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"HANDLING OF LARGE SHIPS"

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PREFACE.

This paper is composed of contributions, presented by:
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Most of section 5 was copied from Mr. F. Visée; see ref. [5].

Most of section 6 was copied from Mr. J.W. Oosterbaan and Ir. J.U. Brolsma; see ref. [7].

1. INTRODUCTION.

Handling of ships comprises all the actions needed to manage the ship dexterously and effectively from one destination to another (see for instance ref. [1]). With small boats all actions can be executed manually. When the dimensions of the ship increase, the number of people involved in the handling of the ship increase as much as the assistance of mechanical and electronical means. Also a separation of expertise among different people has been developed not only on board the ship, but to a larger extent among the people ashore, who are involved in assisting the crew on board the ship in directing her towards her destination. These increments of people and expertise are necessary both from an economical point of view, since greater attention has to be paid to prevent the loss of ship and cargo and from a safety point of view, since greater effort is needed to control larger ships.

The increased attention to the handling of larger ships also follows from the fact that the consequences of a collision or stranding can reach far beyond the interests of the owner, passengers, cargo or crew of the ship and that the environment and the safety of the community can also be affected.

In Fig. 1 and indication is given of the assistance which is given to the ship in addition to the commonly available means on board the ship.

Nowadays, even when navigating in the open ocean (see section 2) additional information can be provided from shore to determine the ship's position and to decide on the continuation of her voyage depending on the environment. This information refers to predicted meteorological conditions (wind, visibility etc.) and oceanographical conditions (seacurrent, waves, ice etc.). Sometimes the actual ship's position and the predicted environmental conditions are processed ashore, from which a routeing scheme can be advised to the ship [3].

When still sailing in the open ocean, information has to be sent to agents ashore about the ship's ETA (estimated time of arrival), so that arrangements can be made for all assistance the ship needs, when entering the port (pilot, tugs, berth etc.).

Entering constrained areas, additional assistance is needed again to handle the ship [4]. This assistance is provided by permanent means (decca system, lightships) and by momentary means especially adapted to the situation and the type of ship (information from shore about the traffic situation and the hydrological and meteorological conditions). In very congested areas a sea pilot is taken aboard.

In the area just outside the harbour entrance, very much attention has to be paid to bring the ship in such a position that she can be directed safely into the harbour [24]. This mostly requires a careful adjustment of the velocity, because at too high speeds it often will become difficult to stop the ship inside the harbour, while enough speed is required during the harbour approach manoeuvre in order to keep the ship controllable. Besides the velocity, also the time at which the ship passes the breakwater has to be chosen appropriately with respect to the current and water depth.

When sailing inland, the seagoing vessels will meet and mix with inland traffic [5]. In this stage the ship often is assisted more or less continuously by radio telephone from shorebased radar-stations. It will be obvious that the lay-out of the harbour very much determines the assistance needed by the ship for a safe passage [28].

When the ship approaches her berth [7], tug-assistance is required during the stopping and berthing procedure. Sometimes adequate means are installed in the ship (lateral thrusters) to replace or complement tugs. Sometimes shore-based instruments are available to indicate the lateral speed of the ship's bow and stern when nearing the berth.

For the very large ships the actions involved in ship handling as described so far, need special attention with respect to both the technical characteristics of ship and harbour facilities and the human capabilities. In some cases ships are so large that they are not able to enter the port [8], [9]. In other cases the controllability of a very large ship during some phases of her voyage is largely affected by human limitations both from a physiological and a psychological point of view [10], [11]. In this aspect it should be noted that yet very little is known about the human behaviour [12], when controlling slowly moving objects [13].

With respect to the control of a ship, as schematically indicated in Figure 2, one can discern that human actions are performed on two levels.

The first is a level of thinking and deciding about the general manoeuvring plan. The actions on this level will lead to commands or instructions as to the method in which a manoeuvre will be executed (predesired manoeuvre). These actions are to be considered as the input (commands) for instance for a desired manoeuvre with respect to time and speed to enter a harbour (reference manoeuvre or reference track).

The second level of human actions contains the detailed actions for the execution of the manoeuvring plan. Some of the actions to control the ship according to the commands are more or less routine. In those cases human actions sometimes are substituted by mechanical or electronical automatic servo-systems (for instance, when sailing in the open ocean, the automatic pilot substitutes a helmsman).

The same considerations about this differentiation in human actions play a role in the design of waterways [6].

2. NAVIGATION IN THE OPEN OCEAN.

Navigation could be indicated as one of the basic tools to accomplish the operational task of the safe and expeditious movement of passengers and goods or to fulfil military ends or recreational purposes (see ref. [15]).

In the history of marine transportation this task has undergone a considerable evolution from a rather uncomplicated effort (involving the moving of a simple craft from one location to another) to the complicated handling of a highly technical object, being part of a mass transport system over sea.

In this context navigation has also developed from the art of finding the way and avoiding natural hazards in areas of sparse traffic into the technology of perception, assessment and decision-making with the aid of a diversity of electronic equipment.

Today's navigation is directed both at the efficient movement of a vessel within an economic time schedule and at its safety; it finds its crucial problems in the handling of ships in poor visibility in dense traffic areas with multiple interactions between ships.

In this paper navigation and its legal aspects will be discussed with a special view to the very large vessels and for that purpose a further specification of matters which are connected with the safety of navigation is necessary.

As has been mentioned before, navigation should serve the safe and expeditious movement of ships.
It includes:
- determination of ship's position,
- selecting of adequate course and speed,
- avoiding of collisions,

whereby due regard is to be given to the internal factors (ship's characteristics and human abilities) as well as to the external factors (local conditions, traffic, weather, visibility, currents, regulations, etc.).

In the above description, navigation is still regarded to serve the safety of the ship itself and of what is transported in it.

However, several marine incidents (the stranding of "Torrey Canyon" in 1967)led to the general awareness that the consequences of collisions and strandings could reach far beyond the interests of the owner, passengers, cargo or crew of the ship and that the environment and the safety of the community could also be affected. With special regard to that aspect many additional regulations and recommendations have been brought into life concerning design and equipment of ships, the prevention of collisions and the separation of traffic, as well as the training and education of crew. To determine the optimal route of a ship it is necessary to have a proper system of position fixing and also a thorough knowledge of the oceanographic and hydrographic conditions of the area which is to be traversed.

A particular technique of route selection is used in the so called weather-routeing of ships. Based on predictions of weather conditions and sea-state the most agreeable route is selected, which will not be - a priori - the shortest way in distance, but more a route of minimum time-loss and least chance of damage to ship and cargo.

Since ancient times ship's positions at sea have been determined by solar and astronomic observation or by soundings and, when in sight of land, by bearings of well defined points. Gradually modern techniques have come into use, such as radio beacons of which bearings could be taken by means of a radio receiver and direction finder aboard ship.

In a more recent stage sophisticated electronic systems followed, such as Decca, Loran and Omega and, very recently, navigation by satellites. Though radar could also be used for this purpose, its relatively short range (approximate 40 miles) and its problems of discrimination and identification at those ranges makes it a less effective aid for long range navigation.

The accuracy of the found position increased with the above developments and, as a main advantage, the systems were independent from weather conditions. The determination of the optimal route could thus be based on a better knowledge of position together with a sufficiently detailed knowledge of meteorological and oceanographic conditions. The system of avoiding adverse weather and sea conditions by deviation from the original course, developed into the set-up of a choice of several alternative routes. The variation in alternatives increased considerably, when a better use could be made of modern ship's speed and engine capacities. Moreover, costs caused by delays reached such a level that even minor improvements in cutting the duration of a voyage were profitable.

In clear weather the process of collision avoidance at sea is based on visual information and the application of the International Regulations for Preventing Collisions at Sea (Rules of the Road). In restricted visibility one has to rely on radar information and sound signals, whilst the Rules of the Road confine themselves to instructions on speed reduction, listening and cautious manoeuvres.

For the very large vessels the parameters of stopping distance and turning circle play a very important role in the required manoeuvres [16] and it seems that in the present development towards the half-million tons vessel, these parameters will eliminate to some extent the increase in safety, which is inherent to the use of large vessels. The last mentioned thesis is based on theoretical grounds and on experiments with mathematical models of free moving traffic.

It appears that the rate of collisions in a given situation is proportional to (see ref. [17]):

1. the square of the density of ships;
2. the average relative speed between ships;
3. the average size of the ships involved, which is connected with the apparent dimension of the ship as seen under the angle of approach (aspect).

Though marine traffic, especially in confined areas will rather be seen as traffic flows, than as a free moving group of vessels, the above principles still apply in substance. Taking into account the above relation between rate of collisions and density, the subject thesis could be based on the fact that the transportation of a certain amount of cargo by large vessels instead of small ones, will diminish the density of ships progressively and that the subsequent increase of the average size of ships will not weigh against the effected decrease in density. However, in this calculation no consideration is given to the fact that the human behaviour and the ship's manoeuvrability could be subject to severe deterioration with an increase in the ship's size and, as is said before, this could eliminate the achieved improvement. The manoeuvrability is further restricted, if the large vessel travels through an open sea area, where she is constrained by her draught because of the available depth of water.

All these facts brought to attention the need to arrange for special protection rules covering the very large vessels and indeed, at the last Conference on the Revision of the International Regulations for Preventing Collisions at Sea, rules were incorporated to provide for a certain privilege to vessels constrained in their draught.

The economic advantages of transportation with large vessels, the problem of finding sufficient capable people to man many small ships and the balance of the above described disadvantages and advantages still place the large vessel in a favourable position.

The chartlets in Fig. 3 and 4 give an impression of the distribution of global marine traffic at present and in the near future. It clearly indicates the existence of traffic flows and also the tendency of traffic to concentrate near coasts - especially N.W. European coasts. Still the chartlet does not show very clearly that the density of traffic in the English Channel, North Sea and Baltic is of a totally other magnitude than for example off the North West coast of Africa. In the first case interactions between ships occur continuously whilst in the latter case one could normally sail for hours without even having a vessel within a range of 15 miles or so.

Studies on marine accidents confirm this situation and it is found for instance that the waters from the Elbe to the western approaches of the English Channel account for over half the world's collisions. Of these casualties approximately 85 % occurred within 5 miles from the coast. Furthermore it must be stressed, that conditions of restricted visibility which have a high frequency in N.W. European waters, also contribute to this figure (see ref. [21] and [22]).

From the above it follows that the risk of casualties in open sea away from congested waters, is relatively small and navigation in these areas is mainly confined to proceeding along the most expeditious route.

Although perhaps the obvious has been proved with the above, there are also some other conclusions drawn from the subject study which throw a new light on the situation with large vessels, and will be dealt with in the next part of the paper.

3. NAVIGATION IN CONSTRAINED AREAS.

Ship traffic areas are considered to be constrained when the waterdepth is restricted relative to the ship's draught (chance of stranding) or the width is restricted relative to the traffic density (chance of collision).
Especially for the very large vessels the knowledge of hydrographic information and the related technical background becomes more important. Until a few decades ago waterdepths of over 20 metres (65 ft) were only considered to be of value in the context of determination of ship's position, selection of anchorage, fishing grounds etc. and not to be critical for ships in relation with their draught. This has changed entirely with the present draughts of 23 metres (75 ft) and more. Consequently, information on waterdepths of up to 30 metres ought to be surveyed carefully in view of possible marginal keelclearance; additionally more accurate tidal information is needed as well as a better knowledge of bottom changes, meteorological effects on the sea level etc. All these questions became urgent for areas where large vessels had to navigate.

In order to expedite matters the hydrographers concentrated their surveys first on specially selected routes where depths were investigated for deep draught vessels.
Besides the above hydrographic considerations there was also a growing need to allow some privilege to very large vessels travelling through dredged channels or surveyed routes i.e. that other ships should avoid to hamper these vessels.

Consultations about the above problem have initiated a new approach in the hydrographic and legal philosophy concerning deep draught vessels and resulted in a clarification of responsibilities with respect to hydrographical information.
The Intergovernmental Maritime Consultative Organization (IMCO) has played an important role in this matter and it has developed in close co-operation with the International Hydrographic Organization (IHC) the concept of "deep water route".

With respect to the navigation in constrained areas much of what

has been said on this subject in the foregoing section is also applicable to coastal waters. However, in these areas the short-range aids to navigation naturally receive more emphasis. These aids are buoyage, lights and short-range electronic aids (Decca). Moreover shipborne radar has developed into a nearly indispensable means for checking ship's positions relative to dangers to navigation, especially in restricted visibility. Also the assistance from shore-based radar stations is becoming a growing practice in congested areas (Dover Strait).
Where the determination of ship's positions in these areas seems to meet less problems, the question of finding the way appears to be increasingly difficult, especially in relation with available waterdepth needed for very large vessels.

In the "Survey of Marine Accidents with Particular Reference to Tankers" by C. Grimes [21], it was found that strandings made up for only 9.8% of all accidents in N.W. European waters, whilst a heavy preponderance of collisions exists. Historically it is interesting to note that at one time risk of stranding represented the major navigational hazard. With the advent of improved charts and better navigational equipment the major risk is now that of colliding with another ship rather than the sea bed. Nevertheless the survey comes to the tentative conclusion that for the over 100.000 dwt class one or two strandings a year in N.W. European could be expected (at 1970 traffic level).

Another interesting detail revealed by the survey is that though the casualty-figure for the world-wide tanker fleet showed a yearly increase over the period 1959-1968 that was proportional to the increase of the number of tankers, the N.W. European tanker casualties remained remarkably steady in number and, as a percentage, showed a gradual decrease.
Traffic separation systems had not been established until the last year of that period, so that the positive effects of these systems could not have been the reason behind this tendency.

It was also found that the over 100.000 dwt tanker showed a significant lower rate of collisions than the classes of smaller tankers. This could be explained by better equipment, highly trained crews and a relatively longer period at sea that larger tankers have. The fact that oil-transportation to Europe is mainly carried out by VLCC's gives ground to the believe that the lowering percentage of tanker casualties in N.W. European waters and the better records 100.000 dwt tankers have, are closely connected matters.

Evidently traffic separation and deep water routes have a very important influence on the handling of large vessels and because of the dominant role Dover Strait played in the development of these principles, it is useful to give the area a more detailed examination. The accompanying chartlet in Fig. 5 shows the actual situation. The traffic separation system shown, is the result of laborious preparation by the Institutes of Navigation in Great Britain, France and West Germany and after coming into effect of the scheme in June 1967 it has been subjected to various improvements. The principal aim of a traffic separation scheme is to separate traffic proceeding in opposite or nearly opposite directions by the use of a separation zone or line and to create traffic lanes inside which one-way traffic is established.
The use of traffic separation schemes is not compulsory; it is for ships' masters to decide after assessing the situation and circumstances whether or not to make use of them.
The general principles for the use of traffic separation schemes are carefully formulated by IMCO and are laid down in a recommendation. Additionally it is recommended to Administrations to make it an offence for ships under their flag to travel in the one-way lanes against the general direction of traffic flow. When the new Convention on the International Regulations for the Prevention of Collisions at Sea will come into force in 1976 or later, the general principles will also become binding by the regulations on the use of traffic separation systems of that Convention.

In the first stages of Dover Strait scheme there were several doubts about its effectiveness. The number of casualties did not show a clear decrease and from surveys in 1971 it appeared that from the approximate 300 ships actually passing Dover Strait each day 5 to 10% were contravening the principles of traffic separation ("rogue vessels"). However, it could be demonstrated that the rate of casualties "per hour of poor visibility" showed a fall of 20%.

Furthermore an improvement could be realized by a stringent system of surveillance and reporting of "rogue vessels" to their Administrations for subsequent actions.

As 52% of the collisions at present involve a ship travelling against the recommended direction, the results of the above improvements could be substantial. On the other hand it must be expected that in one-way traffic lanes, the rate of collisions resulting from overtaking situations will increase.

Together with the above surveillance system of reporting "rogue vessels" also an information system was developed by the bordering coastal states U.K. and France.
The necessity to support shipping in Dover Strait either by an advisory service or an information service arose from a tragic series of accidents in 1970 - the sinking of the Texaco Caribbean, the Niki and the Brandenburg. These accidents cost many lives. and caused loss of all three ships. Apart from these losses, considerable costs were involved in clearing wrecks. It was also clear, that the environment could easily be endangered by marine pollution, if one of the ships would have been a tanker carrying oil or noxious chemicals in bulk. Clearly the safety of the concerning coastal states gave further acceleration to the set-up of such a Service.

Since the traffic separation system lies mainly in international waters, outside the national jurisdictions of both countries, it was impossible to set up a traffic control system in this area without an international agreement. Matters of jurisdiction, but also of responsibility were important issues and finally both countries decided - in consultation with other coastal states, bordering the southern North Sea - to envisage the development of radar surveillance and information services in three phases, respectively to start in 1974, 1975 and 1976. In this service broadcasting will be provided simultaneously by U.K. and France of a purely informative nature, such as:

(I) movements of vessels contravening the rules of the traffic separation scheme;

(II) visibility reports;

(III) tows and hampered vessels;

(IV) other potential hazards and obstructions.

An essential part in the Dover Strait Scheme is the deep water route lying in the North Sea bound lane (see in Fig. 5 dotted line with arrow heads). The available searoom in the area between the banks of the southern North Sea did not allow for a separate deep water route and traffic lanes. Additionally it was impossible to find a safe route for vessels of over 17 metres draught south of the Sandettie Bank. Therefore a solution was found to allow deep draught vessels to pass north of the Sandettie Bank.

In order to keep normal through-traffic away from this route and also to prevent possible head-on encounters with ships proceeding in the nearby lane for south-west bound traffic, it was recommended that:

- the main traffic lane south-east of the Sandettie Bank shall be followed by all such vessels as can safely navigate therein having regard to their draught;
- vessels shall avoid overtaking in the deep water route.

In practice the safe draught for the main traffic lane is 17 metres. It is understood that the deep water route could be used by ships with a draught of 25 metres and over, if use is being made of high water during passage of the critical area. However, yet there is insufficient knowledge available about the instability of the sea bottom, the movement of bottom profiles (sand waves), the influence of meteorological effects (i.e. negative surge) and the accuracy of tidal information in open sea. These questions need prolonged observation and investigation.

At this moment three IMCO adopted deep water routes exist:

1. Deep water route off Sandettie Bank.
2. Deep water route leading to Europoort.
3. Deep water route from North Hinder to the German Bight.

These routes have much in common, but they differ in several important details:

a. As has been described, the Sandettie route is forming part of the north-east bound traffic lane of Dover Strait and consequently the principles of traffic separation schemes are applicable in this route.

b. The deep water route to Europoort is a dredged channel with a maintained depth. Questions about uncertainties of bottom configurations practically do not exist here, because of the very regular surveys and dredging operations.

c. The deep water route from North Hinder to German Bight originally was an area on which the Hydrographic Services concerned had agreed to concentrate their efforts for accurate surveys. On completion of the surveys the route as such was adopted by IMCO as a deep water route, but no other meaning was given to it than that its depth had been closely surveyed for deep draught ships.

Summarizing it could be said that the existing deep water routes fulfil the official IMCO definition, reading:
"Deep water route: A route in a designated area within definite limits which has been accurately surveyed for clearance of sea bottom and submerged obstacles to a minimum indicated depth of water", but that several minor differences exist.
Further IMCO recommendations are:
"A deep water route is primarily intended for use by ships which because of their draught in relation to the available depth of water in the area concerned, require the use of such a route"
and
"Through-traffic to which the above considerations does not apply should, if practicable, avoid following deep water routes".
The privilege for deep draught ships is not limited to the routes described above, but applies also whenever a ship navigates in an area, where she is constrained by her draught.

4. SHIP HANDLING IN HARBOUR APPROACHES.

The characteristics of traffic flow in the open sea differ from those in the proximity of a terminal, which by its nature imposes a congestion of shipping, a convergence of incoming traffic and a divergence of outgoing traffic (see ref. [23]). As it becomes more congested the inward traffic slows down, ships establish contact with their agents ashore, prepare to take on pilots and sometimes drop anchor awaiting further orders or better environmental conditions in which the harbour can be entered.

With respect to the safety of the ship and the capacity of the harbour the following aspects have to be considered:

- The hydraulic characteristics of the harbour (see ref. [24]);
- The hydrodynamic properties of the ship in restricted waterways [25], [26] and [27];
- The capacities of the navigational aids; see for instance the conferences of the International Association of Lighthouse Authorities and the International Association of Navigation Congresses [28] and [29];
- The clarity with which the harbour entrance presents itself to the navigator; for which knowledge about the human behaviour is needed with respect to man's physiological perception of the layout of the harbour and its aids;
- The psychological and physiological characteristics of ship operators in relation to navigation in the entrance and approach channels with the use of the navigational aids under varying circumstances.

With the advent of VLCC's an increasing number of situations have arisen whereby the approaches to existing harbours, which are situated in relatively shallow coastal areas, offer insufficient depth of water for the passage of these vessels. A compromise then must be found between the costs involved in deepening the fairway and the costs involved in additional navigational aids to make use of high tides (see ref. [28]). In the latter case improved pilotage techniques have to be developed (see ref. [30]).

For the admission of VLCC's sometimes also the hydraulic circumstances have to be improved. For this purpose the breakwaters have to be aligned in such a way that current patterns in front and inside the harbour mouth are realized which are favourable with respect to safe traffic (see ref. [31]) and to civil technical aspects (acceptable berthing areas inside the harbour).

With respect to the restrictions of the waterdepth and of the available width of lane for the VLCC's, it will become evident that, when considering the position of the ship, at each moment her operators must have very accurate information about the characteristics of the harbour layout and the environmental conditions at their disposition.

By supplying accurate data on real time basis about the depth of the sea bottom in combination with data about the instantaneously occurring waves, tides and wind in a suitable way for application on board, the handling of the ship can be carried out in a more rational and safer way. The question as to whether the sea is deep enough in a given ship-fairway situation depends among others on the actual ship's draught and whether it is on an even keel. As known the draught of the sailing ship increases due to squat and trim via a quadratic relationship with the ship's speed.
Furthermore when ship motions due to relatively long sea waves occur, the nature of this sinkage has an irregular character analogous to that of the wave motion. These ship motions depend on the prevailing sea state and the response of the ship to the waves. The ship-wave response is influenced by a lot of factors such as ship's form, wave directions, wave periods (type of energy spectra), etc. It will be obvious that, when the ship motions influence the overall strategy of entering the harbour, an accurate prediction of the ship motions dependent on the environmental conditions to be encountered, is much more important than the instantaneous registration on board the ship of the actual ship motions.
Moreover it may be expected that in shallow water the data of the echo-sounder on board the ship has a restricted accuracy.

In the approach of Rotterdam-Europoort two different systems of information presentation are installed; one with an accent on positioning; the other on information about hydro-meteo phenomena.

Both systems belong to an overall strategy to assure an effective approach manoeuvre for the big tanker and also for an effective use of the fairway. This so called hydro-meteo system will only be effective when continuous provisions can guarantee that the sea bottom will remain permanently at the same level.

In the following a description will be given of the services provided to the ship traffic in the approach to Hook of Holland.

Maintenance of fairway: The approach channel to Europoort has a length of about 18 miles and is dredged to a waterdepth over which 65' VLCC's can enter to-day while it is planned to increase the admissible draft to 68'. This channel is traced through megaripples as indicated in Fig. 6. The soundings of this area are performed by means of down looking sonar, while special arrangements for heave compensations are available on board the hydrographic launches.

Dredging in a harbour mouth or river needs special attention due to the existence of silt above the solid sublayer (being sand in the approach area to Europoort). In Fig. 7 an indication is presented of the density distribution of the silt in the approach channel.

With the use of a "normal" echo-sounder a bottom profile will be presented at some depth LT_1 which depends on the density of the silt and the frequency applied for the echo signal. It therefore will be obvious that the underkeel clearance as measured on board the ship will only be the clearance between the ship's bottom and the depth with some unknown density.

Since navigation is sometimes possible through silted water of a high density, it would be convenient when the possibility would exist that the data from the echo-sounder would also provide information on the density of the layer to which the echo signal was reflected.

Further studies are considered nowadays to determine the acceptable density of the silt through which ships can still sail safely.

Shore-based position information: As the approach route to Europoort

is partly situated beyond the range of lighthouses and other land marks a combination of systems, conventional and modern electronic equipment, has been applied [4].
A Decca Navigator Chain has been installed in the western part of Holland to provide accurate position fixing in the southern part of the North Sea, for normal navigation as well as for surveying, offshore investigations and other special purposes. The layout of the system is roughly indicated in Fig. 8.

The transmitter stations of the Holland Chain have been sited in precomputed positions. By doing so the system forms part of the navigational aids for the Europoort approach area.

It is well known, that the combination of a Master and a Slave station in a Decca Navigator System radiates a pattern of hyperbolic position lines. The midperpendicular of the base line (which is the line connecting the Master with the Slave station) is both a hyperbola and a straight line. By situating the transmitters in such a position, that the midperpendicular coincides with the centre-line of a channel, the latter one is marked by an electronic leading line, for the ship follows the centre-line as long as the decometer needle is kept steady on a fixed predetermined reading. This way of sailing through a channel is called for short the "homing lane" procedure.

In a Decca Navigator System all Slave transmissions are phase synchronized with the Master transmission, which implies that two Slave transmissions are also mutually phase synchronized. Consequently two Slave stations also radiate a pattern of hyperbolic position lines. It is evident that the midperpendicular of the Slave-Slave baseline can also be applied as an electronic leading line in the way described for a standard Decca pattern.

Following the homing lane principle, the Master and Red Slave station of the Holland Chain have been situated in such positions, that the midperpendicular of the red baseline coincides with the centre-line of the 82^{o}-30' "Eurogeul". By keeping the red decometer needle on a fixed predetermined reading (being F.0) the ship navigates along the centre-line of the fairway.

The distance along the line is indicated by the green pattern readings.

The centre-line of the "Maasgeul" is marked by the midperpendicular of the hyperbolic pattern, radiated by the combination of the Red and the Green Slave station. Therefore the position of the Green Slave station has also been precomputed in order to fulfil this requirement. The distance along the track can be determined by observing either the red or the green pattern.

It is not possible to observe the hyperbolic pattern, radiated by two Slave stations, by making use of standard Decca Navigator receivers. For this purpose a special attachment to the Mark 21 and Mark 12 receiver has been designed.
The Slave-Slave pattern utilized for the Maasgeul is named a brown Decca pattern and consequently the special attachment is called the "Brown Box". It comprises three decometers, one for each individual, red, green and brown pattern.

Thus the Brown Box is required in order to be able to make use of the electronic leading line in the 112^{o} Maasgeul, provided by the brown Decca pattern (= combination Red/Green Slave).

A number of portable Brown Boxes is available for the Pilotage service to be utilized for deep draught ships, equipped with a Decca Mark 12 or Mark 21 receiver and not having their own Brown Box on board.

In the particular application of the Holland Chain the Master and Slave stations have been designed in such a way that control of all three stations from one control point is possible. No human intervention in the day-to-day running is needed. Using the transmission links the control system permits control action to be taken at each of the stations.
Selection and switching in of standby units and phase shifting adjustments can be carried out as necessary. In line with modern technology digitally coded messages are sent during the transmission period as control functions from the Master and the Slave stations.

In the Control-Centre three monitor survey receivers are installed with receiving aerials at different locations close to the operational area. Using three monitor-receivers guarantees a minimum of system-failures and avoids local influences on the transmitted patterns as observed at the monitor-aerial locations. Continuous registrating recorders give complete information on the behaviour of all patterns. In case corrections have to be applied because one of the patterns has shifted this can be done in steps of 0.01 of a lane width by the operator at the control-desk.

During stability trials the Holland Chain proved to be stable within 0.01 of a lane width which indicates that it is an extremely accurate and valuable navigation system.
The estimated standard deviation as far as repeatability is concerned is for both patterns during Decca summerday 0.01 lane, during Decca winterday 0.02 lane and during night-periods 0.04 lane.

When nearing the coast essential information for the ship operator on the bridge, with all the sophisticated instrumentation, is presented by the outside scenery. Sometimes even more accurate information about the ship's position is obtained from the outside scenery than from the instruments. It will be important, however, that in any case the presentation of the harbour by means of the outside view from the bridge is sufficiently clear to the ship's operator. When approaching a harbour at night it sometimes is amazing, how experienced operators use effectively the lights that matter when a large number of lights is burning ashore. No regulations exist, as yet, to prevent the illumination of lights ashore which hinder the ship traffic.

Besides the lights needed for position identification, lights are also needed to illuminate the boundaries of the fairway and the obstacles in the fairway.

<u>Shore-based information about the environment</u>: In order to advise ship operators about the actual and the predicted hydrological and meteorological conditions, a hydro-meteo centre has been established in Hook of Holland. In this centre the estimated response of a

ship to these conditions is also calculated when needed for advice. The information presented by the hydro-meteo centre is used to prepare the strategy of when and how the ship will be navigated through the approach channel. Since a turn in the approach channel is not possible for the VLCC's, once they have started, it will be obvious that an accurate prediction of the sea and weather conditions is more important than the momentary conditions.

The choice of the ship's speed (propeller revolutions) is an important factor in preparing the navigation strategy. The speed will be adapted to the manoeuvring characteristics of the ship under the sailing conditions which occur instantaneously such as wind, cross currents, waves, other traffic and the geometry of the channel.

Taking in account the effect of squat, ship motions in waves, stability of the controlled ship etc. the choice of the ship's speed is also determined by the available "time window" in which a VLCC can make use of the approach channels (see Fig. 9). The time limits are caused by the vertical motion of the sea level due to tidal motion. The depth of the dredged channels is such that for this type of ships high water navigation is required. Within these time-restrictions "navigable ship speeds" are possible within the ranges of 5-6 knots up to 10-12 knots, depending on external conditions. In preparing the navigation strategy the pilot considers among others the tidal phase and the wave motion to assure the required keelclearances.

5. HANDLING OF SEA GOING VESSELS IN INLAND FAIRWAYS.

When sailing in inland fairways a sea going vessel will not only meet difficulties arising from the limitations of the fairway dimensions (see ref. [32] and [33]), but will also be hindered by the inland navigation [5].

Traffic in very important harbours comprises a great variety of types of both sea going and inland shipping. From the point of view of traffic handling technique the following types can be distinguished, all of which have special characteristics and as such may require special treatment:

a. ships which depend on the tide for passage;
b. ships with a length exceeding the width of the fairway, as, during a mechanical failure, they may block up the river;
c. special transports as oil-rigs, repair ships etc.;
d. maintenance craft as dredgers etc.;
e. push barges;
f. ships with certain dangerous cargoes;
g. recreation craft as yachts etc.

Several types of measures can be taken to improve the capacity (amount of traffic) of a fairway such as to keeping the bottom of the fairway at an acceptable level, to have at disposal a well experienced pilotage and to arrange adequate navigational aids. In some harbours additional information can be provided on request from a shore based radar station, while in others traffic control is managed from a traffic centre.

A quick turn around of the highly specialized ships, which operate at high costs, can only be ensured by very close and efficient co-operation, not only between the principal port authorities themselves, but also with shipping agents, firms operating tugs, the linesmen-organization, customs etc., all of course placed in the total shipping pattern.
It is for this reason, that in some harbours a Harbour Co-ordination Centre has been set up, in which the principal port authorities work closely together and where means are available, or in the process of installation, to ensure efficient co-operation with

"outside" organizations and agencies. In such a centre full advantage is taken of modern technology like computers and other advanced techniques. In this approach a term has been sought to encompass the total treatment of shipping, extending beyond the subject of traffic control, which in itself would only be part of it. In this respect the term "traffic management" has been introduced which terminology is being used in the traffic organization of the St. Lawrence Seaway, and which could be subdivided into the following separate items:

a. the co-ordination of all actions for the individual ship from the moment of departure from a foreign port until the moment of arrival in the port of destination;
b. pilotage procedure;
c. rendering assistance during passage;
d. passive traffic control;
e. active traffic control.

<u>Item a</u> This co-ordination comprises the total handling of the ship (including cargo) by all parties concerned; it is in fact an organization/administrative procedure on behalf of the individual ship against the background of the overall shipping pattern and this can be executed by a competent authority in which all interested parties are represented.

<u>Item b</u> The pilotage procedure is an important part of the treatment of the individual ship and as such of direct influence on the successful dealing with the traffic flow.

<u>Item c</u> With the heading "rendering assistance during passage" is meant furnishing advice and guidance in the form of position information and/or information of other traffic, which information may e.g. be derived from shore radar and other sources. This information is for the convenience of an individual ship in contrast with the meaning of traffic control, which deals with the handling of ships in direct relation to one another. The essential difference between assistance and traffic control is, that the first is an advice, which is not binding, while the latter gives directions, the obeyance of which in general is imperative.

<u>Item d</u> With "passive traffic control" is meant the issuing of written rules and regulations for the individual ship or

the movements of ships in relation to one another, in order to ensure more security. Examples are shipping laws, local by-laws, notices to mariners, ad-hoc rules issued for special situations etc. These rules and regulations can in principle only be given by competent authorities.

Item e With "active traffic control" is meant the issuing in verbal form of ad-hoc directions for a particular ship or part of the shipping, upon which should be reacted instantly.

Traffic control: In contrast with the items a, b and c of traffic management, which items are rather self-evident and which probably will provoke little discussion, the subject of "traffic control" is a hot topic of conversation in shipping circles. It is for this reason, that this subject will be dealt with in more detail.

Until a few years ago, there was little need to subject shipping to an active traffic control, as the intensity was not such that the safety was at stake without interference of the port authority. Each ship sailed "on its own" and the safety was guaranteed by strict adherence to the written rules and regulations. Since however, during the last years the shipping volume has increased while the cargoes carried add greater risk to the general safety, there is a growing necessity to introduce a certain regulation of the traffic flow. This is particularly so in those areas, where both elements, increased intensity and dangerous cargoes, are present. The extent, to which control must be exercised and the way in which it should be executed, will have to be chosen with the greatest care and will differ from area to area, may even be different inside such an area. Starting-point should be that a compromise should be found between two extremes: that is on one side absolute safety, which theoretically can be achieved by forbidding all shipping and on the other side a maximum use of the harbour facilities, which, it is true, will result in a maximum economic yield of the port, but which might well cause a free-for-all shipping flow. This contradictory tendency between safety and economic yield becomes even more apparent by the present development of shipping. On one hand the running costs of the bigger ships are so large that these can only be defrayed by the shortest possible turn-round. This will cause a greater burden on the shipping pattern and in the end might result in an increase of shipping intensity. On the other hand the cargoes carried require a more careful traffic treatment of these ships; for instance, the LNG ships are a typical example of ships, the cargo of which may have a direct influence on the accepted density of the shipping flow.

The aim should be, for the sake of the economy of the country, to shift the compromise as far as possible towards the maximum use of the port facilities without taking too much risk as far as the safety of ship and environment (in view of the cargo) is concerned.

Nevertheless, it is possible to come to meet the port economy to a great extent, with the same degree of safety, by an efficient handling of traffic, provided it is accepted that some standards, which up till now were normal practice, be revised. A typical example is the principle of "first come first served". If we are prepared to do away with it, and in actual practice it is done nowadays on several occasions, one can introduce an element which will benefit both economy and safety.

Although passive traffic control guarantees the safety to a great extent, it certainly does not give an answer to all situations. Even a more strict passive control is no solution, as it would begin to act as a brake and as such would be detrimental to the necessary flexibility. A smooth and safe handling of shipping can therefore only be achieved by the combination of active and passive traffic control, where the active part is complementary to the passive part or, when necessary or unavoidable, even superseding it.

The question now is, how an active traffic control should be executed, to what extent it should be carried through and what requirements are called for. An effective active traffic control can only be achieved, when the operator - the traffic controller - has a complete picture at his disposal of all traffic in his area, is sufficiently informed about the overall shipping situation and is in VHF communication with all ships in his area. When one of these factors is lacking, or partly lacking, an active traffic control might turn out to be unfeasible, or may only be possible to a limited extent. In the latter case it should be handled with greater care, which might imply that greater safety margins should be employed than originally foreseen. Undoubtedly the factor of VHF communication is the dominating and decisive element of active traffic control.

The next question, which turns up, is the extent to which the traffic controller can and is allowed to interfere in the running of the ship by the master or pilot. Under no account should the ship be run "from the shore" for the simple reason that it is impossible to judge from there the behaviour of the ship in the existing meteorological and nautical environment. However, the traffic controller should be adequately schooled to have a professional judgement, what a particular ship might be able to do, but even more what that ship will not be able to do under the existing circumstances. The success of an active traffic control is therefore in the first place dependent on the team-work between traffic controller and master/pilot. For reasons, explained before, it is quite unacceptable that the controller prescribes a manoeuvre which the ship must comply with notwithstanding the circumstance. On the contrary, the controller will ask the master/pilot to execute a manoeuvre, which considering his nautical background, is expected to be feasible without jeopardizing the safety of the ship. On the other hand - and this is most important - the master/pilot should inform the controller timely, when he considers the execution not feasible, so that the latter has sufficient time to adjust his contemplated traffic solution to the new situation. The co-operation is essential for a successful traffic control and it is considered of great importance that the various disciplines bring in a lot of understanding and insight in each others work and responsibilities; a process, which may take time, but which is not unsolvable.

As far as the possibilities for execution are concerned, active traffic control can be divided into three distinct parts:

a. density control (long term);
b. local control (short term);
c. group control (long/short term).

Dependent on the situation in a particular area, one part of the other, or perhaps preferably a combination, may be applicable. Black-white solutions should be avoided as the successful application is highly dependent on a flexible use. The controller should even not hesitate to abstain from any interference, if this is not strictly necessary.

Density control: In every port area there may be localities where a great traffic density at specific moments is undesirable, for instance at the time of departure of large ships from a harbour adjacent to the river. In that case certain ships in the traffic flow should be instructed timely to take greater distance from preceding ships in order to make room for the departing ships. This could also be done by instructing ships not to pass that particular harbour before or after a certain time or not draw near it during that time. The density can be influenced to a certain extent by the frequency in which pilots embark or by regulating the departure time; nevertheless control will have to be exercise during the passage in view of possible changing situations. It is obvious that density control has to take place over a longer period and this type of active traffic control will therefore encompass a larger area.

Local control: In certain areas, where undesirable traffic situations will occur regularly, it might be found necessary to regulate the traffic locally by a traffic controller. The extent to which and the manner in which this has to be done, will be dependent on the local situation. Factors, which could have an influence, are for instance, the geographical situation on the spot, the traffic density, the types of ships participating, the availability of patrol craft and the possibilities of communication.

Group control: When the number of ships taking part in the traffic is such, that individual VHF communication is virtually impossible, group control might be the only answer. In this case the ships are informed about the overall traffic situation in their area by means of a "running commentary" on VHF. By this means the ships as a group will be informed continuously about possible dangerous situations, but can also be given traffic directions as slowing down, keeping more to the starboard side etc.

In as far as directions are concerned this moderate way of active traffic control still differs from "rendering assistance during passage" as mentioned earlier.

6. THE DOCKING PROCEDURE OF A VLCC INSIDE A HARBOUR.

When approaching the berth the ship first has to slow down without the aids of tugboats [34] and [35]. During this procedure much attention has to be paid to a proper manoeuvring of the ship by means of continuously adjusted combinations of rudder angles and propeller revolutions [36].

When the ship then is in the vicinity of her berth, a good team-work between ship's crew, pilots, tugboats, linesmen and berthing-masters is needed for a safe docking procedure [7]. It is of utmost importance to limit the impact velocity of the ship with the berth, so that damages of ship and berth will be prevented [37] and [38].

A few incidents, which occurred with the docking of VLCC's have led to the set-up of instruments, providing additional information for the pilot, when approaching the jetty. The several types of measuring instruments and methods of data information can be divided into two groups, being ship-borne installations and shore-based installations.

The marine sonar-doppler navigation system is a ship-borne installation, which gives the captain nearly exact indications about the ship's movements in relation to the bottom (ground). Small displacements owing to current or wind influences can be recognized much more quickly and with greater reliability than the human eye is able to perceive by direct observation. This phenomenon may be of special interest in manoeuvring VLCC's at low speed in confined waters in the harbour approaches and harbour basins. Only early and accurate observation of these movements (in directions fore and aft, athwart and turning) may prevent incidents and accidents, which are sometimes described as "running out of control".

From an inquiry among pilots the following points should be noticed: Only a very small number of vessels is fitted out with the sonar-doppler system, so not much experience has been gained yet. A majority of the pilots (65%) is inclined to use the information provided, but does not have full confidence in the reliability (lack of experience). When the doppler-sonar is used during stopping manoeuvres, forward speed is the most desired datum, especially when shore recognition is difficult. During the actual berthing operation the sonar-doppler instrument is seldom looked at, as during that stage of the manoeuvre the pilot more or less situates himself on the wing of the bridge and the apparatus is to be found in the wheelhouse. Therefore by lack of sufficient experience it is not yet possible to deepen this subject any further and to draw conclusions.

The second kind of electronic device is shore-based and specially suited for the last phase of the berthing manoeuvre. With the help of Chevron, the Municipal Port Management of Rotterdam has analysed the print-out of 155 berthings with VLCC's during which use had been made of this device.

The system involved consists mainly of three components (Fig. 10):

1. a pair of transducers (echo-sounders)
2. an electronic cabinet
3. one or more velocity/distance indicators.

The transducers are electrostrictive leadzirconatetitanate ceramics, with a frequency of 210 kHz. The beam angle is 9° between the -3 dB points, which is a very sharp beam. Since the transducers are installed 10 m below the level at low water, propeller noise from tugs etc. is avoided. The suspension of the transducer should be done in such a way that the sensor is not influenced by movements of the jetty. The electronic cabinet consists of relays and switching unit, two processing units (one for each transducer) and a digital printer. The indicator consists of a 1.50 metre diameter clock dial and a kind of traffic light, on which the data can be read (one dial and light for the fore and another for the aft part of the vessel). The clock dial indicates the distance from the jetty, from 30 to 0 metre at 5 metre intervals. The dials are illuminated and explosion proof. The speed indicators consist of 3 coloured lights each, mounted at the side of the clock dials and 1 metre above them. The indicator set has to be installed in such a way that it is abreast the bridge, when the ship is moored.
The colour sequence is, as mentioned, identical to a traffic light,

green indicating safe speed, orange indicating critical speed and red unsafe speed. The speed limits can be adjusted.

From the inquiry among pilots it has been found that the additional information provided by this approach speed system is desirable, specially in difficult circumstances, for instance at night, in bad visibility or at ships with a bridge of which the wings do not cover the whole width.

It appeared that plotting on a logarithmic scale the percentage of exceedance of a certain jetty approach speed, the curve is found to be a straight line, which offers of course an excellent possibility for extrapolation. Fig. 11 gives an example of this phenomenon over the last 5 metres from the jetty. The same result, as obtained for other distances, is presented in Fig. 12. It is rather difficult to define the point of contact between ship and fender because of fluctuations in the final score of the print-out: distance can be negative by impressing the fender, but there can also remain some decimetres left between ship and fender. It is advised to count the velocity at 0.5 metre distance as contact speed. It is also possible to draw a diagram velocity versus distance. With the help of some simple calculations the deceleration then can be found. The relations between velocity, distance, time and deceleration are sketched in Fig. 13. The most interesting point is the sharp raise of the deceleration within 2 metres from the jetty, after being constant at wider distances. For example the line of 5%-exceeding shows a peak of 1.6×10^{-3} m/s^2, which means for a VLCC an exciting force of about 50 tf. During the docking procedure usually only two tugs are pulling (the other pushing). This means that 50 tf have to be delivered by two tugs, which in many cases will not be far from the maximum.

The above derived data were gathered from two jetties. Comparing both, a remarkable difference is noticeable. In general jetty 3 presents higher velocities (Fig. 14). The result fairly agrees with the pilots' opinions: 65% think there is a difference in the way of approach of No. 2 and No. 3, all pointing to No. 3 as less favourable. The reasons are said to be stronger current and (chiefly) the longer distance to be travelled athwartships in case of jetty 3 (the longer the distance, the more the danger of an inadmissible yet not noticed rise of velocity).

The question now arises which criterion can be derived to define a safe docking manoeuvre. It is of course a great risk to derive general rules from theoretical indications only, such as presented in Fig. 15, which is based on a 10%-exceeding acceptability. The way the measured velocities should be offered to the pilot is until now mainly based on intuition. The described system gives a simple, not confusing system of stationary velocity limits (Fig. 16), but there are indications that a combination of velocity and deceleration criteria might theoretically be the best solution. However, there is a strong indication that an optimum solution may only be found on the base of an ergonomical survey.

From the study performed it was concluded that in the last 5 metres of the approach to the jetty the two tug-boats (one forward and one aft) mainly determine the speed of that approach (or the deceleration). Therefore - depending on the maximum allowable speed of approach (and impact) of the jetty - the pulling power of the tugboats has to be determined.

The fendering system and the lay-out of a jetty define for a certain vessel the maximum allowable speed and angle of approach. A shore-based speed approach system does give the jetty owner the opportunity to convey to the captain of the vessel the optimal and critical ways of approach.

The "International Oil Tanker and Terminal Safety Guide - Chapter III point 3-4-3" may be quoted in this aspect:
"Precautions for mooring. The capacity of the fendering system to absorb energy will be limited. Masters, berthing masters and pilots should be made aware by the Terminal of the restrictions of the fendering systems and for what maximum displacements, approach velocity and angle of approach the berth has been designed".

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8. POSTSCRIPT.

In this paper only a slight indication has been given of several aspects which concern the handling of large ships. Some of these aspects are problematic, in which case great effort is made to solve the problems; see for instance the considerations about the manoeuvring characteristics of large ships in ref. [39]. It was beyond the scope of this paper to describe extensively the existing or still studied solutions of the various aspects, which deserve attention when considering the handling of large ships.

It also should be noted that for clearness only a limited number of references is presented while much more literature is available.

Also much literature is available about the technical contributions of the several disciplines involved in the overall package of handling large ships. These contributions refer to the following aspects:

- the inherent ability of the ship's hydrodynamic characteristics;
- the characteristics of the servo-mechanisms on board the ship;
- the characteristics of the additional navigational aids;
- the training and education of the crew;
- the psychological and physiological behaviour of man;
- the navigation systems;
- the weather forecast;
- the hydrographic and hydraulic characteristics of a harbour;
- the rules of the road and other regulations;
- the traffic control, including the systems mitigating the chance of collisions;
- simulation techniques of ship traffic to predict dangerous situations;
- the operation of tugs.

It will be obvious that a good co-ordination between these aspects will bring about a ship which can be handled properly (safe and fast). When quoting a pilot [30]:
"A ship can only be handled when she is designed to be handled".

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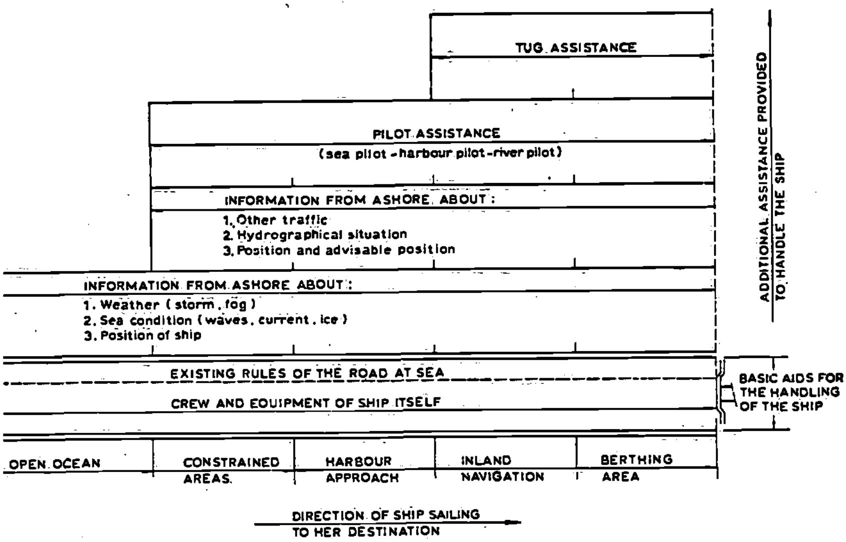

Fig. 1: Schematical review of the increased additional assistance from ashore in the handling of ships when approaching their berth.

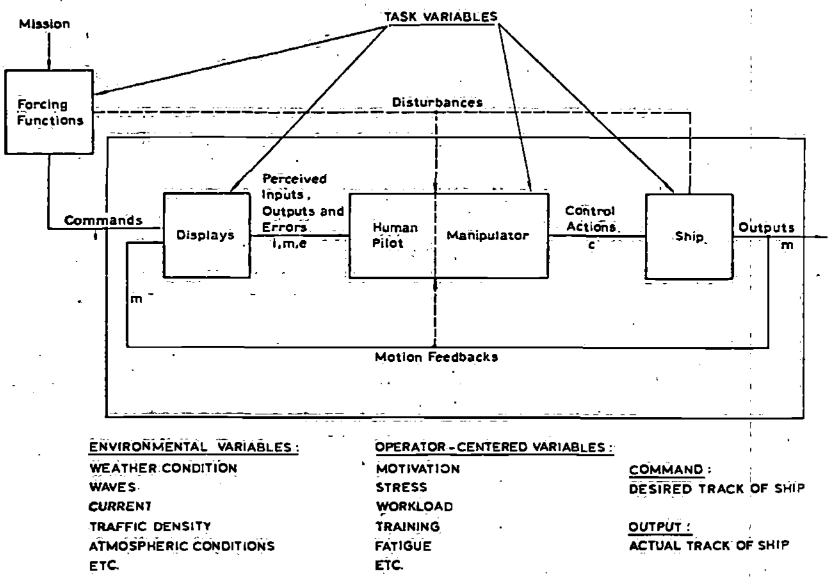

Fig. 2: Description of a controlled ship by means of a block diagram, according to ref. [14].

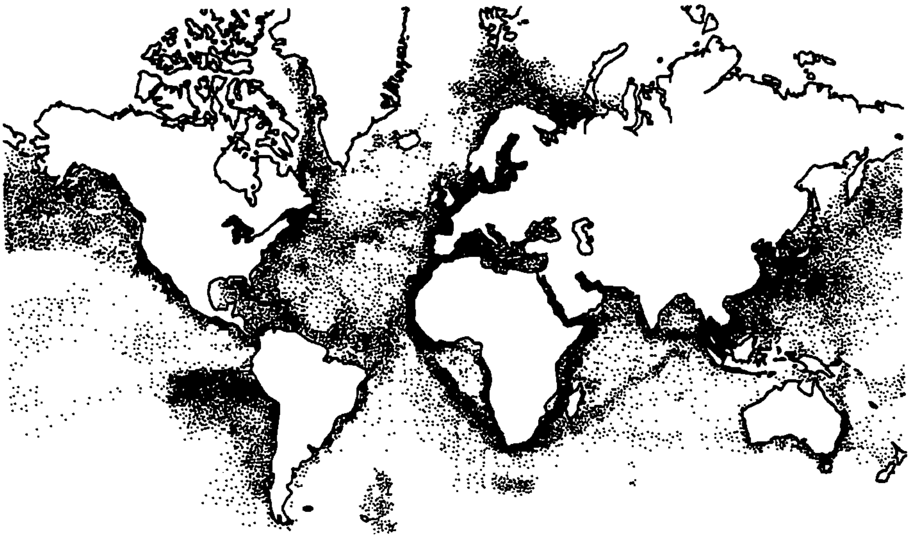

Fig. 3: Distribution of global marine traffic in 1969 according to ref. [20] .

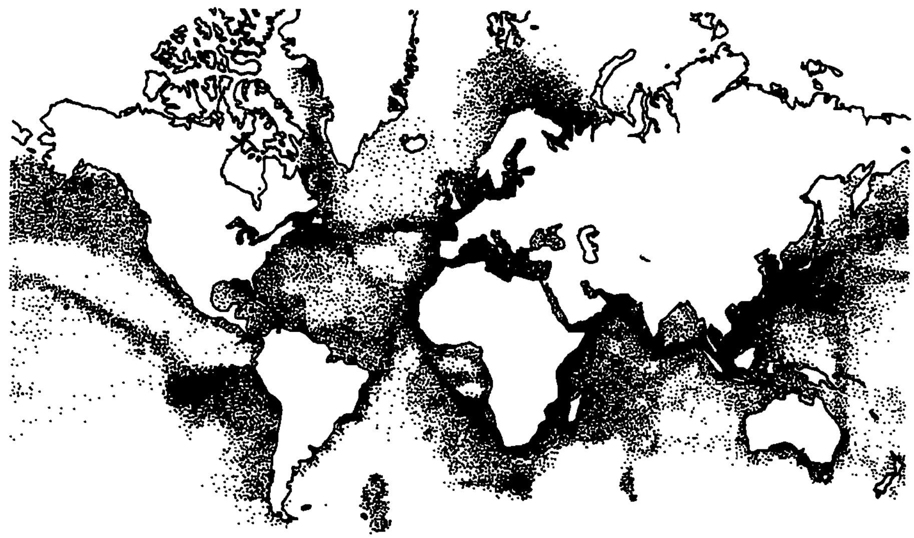

Fig. 4: Estimated distribution of global marine traffic in 1980 according to ref. [20] .

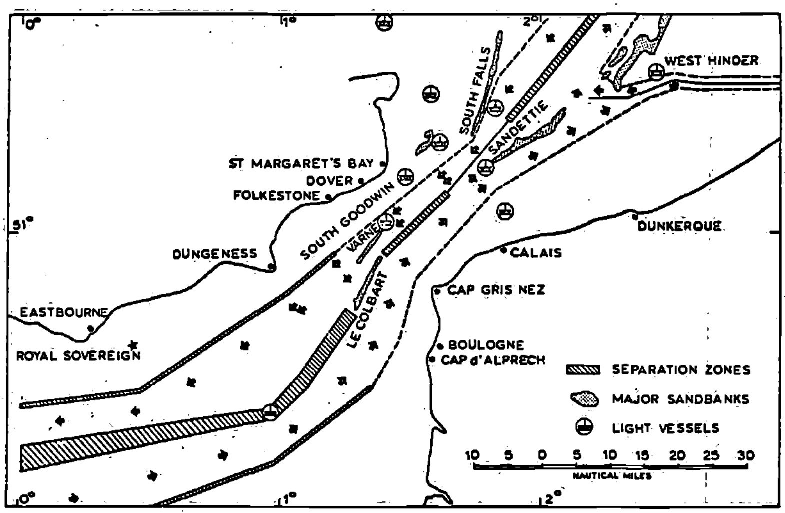

Fig. 5: Review of the traffic separation system for the Dover Strait.

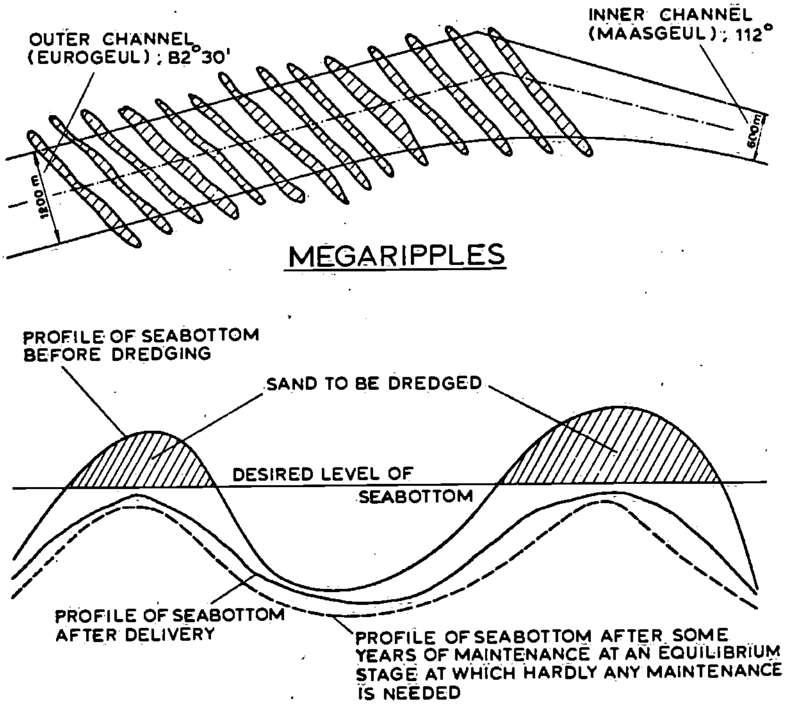

Fig. 6: Schematical indication of the megaripple area through which the approach channel to Europoort is dredged.

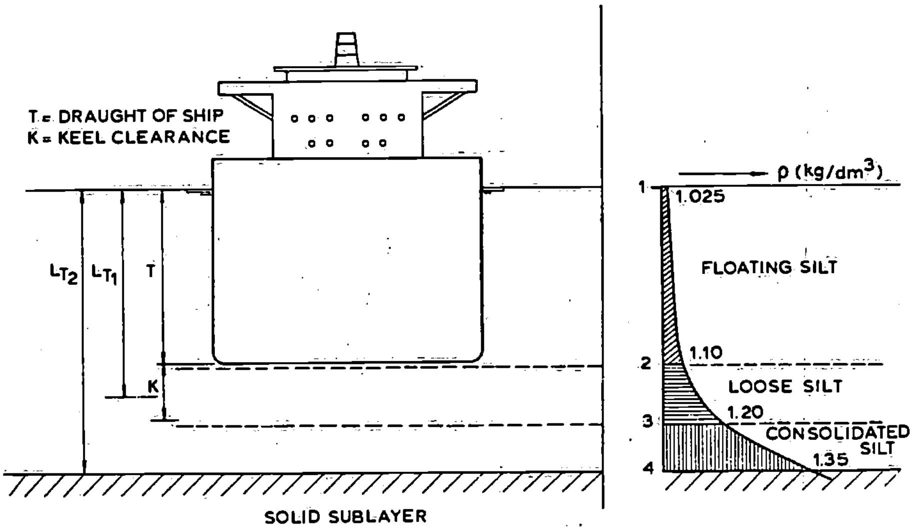

Fig. 7: Schematical indication of distribution of density of the silted water over the height of the water depth.

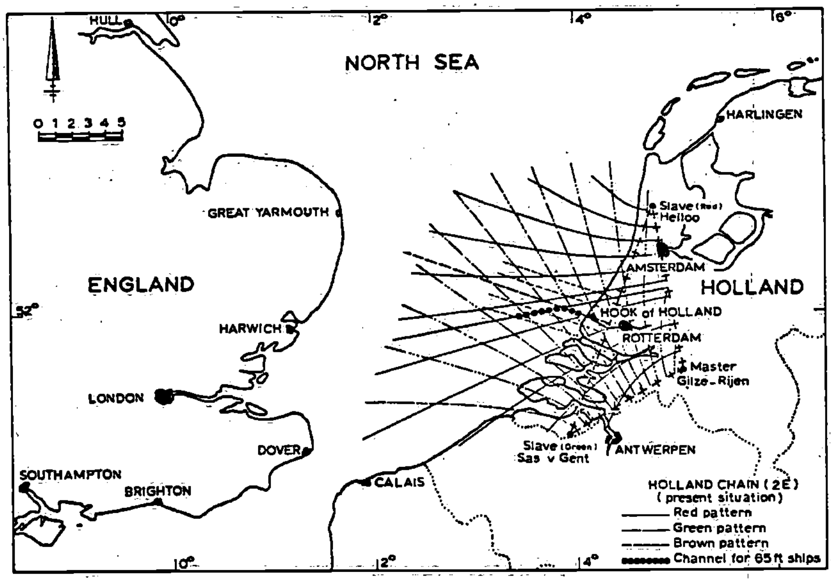

Fig. 8: Schematical indication of lay-out of Decca Navigator Holland Chain.

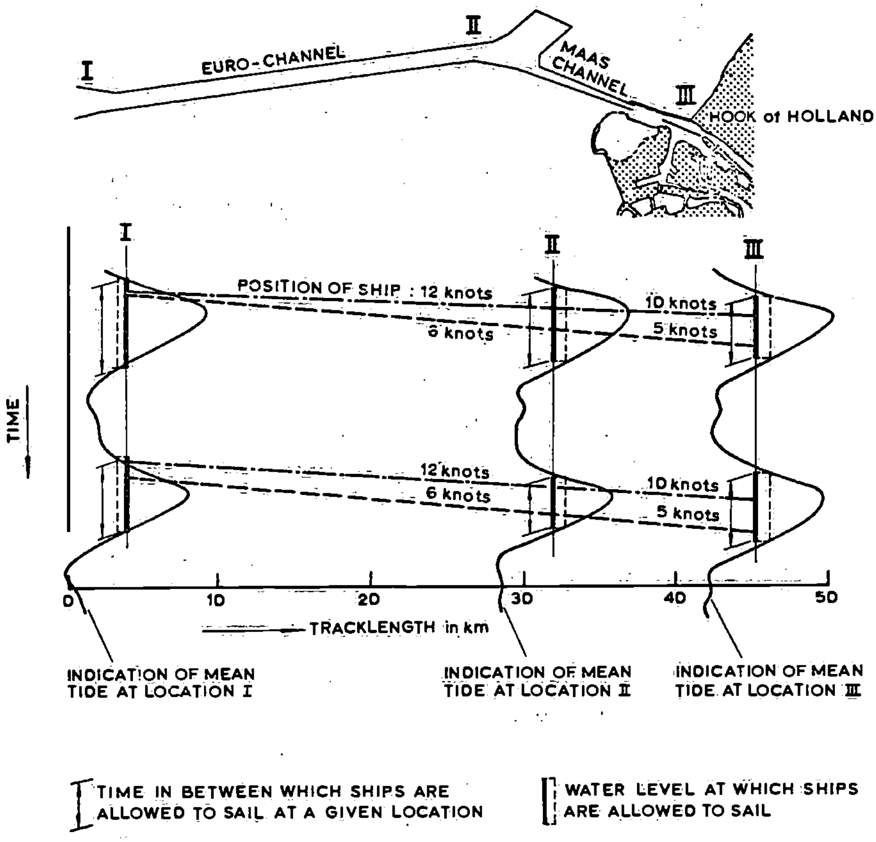

Fig. 9: Time window Europoort channels for 65' tankers (mean tide).

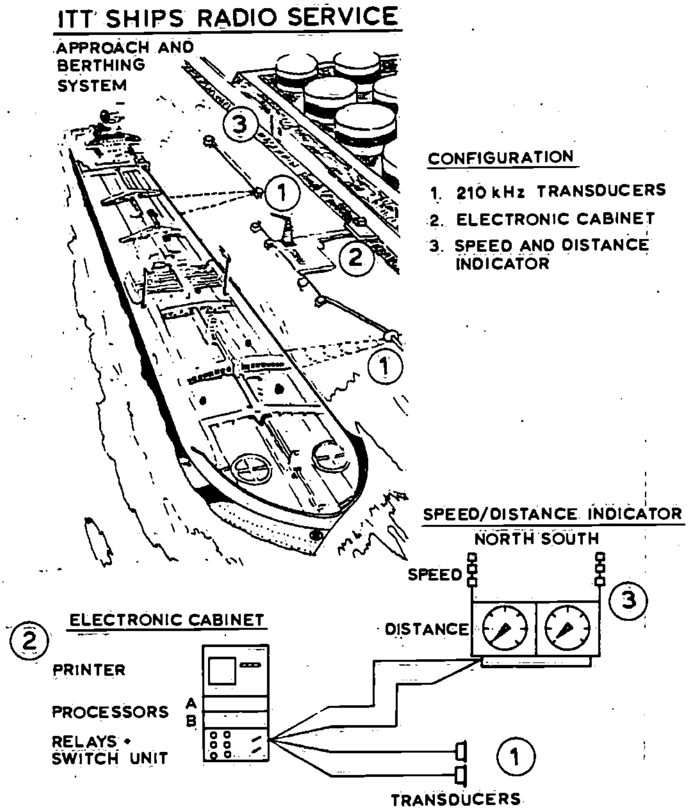

Fig. 10: Schematical indication of shore-based installation for determining the jetty-approach speed.

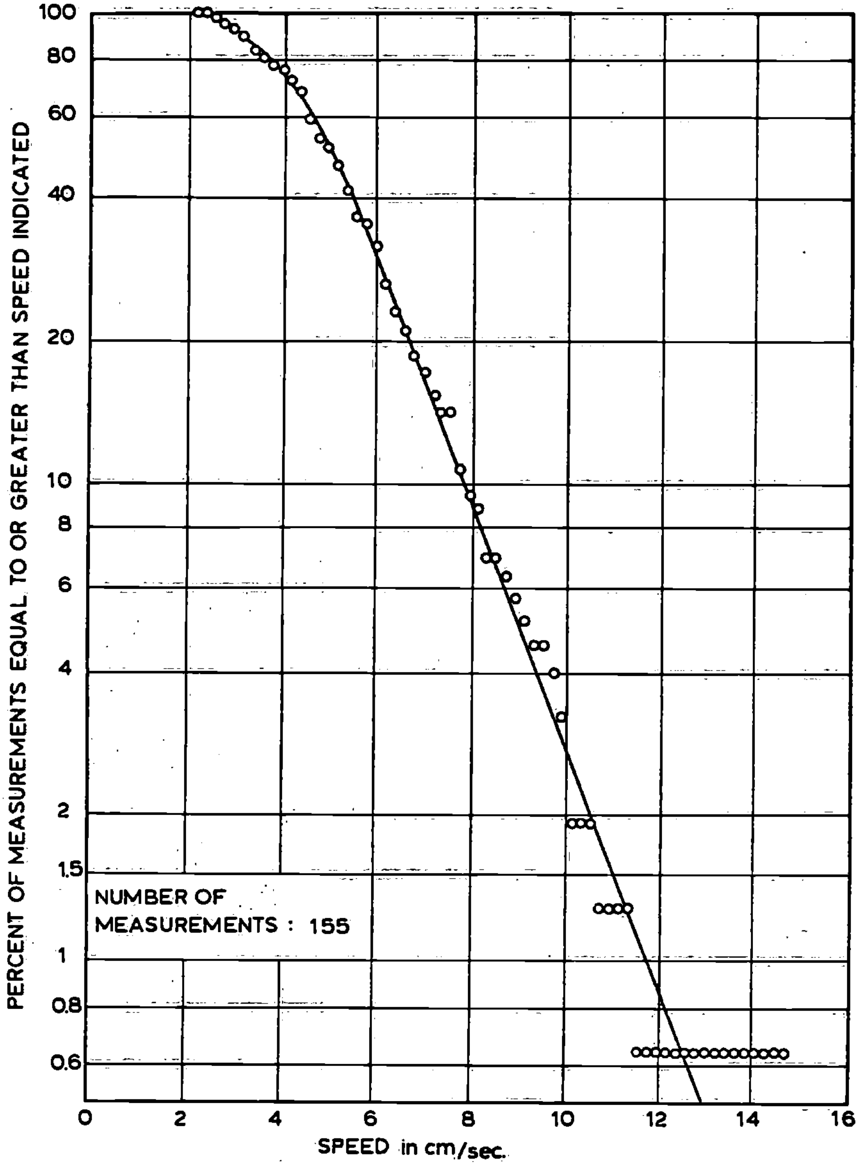

Fig. 11: Cumulative distribution of maximum jetty-approach speeds over last five metres from jetty, as a result of measurements during 155 docking manoeuvres.

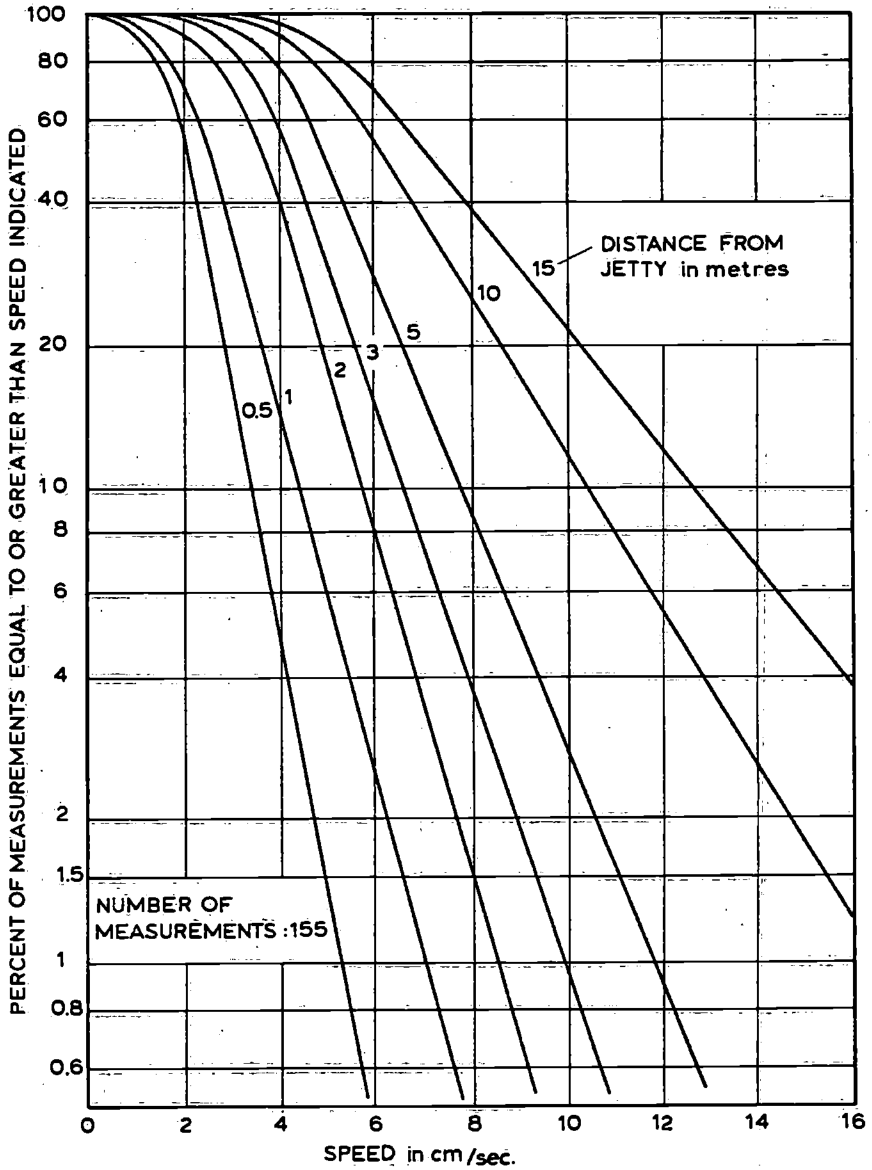

Fig. 12: Cumulative distribution of maximum jetty-approach speeds as a function of the range from the jetty over which the maximum speed was determined.

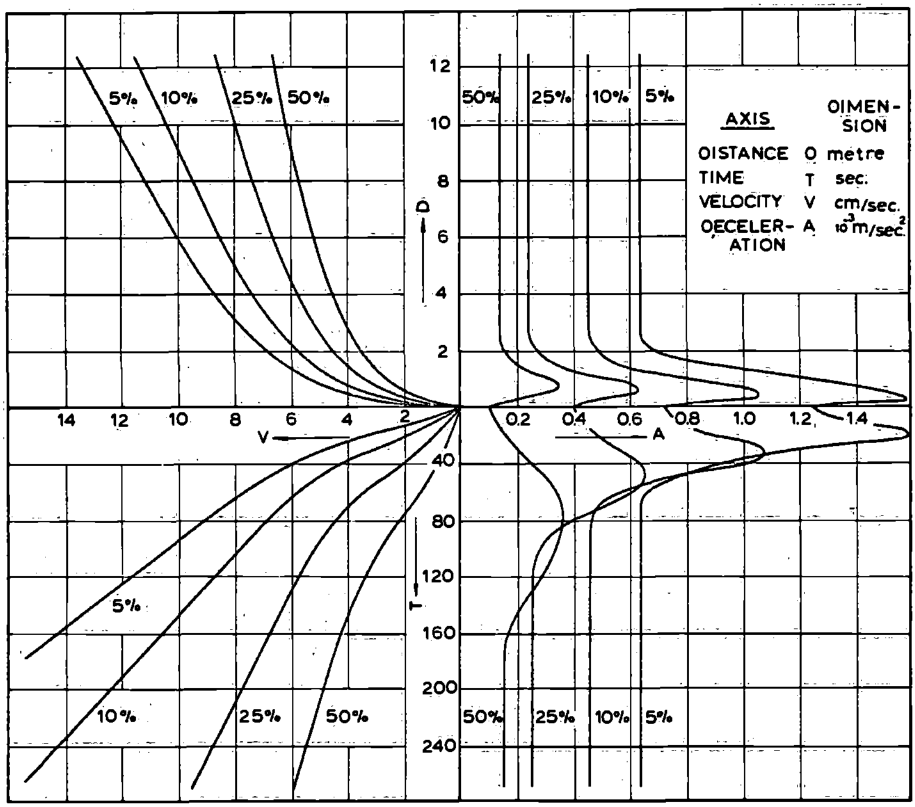

Fig. 13: Chance of exceeding a given jetty-approach speed or acceleration as a function of the distance from the jetty and the time before contacting the jetty.

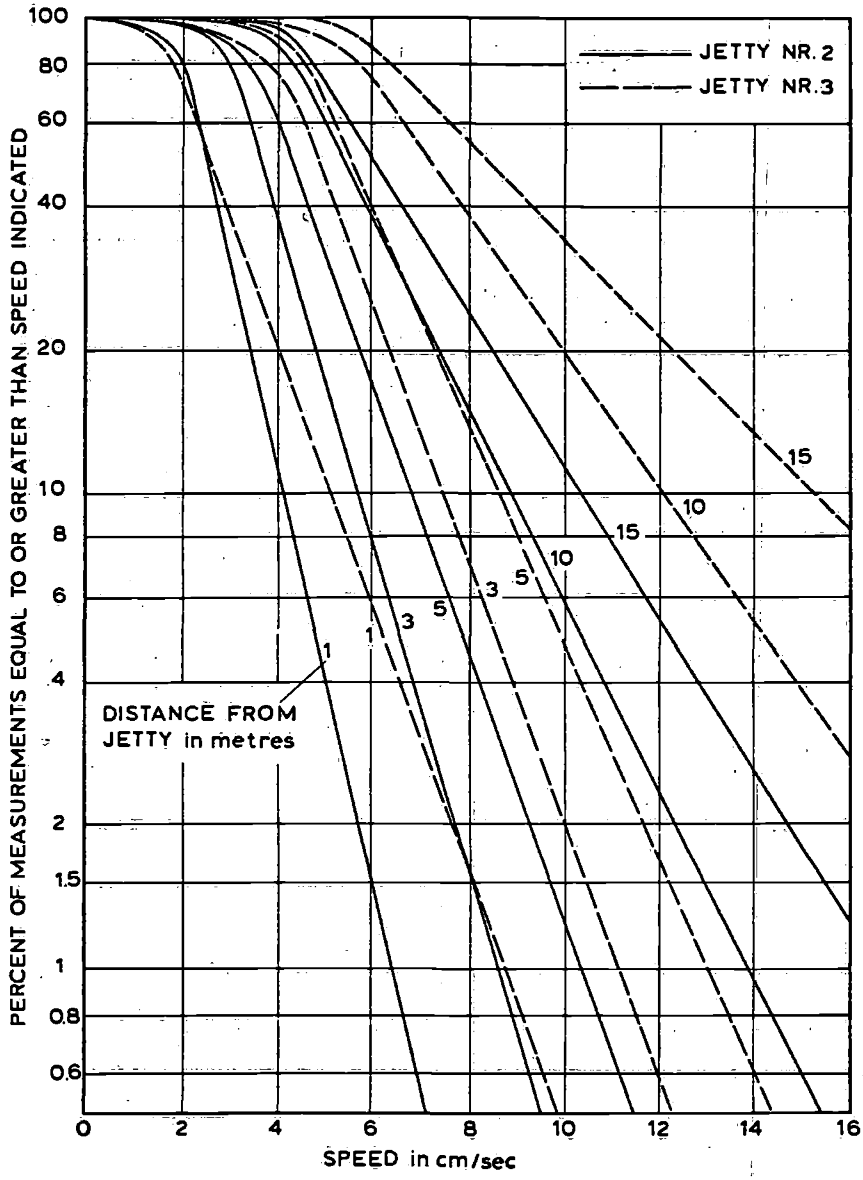

Fig. 14: Cumulative distribution of maximum jetty-approach speeds for two different jetties.

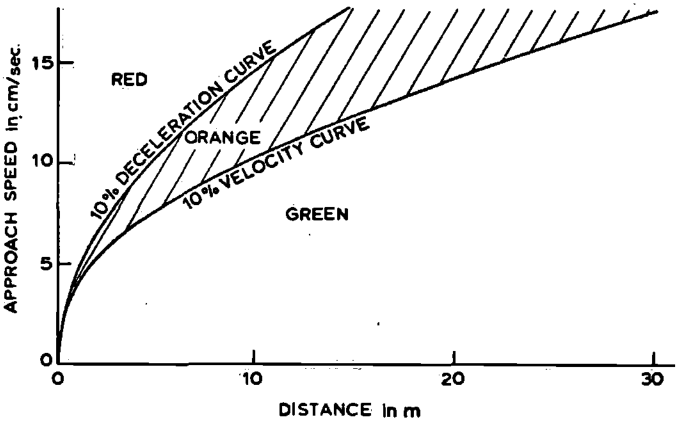

Fig. 15: Theoretical possibility of red- orange- and green indications about the safety of jetty-approach speed of the ship.

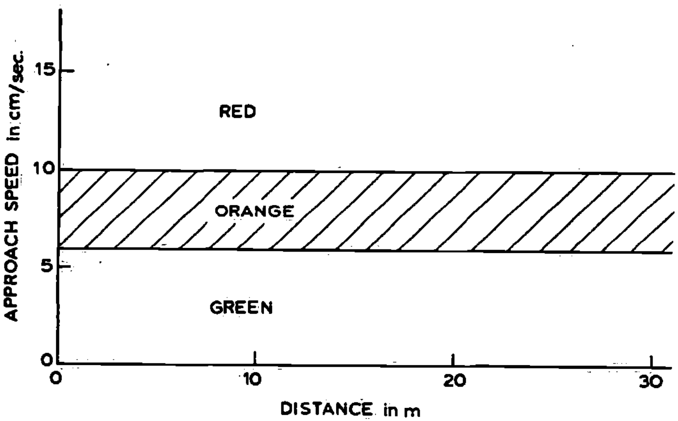

Fig. 16: Existing red- orange- and green indications about the jetty-approach speed of the ship.