SSC-136

ON VARIOUS PROBLEMS OF IMMEDIATE INTEREST TO A SHIP CLASSIFICATION MAN

by

Georg Vedeler

SHIP STRUCTURE COMMITTEE

SHIP STRUCTURE COMMITTEE

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ADDRESS CORRESPONDENCE TO:

SECRETARY
SHIP STRUCTURE COMMITTEE
U. S. COAST GUARD HEADQUARTERS
WASHINGTON 25, D. C.

August 1, 1961

Dear Sir:

Dr. Georg Vedeler, Managing Director of Det Norske Veritas, Oslo, Norway, recently participated in a meeting of the Committee on Ship Structural Design of the National Academy of Sciences-National Research Council, one of the principal advisory committees to the Ship Structure Committee.

The enclosed report, entitled <u>On Various Problems of Immediate Interest to a Ship Classification Man</u>, was prepared by Dr. Vedeler to summarize his remarks for the Committee on Ship Structural Design. This report is being distributed by the Ship Structure Committee because it represents an important current approach to these problems.

Please send any comments on this report to the Secretary, Ship Structure Committee.

Sincerely yours,

J. A. Alger, Jr.

J. A. Alger, Jr.
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

Serial No. SSC-136

Special Report

ON VARIOUS PROBLEMS OF IMMEDIATE INTEREST TO A SHIP CLASSIFICATION MAN

by

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Oslo, Norway

Washington, D. C.
National Academy of Sciences-National Research Council
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The Load Line Convention formula for the midship section modulus

Six years ago the seven western classification societies agreed that the midship section modulus formula of the Load Line Convention was out of date and might be dangerous. The formula does not take into consideration the arrangement of the ship, i.e. the possibility of a very wide variation in load distribution, which in some cases may result in dangerously large still water bending moments. It makes the section modulus proportional to the draft, which is obviously not correct. And it has for many years made a lot of people believe that the nominal stress increases considerably with length of ship, which is not in accordance with practical experience. We cannot say that we have more trouble with large ships than with smaller ones.

The best form for government or classification longitudinal strength requirements is by some people considered to be the specification of an allowable nominal stress and a modernized standard procedure for the calculation of bending moments. In some engineering branches such a procedure is normal, in others it has been substituted by more modern methods. In shipbuilding it may yet be too early to do this unconditionally. The classification societies suggested that the revised Load Line Convention should contain no strength formula, but that the rules of each approved society should be followed. Some of the government bodies have, however, expressed the view that they prefer to have the practice tied down by a formula. By collaboration between some of the societies some formulae have been agreed upon with the purpose of proposing them for unclassified ships of certain types and arrangements at the coming Load Line Convention.

In this proposal the main formula for the midship section modulus will consist of two terms, one proportional to $(L^{2.5})(B)$ representing the influence of a wave bending moment with wave heights proportional to the square root of the ship length L, plus one term proportional to L^2Bd representing the influence of a still water bending moment. The coefficients for both terms are functions of the fullness of the ship, say the block-coefficient. The coefficient of the second term is also a function of the ship arrangement, such as e.g. for tankers the relative length of all the cargo

When the still water bending moment is below a certain value only one term similar to the first, i.e. proportional to the wave bending moment, is used, giving a minimum section modulus more in line with the previous formula, but independent of the draft. Such a minimum is considered necessary because in practice the still water BM may be very different from the one obtained with homogeneous cargo. For ships with special arrangements, e.g. some refrigerated cargo space, a deep tank or a similar space kept empty when the ship is loaded, a formula will soon be rather unwieldy. In such cases it may be more natural to require an actual calculation of the still water bending moment.

Now whatever formula may be agreed upon it should not be included in the Convention, but given in a separate Appendix which can be altered from time to time when new experience should so require. For example, when we speak about a still water bending moment and a wave bending moment as mutually independent quantities we know already that this is a simplification which may not be justified.

In the program of testing T2-tanker models in regular waves which we carry out at the Trondheim tank in collaboration with the Davidson and the Delft tanks, we have varied the distribution of load and intend also to vary the mass moment of inertia. We have run tests with three different distributions of load, one with even distribution, one with the load more concentrated amidships and the third with the load concentrated more against the ends. The total mass moment of inertia being the same in all three cases the motions were the same, while the still water bending moments varied with the load distribution.

The bending moment being measured at midlength and at the quarter lengths and the shearing force at the same three positions, the curve representing the distribution of the wave bending moment over the ship length could be drawn fairly accurately. By taking the derivative of this curve twice the curve of wave load distribution was obtained. A certain part of the values given by this curve is due to the local mass per unit length times the vertical acceleration. Having measured the motion of the ship at each time interval this part could be calculated. It adds as a dynamic part to the static weight distribution and clearly depends upon this. The remaining part of the wave load distribution is due to the hydrodynamic forces acting on the hull and adds to the buoyancy distribution in still water. It does not depend upon the weight distribution, which was a check to our calculations, because it had to be the same for all three different weight distributions at corresponding times when the motions of the models were the same.

In Fig. 1 the weight distributions have been shown for the three conditions tested. Also the dynamic mass times vertical acceleration load distributions have been shown for the same conditions, in the same scale, and valid at two arbitrary equivalent instances when the accelerations were the same for the three conditions. The first instance was chosen an eighth of the period of encounter after the bow had been at its highest position, the second instance when the bow was at its lowest position.

On the same three diagrams of Fig. 1 also the static buoyancy distribution curve in still water has been shown. To this static buoyancy distribution curve have been added the curves due to the hydrodynamic forces in regular waves for the same two instances. They are the same for all three loading conditions.

The mass times accelerations as well as the hydrodynamic forces are, at least within reasonable limits, proportional to the wave height, which for the experiments, the results of which have been shown, was 1/41 of the ship length. For higher waves these dynamic influences will be proportionally larger.

Figure 2 gives the distributions over the ship's length of the still water bending moment and added to it the measured wave bending moments at the same instances for which the dynamic load distribution was given in Fig. 1. Again it should be remembered that the wave bending moments for higher waves will be proportionally larger. All diagrams are for a wave length equal to the ship length and a speed of 14 knots for the full size ship.

Figure 3 gives enveloping curves for the maximum of all wave bending moments measured during a full period of encounter for four different velocities at a wave length equal to the ship length. Similar measurements were also made for several other wave lengths. But the largest wave BM occurred at wave lengths equal to L and 1.25 L. One will notice how far forward the maximum wave BM may occur for certain of the loading cases. It is obvious that for these cases it is not sufficient to make measurements amidships only.

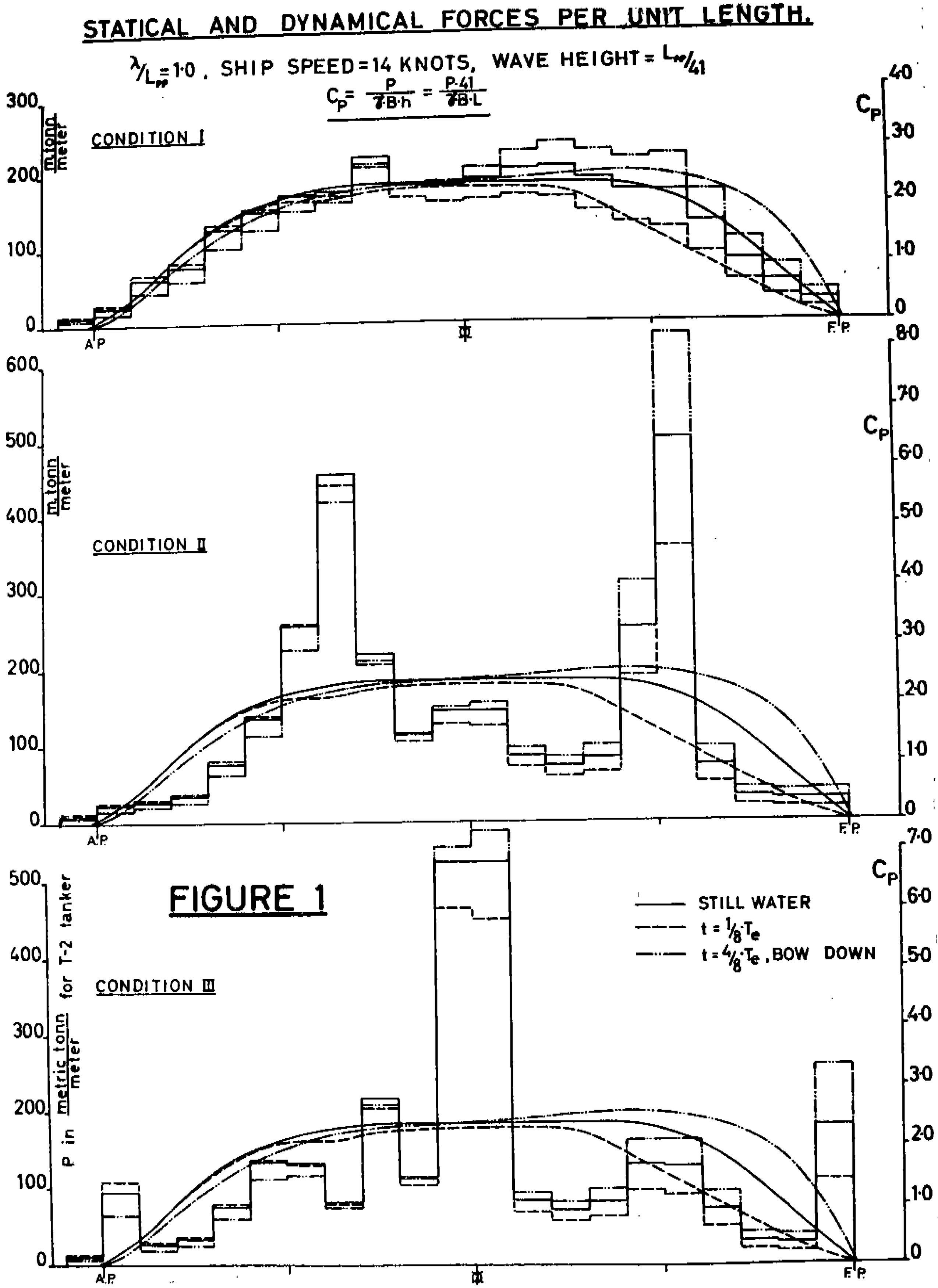

STATICAL AND DYNAMICAL FORCES PER UNIT LENGTH.
λ/L = 1·0 , SHIP SPEED = 14 KNOTS, WAVE HEIGHT = L/41
$C_P = \frac{P}{\gamma B \cdot h} = \frac{P \cdot 41}{\gamma B \cdot L}$
CONDITION I
CONDITION II
CONDITION III
m.tonn/meter
P in metric tonn/meter for T-2 tanker
C_P
A.P
F.P
STILL WATER
t = 1/8·Te
t = 4/8·Te , BOW DOWN

FIGURE 1

INSTANTANEOUS DISTRIBUTION OF BENDING MOMENT.

$\lambda/L = 1.0$, SHIP SPEED = 14 KNOTS, WAVE HEIGHT = $L/41$

$$C_M = \frac{M}{\gamma \cdot L^2 \cdot B \cdot h} = \frac{M \cdot 41}{\gamma \cdot L^3 \cdot B}$$

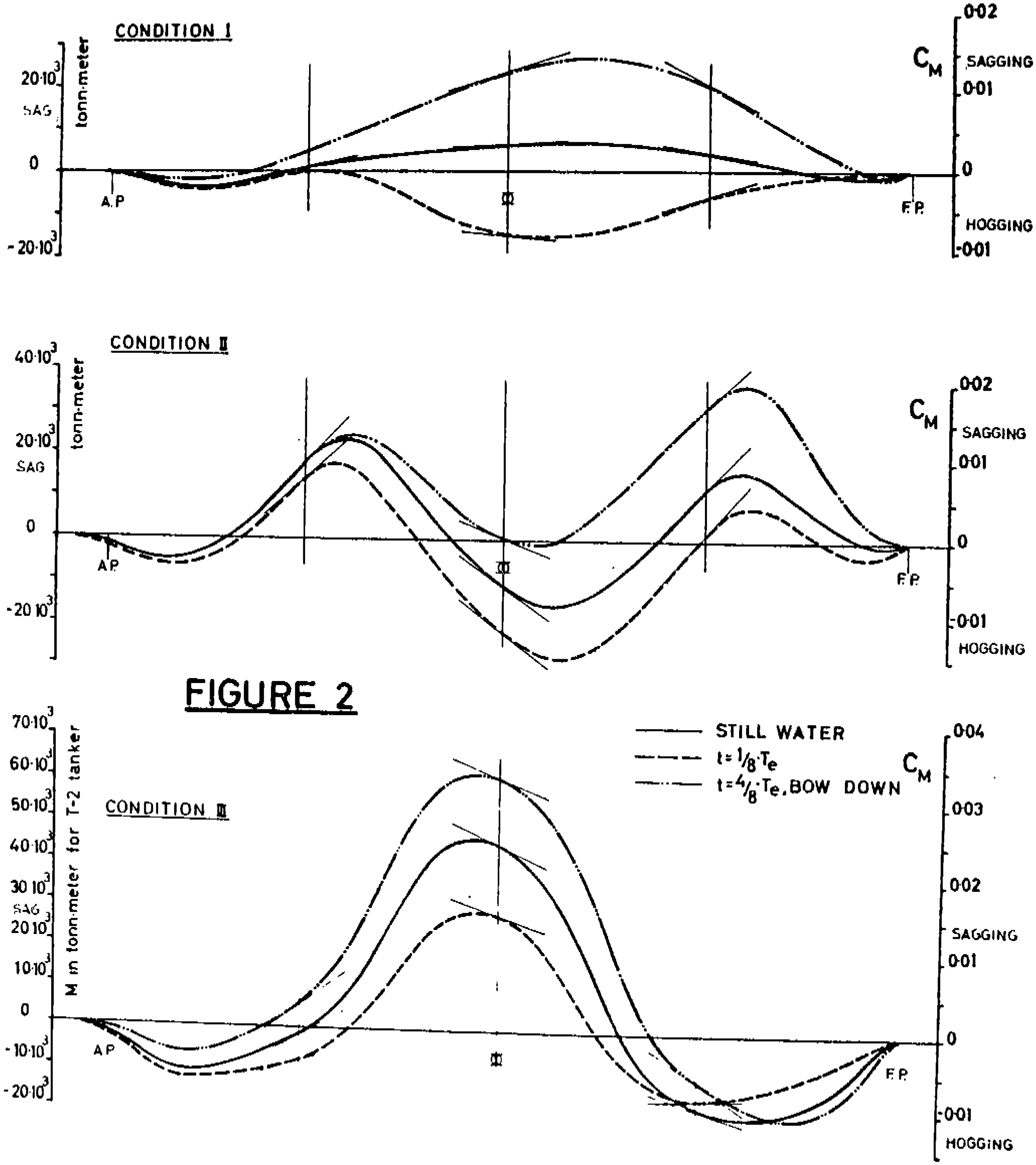


FIGURE 2

ENVELOPES FOR DISTRIBUTION OF MAXIMUM BENDING MOMENT

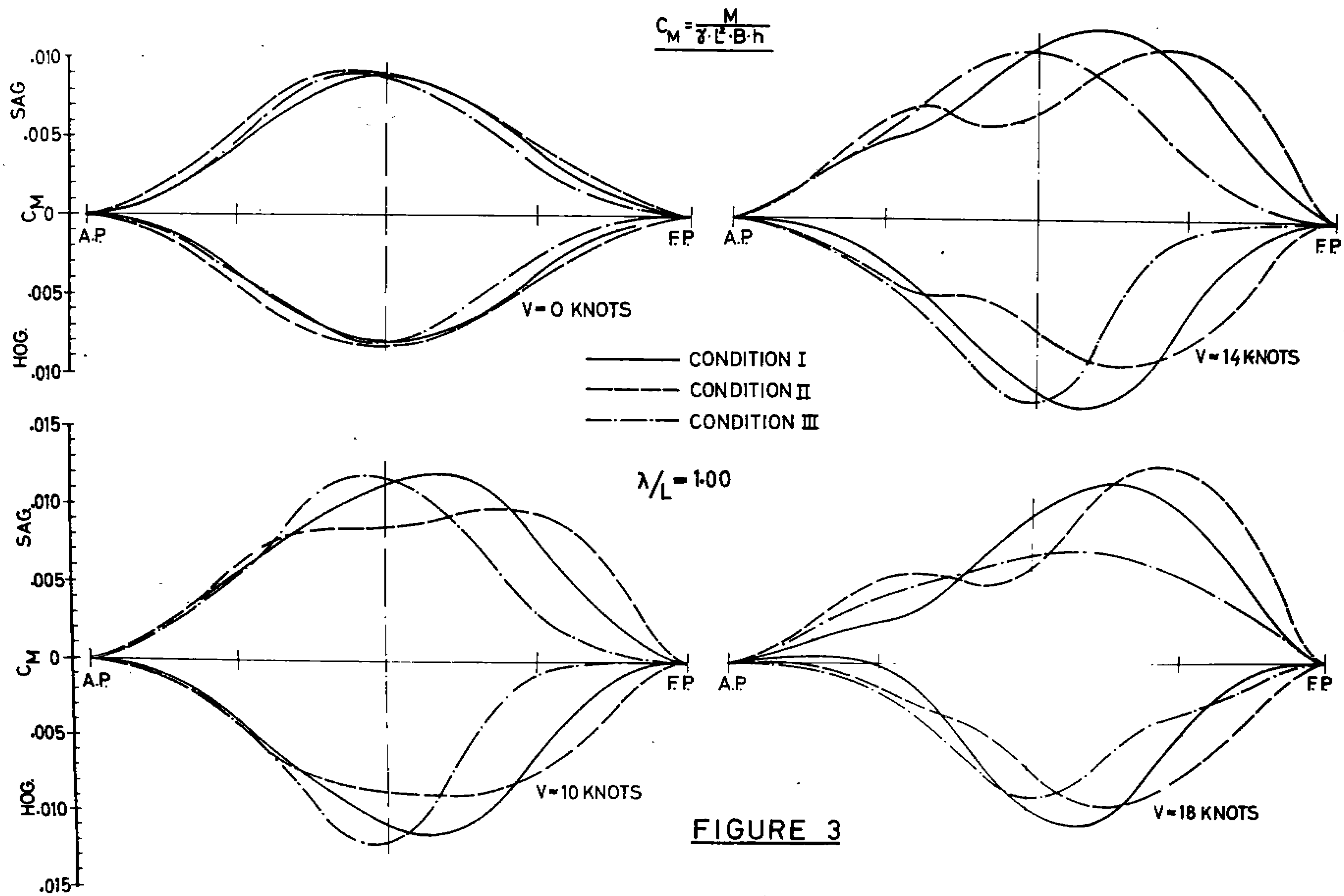


FIGURE 3

We have to obtain much more information about the dynamic BM before the classification rules can consider the fact that the wave BM depends upon the mass distribution, or in other words, upon the stillwater BM. Model tests in regular waves for obtaining curves for the dynamic BM for other block coefficients should be a very useful field of research of immediate interest.

A survey of recent cracks in shell and deck

Figure 4 is a diagram showing the cracks in shell and deck reported upon during the 4 years ending September 1960 in those of our tankers which have been built after the war and are more than 400 feet in length. 66 tankers have had cracks of this nature. They have all been shown in this diagram. Each number in a small circle represents a ship. Only one of these ships, viz. No. 37, has had brittle cracks. She was built in 1945. All the other cracks are of a fatigue nature and have occurred at points of stress concentration.

The most frequent cracks are those which have appeared at the crossing of orthogonal stiffeners such as longitudinals and girders. The two types of stiffening members having very different stiffnesses have a tendency to differ in their deflections at the point of crossing, which after some time may result in a crack in the plating. A sufficiently good connection between longitudinals and girders will cure this This is a type of crack which has occurred for over 50 years, also in riveted ships, and it is a pity that they have not been given more attention at the design stage.

Other cracks have occurred at such hard points as the ends of bilge keels, holes in the bilge keel bars where they cross a butt, corners of pump room ballast openings when they have not been sufficiently rounded, etc. The deck is remarkably free of cracks, which may be partly due to the fact that we have tried to avoid all doublers and have watched that the hatch openings have been well rounded. In later years we have made these openings elliptic instead of oval. We have for some years practiced the requirement that the deck section modulus must be at least 96 per cent of the bottom section modulus. Due to the absence of brittle cracks and the very small number also of other cracks in deck we have recently modified our requirement for the deck section modulus to be at least 90 per cent of the bottom sec-

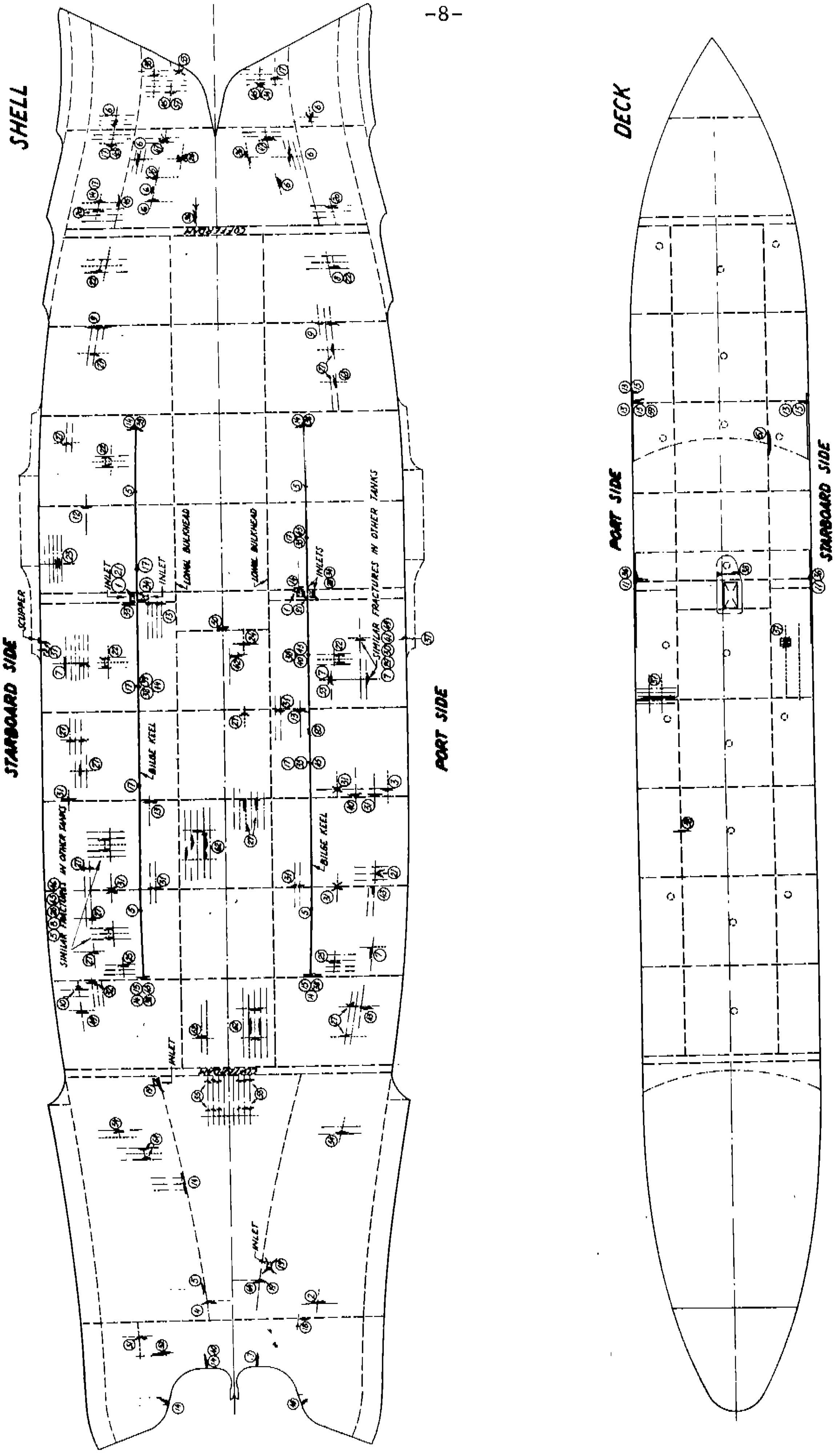

SHELL
STARBOARD SIDE
PORT SIDE
LONG'L BULKHEAD
BILGE KEEL
INLET
INLETS
SCUPPER
SIMILAR FRACTURES IN OTHER TANKS
DECK
PORT SIDE
STARBOARD SIDE

Fig. 4.

tion modulus. This is an example of the merely practical way of progress: reduce stress concentrations by better detail design, follow up result and allow a somewhat higher nominal stress if the result is good enough to warrant it.

Figure 5 is a similar diagram showing all the shell and deck cracks which have been reported during the 4 years ending September 1960 in those of our dry cargo ships which have been built after the war and are more than 400 feet in length. 55 ships have had such cracks. Only two of them, Nos. 11 and 18, had brittle cracks. They were both delivered in 1949. The remainders of the cracks were high-stress low-cycle fatigue cracks, most of them of a similar nature as in the tankers. But the dry cargo ships, in contrast to tankers, have large rectangular cargo hatches in the deck, and the hatch corners show a considerable number of cracks. It is therefore still important to try to improve the design of hatch corners in dry cargo ships.

I mentioned that we try by all means to avoid doublers because they will always cause stress concentration. The expression "shell modulus" is unknown in our vocabulary. If the longitudinals are continuous they carry just as much longitudinal stress as the plating. We consequently consider continuous longitudinals plus plating as a unit and allow a considerable increase in the relative cross-sectional area of the longitudinals if this is necessary to avoid doublers and keep the thickness of the plating at a recommendable value. We of course watch that the design is such that we need not fear buckling either of plating or of longitudinals. To our opinion it is not necessary to use doublers even in the biggest tankers which have been built.

Buckling of deck

The transverse system of framing is still used to some extent in the decks of dry cargo ships. The formula for the thickness of the plating necessary to avoid buckling between two transverse beams is known by all naval architects. But not all of them seem to be aware of the fact that it may sometimes be necessary to watch the dimensions of the beams to avoid buckling of plating plus beams over two or more beam distances. According to a formula which I have developed*

*"Grillage Beams in Ships and Similar Structures," Grøndahl & Søn, Oslo, 1945 p.158, and "Calculations of Beams," T.I.N.A. 1950 p. 42.

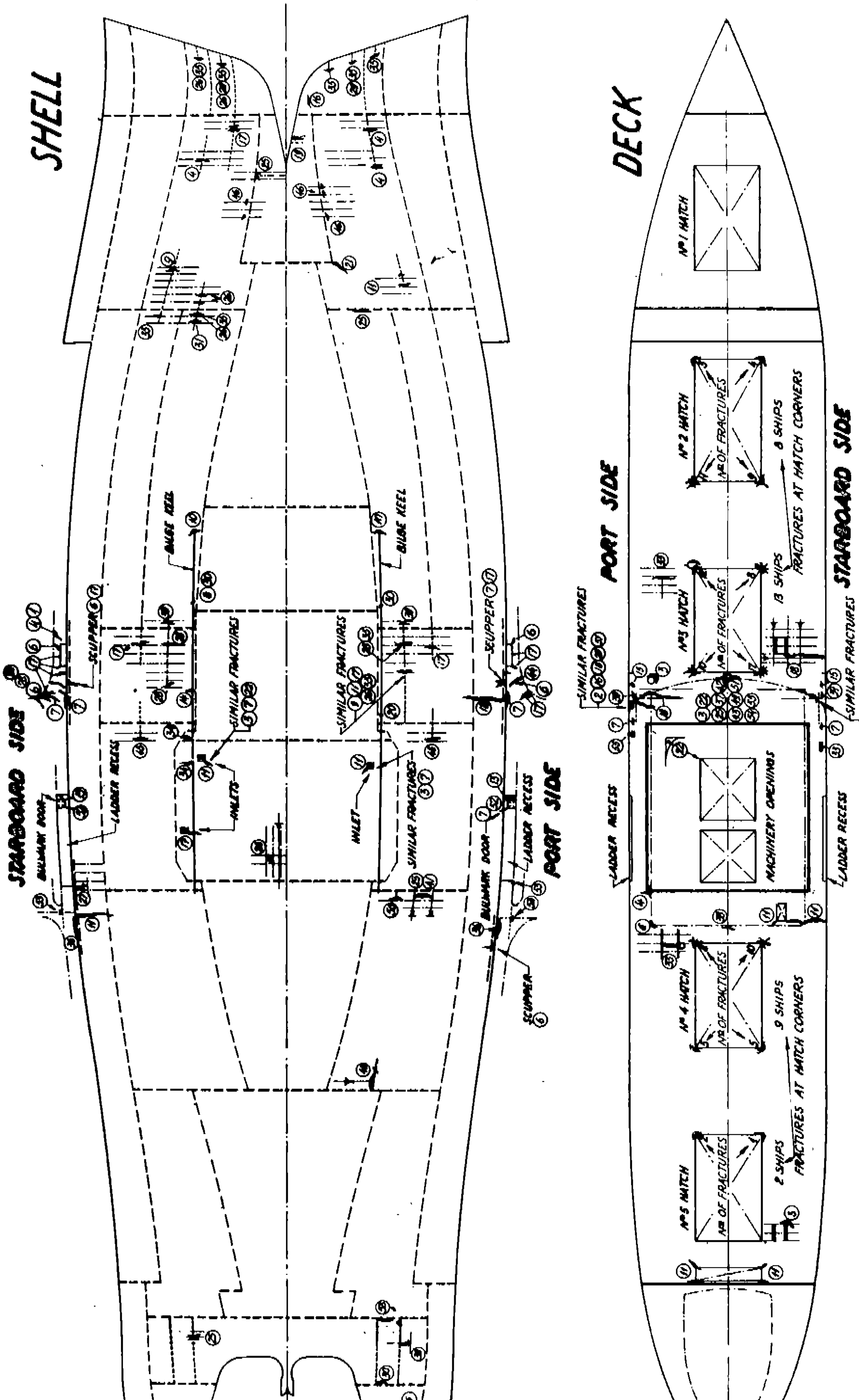

SHELL
DECK
STARBOARD SIDE
PORT SIDE
BILGE KEEL
SCUPPER
LADDER RECESS
BULWARK DOOR
SIMILAR FRACTURES
INLETS
INLET
Nº 1 HATCH
Nº 2 HATCH
Nº 3 HATCH
Nº 4 HATCH
Nº 5 HATCH
Nº OF FRACTURES
MACHINERY OPENINGS
8 SHIPS
13 SHIPS
9 SHIPS
2 SHIPS
FRACTURES AT HATCH CORNERS

Fig. 5.

to avoid this type of buckling beams must have a moment of inertia of

$$I = C\ell^4(t/s)^3$$

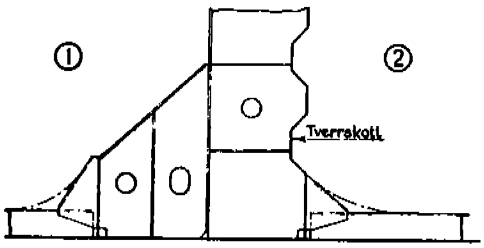
where ℓ is the unsupported span of the beams, s the beam spacing and t the plate thickness. $C = \ell/58$ when there is only one beam in the plate field considered, and $C = \ell/44$ when there are two or more such beams. With these numerical values the beams are assumed to be hinged at both ends. In Det Norske Veritas' rules the formula appears in the following form

$$I = C\ell^4 \sqrt{L} \text{ in}^4$$

where ℓ = span of beam in feet, L = length of vessel in feet and C = 0.80 for half beams and beams between deck girders, C = 0.63 for beams between the ship's side and a deck girder. It is not often necessary to control that the beams fulfill this requirement, wherefore it has happened that our people have forgotten to do so. We had a reminder of this in 1959 when a new ship of about 340 feet length had her deck buckled between hatches Nos. 2 and 3. For four beam spaces there was no deck girder in line with the hatch side coaming and for three beams the unsupported span, therefore, was from the ship's side to the centerline girder. In this case the formula just given required larger beams than did the ordinary beam formula. If the three beams had been given the larger dimensions required the deck would probably never have buckled. It was also sufficient to fit a girder on each side in line with the hatch sides.

T2-tankers

It may perhaps be of interest to mention another case which was an important lesson to us. It concerns T2-tankers. On the 18 of February 1952 two American T2's broke in two in a gale outside Cape Cod. A Norwegian T2 happened to be in the vicinity in the same gale. When she was afterwards examined in Boston it was found that in cargo tanks 3 to 8 practically all those bottom longitudinals which were connected to vertical web girders on the transverse bulkheads were broken at both ends of the tanks. The fractures have been marked by a small circle in Fig. 6. All the other longitudinals were intact. We repaired the damage simply by welding the fractures and adding a web on top of these longitudinals thereby



SNITT VED VERT. BÆRER 10'-0" & 25'-0" FRA ℄.

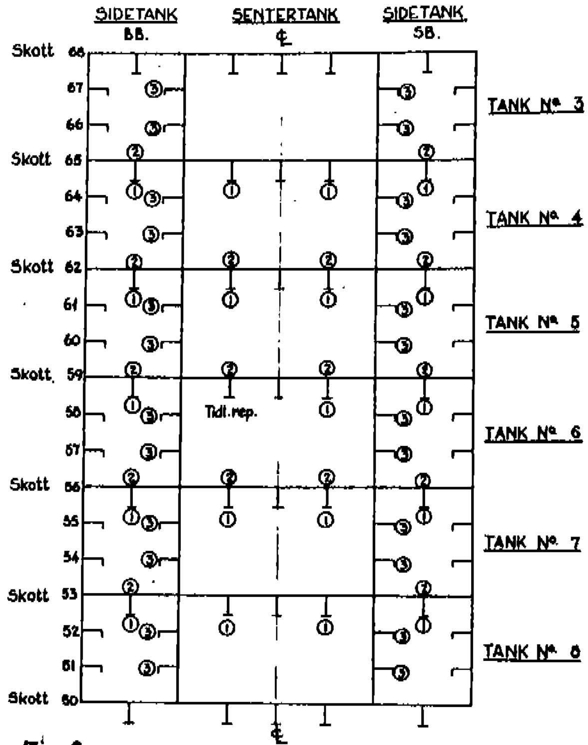
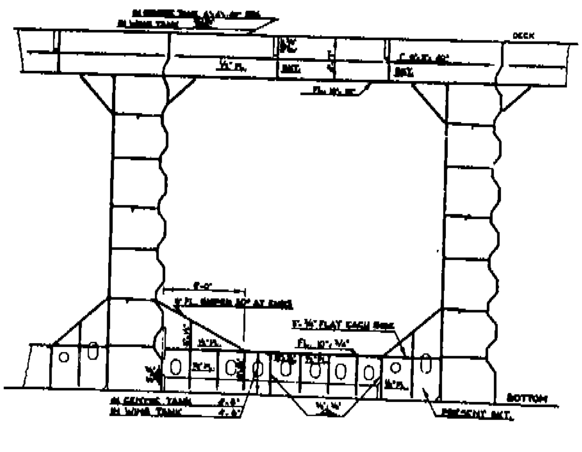
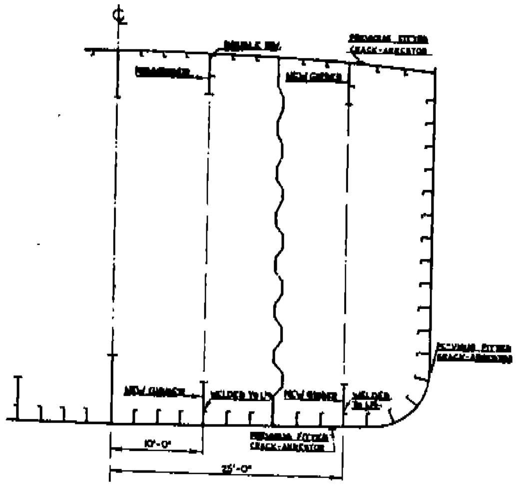


Fig.6.



NEW DECK & BOTTOM GIRDERS 10'-0" & 25'-0" FROM ℄



SECTION

Fig. 7.

making their stiffness similar to the stiffness of the vertical bulkhead girders as shown in Fig. 7. We thus at these positions obtained longitudinal frameworks of equal stiffness in their horizontal and vertical members. We did the same in all our other T2-tankers. And this was all we did. We never attempted to increase their midship section modulus which was not below the usual standard. And we did not like the idea of doubling any of the deck- and bottom-plate strakes. Our way of repair has proved to be adequate. We have never had trouble with our T2-tankers since (except some of the usual leakage in bulkhead corners). At sea much depends upon good luck, judicious loading and good seamanship, so we never have the right to feel 100 per cent safe. But at least up till now our experience seems to be an example showing that ship structural design is often much more an art of watching details than adding weight.

Corrugated bulkheads

In some of my publications I have given many other examples of the necessity of watching details. I hope they may be of use to young ship designers who have not themselves had the experience which we can accumulate in a classification society. I shall not repeat them here. I would only like to mention one thing. Since we realized that no part of the bulkhead plating could be included as a flange in the calculation of the strength of web girders on corrugated bulkheads we have had no trouble with this type of bulkheads. In fact corrugated bulkheads are very often used in our tankers. In contrast to the practice with plane bulkheads we recommend girders on corrugated bulkheads to be made symmetric, i.e., with equal webs and flanges on both sides of the bulkhead, which will then have its plating near the neutral axis of the girder. In this way there will be no difficulties with the stress concentration at the corrugation corners. I may add that we have had valuable assistance from laboratory tests when studying these stress concentrations.

Absence of riveted crack arrestors

Here in America it may also be of interest to mention that we use no riveted crack arrestor whatsoever and have never done so in ships built after the war. The diagrams I have shown with the cracks experienced in shell and deck may have shown that brittle fracture is not an important problem any more in ordinary ships. The ship steel used during the last decade seems to have been sufficiently good for an all-welded design when care is taken in watching detail and workmanship. And we have considered it an advantage to let the shipbuilders have a fairly free hand if they prefer to have no rivets in their ships in accordance with modern production methods. Riveted crack arrestors and riveted gunwale bars are not very neat solutions in modern ships. We prefer gunwales which are well rounded with all seams butt welded, even if we cannot obtain the same radius as in a bilge.

Broken Scandinavian tankers

I like to use this opportunity, when speaking to an audience of American experts, to mention also the broken Scandinavian tankers. Between 1939 and 1958 seven Norwegian tankers and a Swedish one have broken in two in the open sea. All the Norwegian ones were built before the war, the Swedish one just after the war. They were all built to the 'thwartship system of framing, the so-called Foster King system. Most of them were all-riveted. Only one of them had our class, and for this one at least I can say that the distribution of the heavy oil cargo on her last voyage was not very happy. It gave a much larger sagging still water bending moment than would have been the case with an even distribution. There is no doubt that the deck plating between the transverse beams, at least for the plate strakes between the oil hatches, was not sufficiently strong against buckling.

It has been said that even if this was the case the deck should have stood the critical buckling load and that the midship section modulus should, therefore, not have suffered such a substantial loss of magnitude that the ships, for this reason, could suddenly have broken in two.

There still exist some ships of this type. The buckling strength of their decks has been improved by some longitudinal bars. But I must confess that I am somewhat nervous about them. In one of them which entered the harbour of London in December 1960 we found a pronounced buckle between two beams right across the deck and some distance down on each side. It was in No. 2 tank at about 1/4 L forward and forward of where the longitudinal bars had been fitted. I have not sufficient details yet to go further into the case here. But we shall of course study it thoroughly. We have given great publicity to our instructions about distribution of cargo, so we hope a disaster will not happen. And since 1951 the building of tankers to the transverse system of framing has been completely terminated.

But still it is not quite satisfactory that a full explanation of why the eight Scandinavian tankers broke so suddenly in two has not been given. It is known from Professor Hoff's Wilbur Wright Lecture that ordinary stanchions under certain circumstances can snap-through and collapse suddenly at a load which may be only about a third of the usual critical load. It is also well known that the same phenomenon of snap-through can occur with curved plates. Professor Hoff on request a couple of years ago gave me a reference which should show that even with plane plates snap-through can occur. To my understanding the proof has not yet been given. It would be interesting if the possibility of snap-through for plane plates in compression could be studied in detail to see if we can here find a reasonable explanation of the disasters with the Scandinavian tankers. Snap-through is of course also of great general interest. Most papers and book chapters on buckling load do not seem to consider it at all.

Why tankers must be stronger than dry cargo ships

It has been a general practice for many years to make the midship section modulus for tankers about 10 to 20% larger than for ordinary dry cargo ships of the same dimensions. This has been based upon experience. One may ask why this should be so. It is often said by sailors that a loaded tanker behaves like a rock in the sea. It is not unreasonable to believe that this peculiar behaviour must be due to the cargo being liquid in contrast to dry cargo. If this is so it must be due to a damping effect of the liquid. Trying to separate variables one arrives at the conclusion that if such a damping effect exists it should be possible to ascertain it simply by swinging a model in air. We therefore in Det Norske Veritas made a simple tanker model of plastic and hung it by a ball bearing on each side amidships, whereby we were able to give it a kind of pitching motion in air. The stern was raised to a predetermined angle and let go, whereafter the amplitude of the following oscillations was read off until it was practically nil. Experiments of this kind were made with water filled to different heights in the cargo tanks and repeated with dry cargo distributed similarly so as to give the same height of the center of gravity and the same mass moment of inertia, i.e., the same swinging period. The result of the experiments was that there was no measurable difference in damping between liquid cargo and dry cargo except when there was so little liquid in the tanks that part of the bottom might become dry during the swinging, a condition which is of very limited interest.

The difference in the behaviour of a loaded tanker and a dry cargo ship must, therefore, be solely due to the difference in freeboard. When loaded most tankers will be so deep in the water that in bad weather the sea will wash over them almost like the way it does with a submarine in surfaced position. Water on deck amidships will increase the sagging bending moment. This was clear in the minds of those who many years ago introduced the requirement that there must be no continuous bulwark along the midship half of the open deck. But even with an open rail a tanker will not immediately get rid of all the water which washes over her deck.

Intersecting girders

We are still far from the ultimate goal which we aim at for the design of local members of a ship structure. For example, we still stick to a tabulated standard for double bottoms of dry cargo ships irrespective of the distance between transverse bulkheads and irrespective of the existence of pillars or not, which is not quite as it ought to be. We have not yet been able to spend the necessary time to get reasonably simple and reliable solutions to this orthotropic plate problem. It has actually not been very urgent because double bottoms have not caused us any trouble.

But we deal with the intersecting girders in the single bottoms of tankers in a way which may perhaps be called modern. We have made an electronic computer program for the local hydrostatic pressure on a rectangular plate field stiffened by any number of longitudinal and transverse girders with any end fixity, taking into consideration bending as well as shear deflection and also the influence of end brackets. The equipment gives us in a dimensionless form deflections and reaction forces at all crossings as well as girder bending moments at the ends and at the crossings and for the transverse girders also at midspan between the crossings. All large tankers which are to be built to our class have to pass this control by the computer during the design stage.

All firms who build these ships have been informed that our computer program is at their disposal, but we have the impression that shipbuilders as a rule are not yet accustomed to take advantage of electronic computers for the purpose of structural design. I feel sure, however, that the day is not far away when they find out that it is easy to feed a computer with different alternative proposals and thereby arrive at a kind of optimum design which will also mean saving of weight. For example, it is easy to predict that the present practice of fitting very heavy vertical plate girders with only small longitudinal horizontal girders in wing tanks will for large tankers fairly soon be changed to the opposite system, viz. reduced vertical girders combined with large horizontal ones. In large tankers the horizontal span or length of tank is shorter than the vertical span or depth of ship. And it will always be more economical to have the heavier girder bridge the shorter span.

Transverse frames

The dimensioning of vertical frames in the sides of dry cargo ships has caused us much concern. It does not seem possible to get modern calculation of frames as members of frameworks to fit with present practice. And we do not like to deviate too much from the old practice as long as we use the age-old hydrostatic triangle or trapezium as load curve. Usually the frames are adequate. In some cases we have the feeling that they may be stronger than necessary. But in other cases, e.g., large single deckers carrying heavy ore without being specially made for this type of cargo, we may happen to find broken frames. There may be some dynamic effect which it may be necessary to consider when the metacentric height is large and the rolling period short, but which our present rules do not take account of. It should be worthwhile to make some strain gage measurements on the frames in ships of this type.

and with such cargo. In addition we think that the ordinary idealized framework calculation, where each member is substituted by its neutral axis, does not take sufficient account of the influence of the brackets at the joints. We know fairly well how to consider brackets for single beams although this has not yet been correctly expressed in our printed rules. But the problem is more complicated for frameworks and seems to need some more investigation, which we are now carrying out. Several investigators have tested brackets separately. To be as useful as they ought to be these results should be coupled with those obtained on members of frameworks.

Classification societies

To a modern scientist the building rules of a classification society may look very old-fashioned. We who work with such a society try to introduce improvements every year, very often to the despair of shipbuilders who often prefer to keep their drawings unaltered for decades. But we have to make our improvements gradually and cautiously, first of all because a ship is such a complicated structure that no method covering the strength of every member is yet available or could be carried out during the short time usually at disposal between the signing of the contract and the ordering of the material. Also our rules must be such that every detail in a ship can be designed with a minimum of mathematical calculation and so quickly that a price can be quoted before the contract is agreed upon. These are hard conditions.

Some fifty years ago it was sometimes said that the classification societies should prescribe as little as possible and leave the shipbuilders a free hand. Today most shipbuilders have not got the staff necessary to have a free hand. And automatically the development has been that nearly every year new details have been added to the rules. Shipbuilders do not seem to protest any more against this development. Owners like it and ask for more. Both seem to think that the classification societies have large and trained staffs and a large fleet of ships to gather experience from, so why not rely upon them. Shipbuilders give no guarantee for those things which have been prescribed and controlled by a classification society. Owners say that the shipbuilders give no guarantee anyway wherefore it must be better to rely upon the experience of a classification society. And the whole arrangement seems to work, with a growing tendency to make the classification societies also serve as consulting engineers with regard to structural design. The research departments of the societies are, consequently, growing, which means that they may gradually be able to master improved methods and also to utilize the wealth of experience which can be gathered from all the survey and repair reports. And in contrast to other types of consulting firms their knowledge is published and available to anybody. This is so because their aim is not to make money, but to work for the safety at sea, with ships which are efficient and not unnecessarily expensive.

In this endeavour we appreciate and try to follow the work done by all research people and are grateful for all the advice which they can give us. Our experience seems to tell us that to a large extent development is delayed by details in design and workmanship which may cause such high stress concentrations that we get local fatigue cracks a long time before any main part of the material reaches the yield point. A study of fatigue at points of stress concentration, therefore, at the moment seems to be more important than a philosophy of design based on the yield point. Perhaps this could be a useful start for a discussion between scientists and classification people.

Another point is the one I touched upon in connection with the T2-tankers. It seems to be important also for the longitudinal strength that the different frameworks in a ship have their members correctly balanced. Every hold in a ship is like a cage with plating over. The framework problem is three dimensional. The necessity of taking into account shear deflection of web members and also the influence of brackets increases the difficulty of obtaining a useful and manageable solution. The same may be said about the importance of considering the continuity of plating and stiffening members in the relevant directions. An electronic computer program for this problem would be very welcome to us classification people and might gradually increase our possibility of improving the structural design of ships.

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