MANŒUVRABILITY OF MERCHANT NAVY SHIPS A REVIEW OF DEVELOPMENTS SINCE 1900

BY

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Although naval architects and mariners do not always attach exactly the same meaning to the expression "manœuvrability", broadly speaking they mean in fact the same thing [1].

Some authors, however, write about the "navigational properties of a ship" [2], by which they mean the ship's speed, seakeeping, stability and manœuvrability. In this context, manœuvrability is limited simply to course changes by means of the rudder.

For mariners manœuvrability means much more. The term covers among other things (and I quote only the most important) :

- speed and speed control ;
- stoppig capability ;
- course stability [3], sometimes called dynamic stability, in this sense meaning the ability of the ship to stop turning when under way and follow a straight course when the rudder is held amidships [4] ;
- turning capability, which means that the ship responds quickly to the rudder and that the size of the turning circle is acceptable.

The manœuvrability problem, or more precisely the ship's behaviour problem, can schematically be represented as follows (fig. 1).

It is clear that the ship's behaviour will be determined by a number of constant and variable ship-intrinsic elements, by the environment and, last but not least, by the

[1] For definitions, see among others : R. AMERDORFFER, *Manövriereigenschaften von Schiffen*, in : *Hansa*, No. 1, 1978, pp. 25-28 ; P. DEVAUCHELLE, *Dynamique du navire*, Paris, 1986, pp. 136-166 ; *Focus on Manœuvrability*, in : *Marine Week*, January/February 1977, pp. 31-47 ; C. GLANSDORP, *Sturen en stuureigenschappen van zeer grote schepen*, in : *Schip en Werf*, No. 13, 1970, pp. 263-275 ; B. NIZERY, *La manœuvre des navires*, in : *Nouveautés Techniques Maritimes*, 1977, p. 88 ; K. RAWSON & E. TUPPER, *Basic Ship Theory*, vol. 2, London, 1983, p. 476.

[2] J. DIRKZWAGER, *Geschiedenis van het scheepsbouwkundig modelonderzoek*, in : *Schip en Werf*, No. 15, 1986, p. 266.

[3] Course stability may be positional motion stability, directional stability or straight-line stability.

[4] D. CLARKE, *Considerations of Shiphandling in Hull Design*, in : *Conference on Shiphandling*, Plymouth, 24-25 November 1977, p. 119.

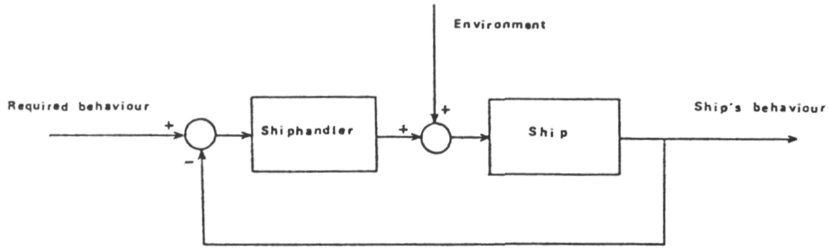


Fig. 1. – The ship's behaviour problem.

shiphandler himself, as any difference between the ship's actual behaviour and the behaviour required calls for action on the part of the shiphandler.

Constant ship-intrinsic elements include :

– shape of the hull ;
– type and capacity of the propulsion plant ;
– number, type and position of the propelling devices (one or more propellers) ;
– type, dimensions and position of the rudder or rudders ;
– availability of manœuvring auxiliaries such as transverse thrusters.

Variable ship-intrinsic elements that certainly should be mentioned are :

– draught and trim ;
– loading condition and weight distribution ;
– state of marine fouling.

As to the environment, the following elements constitute important outside influences :

– wind and state of the sea ;
– current ;
– depth and width of the fairway ;
– proximity of other vessels.

Finally, as long as vessels are manned, the ship's behaviour will, to a large extent, be determined by the shiphandler. His theoretical background, acquired during nautical training, the information available to him on ship and environment, as well as his experience are important factors influencing the final behaviour of the ship.

It goes without saying that changes with regard to manœuvrability that have occurred this century concern only the "ship" and "shiphandler" blocks in our schematic representation.

An attempt is made here to indicate very briefly the most salient and relevant changes in respect to ship behaviour that have come about since the beginning of the 20th century.

In most cases our choice has been restricted to those things which are of interest to the practical shiphandler rather than the naval architect.

Let us first consider the "ship" block in the schematic representation of the problem.

Speed and speed control, extremely important elements for the shiphandler, are intimately related to hull shape, propulsion plant and propeller(s).

Scientific-minded shipbuilders have been interested in the influence of hull shape on the navigational performance of ships since as long ago as the 17th century. Indeed, model experiments were then already being carried out by Fortree, Witsen and others [5].

A lot has changed since. Considerable advances have been made in the study of hull shape and ship's resistance, and names such as Russell, Rankine, Froude, Tidemann, Reech and innumerable others form the pre-twentieth century history of shipbuilding and shipbuilding research. The improvements realised in this field since then will be dealt with later by Doctor Oosterveld [6].

The evolution of the propulsion plant since 1900, with, at the outset, the gradual introduction of diesel engines and turbines replacing the old steam engines, and later, after World War II, the supremacy of the diesel engine with its steadily improved types as far as efficiency, capacity and manœuvrability are concerned will be treated by Prof. Lederer [7]. However, I want to mention two elements in this respect which, from the point of view of the shiphandler, have enormously improved the ship's manœuvrability, namely :

- the increased reliability of the propulsion plant in respect of quick and safe starting and reversing of the engines ;
- and of course the automation and the remote control of the plant.

The history of the propeller, the most effective way of converting engine power into thrust, goes a long way back in time. Let us simply mention that as far back as the year 1752, Bernouilli received an award from the French Academy of Sciences for the construction of a wheel equipped with wooden inclined planks fixed on spokes [8].

Much later after the invention of the propeller, theories on the propeller action were developed [9]. Since the thirties it has been possible to calculate and construct

[5] G. Baker, *Development of Hull Form of Merchant Vessels*, in : *Transactions of the North East Coast Institute of Engineers and Shipbuilders*, 1937-1938, p. 66 ; N. Witsen, *Scheepsbouw en bestier*, s.l., 1671, p. 274.

[6] M. Oosterveld, *Advances in Maritime Hydrodynamic Research during the Last Century*, Industrial Revolutions and the Sea (19th-20th Centuries), International Colloquium, Brussels, 28-31 March 1989.

[7] A. Lederer, *L'évolution de l'appareil moteur des navires*, Industrial Revolutions and the Sea (19th-20th Centuries), International Colloquium, Brussels, 28-31 March 1989.

[8] W. van Lammeren, *Weerstand en voortstuwing van schepen*, Amsterdam, 1942, p. 113.

[9] J. Pascault, *Des progrès et de l'état actuel de la technique des hélices marines*, in : *Nouveautés Techniques Maritimes*, 1961, pp. 143-157.

propellers with great precision, based on the theory, which was quite impossible before.

Experimental research is still necessary as a check on calculated propellers, but also in order to determine the cavitation properties of the propeller as well as the interaction between ship and propeller [10].

A theoretical study of the capacity/revolution characteristic of the engine/ship propeller system shows that a monobloc propeller can use the full engine capacity for one particular speed and one typical loading condition of the ship only.

For all other speeds and loading conditions the available capacity is underutilized. Indeed, in order to make full use of the capacity of the power plant, the propeller should have a controllable capacity/revolution characteristic, namely a mechanism making it possible to adjust the pitch of the propeller, a mechanism to control the position of the rudder blades.

As long ago as the nineteenth century experiments were being carried out with so-called pitch propellers. In 1849 a pitch propeller with a spring mechanism was devised by R. Griffiths, while in 1901 Zeise constructed a propeller with partially movable propeller blades [11].

It was the German-Swiss concern Escher-Wyss, however, which undertook the construction of pitch propellers, while all previous attempts to manufacture a serviceable pitch propeller had stranded on mechanical difficulties. The Escher-Wyss concern developed the pitch propeller, taking advantage of its experience with the well-known Kaplan water turbines [12].

As engine power increased and propellers became larger, the initial mechanical actuators were not strong enough to overcome the high blade forces. From 1934 on, oil hydraulic power was introduced to change the blade position over the whole range of pitch : from full ahead through neutral pitch to full astern, and vice versa. In fact this marked the first breakthrough with the controllable pitch propeller [13].

Over the fast few decades many manufacturers all over the world have improved the pitch propeller to such an extent that today it can be reversed from full ahead to full astern in about 8 to 10 seconds.

Modern pitch propellers (fig. 2), controllable from the bridge or any other steering station, contribute enormouly to increasing manœuvrability and reliability. Let us mention in this connection :

- the stepless control of the position of the propeller blades, in other words the stepless control of the pitch ;

[10] J. van Lammeren a.o., *The Wageningen B - Screw Series*, in : *The Society of Naval Architects and Engineers*, no. 8, 1969.

[11] J. Dirkzwager, *Some Aspects on the Development of Screw-Propulsion in the 19th and Early 20th Century*, in : *4th Lips Propeller Symposium*, Drunen, The Netherlands, p. 193.

[12] R. Schwyzer, *Verstellpropeller für Schiffe*, in : *Schiffbau*, 1935, p. 403.

[13] *Lips Controllable Pitchpropeller Type C Mark 3*, Drunen, s.d.

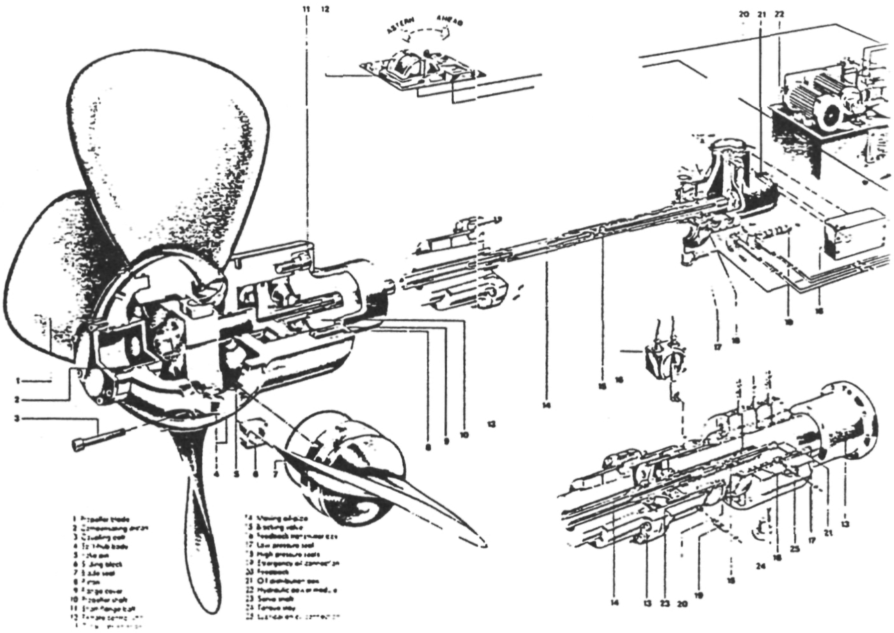


Fig. 2. – Pitch propeller (Lips, Drunen, The Netherlands).

– the fact that when manœuvring the ship, the engine is continuously running, so that there is no need to stop, restart or reverse it ;
– and finally, pitch propellers are also operational when running at very low speeds, which is of the utmost importance when manœuvring in restricted waters such as canals, docks, locks, etc.

Contrarotating propellers, that means propellers placed one behind the other working in tandem, provide greater propulsion efficiency and higher speed and thrust with the same power (fig. 3). Such greater efficiency can be thought of as the result of two different factors : first, rotational losses can be avoided and, second, the load is divided between the two propellers.

Contrarotating propellers were invented by W. Chuch in 1829 and J. Ericsson in 1836 [14]. Once invented, however, they simply remained an object of interest and study for professors and students in universities without any practical applications [15]. Mechanical difficulties with complex structures and poor reliability have prevented the use of contrarotating propellers in normal ship propulsion, with a few exceptions (for instance on board submarines). Nowadays, contrarotating propellers are com-

[14] JARMO SAVIKURKI, *Contra-Rotating Propellers*, in : *Hansa*, No. 12, 1988, p. 657.

[15] G. ROTA, *Further Experiments on Contrary-Turning Co-Axial Screw Propellers*, in : *Transactions of the Institution of Naval Architects*, 1922, p. 354.

bined with Z-drive equipment, and some manufacturers are currently trying to conquer the cargo vessel market with this type of equipment (fig. 4).

The Z-drive, also called rudder propeller, considerably increases ship manœuvrability. By virtue of the possibility of controlling the direction of thrust from this equipment through 360 degrees, the ship can be propelled by it under full control in virtually any direction (fig. 5).

Rudder propellers (such as Schottel, Aquamaster, etc.) have already been used for ship propulsion (and steering) for 35 years, not only in tugs but also in cargo vessels, ferries and passenger vessels.

Another particular type of propulsion equipment is the ducted propeller. A ducted propeller is one in which the screw operates within a shaped duct or tunnel, thereby increasing propulsion efficiency (fig. 6).

The ducted propeller was invented by Kort and already in 1932, more precisely on 7th June of that year, trials were carried out at Minden, Germany.

Since then ducted propellers have been installed not only on board tugboats and coasters but also on bigger cargo vessels and, since the seventies, even on board VLCC's.

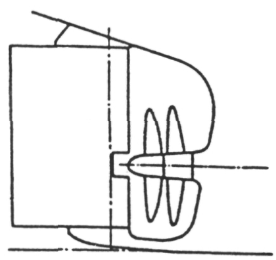
A special type of ducted propeller is the steerable ducted propeller, in which the whole duct is turned to affect steering. A vertical fin is usually installed at the exit of these ducts (fig. 7).

Though perhaps somewhat less important for merchant navy vessels, the Voith-Schneider propulsion system must also be mentioned. Early British and American attempts to produce a vertical-axis propeller were carried to a practical conclusion by the Austrian naval architect Ernst Schneider, who formulated the correct law of blade motion [16]. The device described in Schneider's original patents during the late twenties was constructed by the firm of Voith in 1929 and so the now well-known Voith-Schneider propeller was born.

The Voith-Schneider propeller comprises a rotor installed in the lower part of the hull and turning around a vertical axis, on which a certain number of blades are mounted, each of them also movable around a vertical axis. During one rotation, the blades oscillate by means of a specific mechanism so that at each point of the circumference of the rotor a thrust is given in a well-defined direction. From the bridge, the direction as well as the amount of thrust can be controlled. As was the case for the Z-drive, propulsion and steering are also combined in one piece of equipment (fig. 8).

It was not until 1939 that for the first time a seagoing vessel, namely the "Helgoland" of 2.947 gross tonnage, was equipped with a Voith-Schneider propeller. Nowadays Voith-Schneider propulsion is widely used on tugboats, ferries and other vessels which frequently have to manœuvre, especially in restricted waters.

[16] W. JUST, *Theorie des Voith-Schneider Propellers*, in : *Werft-Reederei-Hafen*, 1939, p. 4.



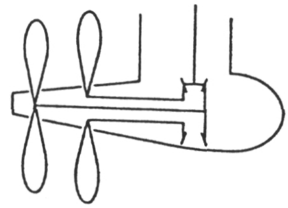


Fig. 4. – Z-drive with CRP.

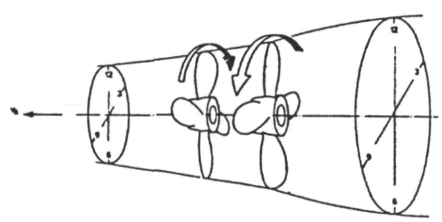


Fig. 3. – Contrarotating propellers.

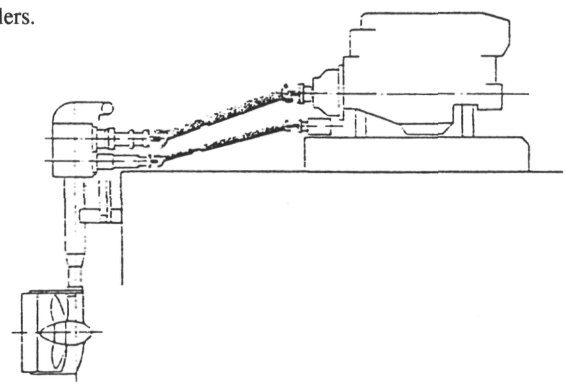


Fig. 5. – Rudder propeller (Z-drive).

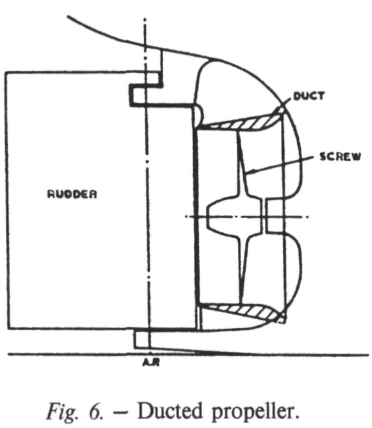


Fig. 6. – Ducted propeller.

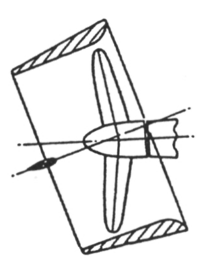


Fig. 7. – Steerable ducted propeller.

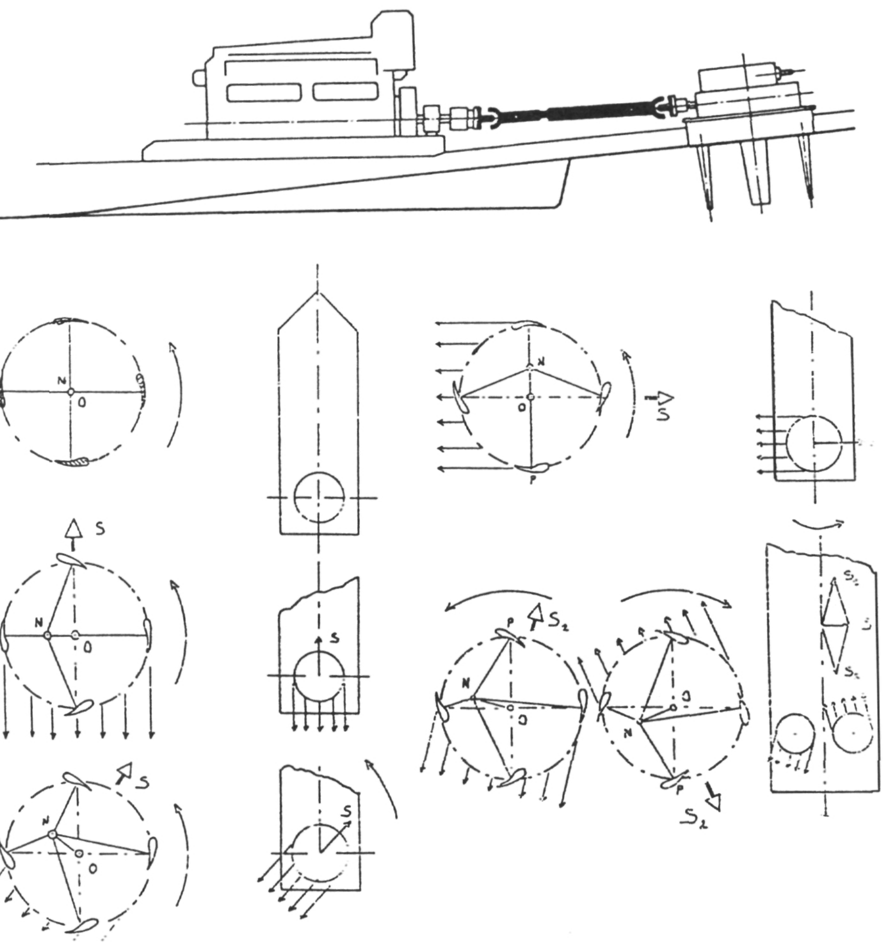


Fig. 8. – Voith-Schneider propulsion.

For centuries ships have been steered by means of rudders, and this is still so, except for the already mentioned Z-drive and Voith-Schneider propeller.

The "ship-rudder" combination aims at effecting quick course changes when the rudder is activated, quick stopping of turning, good course keepig and small turning circles. Depending on the type of ship and her trade, one or more of these objectives will be more important than the others.

Single-plate rudders (fig. 9), almost universal 40 or 50 years ago, have since been superseded by castings or welded fabrications streamlined in form [17]. Many different designs have been produced, most of them based on the results of experiments on rudder-equipped single- and multi-propelled ship models. A lot of research

[17] F. LAST, *Rudders and Sternframes*, Lloyd's Register of Shipping, London, s.d., p. 1.

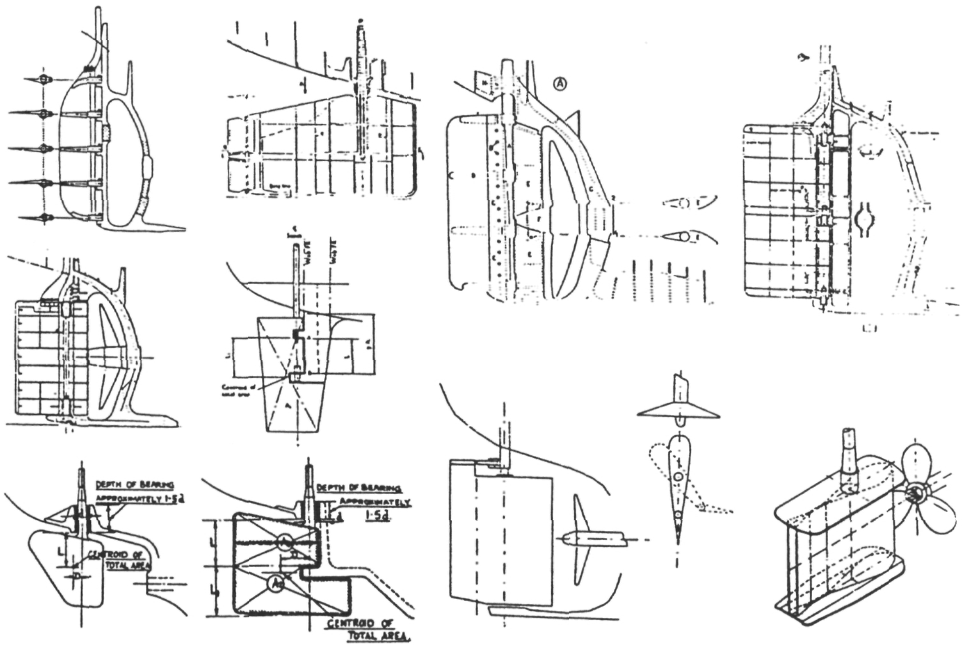


Fig. 9. — From single-plate rudder to modern type rudders.

has been done on shape and dimensions of the rudder blade, on horizontal sections of the rudder blade, on the influence of the shape of stern frames, and so on [18].

The list of rudder types designed during the 20th century, all designed to improve steering and reduce resistance, is quite long. Some in particular are worth mentioning, such as the Flettner rudder, the Star contrarudder, the Oertz rudder, the Simplex balance rudder, the Becker rudder, and many others [19].

The Schilling rudder deserves to be mentioned separately. This rudder, with a special hydrodynamic profile, makes it possible to use rudder angles as high as 75 degrees. At these helm positions the propeller slipstream is diverted by more than 90

[18] G. Flügel, *Vergleichsversuche am Rudermodelle,* in : *Schiffbau,* 1940, pp. 167-189 ; Hebecker, *Manövrierversuche mit Modellen,* in : *Werft-Reederei-Hafen,* 1934, p. 181 ; A. van Lammeren a.o., *Weerstand en voortstuwing van schepen,* 1942, pp. 304-317.

[19] V. Bingham, *Schilling Rudder Developments,* in : *Conference on Shiphandling,* Plymouth, November 1977, pp. 158-165 ; E. Chicot, *Construction du navire de commerce,* Paris, 1960, pp. 273-279 ; M. Denny, *The Design of Balanced Rudders of the Spade Type,* in : *Transactions of the Institution of Naval Architects,* 1929, p. 117 ; A. Flettner, *Mein Weg zum Rotor,* Leipzig, 1926 ; G. Flügel, *Vergleichsversuche an Rudermodellen,* in : *Schiffbau,* 1940, pp. 167 & 189 ; J. Gugelot & A. Helwig, *Scheepsbouw,* Amsterdam, 1962, pp. 237-253 ; K. Rawson & E. Tupper, *Basic Ship Theory,* vol. 2, London, 1976, pp. 502-508 ; W. van Lammeren a.o., *Weerstand en voortstuwing van schepen,* Amsterdam, 1942, pp. 285-323 ; R. Wereldsma, *Modelproeven ter bepaling van kritieke trillingen in de roeruithouder van een "Mariner" scheepsroer,* in : *Schip en Werf,* No. 14, 1960, pp. 394-400.

degrees, which results in a rapid helm response to course alterations and, when manœuvring at rest, permits a vessel to turn within its own length.

Another very particular one, certainly, is the active rudder. In the rudder blade a remote-controlled electromotor is installed, powering a small ducted propeller, which is in line with the main propeller shaft (fig. 10).

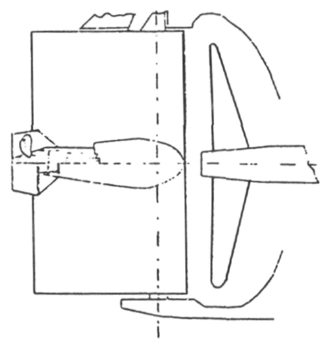


Fig. 10. — Active rudder.

Instead of the maximum 35-degree rudder angle for normal rudders, 90 degrees is allowed for the active rudder when manœuvring at slow speeds, producing a transverse thrust in this position [20].

It is not only the rudder itself that has been considerably improved this century but also the complete steering equipment, comprising the bridge equipment (wheel or tiller), transmission to the steering gear, the steering gear itself and transmission of the steering gear movements to the rudderstock and rudder.

It is the complete steering equipment which enables the rudder to be kept amidships and the rudder angle to be altered for coursekeeping and changing heading.

At the beginning of this century handsteering, that is to say moving the rudder by hand, was still in use on smaller ships. On bigger vessels, however, handpower had already been replaced by steampower.

Initially, the steam steering gear was located near the bridge and the transmission to the rudder was a mechanical one. Later on the steering gear was installed near the rudderstock and transmission was effected by hydraulic or electric means.

Since the disappearance of old steam engines on board ships, steering gears are of the electric-mechanical type or the electric-hydraulic type, enabling manœuvres to be executed easily and quickly.

Another remarkable improvement this century in respect of steering is the automatic pilot. It was aboard the Standard Oil tanker "J. A. Moffett" in 1923 that

[20] *Erfahrungen mit dem Aktiv- und Querstrahlruder auf dem Frachter "Ville de Nantes"*, in : *Hansa*, April 1963, p. 761.

the Sperry Gyro Pilot was nicknamed “Metal Mike”, a term known by mariners the world over today [21].

The automatic pilot is replacing the helmsman and, it must be admitted, doing a far better job of steering the ship (fig. 11). The automatic pilot, used in ships the world over, is nowadays really a very sophisticated piece of equipment allowing the ship to be steered taking the wind and state of the sea, etc., into account.

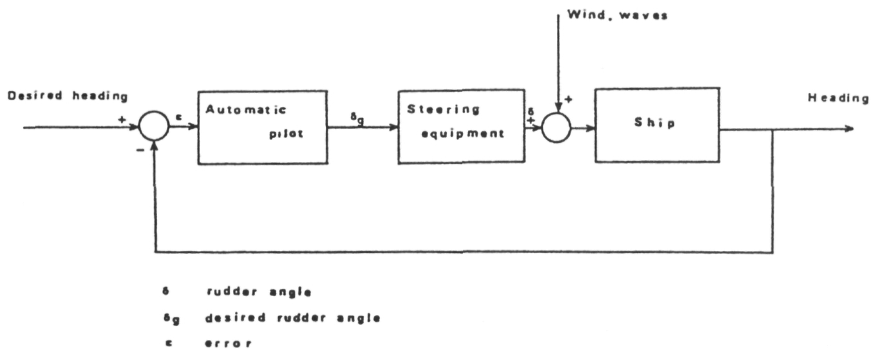


Fig. 11. – The automatic pilot.

The introduction of transverse thrusters (bow- and sternthrusters), also called lateral thrusters, producing a transverse thrust, has meant a considerable improvement in ship manœuvrability, which has found a practical application since the fifties.

The idea was not a new one, however. Indeed, in the 19th century, during the changeover period from sail- to power-driven vessels, the first tests with transverse thrusters were already taking place.

In a letter to the Lords of the Admiralty Foulerton drew attention to his “ship manœuvrer” in the following way : “The subject is, my Lords, the power of turning a ship so as to direct her head to any given point, independently of rudder and sails, a desideratum so long felt by practical seamen, and which, if possessed, would have prevented a long list of disasters in your annals...” [22].

The tests with Foulerton’s “ship manœuvrer” were executed at the Woolwich yard on board the collier “Stockton”. The yard’s report to the Lords of the Admiralty was convincing and I quote : “With reference to your memorandum of the 22nd instant, directing us to report on the trial of Foulerton’s Ship Manœuvrer, we beg to acquaint you that we have this afternoon witnessed its operation in a most satisfactory manner, on the new barge, to which it has been fitted, and that the vessel made a complete revolution in four minutes and twenty-five seconds, with ten men at the

21 Sperry Gyroscope, *The Gyroscope through the Ages*, s.l.s.d., p. 18.
22 R. Foulerton, *A Letter to the Lords on the Ship Manœuvrer*, London, 1846.

winches"[23]. As can be seen, Foulerton's "ship manœuvrer" was a hand-powered device.

The first generation of transverse thrusters, as already mentioned, was developed in the fifties. One of the first types was a Voith-Schneider propeller installed in a transverse rectangular tunnel. Later, contrarotating propellers, fixed and controllable pitch propellers were used instead (fig. 12). Problems such as cavitation and streams of turbulence in and at the ends of the tunnels were partially or completely solved in the meantime by adapting the tunnel design[24].

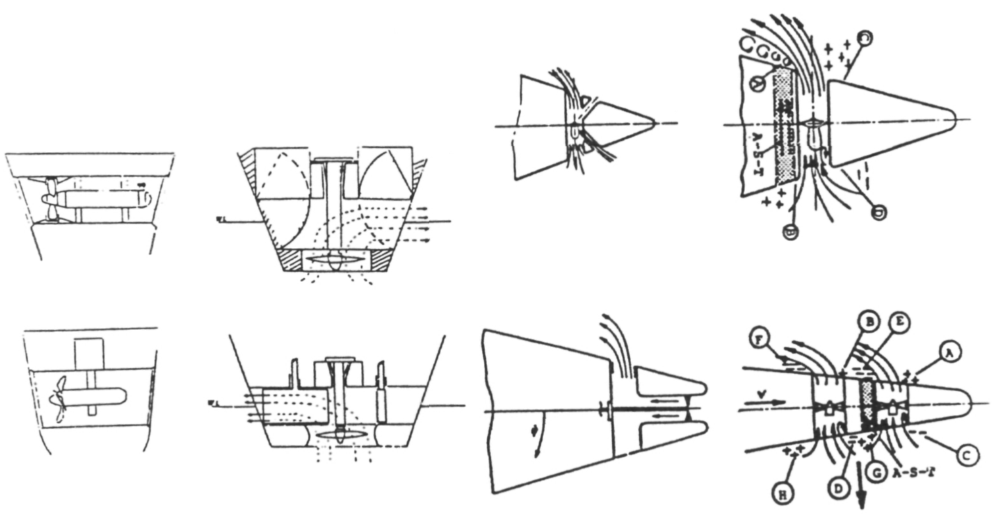


Fig. 12. — Transverse thrusters : some variants.

One particular thruster is the so-called azimuth thruster. It is a thruster of the ducted propeller type which can be lowered beneath the hull to provide a transverse thrust or a thrust over the complete 0- to 360-degree arc.

Transverse thrusters, ensuring better manœuvrability in the low speed range, contribute to meeting the demand of ship operators for shorter stays in port and thus quicker turn-rounds.

A first item to be dealt with in respect of the "shiphandler" block in our schematic representation is the education and training of mariners.

[23] R. FOULERTON, *op. cit.*

[24] M. VISCONTI, *Applications nouvelles du réacteur d'étrave en Y*, in : *Nouveautés Techniques Maritimes*, 1972, pp. 105-109 ; *Thrusters for Manœuvrability*, in : *The Motorship*, January 1981, pp. 67-75 ; *Schottel-Jet-System, leistungsfähige Flachwasserantriebe*, in : *Hansa*, 1981, pp. 922-923 ; B. GLEISZ, *Ausführungsformen von Querstrahlsteurn* in : *Seewirtschaft*, No. 3, 1978, p. 133 ; O. LORENZ, *Der K-Strahler*, in : *Hansa*, No. 5, pp. 389-392 ; D. RIDLEY, *Effect of Tunnel Entrance Configuration on Thruster Performance*, in : *Marine Technology*, January 1969, pp. 60-65.

It can be said that during this century and even nowadays, shiphandling training has been and still is mainly theoretical, received by students while at nautical college and, thereafter, followed by "on the job" training.

Textbooks on shiphandling used at nautical colleges during this century give a fairly good idea of what has been taught [25]. Comparing these textbooks, one notices that the same topics are dealt with in almost the same way at nautical colleges all over the world and that not so much changed until the late sixties. From that moment on, a more complete theoretical insight was given to nautical students [26].

Practical shiphandling training of students at nautical colleges was and is still limited in most cases to manœuvring small boats, such as lifeboats. Of course, it cannot be denied that this elementary practical training has some merit. Indeed, once the principles have been acquired, it is then important to learn how to apply them in more realistic situations.

Although "on the job" training should not be underestimated, it is a fact that safe practice and economics make "on the job" training impractical.

A much better complement of shiphandling fundamentals is to be found by appealing to simulation techniques.

The potential use of scale models or real-time shiphandling (and navigation) simulators for training as well as for operational analysis has been recognized since the advent of the supertankers over 20 years ago.

Simulation techniques provide a means of studying the total man-ship environment system, of making captains and officers familiar with the properties of the system and so of improving their skills.

Radar simulators were one of the earliest devices used for additional training. Originally intended as a means of instructing mariners in the correct use of radar, as soon became evident they could provide watchkeeping officers with useful experience in navigation and collision avoidance, especially in bad visibility. Lack of visual display, however, limits their capability for training in shiphandling.

The year 1967 saw the first major step forward with the opening of the lake at Port Revel near Grenoble in France. Scale models (1/40, 1/25) were used, large enough for a person to position himself in the model with the same relative field of view that he would have from the wheelhouse of an actual ship. Although the models at Port Revel do not claim to include an exact reproduction of the bridge, the controls (for speed, rudder angle, etc.) are the same as those found in a real ship.

[25] C. Brown, *Nicholl's Seamanship and Nautical Knowledge*, Glasgow, 1953 ; G. Danton, *The Theory and Practice of Seamanship*, London, 1974 ; S. de Boer, *Manœuvreren met zeeschepen*, Amsterdam, s.d. ; S. de Boer & J. Schaap, *Zeemanschap voor de G.H.V.*, vol. 2, Amsterdam, 1965 ; de Kerviler, *Traité de Manœuvre*, Paris, 1957 ; D. Gladisch & H. Schulze, *Leitfaden der Seemannschaft*, Berlin, 1935 ; Isabey a.o., *Manuel du Manœuvrier*, Paris, 1910 ; G. Massenet a.o., *Gréement manœuvre et conduite du navire à voiles et à vapeur*, 2 vol., Paris, 1915-1918 ; Möller-Krausz, *Schiffsführung*, Berlin, 1925 ; T. Noordraven & S. de Boer, *Zeemanschap*, Amsterdam, 1947.

[26] K. Glas & J. Schutte, *Zeemanschap voor de grote handelsvaart*, vol. 4, Amsterdam, 1976 ; H. Hilgert, *Manöverkennwerte in der Schiffsführung*, Berlin, 1976.

All influences of the environment such as shallow water, bank effect, proximity of port structures and other ships (ship interaction) are realistically taken into account.

The lake at Port Revel, an area of about 40,000 square metres, was carefully graded to provide shallow water areas, and a representative section of the Suez Canal has been constructed as well as single point moorings, piers, etc. (fig. 13).

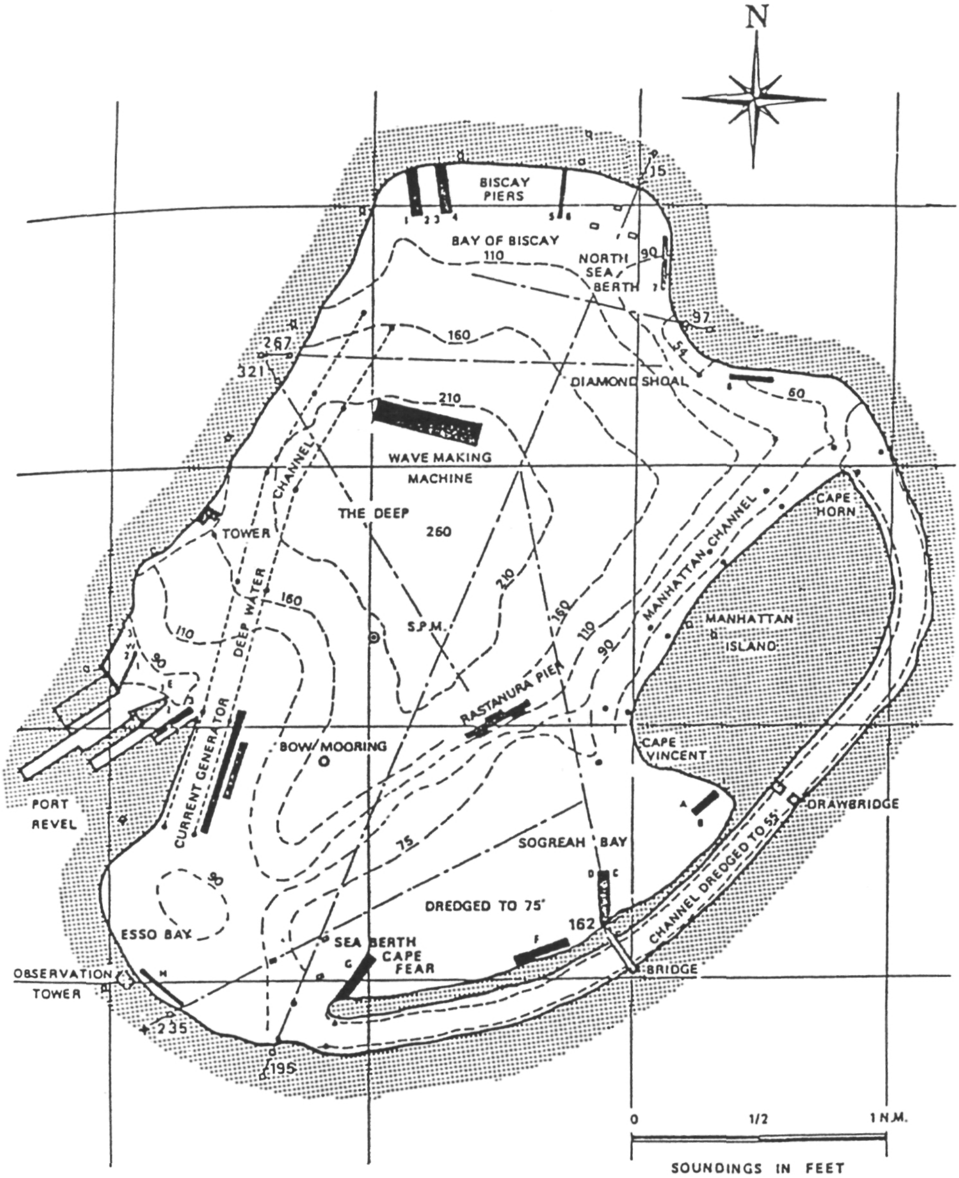


Fig. 13. – The lake at Port Revel, Grenoble (SOGREAH, France).

It is obvious that, in order to respect the law of similitude, a contracted time scale is to be applied when using scale models. Experience has indicated that this detracts little from the training, while it does enable one to perform more manœuvres in a specific time.

The 1970s saw the introduction of computer-steered simulators with visual display. Two shiphandling simulators were ready for commercial use in Holland by the latter half of 1971.

Computer-steered shiphandling simulators are very complex pieces of equipment, comprising – among other things – a simulated bridge, a projection system with screen, a control station for the instructor, and a central computer. The bridge is elaborately equipped with all instruments currently available for navigation as well as for manœuvring (fig. 14).

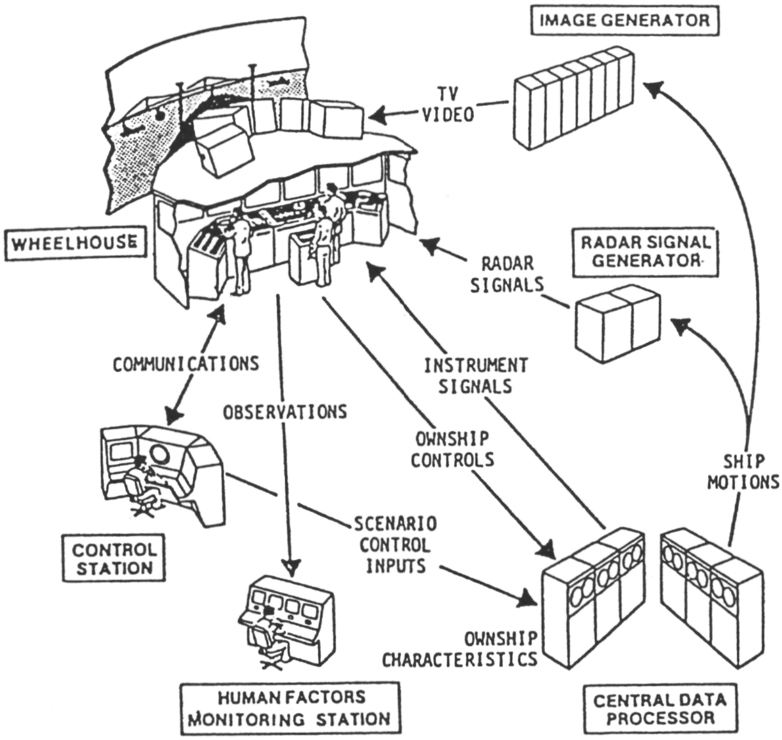


Fig. 14. – Computer-steered simulator.

Although simulators have their limitations (for example, the angle of view from the wheelhouse is sometimes limited to a certain number of degrees to starboard and to port), they can produce a very realistic interpretation of actual situations if, of course, sufficient information about the ship and the environment is fed into the computer. The information about the ships used during simulations can be very comprehensive. For instance, the results of spiral tests, turning circles, zig-zag tests, stopping manœuvres, stopping curves and deceleration curves, etc., for fully laden or ballasted ship, manœuvring in deep or shallow water, may be given.

Simulators also have great potential as a means of developing bridge discipline and a better understanding of the value of different instruments relative to circumstances and conditions.

The availability of pertinent manœuvring data of one's own ship is certainly of the utmost importance to the shiphandler. At the beginning of this century far less information was available on board for captains and officers. And even much later, after World War II, the information gathered during the ship's sea trials was very often rather scarce or unavailable to the mariner. As an example, in the "Sea trial results" booklet of one of the first so-called automated ships [27] only the following items could be found : speed, acceleration data, stopping distance and stopping time, turning circles over starboard and port for full-ahead speed, and steering gear tests. All these tests were carried out for the ship in ballast condition.

Fortunately, in the meantime, proposals that ships over a certain tonnage should keep a booklet on the bridge giving certain pertinent manœuvring data turned into a firm requirement by Governments.

On the 12th October 1971 the "Recommendation on information to be included in the manœuvring booklets" was adopted by IMCO, the Intergovernmental Maritime Consultative Organization.

Although the information required by IMCO was rather brief, this certainly marked an important step forward.

At present IMO, the International Maritime Organization, formerly IMCO, has prepared a new resolution [28] named "Recommendation for the Provision and Display of manœuvring information on board ships". This recommendation is divided into three parts, namely :

- display and graphs to be posted on the bridge [29] ;
- a pilot card to enhance communication between master and pilot [30] ;
- a detailed manœuvring information booklet for study by the master and navigation officers.

The information referred to in the above-mentioned IMO resolution, especially in the detailed manœuvring information booklet, is certainly abundant. Indeed, mariners find ample information on manœuvring characteristics of their ships for deep and shallow water navigation, such as : course change performance, turning circles, accelerating turns, yaw checking, man overboard and course deviation

[27] M.S. "Mokaria", Sea trial results, 1964.
[28] IMO, Resolution A.601 (15).
[29] See annex 1.
[30] See annex 2.

manœuvres, lateral thrusters capabilities, stopping capability, acceleration and deceleration performance, and so on.

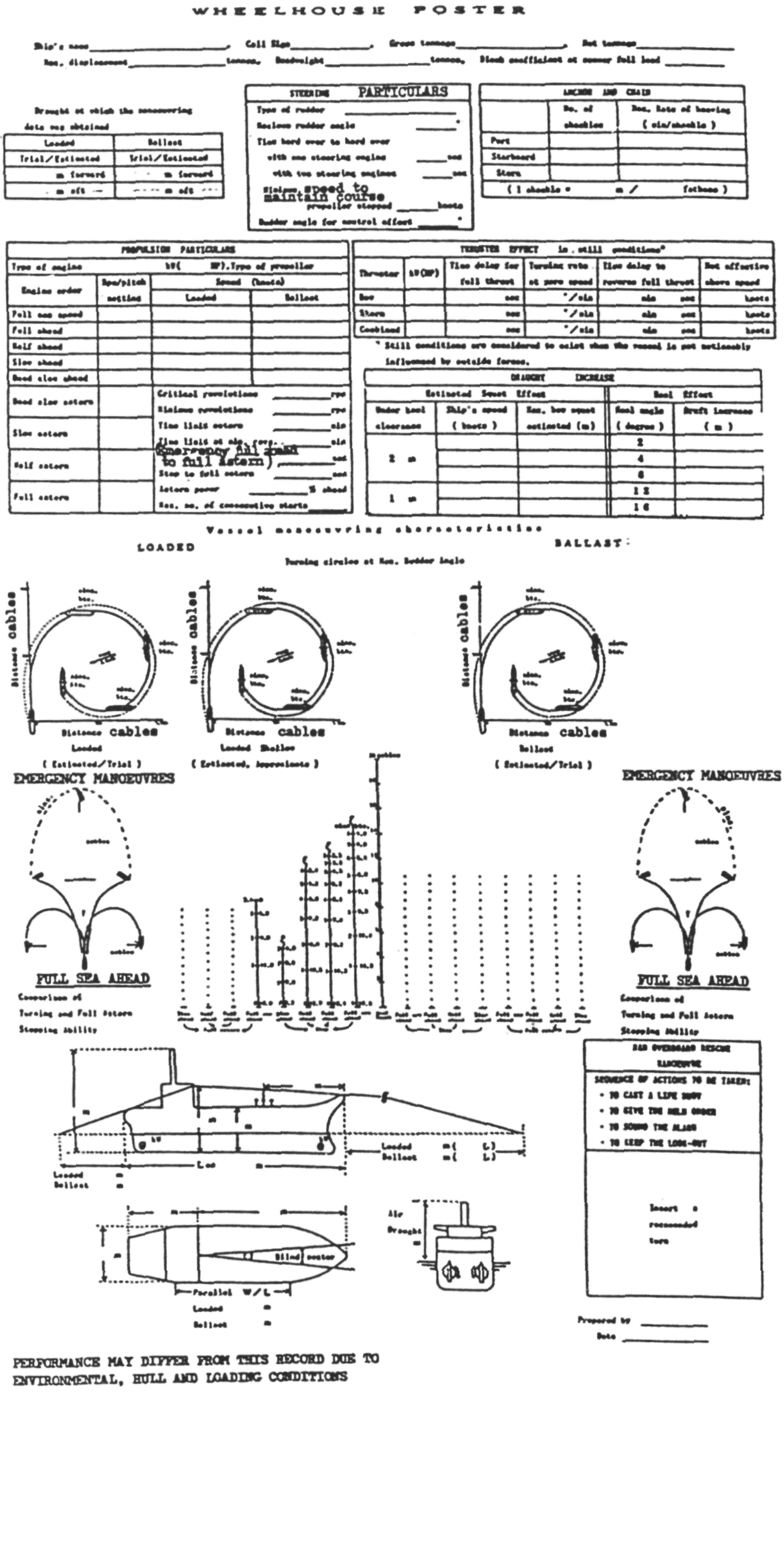
Undoubtedly there is also a great deal of benefit to be obtained in shiphandling by using information about one's own ship and the environment, supplied by the modern technological equipment available since the end of the second world war, such as radar, rate of turn indicators, doppler logs, doppler docking devices, etc.

The time available here today has not allowed me to make more than a very brief, and as I am well aware, incomplete review of the development in manœuvrability of merchant navy vessels during this century. Particular items such as braking devices for stopping especially big ships, rotating cylinder-rudders and other equipment and instruments have not even been mentioned. Nothing was said either about bridge design, bridge lay-out, which may certainly affect, albeit indirectly, the final behaviour of a ship.

Looking back and comparing the oldtimers at the beginning of this century with the modern ships of today, one can observe that, notwithstanding the increase in ship size, their manœuvring capabilities have improved enormously. Nevertheless, it is rather difficult to detect radical, revolutionary changes affecting the manœuvrability of merchant navy vessels that, at the time they were introduced, affected the ship's behaviour to any great extent.

We may conclude by saying that during this century manœuvrability has undergone a step-by-step evolution accumulating, of course, the improvements of the past, an evolution that has certainly accelerated since the fifties.

Annex 1.


WHEELHOUSE POSTER
PARTICULARS
speed to maintain course
Emergency full ahead to full astern
LOADED
BALLAST
cables
EMERGENCY MANOEUVRES
FULL SEA AHEAD
PERFORMANCE MAY DIFFER FROM THIS RECORD DUE TO
ENVIRONMENTAL, HULL AND LOADING CONDITIONS

Annex 2.

PILOT CARD

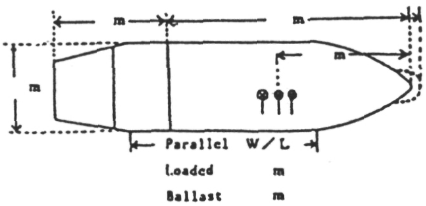
Date______________

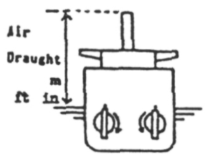
Ship's name / Call Sign ________ Deadweight__________tonnes Year built________

Draught Aft ______m. Forward ______m. Displacement __________tonnes

_____ft in _____ft in

SHIP'S PARTICULARS	
Length overall ________m.	Anchor chain : Port ______shackles, Starboard ______shackles,
Breadth ________m	Stern ______shackles
Bulbous bow Yes / No	(1 Shackle = ________m / ________fathoms)





Type of engine ______________________ Maximum power ________kw (________HP)

Manoeuvring Engine order	Rpm/pitch	Speed (knots)	
		Loaded	Ballast
Full ahead			
Half ahead			
Slow ahead			
Dead slow ahead			
Dead slow astern		Time limit astern	________min
Slow astern		Full ahead to full astern	________sec
Half astern		Max. consec. no. starts	________
Full astern		Minimum RPM ______rpm,	______knots
		Astern power	________% ahead

STEERING PARTICULARS
Type of rudder ____________, Maximum angle ______° , Hard-over to hard-over _____sec
Rudder angle for neutral effect ______°
Thruster : Bow ________kW(________HP), Stern ________kW(________HP)

CHECKED IF ABOARD AND READY

- Anchors [ ]
- Whistle [ ]
- Radar [ ] 3cm [ ] 10cm
- ARPA [ ]
- Speed log [ ] Doppler: Yes/No
  - Water speed [ ]
  - Ground speed [ ]
  - Dual-Axis [ ]
- Engine telegraphs [ ]

- Number of steering pumps operating [ ]
- Indicators : Rudder [ ]
  - Rpm/Pitch [ ]
  - Rate of Turn [ ]
- Compass System [ ]
- Constant Gyro Error ± _____°
- VHF [ ]
- Elec. Pos. Fix. System [ ]
  - Type ______________

OTHER INFORMATION :