

CONCERNING THE MARGINS BETWEEN THE DRAUGHTS OF SHIPS AND THE DEPTHS OF FAIRWAYS

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SUMMARY

The fast increase in the draughts of the merchant fleets of the world has caused many problems. This paper deals with the safe distance between ships' hulls and the sea bottom. It is here especially pointed out that the movements of a ship may cause a considerable momentary increase in its draught. A working group has been organized in Sweden to study this tangle of problems, which are largely correlated.

The margin (the difference between the water depth and the draught of a ship at low speed in calm water) when passing a shallow area or a threshold may be divided into two categories, "normal margin" and "extra margin". The normal margin calls for exterior conditions, such as sea level, wind pressure, waves, etc., to be "normal". The normal margin is, however, influenced by speed which causes the squat-effect, and which may sometimes be dangerous. Furthermore the normal margin should be based on the assumption that the surveys on the shallowest parts of the fairways are accurately checked, with bar-sweeping for example. When abnormal conditions exist, *extra margins* should be added to the normal margins.

Both the normal margins and the extra margins have been largely based on so-called "experience". In so far as such margins have above all an influence on the safety of navigation, this might be acceptable.

The fast increase in draughts and the increasingly high construction and dredging costs mean that the margins are of great economic importance. Moreover, the limitation in allowable draught for a harbour has a great influence on shipping and port economy.

This paper discusses how "experience" may be substituted by "real knowledge" based on studies, experiments, etc. The various influencing factors are treated one by one.

The limited activity of the working group up to November 1964 is reported, as well as its present plans. The paper ends with a recommendation to increase research in this field and to promote international cooperation. The need to keep ships' officers informed about these problems is stressed.

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The development in shipping economy has caused, and is still causing, a rather fast increase in the size of ships and consequently in the maximum draught. This applies to the traffic in certain trades as well as to the shipping fleets of the world in general. In shipping economy analysis the mean size of ships is often used but then certain deviations around this mean value must be taken into account. As regards fairways and harbours, as well as shipping safety, interest is concentrated not on the mean size but on the maximum size, as this gives the required depth for the fairways. The simplest way to tackle this problem is, of course, to stick to a certain maximum value for a harbour or a fairway and not to try to compromise in order to allow the greater draughts desired by shipping interests. The consequence will, however, be that the choice is then limited to a smaller group of ships. This will most certainly have negative economic consequences. In reality shipping and harbour authorities, as well as pilots and indirectly the responsible ships' officers also, will unofficially be asked to compromise. No doubt every day many such unofficial reductions of the margins are accepted under pressure from economic interests.

The increase in ship dimensions has caused a lot of problems regarding strength which basically have been solved by naval architects. Naturally development continues in this complicated field. It should also be mentioned that there is a certain trend, when designing mammoth tankers, to decrease the width and to increase the moulded depth of those ships, with the resulting inconvenience of increased draught.

Civil engineers have solved the primary technical problems at the terminals, problems caused by the increase in ship dimensions, but of course this trend continues.

Economists have focussed their attention on the optimum cargo size, the economic dimensions of storage space in ports, as well as on variations in storage expenses. Even if economic analysis points to a rather limited optimum size for a certain type of transport to a certain area, the shipping situation must be realistically considered and competition between various shipping firms, as well as the occasional availability of ships larger than the optimum size, must be taken into account. It may be quite reasonable to use such ships in isolated cases. Moreover rapid economic development quickly changes basic factors, and experience shows that there are certain difficulties in making accurate prognoses even for a period of 5 to 10 years.

Between the high seas and the port terminals there are, as is well known, shallow areas which are a hindrance to shipping over a certain draught. These shallow areas may either be situated close to ports, in entrance channels or in approach areas, or they may constitute thresholds between regions of the high seas. The shoals may even occur as isolated cases in the open sea obliging deep-draught shipping to make fairly long detours to avoid them.

If shipping over such shallow areas or shoals is to be regarded as acceptable, safety measures call for a certain margin between the bottom of the ship's hull and the sea bottom. This consideration and the size of this margin have an influence on the following problems :

1. What accuracy is required for information regarding depth on charts ?
2. What maximum draught should be allowed under normal conditions for a particular fairway ?
3. What extra margins are called for under abnormal conditions ?
4. To what extent should a fairway be cleared or dredged in order to allow a certain maximum draught ?
5. From the economic point of view, what probability of delays whilst waiting for "normal" conditions can be accepted ?

These five problems must all be discussed from both the safety and the economic point of view. If the analysis is confined to the point of view of safety alone, it is easy to choose such large "safe" margins that even "normal abnormal" conditions do not call for special measures. Such a far-fetched standpoint is, however, very uneconomical and could even cause a harbour or an industry to become strangled. It is quite obvious that safety must not be disregarded, but decisions about the size of the margin should be based on *real knowledge* and special measures be prescribed when abnormal conditions exist. At worst these special measures, which may mean that shipping is kept waiting for more normal conditions in the most critical parts of the fairway, will be chosen according to their influence on the real margins.

This idea is of course not new in principle. In most harbours situated on open coasts, shipping has to wait regularly for certain tide and current conditions. It is also quite normal that a ship, entering into a fairway having a "controlling depth" close to the draught of the ship, should request information about water level and must reckon in decimetres when deciding whether or not it is acceptable to proceed. On the other hand ships very often neglect the rather important *increase* in draught when passing over shallow areas at fairly high speed. Many contacts with the sea bottom, e.g. in the entrances to the Baltic as well as in the entrance to New York, have been explained through this squat-effect.

When a ship approaches a fairly shallow area exposed to rough sea, the movement of the ship may cause rather a great and therefore dangerous momentary increase in draught. The magnitude of this momentary increase appears to be little known, and moreover it varies with several factors. If the influencing factors happen to coincide, this increase in draught can be quite large. The local conditions, as well as the type of ship and the course set in relation to wave direction, may in certain cases substantially reduce the movement of the ship. In other cases these factors can cause a great increase in the movement.

Very little is known about what influence a water mass moving with the ship has on a ship's movement when it is pitching and rolling in shallow water. If the speed is low, this may produce a reducing effect.

The question arises whether in practice it is possible to take into account such a number of interacting and counteracting factors when the "safe" draught for each occasion has to be decided upon. In comparison with many other problems of modern society and modern techniques, this problem should not be regarded as either insoluble or extremely difficult

unless very high accuracy is necessary. There are several reasons for limiting this study to guiding principles and values for margins and extra margins.

A further question is whether it is possible in practice to teach ships' officers of various nations to make even rough calculations when local conditions have such a great influence. No doubt it is desirable that the ships' officers acquire a better knowledge of these problems since they have such great influence on the safety and economical use of ships. But calculations for a particular part of a certain fairway under special conditions should not be expected from ships' officers. The shipping authorities of the region must therefore solve the problems and forecast simple and typical cases so that the pilots may give ships' masters information and advice. Sailing directions and charts could emphasize the cases where special rules exist for ships with a draught above a certain magnitude. That would not however relieve the master of the ship of the responsibility for his own choice, although this would be made mainly on the advice of the pilot. Today such decisions, which are usually not based on real *knowledge* about the momentarily increased draught, have become a very thankless task for the master of the ship. Very often such decisions have to be based on so-called "experience". But such experience is normally based on the fact that nothing has happened previously with that draught in this particular passage, and it is not possible to know how close to an obstacle the ship's hull has been during the passage. In some cases the "experience" goes back to contacts under abnormal conditions or those caused by facts remaining unverified. Nor is it possible to know if the unfavourable factors have been in phase or have more or less cancelled each other out. It is also possible that ships' masters have on many occasions decided to wait for better conditions when such precautions were unnecessary, with an equally unnecessary loss of time and money.

We are very anxious to stress that we do not argue in favour of taking more risks, but only that margins and extra margins for draughts should be based on the actual facts expressed in metres or feet. If and when our investigations give rise to results, it will quite possibly be realized that in certain cases and places, even if no grounding has occurred, the safety margins have been too small and should be increased.

The Swedish Hydrographic Service raised the question of draught margins at the end of 1962 for the four following reasons :

1. Rather large differences in depth margins were found in the different Swedish fairways.
2. There was need for a technical and scientific basis for specifications for hydrographic surveys.
3. The International Hydrographic Bureau has appointed a working group to study specifications for hydrographic surveys.
4. The studies and surveys for a deep-draught corridor to the Baltic raised the question of margins in the shallow south-west parts of the Baltic.

Preliminary contacts with various specialists and authorities in other countries, as well as preliminary studies of the literature, showed that with the exception of canals very little emphasis had been laid on this question.

On the other hand it must be presumed that the question has been discussed at the planning stage for every big harbour on an open coast, but that as a rule decisions have been based on "experience values" of the type criticized above. It should be noted that in many cases even small differences in the required margins have had a great influence on building costs as well as on the shipping economy of the harbours.

It was noted that naval architects have shown great interest in the movement of ships and also in the wave patterns that cause this movement, but only on the open sea and in deep water. Their main interest has been in the strength of a ship, and consequently in influences on the steel portions of the hull, as well as in the importance of warships being used as stable platforms for weapon systems.

It was further noted that civil engineers have devoted their interest mainly to waves in shallow water so as to work out how to build piers and lighthouses, etc. that are sufficiently strong.

The movements of a ship in shallow water had, according to our preliminary survey, gained very little attention. Certainly ships' officers have always been very interested in movements in deep as well as in shallow water, but the observations have been mainly subjective, and only occasionally have numerical values for the rolling movement been stated.

The National Board of Shipping and Navigation therefore initiated the setting up of a working group for the study of this tangle of problems. It was natural that the working group should be composed of a specialist in ship hydrodynamics, a civil engineer specializing in the calculation of wave forces on structures, a ship's officer with experience of supertankers and a hydrographer. Their names are : Mr. WAHL, research assistant at Chalmers University of Technology in Gothenburg (in the department of Professor FALKEMO), who is secretary of the group; Dr. Tech. RUNDGREN at Vattenbyggnadsbyrån; Captain ASKLUND, retired master of the tanker *Esso Stockholm*; and myself as chairman of the working group. The working group has the privilege of having as adviser Professor FALKEMO of Chalmers University of Technology.

The working group is charged with putting this group of problems on the agenda as one of the subjects to be treated at the International Navigation Congress scheduled for July 1965 in the northern countries. Certain financial support from Malmfonden has been secured.

The working group has accepted the following general outlines of a programme of seven points. Modifications will certainly occur for several reasons, which include lack of personnel and money. The seven points are :

1. Systematizing the problem, including an inventory of the factors which have an influence on depth margins.
2. Study of the literature.
3. Collection of data about the influencing factors, at an early stage possibly including some observations on ships.
4. Statistical studies of the duration of the various factors, as well as of the coincidence of extreme values.

5. Theoretical and experimental deduction of the influence of these factors on the movements of ships.

6. An analysis of the influence of different combinations of numerical values for the different factors on the real momentary draught.

7. Practical verification by measurements on board ship and an analysis of the results.

This study is particularly complex since the measurements of waves and the ship's movement must be coordinated in time and place, and because they are of interest only in regard to rather shallow water for certain wind directions and forces. The probability that a single ship equipped with measuring instruments might be able to collect significant material has been regarded as rather low. The working group is therefore aiming at a system of measurements of varying quality combined with visual observations and estimations. This calls for an active cooperation from ship owners and ships' officers. The work, however, will not be continuous, since observations will be made only if certain weather conditions exist when the ship passes along certain limited observation tracks.

The working group has found that the following five factors should be especially considered when determining or studying depth margins :

1. The correctness of hydrographic surveys.
2. Sea level.
3. Squat.
4. Heeling.
5. Movements due to waves.

These factors will be studied both separately and in combination with each other.

The correctness of hydrographic surveys is logically the first factor to be discussed. It is to be noted that it is not a question of the intrinsic correctness but of the negative errors in depth on the shallowest parts along the track. A discussion on the correctness of hydrographic surveys is dependent on the survey techniques used in various countries and those techniques vary considerably. On the other hand mechanical checking (bar sweeping or similar method) over the depth-limiting points of a fairway is to be absolutely recommended, especially if isolated rocks or stones are to be expected. For the first stages of its studies the working group has assumed these types of errors to be non-existent. If the surveys are old, or if the survey technique gives rise to suspicion, a certain margin for unreliable surveys must first be subtracted from the "measured" water depths. Such extra margins could be regarded as reflecting the existence of hypothetical boulders immediately over the shoals. Moreover it should be observed that the existing "margins estimated by experience" have to a great extent been influenced by the lower reliability of surveys in earlier times. Unquestionably the shallowest part of a fairway, which in fact limits the allowable maximum draught, should be treated and investigated as accurately as a bridge on a highway when an increase of the maximum load is discussed. With similar treatment we should be able to reduce the margin for unreliable surveys to about zero.

Sea level is the factor that seamen have for centuries taken into consideration in areas both with and without tide. Shipping has accepted

the fact that variations of tide between spring and neap periods are large and have a great influence on access to harbours. It has also been accepted that from the safety as well as the economic point of view these variations are influenced by varying meteorologic conditions. Consequently we should also be willing to accept situations when a normal low sea level hinders access to the entrance to a harbour without tide. In this connection it is of great interest to know for a particular coastal district whether there is a high probability of a combination of low water and a bad storm from the sea. Furthermore it is very important for ships which have to pass with small margins to get "up to the minute" information on sea level. It is also important to know if the risk of fast changes of sea level exists in a certain area, and this is especially important if ships have to pass for a long period of time over a shallow area. Water-level gauges must be positioned taking this problem into due consideration.

Squat was first studied in narrow canals where this phenomenon explained many contacts with the bottom. Later the phenomenon was also investigated over flat shoals and considerable increase in draught was found. A means to reduce this increase, however, is always available, namely to reduce speed substantially. In some cases where there is very strong side current this might be difficult, but in most cases this means of counteraction is not used, many ships' officers and pilots not realizing the danger of squat in open sea channels and not being willing to lose the few minutes which a reduced speed represents.

Heeling of a ship may be caused by wind pressure or dynamic forces occurring in a yaw. Such an inclination in a fairly wide modern ship may cause a considerable increase in draught. On one hand the working group believes that loaded bulk-carriers are little influenced by these factors. On the other hand however the influence on fast-going cargo ships of average size may be greater.

Movements of ships due to waves are, without doubt, the group of causes of increased draught the most difficult to deal with due to the possibility of various combinations of pitching, rolling and heaving, as well as to the intricacy of wave patterns. Furthermore it should be noted that movements vary for different types of ships, for different ships, and for different load distributions in the ship. Active as well as passive stabilizers have quite different influences under different conditions. It should also be noted in this connection that the problem is only of importance for the big or biggest ships. Every combination of a fairway and the maximum or near maximum draught for that fairway creates a problem.

From the above we must conclude that several facts require consideration before deciding to use a ship with maximum or near maximum draught in a shallow fairway. When approaching limiting points of the fairway, the bottom topography must be considered together with the sea level variation and the movement of the ship due to the waves and its speed, and the risk of grounding should be reduced through the suitable choice of route and speed over the shoal. In special cases more normal conditions should be awaited.

Since it is sometimes very important for a harbour or an industry to be able to accept a ship with a draught somewhat deeper than the official maximum draught, it is important to know how margins are calculated and what possibilities there are of reducing these margins if special precautions are taken. Such reductions must be combined with special rules for making the passage. As a parallel, the various measures taken when transporting a very heavy and bulky load on a highway could be mentioned. In such cases the police arranges special traffic solutions. Bridges are strengthened and structures over underpasses are even sometimes lifted. The economic point of view must be analysed of course to see if special measures are warranted for bringing an oversized ship into a harbour or for allowing a ship of maximum draught to enter the harbour at low sea level.

THE ACTIVITIES OF THE WORKING GROUP UP TO NOVEMBER 1964

Quite naturally the working group has not been able to reach any results as yet. The group has had various deliberations and has arranged a symposium in order to outline and, if possible, to simplify the study programme. Two main literature studies have been performed and were presented at a symposium in Gothenburg in October 1964 :

1. " Search in the literature about the changes in draught of ships on shallow waters due to ship movements ", by Lars-Ola ENGVALL in Gothenburg.

2. " PM Oct. 1964 about sea-wave prediction ", by Lennart RUNDGREN and Alf ENGELBREKTSSON.

Furthermore an experimental model of a simple pitch and roll measuring device has been built for either registering or direct readings. A design for a wave gauge according to the pressure principle has been started. Special problems and the limitations of available funds have made it impossible to use the very good but costly instruments which have been described in the literature.

According to present plans the intention is to test during the winter 1964-65 the reliability of two instruments, the pitch and roll instrument and a more sophisticated gyro instrument.

An experimental analysis of weather statistics for the sea around Utklippan lighthouse (at the south-east corner of Sweden) has been begun in order to find suitable methods for this new type of problem.

Approximate calculations for the movements of two ships have just been started. These ships are a mammoth tanker in the 90 000-ton class and a dry-cargo ship in the 10 000-ton class. Two wave types at two different places along the coast will be used. A ship's movements will be calculated when the ship is heading in different directions in relation to the wave direction, and certain other factors which have a momentary influence on the draught will also be taken into consideration in this very

approximate calculation. The goal of this calculation is to give a general idea about the magnitude of the influence of the various factors as a guide for further analysis and investigation.

The intention of the working group is to select one or two places along the Swedish coast where there are both shallow water and a great intensity of shipping. On several of the ships which pass regularly we shall try to arrange a complete set-up for movement measurements and at the same time the ships' officers will be asked to make visual and semi-visual observations of waves and ship movements in order to find out the correlation between the various types of observations. Wave-measuring devices will be placed rather far from shore but in shallow water, in all probability with cable connection to the shore. On a few other ships we intend to arrange simple pitch and roll instrumentation of the type mentioned above. On a greater number of ships we hope to be able to arrange visual wave and movement observations. In order not to restrict the measurements and observations to one or two places along the Swedish coast, we intend to ask some of the ships to make observations in other shallow passages all over the world when they pass over them in bad weather. By step-by-step statistic comparison between the observations and the various methods we hope to get some kind of a calibration. Visual observations are of course not very accurate, but on the other hand it must be realized that to a great extent such observations will still form the basis for future decisions on extra margins by ships' masters and pilots.

The working group will use the significant wave heights as a basis for its studies. This does not mean including the maximum waves which may sometimes occur. Such maximum waves will normally be wind-generated and wind-influenced (i.e. not swell or earthquake waves). Consequently they are rather irregular and to a certain extent will reduce their own effect because of their irregularity in comparison to the influence on ship movements of quite regular waves. Therefore we do not think that the approximation will be very accurate but we shall try to make a further study of the consequences of the approximation.

In order to obtain a better knowledge of the waves in rather shallow water, we intend to make topographic surveys of waves from big tankers or similar stable platforms using photogrammetric methods. The limited resources of the working group will probably allow only a few such surveys and not yield sufficient results for statistical treatment.

The above discussion and very preliminary report will show how complicated is the problem of draught margins for ships. The working group has only just started its activities, and it is not certain whether it can reach a comprehensive result with its present resources. It is obvious that the problem of margins is of great economic importance — not to mention the safety point of view — for international shipping as well as for harbour and shipping authorities in many countries. Some countries have already made it known that they are interested in cooperating in this matter. It is to be hoped that research and experiment will be started, or continued, in other countries (if possible with greater resources than those available in Sweden) and that there will be a running exchange of informa-

tion. As examples it may be noted that extensive wave measurements in offshore shallow areas with modern instrumentation have been started by the German Hydrographic Institute in Hamburg, and also that a very suitable test basin for model tests of this type of problem is now available in Wageningen in Holland.

CONCLUSIONS AND RECOMMENDATIONS

It is noted that the required margin between the bottom of a ship's hull and the sea bottom varies greatly with several exterior as well as interior factors both fixed and variable, and that this margin can be influenced by the manner in which the ship is navigated.

Inasmuch as the magnitude of the margin either restricts the actual or permanent upper draught limit for ships which should be allowed to pass, or causes costly waiting time, or calls for very expensive dredging operations, this question has a great economic importance in addition to its importance for the safety of shipping.

The conclusion is that research and experiments are urgently needed within this tangle of problems in order to clarify the correlation between the various factors; and that results of such studies should be applied to various approach areas and fairways and if possible verified by full-scale checks (as in the Maracaibo entrance for example); and that these results should be embodied in simple rules for the extra margins to be added to a sound basic draught margin.

Thus it is recommended that intensified international cooperation within this field of problems be started, and as a first measure due publicity should be given in journals, etc., to investigations already existing or commenced.

Further it is recommended that the attention of those concerned (i.e. active ships' officers, harbour and shipping authorities, pilots, etc.) should be drawn to the problem of the necessary margins between the draught of ships and water depths.