichlorethane-petroleum appeared to be most convenient. The influence of the mud layers (on

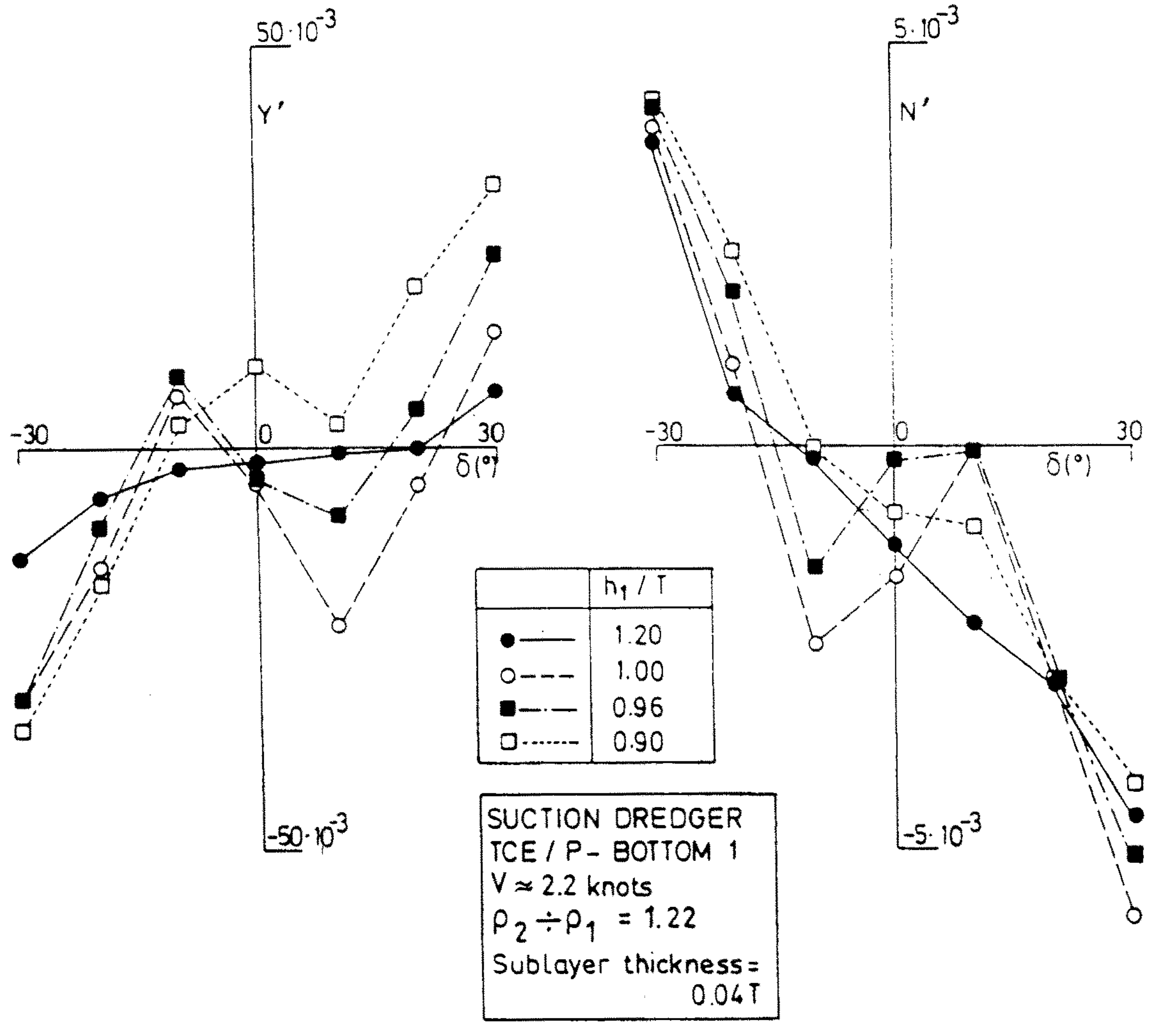

Fig. 1

speed–rpm relation, sinkage and trim, propulsion characteristics, and in particular rudder forces) is most important when the ship's speed

$$V < [\frac{8}{27}(1-\frac{\rho_1}{\rho_2})\, gh_1]^{1/2} \qquad (1)$$

(ρ_1 and ρ_2 = water and mud density resp., h_1 = water depth), except at very low speed (a 1st speed range), [2]. Some results, like lateral forces and yawing moments in function of the rudder angle, are given in [3]. Y'(δ) and N'(δ) curves behave as should be expected above a solid bottom for h_1/T = 1.20, but show important instabilities for small rudder angles (δ < 20°) if $h_1/T \leq 1.10$, see Fig. 1 and 2. When V is larger than the value in (1), (a 3rd speed range), rather small instabilities are observed for negative keel clearance ($h_1/T \leq 0.96$). For all speeds, the mentioned instability effects decrease for large negative values of the keel clearance (h_1/T = 0.90) but in this case forces and moments induced by rudder action take very large values.

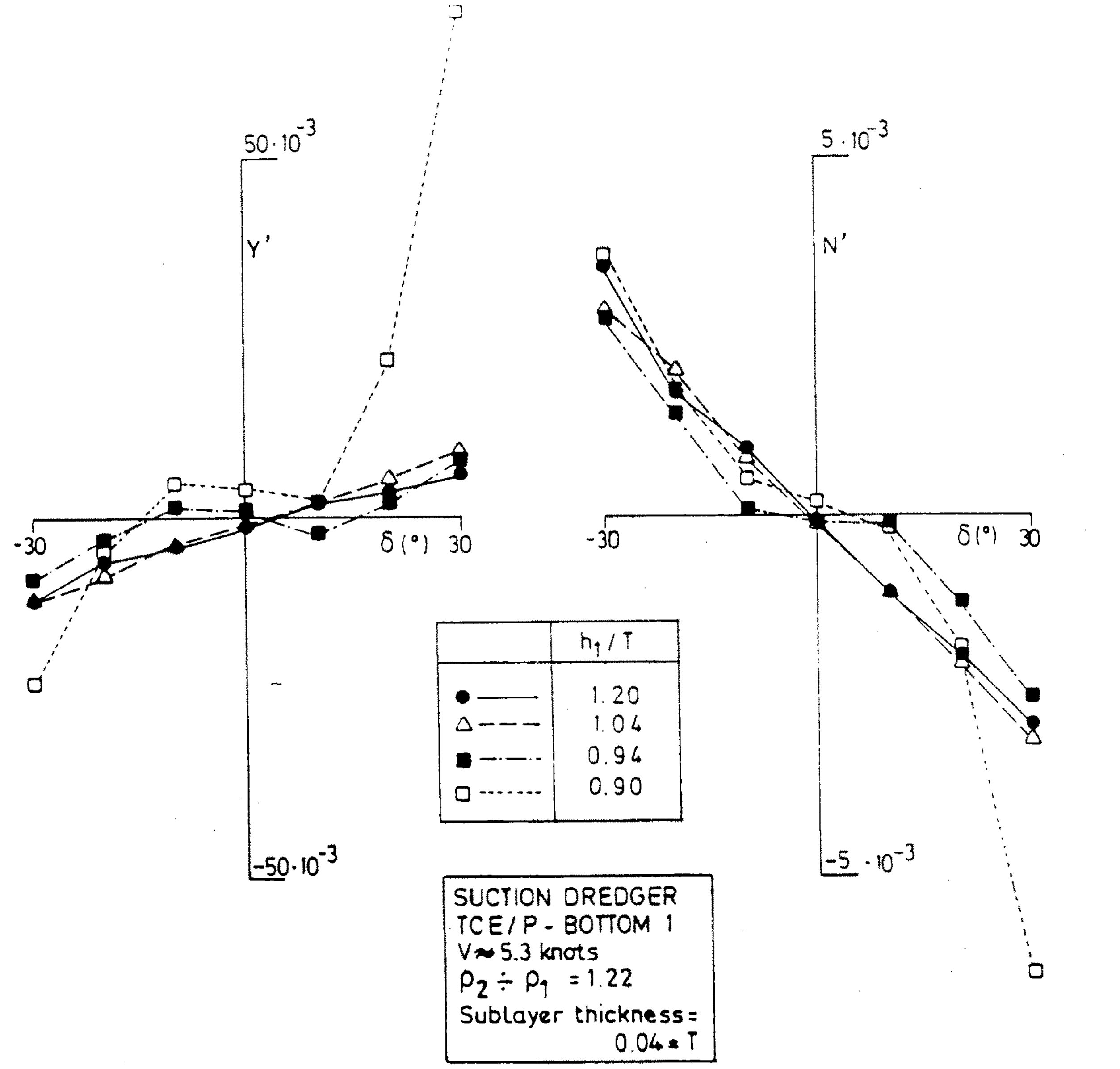

Fig. 2

- In the Report (chapter II, paragraph 3.4) is referred to **Vantorre** (1988), whose theoretical investigations led to expressions for the relative errors on the phase and quadrature components measured during harmonic swaying and yawing tests.

It should be mentioned that these relative errors do not only depend on the accuracy of the mechanism used for carrying out captive manoeuvring tests, but also on the choice of a number of test parameters, such as PMM frequency and number of cycles executed.

An extension of the study referred to in the report is presented by Dr. Vantorre in a special Dissertation (in Dutch), [4], in which a general theory is developed for determining the influence of divergences of the trajectory of ship models during captive model tests on the accuracy of test results. This theory is applied to a conventional captive model test program (bollard pull, resistance, propulsion, rudder, oblique towing, harmonic sway, harmonic yaw, harmonic yaw with drift) executed with a computerized planar motion carriage, and finally results into an optimal choice of test parameters and a series of guide-lines for optimal use of the test installation.

An example or two of practical conclusions from his work:

- Resistance tests result into a value of the coefficient X_{uu}. The influence of a difference δu between prescribed and actual carriage speed on the accuracy of X_{uu} depends on the frequency of the carriage speed error and on a factor C_1:

$$C_1 = \frac{X'_{\dot{u}} - m'}{2X_{uu}} \frac{1}{\pounds'}$$

where £' = £/L represents the undimensioned measuring length. If the speed fluctuation δu can be written as

$$\delta u = \delta u_A \cos[\frac{2\pi\alpha}{\pounds'} t + \phi]$$

it is shown that

$$\frac{\delta X_{uu}}{X_{uu}} = 2f_1(2\pi\alpha, C_1)\ \frac{\delta u_A}{u}$$

The function f_1 is shown in Fig. 3 as a function of α for several values of C_1. The relative error on X_{uu} will be twice the relative error on the carriage velocity if the latter is constant in time ($\alpha = 0$). If the measuring length is very large ($C_1 < 12^{-1/2}$ or £' = 20 to 40), the relative error on X_{uu} caused by time dependent error on the carriage speed never exceeds 2 $\delta u_A/u$. If a shorter measuring length £ is chosen (e.g. $C_1 = 1$ or £'= 5 to 10), $\delta X_{uu}/X_{uu}$ can take values up to 4.2 $\delta u_A/u$. This explains the difference between acceptable tolerances on "speed setting" and "speed maintenance".

- Similar conclusions can be drawn for rudder tests and oblique towing tests. It can be shown that a measuring length £' = 2 to 3 leads to acceptable results for rudder tests. The same length is required for oblique towing tests executed with small drift angles ($\beta < 10°$); for larger drift angles, £' = 0.5 to 1.5 seems to be sufficient.

- In the case of harmonic swaying tests the PMM frequency has to be chosen very low if both acceleration and velocity derivatives have to be determined: the optimal $\Omega' = \Omega L/u$ depends on the ship type and waterdepth, and varies between 0.25 and 2. However, velocity derivatives can be determined more accurately by means of oblique towing tests, so that Ω' can be chosen somewhat higher. The optimal Ω' for harmonic yawing is situated between 2 and 4. Principally, nonlinear velocity derivatives ($Y_{v|v|}$, $N_{v|v|}$, $Y_{r|r|}$, $N_{r|r|}$) can be determined directly from the third harmonic of lateral force Y and yawing moment N measured during harmonic PMM-tests. However, it is shown that the quality of these results is very poor.

It is also shown that the influence of trajectory divergences with higher frequency can be supressed if the integration of the force signals starts at a carefully chosen moment.

Dr. M. Vantorre intends to prepare an English summary of his dissertation during the following months, and I hope the Committee can dispose of its published form in the very near future.

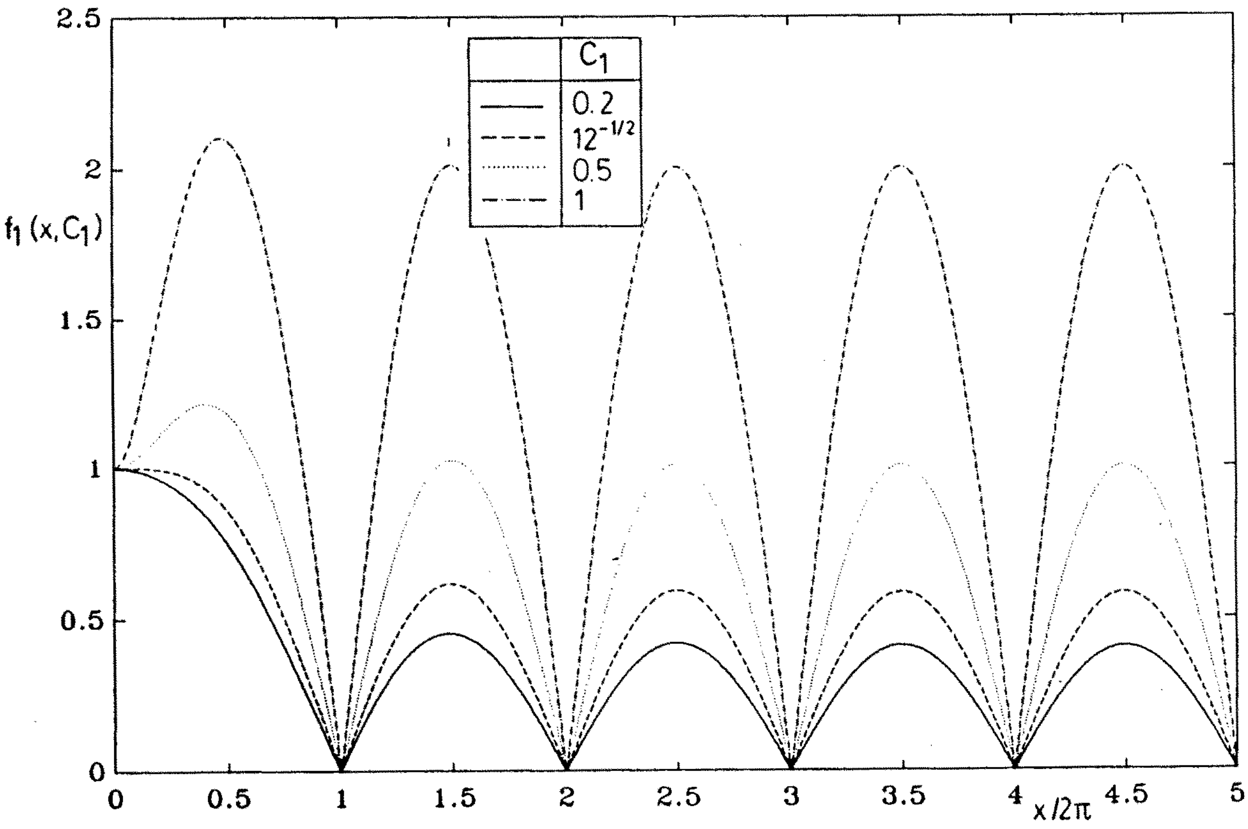

Fig. 3

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[4] Vantorre, M.: "Nauwkeurigheidsoverwegingen en optimalisatie van de parameterkeuze bij gedwongen maneuvreerproeven met scheeps-modellen (Considerations on precision and optimization of parameter choice for captive manoeuvring tests with ship models)", Dissertation submitted for acquiring the degree of "agregate for university education" -special doctorate-, State University of Ghent, Faculty of Applied Sciences, Ghent, 1989.

MN-7

M. HIRANO
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A COMMENT TO THE COMMITTEE REPORT

I would like to make one comment on the item 1 of "Draft Recommendations for the Future Work of the Committee".

As a background of increasing problems in the area of ship manoeuvring safety, extensive efforts to develop the manoeuvring standard are now being made at IMO. Resolution for this manoeuvring standard is expected to be adopted in a few years, and in relation to this, two substantially important matters will soon be needed for ship designers. One is to accurately predict ship manoeuvrability at the phase of preliminary design, and the other is to confirm ship manoeuvrability through full scale trials. For many ships except such a ship as an oil tanker, full scale trials can not be carried out at fully loaded condition. This implies significance of ship manoeuvrability prediction for its ballast condition.

In my view, accurate prediction for fully loaded condition may be made, in a practical sense, with the use of well-established mathematical model. However, there still remain problems to be solved in the aspect of ship manoeuvrability prediction for its ballast condition.

From this point of view, I would like to point out that accurate prediction of ship manoeuvrability at ballast condition in deep water may at first be important among several aspects listed in the item 1.

MN-8

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EFFECTS OF SHIP'S LOADING CONDITIONS ON HER MANOEUVRABILITY

It is of vital importance to estimate the relation between ship's manoeuvrability and her loading conditions. For the difficulties in carrying out trials at the full-loaded condition for many kinds of ships but tankers are well known, and without understanding this relationship, the full-scale trial results can be well fed back into designs by no means. It is a matter of importance to pay enough attention to the worst manoeuvrability at various loaded conditions from the view-points of manoeuvring safety. Therefore researches on the effects of loading conditions are necessary too for the discussion on the manoeuvrability standards.

A series of captive model tests were carried out at Hiroshima University to develop the data-base system for predicting the manoeuvrability of full ships with Cb in the range of 0.78 to 0.84 and L/B in the range of 6.0 to 5.0. The parent model with Cb = 0.81 and L/B = 5.5 was tested at three loading conditions, as shown in Table 1. Total results of this data-base development will be reported in the near future and the partial results on the loading condition effect are reported in the present contribution.

The hydrodynamic derivatives of hull forces were estimated and the performance of propeller and rudder was analyzed from the captive model tests. The mathematical model of manoeuvring motions, so called MMG model, was also determined and the manoeuvring performance was calculated.

Fig. 1 shows the results of simulated reverse spiral tests. Generally speaking, it is widely known that the directional stability is worst in the full-loaded condition. However, it has been found that the directional stability in the half loaded condition of even keel is worse than in the full-loaded one. To examine this result, the contributions of the hull and the rudder to the directional stability were estimated respectively.

Fig. 2 show the well-known term of stability discrimination estimated for the hull force. The directional stability is found the worst in the full loaded condition, as expected generally.

Fig. 3 shows the lateral inflow velocity at the rudder position, estimated from the oblique towing tests with various rudder angles. δ_R is the inflow angle at which the rudder normal force becomes zero. uR and U are the longitudinal component of the rudder inflow and the model speed respectively. It is clearly pointed out that the lateral component of the rudder inflow is kept about zero within the model's drift angle of about 15 degrees in the half loaded condition. This means that the rudder contributes little to the directional stability in the half loaded condition. On the contrary, the lateral component of the rudder inflow increases with the model's drifting angle and the rudder can improve the directional instability in the full-loaded condition.

Model Particulars and Tested Conditions.

L/B	5.5
B/d designed	2.8
C_b	0.81

	B/d.	Ld./L.
Full Loaded	2.8	50.0
50 % Loaded with even draft	15.3	26.4
50% Loaded with 1.5 % trim	5.2	26.8

Table 1.

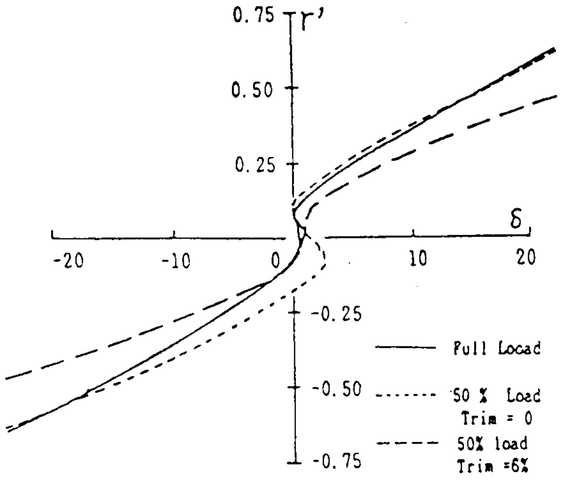

Fig. 1. Estimated Reverse Spiral Results

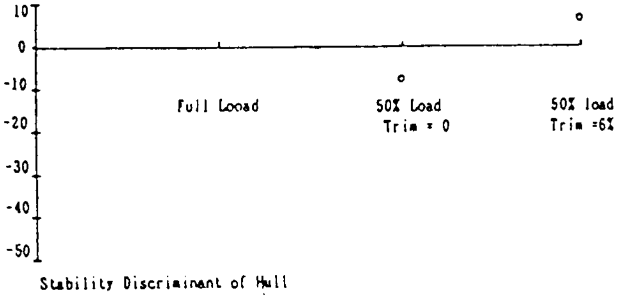

Fig. 2. Stability Discriminant of Hull Force

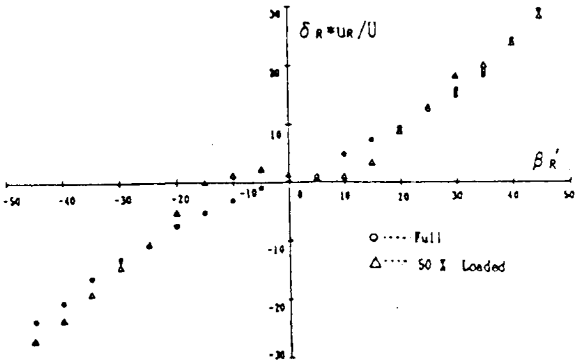

Fig. 3. Lateral Velocity Component at Rudder Induced by Model's Drifting Motion

It is finally concluded that the directional stability of full ships happens to be the worst one in the case of some practical loaded condition and this trend comes from the rudder performance. This trend has already been found in the test results of three full-bodied models investigated at Hiroshima University. Besides, Mr. M. Tanaka of Ishikawajima-Harima Heavy Industries Ltd. reported some results of a remarkable self-excited yawing motion observed under the control of an autopilot at the reduced load condition of the ship whose directional stability was not so inferior at the full loaded condition.

Therefore, the author would like to propose the manoeuvrability committee of ITTC to pay an enough attention to the manoeuvrability of full-bodied ships in the ballast conditions as well as in the full loaded condition.

MN-9

H. EDA
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DISCUSSION ON THE MANOEUVRABILITY COMMITTEE REPORT

As a former member of the committee for three terms, I would like to congratulate an excellent job done by the Manoeuvrability Committee. I have three points for discussion:

1. Ship Trajectory During Overtaking

Fig. 21 of the report shows ship trajectories in overtaking condition. In 1989, in response to a request by National Transportation Safety Board in Washington, I carried out a reconstruction of two ship collision trajectories during overtaking, which occurred in Galveston Entrance Channel in Texas in November 1988. Two ship trajectories were reconstructed fully utilizing pertinent data such as ship configurations, channel dimensions and course recorder trace.

It is interesting to note that the result shows striking similarity to those shown in Fig. 21 in the report (see Figure A).

2. Hydrodynamic Interactions Between Ships

Fig. 8 in the report shows examples of hydrodynamic interactions between two ships. I would like to show remarkable examples of hydrodynamic interaction which recently ocurred in a channel in Texas. A 100.000 DWT tanker was unloading crude oil at the berth along the channel. A 50.000 DWT tanker, proceeding outbound in the channel, passed the unloading tanker in the close proximity. Due to the hydrodynamic interaction, the unloading tanker moved in an oscillatory manner due to the load generated on the mooring lines. The mooring lines were ruptured one-by-one. As a result, the unloading tanker started to move along the jetty, producing sparks. The unloading pipes were also ruptured, spilling crude oil all over the dock. Fire started. In this case, analyses of ship motion and mooring line load were made utilizing hydrodynamic interactions.

3. Principles of Naval Architec. Soc. of Naval Arch. and Marine Eng.

A 250 page Controllability chapter was finally completed and published in 1989. It is Volume III of

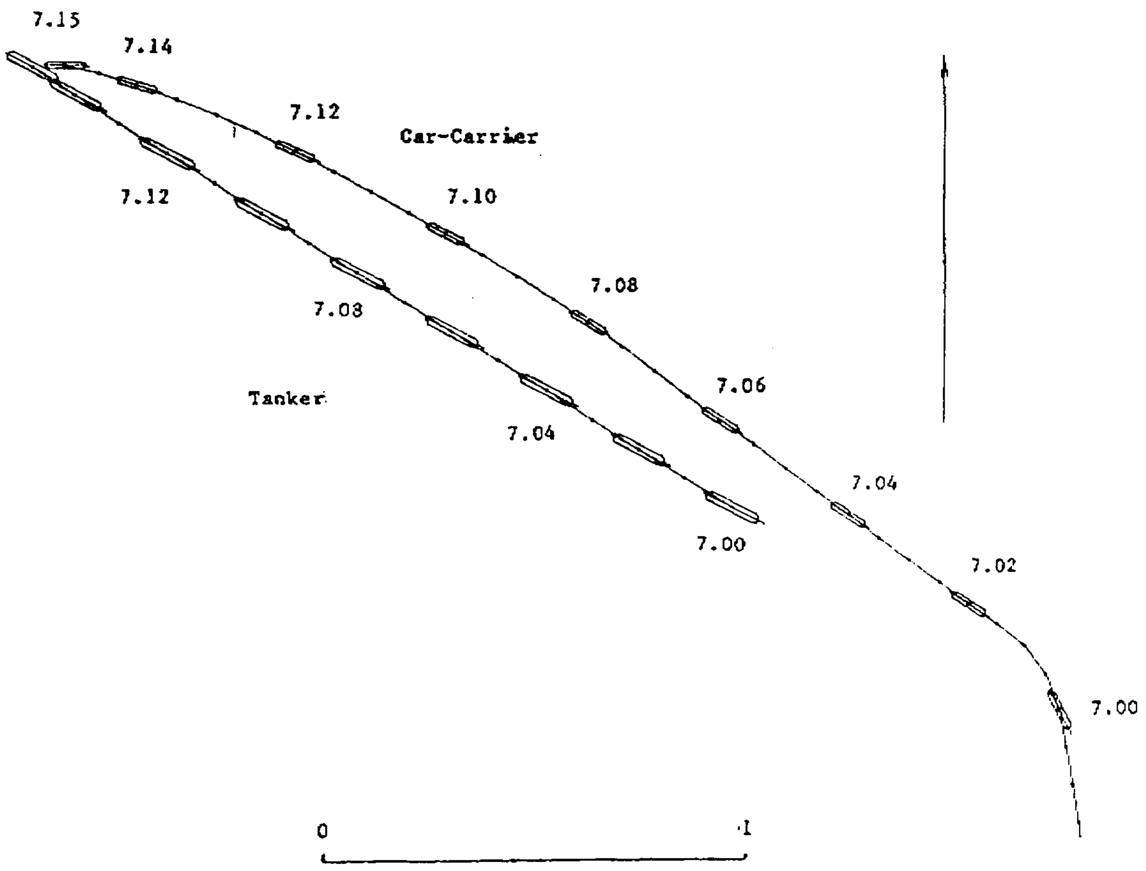

Fig. A. Reconstructed Ship Trajectory

Principles of Naval Architecture. The chapter was prepared by three authors, including the late C.L. Crane, Jr. of Exxon, Haruzo Eda and A. Landsberg.

We hope that this book is a useful addition in literature to the field of maneouvrability.

MN-10

D. VASSALOS
University of Strathclyde, U.K.

COMMENTS ON THE REPORT

The committee remarked accurately, and in good time, that activity towards the determination of manoeuvring criteria has been considerably reduced.

In relation to this, I would like to bring to the committee's attention recent work carried out at the University of Strathclyde where, in collaboration with

Lloyd's Register, effort has been expended over the last 2 1/2 years towards the development of manoeuvring criteria. In addition, I would like to raise one specific point.

The basis of our work was presented in this year's RINA Spring Meeting. It focusses on developing a single manoeuvrability index for each one of 5 ship classes (tankers–bulk carriers, containers, Ferries–Roro's, General Cargo Ships and others).

Such an index derives from multiple–objective decision analysis and encompasses, what we believe to be, the three essential and distinct ship manoeuvring characteristics, namely: turning performance, directional stability and stopping ability. Quantitative measures for each one of these have also been provided.

The "tool" used for developing and testing the proposed criteria is a non–linear modular manoeuvring model where non–linear manoeuvring behaviour is studied on the basis of dynamical systems theory. Emphasis in our work is placed on inherent manoeuvrability.

Considering the above, it would be of great benefit to us at Strathclyde and, we believe, to the profession as a whole, if the committee could indicate wether the route to a single index (for a number of ship classes) is worth pursuing or should one aim towards the development of multiple indices criteria even though these may address characteristics of conflicting nature.

II. REPLIES BY THE MANOEUVRABILITY COMMITTEE

Reply to Drs. HOOFT and HASEGAWA

The Committee thanks Drs. Hooft and Hasegawa for their comments and would mention that it is well aware of the value of simulation in providing information about the manoeuvring dynamics of ships at all stages of design. This may or may not involve the "man–in–the–loop", depending on the stage of design which has been reached.

Additional information on the relative navigational safety and operating limits of a ship in various situations may also be determined. This is pointed out by Dr. Hasegawa and the part played by manoeuvring simulation in the investigation and alleviation of maritime accidents should not be underestimated. The age of the "marine impact study" is with us and manoeuvring simulation is playing a central role in determining the limits of safe operation and port approach design.

Whereas this is an expanding and active area of work and while we, as a committee, may agree that "man–in–the–loop" simulation studies are important, we feel we must offer a word of caution. The use of simulation and simulators, especially the real time, full–mission bridge simulators, is also the province of the International Marine Simulator Forum, who have reported on human factors and other work in the various MARSIM conferences. We would ask the

Conference for guidance as to whether they feel we should cover work in this area. In the meantime we agree with Dr. Hasegawa that progress in navigator models, using knowledge engineering, should be clearly monitored.

To this end we would suggest that, rather than adding Dr. Hooft's Sixth Recommendation to the next Committee, we simply change our existing recommendation to read "Progress in ship handling simulators, and their use, should be reviewed".

Reply to Prof. FUJINO

Prof. Fujino's contribution to the discussion, coming from one who was an active member of the Committee for many years, is very welcome. We are familiar with the variations of force and moment in shallow water which he mentions and, although we believe either of his explanations are plausible, we incline to the former. We have observed well-formed two-dimensional Karman vortex streets left in the wake of a tanker model moving ahead in shallow water at zero yaw and constant velocity. These persisted for some time and, if insufficient interval was left between runs for their dissipation, there was a danger of running into these vortices in the next run. We believe that, in cases of low underkeel clearance and, with squat by the head, the flow "chokes" under the keel and periodically releases eddies to form the Karman vortex street.

Reply to Drs. J.P. HOOFT, G.K. KAPSENBERG, A. REM and H.J. VAN WIJBE

The Committee thanks Dr. Hooft and his colleagues for reminding them of the importance of heel angle, and the consequent yaw-heel coupling, in a turn. This is, as they point out, especially relevant to modern cruise liners to which we would add ro-ro ferries and cointainer ships, who, should they ever execute a hard-over turn at full speed, can heel alarmingly. Simulation models, capable of taking roll into account, have existed for some time and these certainly indicate the destabilising effect of heel in a turn. We imagine that in a practical situation, as is the case with some narrow-beamed warships, care would be taken to avoid hard-over turns at full speed if at all possible, thereby giving due regard to passenger safety and comfort.

The Committee fully agrees with the comments of Dr. Hooft and his colleagues regarding model-ship correlation. It is assumed that the next Manoeuvrability Committee will follow our recommendations and pay attention to any developments in full scale measurements, scale effects and, therefore, ship-model correlation.

The handling behaviour of low-speed energy-efficient ships is well known to the Committee. Operational limits in ports and harbours must be set to take their particular behaviour into account and, although allowances must be made for their handling characteristics, we do not believe they have a poor safety record. Some are fitted with controllable-pitch propellers which improve their response and pilots handle them rather as the, by now almost obsolete, turbine-driven ships, at low speeds.

Reply to Dr. NORRBIN

The Committee appreciate to Dr. Norrbin for the useful comments. As you pointed out, the modular model as a mathematical model describing ship manoeuvring motion is one of the very useful methods for predicting ship manoeuvrability at the present time. But we have certainly some problems relating to the scale effect and also interaction factor in hull, propeller and rudder in the mathematical model.

For example, when the ship's body shape changes a little from the original body shape in the case of a certain sister ship, we have quite different manoeuvring characteristics from the ship of original shape in some cases in spite of the same ship length, same width and same draft. Particularly, the change of stern shape will greatly affect to the manoeuvring performance.

It is considered that this is mainly dominated in the variation of stern flow due to the frame line of ship stern. This means that even if the hydrodynamic force acting on hull are the same with it acting on original shape, the interactions such as hull, propeller and rudder give the great effect to ship manoeuvrability.

The stern flow phenomena is closely connected with the manoeuvrability. It is well known that the stern flow in stopping manoeuvre is much more complicated.

But we have the data base on the estimation for the hydrodynamic force acting on hull, propeller and rudder independently. For developing the prediction of ship manoeuvrability, we have to collect the data much more and to investigate the interaction forces among them due to stern flow as function of drift angle and angular velocity.

The Committee continue to keep attention to the hydrodynamic interaction due to phenomena such as hull, propeller and rudder interactions as well as the force acting on the hull.

The second point is on the manoeuvring criteria relating to the discussion of IMO. The Sub-Committee of Ship Design and Equipment of IMO has proposed the tentative criteria as the manoeuvrability standard.

The aim of establishment of manoeuvring standard is to eliminate the extremely poor manoeuvrability of ship from viewpoint of marine safety. In general, the evaluation of manoeuvrability must include several significant factors, that is, we have to consider mainly the ship manoeuvrability from the point of environmental condition, human factor and the inherent performance of ship.

The Committee understand that ITTC should help them for establishing the manoeuvrability standars from the scientific field on the problem such as the information about the manoeuvring criteria and how to estimate the manoeuvrability etc., and also taking into account the comments of ship master and pilot.

The third point is a new concept replacing the conventional rudder by new type of contra-rotating propellers. This is also very useful comment for improving ship manoevrability, specially for control in dynamic positioning system, control in slow-speed and to maintain her course.

The Committee appreciate again to Dr. Norrbin who have given us so many contribution to the committee during past years as well as the comments to this session.

Reply to Prof. FERDINANDE

The Committee would like to thank Prof. Ferdinande for his comments on two points of the report.

Regarding his first comment on the manoeuvrability in shallow water as affected by the presence of a mud bottom, the Committee agrees that it is difficult to define an absolute keel clearance in these circumstances, especially if one takes also account of the change of the shape of mud bottom generated by the pressure field moving ahead of advancing ship. Moreover, the Committee encourages the idea of model tests aimed at measuring the influence of the mud on rudder forces, and would like to suggest that such tests include also measurements of other relevant hydrodynamic forces as well as flow observations which altogether could help to attempt to define a new mathematical modelling of the manoeuvrability in shallow water including the effect of mud bottom.

With regard to the second point raised by Prof. Ferdinande, the Committee appreciates the work done by Dr. Vantorre in extending the study referred to in the Committee report, and feels that the results of such a work will be certainly considered in detail as soon as his special dissertation, as referred to by Prof. Ferdinande, will be available for the Committee itself.

Reply to Dr. HIRANO and Prof. KOSE

The Committee like to thank Dr. Hirano and Prof. Kose for their contributions to our report, because both fully support the Committee's ideas regarding the future work as outlined in the complete draft recommendations.

Prof. Kose presented us results from model tests and corresponding computer simulations showing the, we feel, expected alterations of directional stability due to changes of the loading condition of the full-bodied vessel.

Dr. Hirano, however, focussed on the present efforts of IMO to develop manoeuvring standards and to give sufficient information about the manoeuvring performance of a particular vessel in full-load as well as in ballast condition.

In this respect two points are of importance. One is the lack of sufficient data regarding the hydrodynamic coefficients needed in the known mathematical simulation algorithms for the ballast condition. This is of course a gap which obviously has to be filled up very soon.

The other one is related to the fact that yard trials normally are carried out on ballast draught rather than on design draught.

In this case we feel if it can be shown that preceeding simulations for the appropriate ballast condition show good agreement with the trials performed, the ship owner will indeed trust also into the corresponding simulations for the full-load condition.

In this connection we like to hint to the introductory remarks of Prof. Kijima et al. at the Group Discussion on "Manoeuvring Simulation" treating the subject of numerical simulation for the prediction of manoeuvring performance. They did not concentrate on the full-load condition alone, but also present results for different draughts including ballast conditions.

Reply to Prof. EDA

The Committee would like to thank to Prof. Eda for the very intersting contribution. We understand that ship manoeuvrability should pay attention to specially restricted water such as harbour, bay and canal, that it is shallow water and narrow water channel.

Prof. Eda shows the actual example on two ships collision trajectory during overtaking in canal, and also shows of importance in the hydrodynamic interaction force between ship and ship, ship and bank wall.

The Committee continue to pay full attention to the problem of ship manoeuvrability in restricted water such as canal.

The Committee thanks again to Prof. Eda.

Reply to Dr. VASSALOS

The Committee thanks Dr. Vassalos for his interesting contribution and remarks about the possibility to obtain a single index representing overall manoeuvrability properties. The idea is quite atractive from the point of view of qualifying the degree of goodness of a ship manoeuvring behaviour. However, it is necessary to remind that several characteristics like turning ability and course-keeping are ordinarily opposite and, therefore, a ship with e.g. very good turning ability and unsatisfactory directional stability (as a large tanker) may counteract his performances and obtain a single index of satisfactory value, but it is evident that the design is rejectable. On this context IMO and main Regulatory Bodies are working on the basis of several indexes related each one to different manoeuvrability characteristics.