CHAPTER 10

# DAMAGE CONTROL BILL
(PLATE II)

10-1 GENERAL:-

(a) As defined by the Manual of Interior Control, 1929, Damage Control comprises the entire system of maintaining watertight integrity, control of stability, repairs to damage, gas defense, and caring for injured personnel, including material, personnel, operations, methods and organization. The most important requirements under this definition are, first, the preservation of the buoyancy and stability of the ship, and second, maintenance of zero or minimum list and a satisfactory trim. In action it is essential that warships remain not only afloat, but that they remain in action with as little list and as favorable a trim as possible, in order that their offensive and defensive qualities may be utilized to the best advantage. The most highly trained gunnery and engineering personnel and the most highly perfected gunnery and engineering material are of no avail if the hulls on which they are carried into action sink, or assume lists which prevent the guns of a ship from bearing on the enemy or if the hulls assume a trim which necessitates reducing speed and dropping out of the battle formation.

(b) The safety of a ship depends partly on the buoyancy and partly on the stability, but in most warships much more on the latter than on the former. A ship must be considered lost if she capsizes, even though she continues to float. The reserve buoyancy, which is the surplus of buoyancy due to the portion of the watertight hull above the waterline, forms a margin of safety against bodily sinkage which, in warships, usually amounts to from 50 to 100 percent of the displacement, and generally stability is destroyed long before this margin is absorbed by sinkage. The utility of this margin of safety is dependent on the maintenance of watertightness, and if watertightness of the hull above the waterline is impaired by damage, the reserve buoyancy may be reduced to a dangerous extent. The tendency to capsize will generally be also greatly increased by such damage.

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10-1 GENERAL:-

(c) The first requisite for maintenance of buoyancy and stability in a damaged condition lies in preventing the spread of water to other portions of the ship; in other words, localizing the damage. To accomplish this, it is necessary that all watertight appliances, such as doors, hatches, manholes, ventilation duct covers, valves in damaged pipe lines, etc. in the vicinity of the damage be closed, either by the functioning of a Damage Control organization, which insures that they are closed to the maximum extent before the damage occurs, or by quick action afterward. It must be remembered, however, that even this is not sufficient if the material condition of bulkheads and decks and watertight appliances is such that they are not completely watertight, due to deterioration, the existence of unnoticed holes, etc. The maintenance of watertight integrity through frequent inspections and efficient material upkeep is of the highest importance in either peace or war, and, for the reasons mentioned above, is equally important above and below the waterline. The problem of gas defense increases the importance of watertightness, since watertightness is, of course, gas tightness as well.

(d) The ability to control the effects of damage received depends on two equally important factors:

(1) The material features of the vessel incorporated in its design to limit the extent of damage and to permit control of damage.

(2) The effectiveness of the ship's organization in making the best use of these material features.

The purpose of this bill is to furnish for the use of the ship's organization, information in compact and usable form relating to Damage Control, particularly the features of buoyancy, stability, list and trim.

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10-2 EFFECTS OF FLOODED COMPARTMENTS:-

(a) When water enters the hull as a result of damage, one or more of the following changes in the position of the hull in the water takes place:

(1) Mean draft increases.
(2) The trim changes.
(3) A list develops.

(b) If the boundaries of the damaged compartments are watertight and the leak is not checked, the draft, trim and list will cease changing when equilibrium is reached in one of the following ways:

(1) The damaged compartments fill completely.
(2) The damaged compartments fill up to the external waterline.
(3) The damaged compartments fill until the pressure of the entrapped air is equal to the water pressure outside at the same level.

(c) If the boundaries are not watertight, water will continue to infiltrate until watertight boundaries are reached. Consequently, maintaining the watertight integrity of all internal bulkheads and decks is of first importance in accomplishing the aim of Damage Control. Unless the leak can be quickly stopped, the safety of the damaged vessel depends on the watertight subdivision. If watertight bulkheads and decks remained watertight at all times, the subdivision of large modern warships is generally sufficient to prevent a single source of damage from seriously menacing either the buoyancy or the stability of the vessel; but since practically all bulkheads and decks are extensively pierced by doors, hatches, piping ventilation ducts, wiring, etc., it is always probable that the water may spread further; this has happened on numerous occasions after collisions. It is also possible that bulkheads and decks may yield under water pressure and begin to leak, but a serious collapse need not be feared unless the bulkhead or deck is already weakened by damage.

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10-2 EFFECTS OF FLOODED COMPARTMENTS:-

(d) Increase of mean draft as a result of damage will almost invariably be accompanied by a list or change of trim or both since it is unlikely that only compartments in the center of the ship would be flooded. The speed and maneuverability are certain to be adversely affected. The effect on initial stability, i.e., on metacentric height, depends on the method by which equilibrium is reached. If the damaged compartments fill completely, the metacentric height always increases, and initial stability is correspondingly increased. If the damaged compartments do not fill completely, leaving a free water surface, the initial stability may either increase or decrease, depending on several factors. In most cases the change will not be great in either direction. Generally, however, the range of stability and the maximum righting arm will be decreased, and of course, the reserve buoyancy is always reduced. Consequently, increase in mean draft beyond the normal always reduces the seaworthiness of the vessel. The reduction in freeboard may affect the efficiency of the guns if a heavy sea is running.

(e) List and change of trim, in addition to affecting speed and maneuverability, may affect the offensive power of the battery by making it impossible for guns to elevate or depress sufficiently, and by making it difficult or impossible to handle ammunition and serve the guns. The adverse effects of a heavy list are manifold, not least important of which is the effect on morale.

10-3 MEASURES AFTER DAMAGE OCCURS:-

(a) When damage occurs, resulting in bilging one or more compartments, immediate efforts must be directed towards insuring that the damage is localized, that is, that the water is confined within limits as small as possible. All watertight appliances not already closed in the vicinity of the damage must be closed. Watertight appliances already closed must be examined, for loose dogs, nuts, bolts, etc. After every effort

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10-3 MEASURES AFTER DAMAGE OCCURS:-

(a) (cont'd.)
has been made to make the watertight sub-division in the vicinity of the damage perfectly watertight, the exact location of the leak, and its extent, should be determined if it is possible to do so. It may be necessary to enter flooded compartments, for which purpose diving equipment should be available. Compartments adjacent to the bilged compartments may be leaking slowly, but not seriously damaged, and they should be kept pumped down. Bulkheads subjected to water pressure on one side must be kept under constant observation, particularly to determine whether or not excessive deflections are taking place. The deflection of a plane bulkhead or deck may be approximately determined by stretching a cord across its surface. Shoring may be necessary, not only of bulkheads or decks, but of doors, hatches, etc. For this purpose shoring timber and wedges should be available; mess tables, or benches may be used if necessary. Small leaks may be plugged or caulked. Wooden plugs for plugging rivet holes, and flashlights should be kept available in all parts of the ship ready for immediate use. The material which should be stowed in the Damage Control lockers is listed in the vessel's allowance list.

(b) Once the water is definitely confined within watertight boundaries, there are generally three measures which may be taken to reduce or eliminate its adverse effect on the fighting efficiency of the ship.

(1) Pumping the water overboard, in cases where the leak can be stopped or checked by such means as collision mats, etc., or where the leak is so small that the drainage pumps can handle the water.

(2) Shifting solid or liquid weights already on board, such as fuel, water, stores, or ammunition, in such manner as to counteract the effect of the bilged compartments on list and trim.

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10-3 MEASURES AFTER DAMAGE OCCURS:-

(b) (cont'd.)

(3) Counter-flooding, that is, flooding compartments or tanks diagonally opposite the damage with salt water to produce heeling and trimming moments which will reduce the list and change of trim.

(c) Of course, the preferable method of reducing the effect of bilged compartments is pumping the water overboard. Only infrequently will it be practicable to do this, particularly in cases of shell or torpedo damage in battle. Even where it is possible to check the leak to the point where the pumping arrangements can take care of the water, this would generally take considerable time, and the exigencies of the moment may make it necessary to use other means to remove the list or change of trim as quickly as possible in order to continue to efficiently fight the ship without delay.

(d) Shifting of weights already on board may take the form of pumping fuel oil, pumping water or moving solid weights such as stores. Pumping liquids, particularly fuel oil, is very slow, due to limited pumping facilities, and considerable time would probably be required to correct any considerable list or trim by this means. Shifting solid weights will generally not be practicable. When time permits, however, shifting weights already on board has the advantage that reserve buoyancy is not reduced by the corrective measure. A variation in this method, possibly useful at high speeds when large quantities of fuel oil are being consumed, consists in taking fuel oil suction only from tanks on the low side, thereby reducing the list as fuel is consumed.

(e) Counter-flooding should be resorted to only as an emergency measure when the tactical situation demands that the ship be brought upright immediately. When counter-flooding is resorted to, the vessel not only suffers a loss of reserve buoyancy and possibly of stability due to the damage sustained, but it

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10-3 MEASURES AFTER DAMAGE OCCURS:-

(e) (cont'd.)
suffers an additional loss of reserve buoyancy and possibly of stability due to the counter-flooding itself. Mean draft is likewise doubly increased with attendant increase in adverse effects on the vessel. The fundamental principle which governs in correcting the list or trim by counter-flooding is that such corrections should be accomplished with the minimum added weight. When counter-flooding is resorted to, and the list and trim are brought to the desired values, immediate efforts should be directed towards shifting weights already on board before the damage, securing listing and trimming moments equivalent to those furnished by the intentionally flooded compartments so that the added weight of water may be eliminated or reduced by pumping overboard again as quickly as possible.

10-4 SHORING:-

(a) There are three rather widespread misconceptions regarding the strength and shoring of structure. They are:

(1) That test pressures, sometimes arbitrarily limited by instructions regarding testing, represent the maximum pressure which the structure is capable of withstanding.

(2) That watertight structure cannot withstand the pressure which would be put upon it as a result of flooding. This lack of confidence in the strength of watertight structure is a corollary of (1) and is evidenced by the general practice of "shoring" all bulkheads surrounding supposedly flooded spaces in the damage control practices.

(3) That the erection of effective shoring is a simple matter which can be accomplished satisfactorily by fitting one or two wooden braces between the bulkhead and the deck.

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10-4 SHORING:-

(b) The following paragraphs have been prepared for the purpose of correcting the misconceptions noted above:

The maximum pressure which the structure is capable of withstanding is far greater than the test pressure specified. To prevent unsightly permanent deformation of the structure, test pressures are purposely kept low. Deformation resulting from greater pressures, occurring as a result of damage, are acceptable, however, and it must be recognized that, in most cases of flooding due to damage, deformation will occur.

The various bulkheads are designed to withstand heads of water depending on their location in the vessel. Bulkheads in good condition may be relied upon to withstand any static pressure to which they may be subjected due to hull damage.

(c) Failure of bulkheads, however, may occur from the following causes:

(1) If the bulkhead is old and particularly if it has been subjected to considerable corrosion, it may have been weakened by deterioration.

(2) The explosion causing hull damage may weaken the bulkhead and probably will weaken all bulkheads close to it which are not extensively damaged.

(3) The bulkhead may, subsequent to the damage, be subjected to pressures greater than the static head due to flooding by the dynamic action of the ship's movement, either in a sea-way or due to her speed.

(d) Unless one or more of the conditions enumerated above exist, there is no necessity for shoring bulkheads. Shoring is not required as a matter of routine in case of hull damage. In cases where it

10-4 SHORING:-

(d) (cont'd.)

is necessary, the extent of shoring sufficient to be of any value will be such that the operation will be a major one. Two or three shores placed at random will generally be of no value. Effective shoring will, in most cases consist of a fairly complete net-work of reinforcement to the critical area.

It is apparent that no hard and fast rules can be given as to when the shoring is necessary, nor can any set methods of shoring be established.

Whether or not shoring is required is a matter of judgment, with consideration being given to the known state of preservation of the bulkhead before the damage, the probability of its having been weakened by the explosion, the load on the bulkhead as evidenced by its appearance and action, and existing or probably dynamic forces working on the critical area. For riveted bulkheads, it should be safe to assume that until leakage occurs around rivets or through seams, the bulkhead needs no shoring. However, under some circumstances, even this limit might not be safe; that is, leakage and collapse might occur simultaneously.

(e) The methods and extent of shoring are likewise matters of judgment. The following principles, however, should be followed:

(1) Bulkheads should be shored to decks either through obstructions on the decks, such as stanchions, hatch coamings, etc., or through the beams overhead.

(2) Pressures should be distributed over as wide an area as possible to avoid local failure.

(3) Every effort should be made to avoid damaging the caulking around bulkheads.

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10-4 **SHORING:-**

(e) (cont'd.)

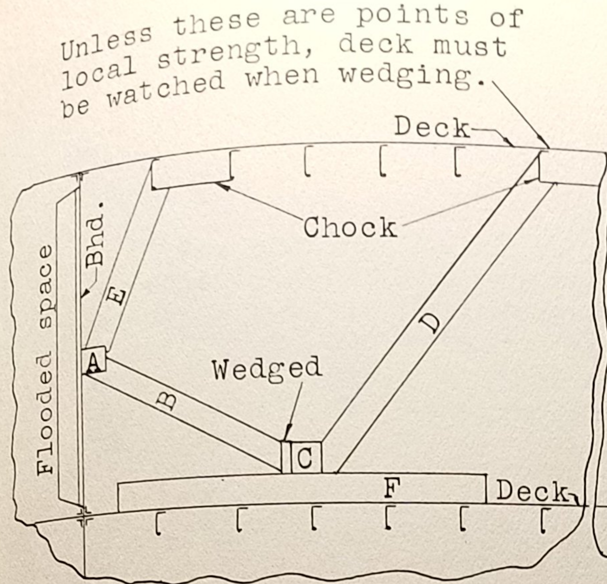
(4) In wedging up, sufficient pressure should be exerted to relieve the load, but care should be taken that flanges of bulkhead stiffeners, deck beams, etc., are not caused to buckle from excessive pressure.

(f) Where necessary, decks may be shored to decks overhead. The shoring should extend to headers, under the overhead deck beams which are so arranged as to distribute the load over a large area or to carry it to some point of local strength, such as a bulkhead overhead. The same procedure should be followed in shoring one bulkhead to another.

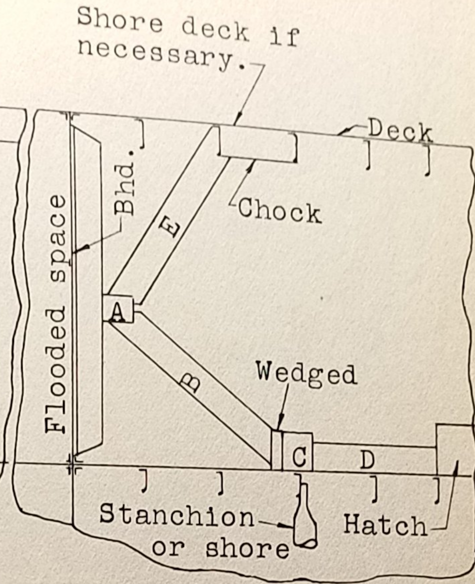
In common with other features of Damage Control, the possible necessity for shoring bulkheads must be recognized and general provision for accomplishing this operation must be made beforehand. The actual operation must, however, be governed by conditions which exist when and if shoring is found necessary.

(g) Figures 1 and 2 are sketches which are intended to illustrate how bulkheads may be shored through obstructions on the decks or to the deck beams overhead. They are not intended to apply to any particular bulkhead nor to any particular ship. They are for guidance in case shoring is found necessary.

(h) It should be noted that all effective members, except those used to distribute pressures over wide areas, are direct compression members. The material at hand, assumed to be wood, should be arranged so that the length of direct compression members is between fifteen and thirty times the dimensions of the least side, or diameter. Thus a 4" x 4" timber could be ten feet long, but were it only five feet long it could take a fifty percent greater load.




ELEVATION

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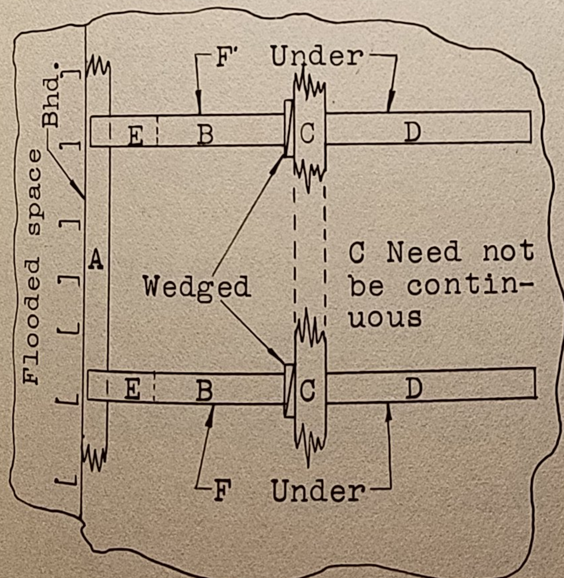
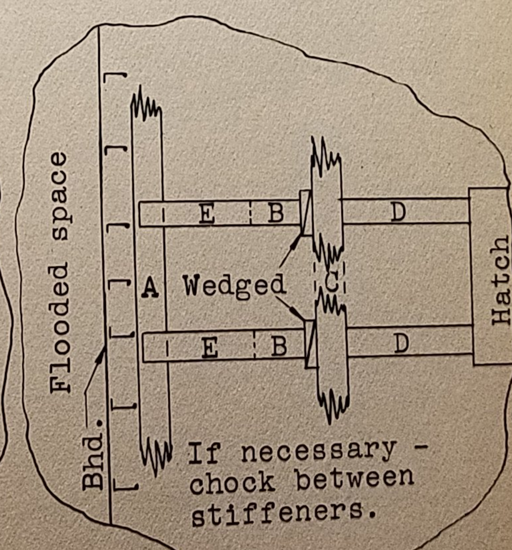



PLAN UNDER DECK




PLAN

SHORING BULKHEAD TO DECK OVERHEAD

Figure 1

SHORING BULKHEAD TO OBSTRUCTION ON DECK

Figure 2

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10-4 SHORING:-

(i) For shoring, which is a temporary emergency expedient, materials may be stressed almost to the breaking point. Having determined the necessity for shoring, and the type and arrangement, the extent of shoring is largely a question of trial-error; in other words, add more shores until the bulkhead is held securely.

(j) Material which is too small in cross sectional dimensions to be of value may be used to form built-up sections of reasonable dimensions. Thus two 2" x 4" members could be nailed, lashed, or clamped together to form 4" x 4" piece. A built-up piece would not be quite as strong as a single piece of the same dimensions, however.

It is also worthy of note that materials for shoring need not always be wood. If necessary, stanchions, pipe, and similar material could be cut from their proper places and used to support the failing bulkhead.

Although the discussion above refers particularly to shoring bulkheads, it applies with equal force to shoring decks.

10-5 OCEAN CONDITION DATA:-

(a) The data given below corresponds to the Ocean Condition of the vessel. The condition is described as the displacement of the vessel fully loaded and trimmed for ocean travel.

The following figures are based on estimated data:

| | |
|---|---|
| Displacement . . . . . . . . . . . | 912.3 tons |
| Draft forward . . . . . . . . . | 4'-3" |
| Draft aft . . . . . . . . . . . | 7'-2-3/4" |
| Transverse metacentric height (GM) . . . . . . . . . . | 10.34 |
| Moment to alter heel one degree. | 164.6 ft. tons |
| Moment to alter trim one inch . | 198.3 ft. tons |
| Tons per inch immersion . . . . | 14.31 |

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10-5 OCEAN CONDITION DATA:-

(b) The table below shows the effect on the transverse metacentric height (GM) of adding 50 tons additional weight at various heights. Weights up to two or three times this amount will have approximately proportional effects on the metacentric height (GM).

| CG of Added Weight Above Baseline | Location | Change in GM |
|---|---|---|
| 5'-3" | Top of Inner Bottom | - .43 |
| 13'-3" | Main Deck | - .84 |

10-6 THE EFFECTS OF FLOODED COMPARTMENTS ON LIST, TRIM, DRAFT AND STABILITY:-

(a) Water taken aboard as a result of damage will affect not only the list, trim and draft of the ship but also the stability as well. It is not difficult to predict with fair accuracy the resulting list, trim and draft after specific damage, but the prediction of remaining stability is a much more complex problem, and with the infinite number of possible damages which may occur in a ship with a large number of compartments it is practically impossible to present in usable form information which will indicate what the stability characteristics of the ship may be after damage. Damage Control operations which may affect the stability characteristics should be conducted only by one who has a thorough knowledge of the subject of stability in order to avoid making dangerous or even fatal mistakes. Consequently, in order to use safely and intelligently the information given here and in the Flooding Effect Diagram, PLATE II, the Executive Officer (Damage Control Officer) and other officers concerned should be thoroughly familiar with the contents of the pamphlet "The Stability of Ships and Principles of Damage Control," published by the Bureau of Ships, particularly Chapters II, III and IV.

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10-6 THE EFFECTS OF FLOODED COMPARTMENTS ON LIST, TRIM, DRAFT AND STABILITY:-

(b) List, Draft and Trim:-

In order to show in a compact manner the effects of compartments flooded as a result of damage, on the draft, trim and list, and as a guide in conducting counter-flooding operations or in shifting liquid already on board to reduce list and change of trim resulting from damage, the Flooding Effect Diagram, PLATE II is furnished. This consists of deck plans for the hold and the inner bottom, showing the watertight compartmentation of the ship on those decks. In each compartment a number appears in each corner as follows:

(1) Upper left corner - weight of salt water in tons which will completely fill the compartment.

(2) Upper right corner - list in degrees resulting from complete flooding of the compartment with salt water.

(3) Lower left corner - change in draft aft in inches resulting from complete flooding of the compartment with salt water.

(4) Lower right corner - change in draft forward in inches resulting from complete flooding of the compartment with salt water.

The data on capacity in tons are based on complete flooding with salt water, density 35 cu. ft. per ton, with assumed permeability factors as follows:

| | |
|---|---|
| Storerooms, living spaces, magazines, voids, tanks . . . . . . . . . . . . . . | 95% |
| Machinery spaces . . . . . . . . . . . . | 85% |

In estimating the changes of list, draft and trim resulting from flooding a number of compartments, it may be assumed in each case that the total change is

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10-6 (b) (cont'd.)

the sum of the individual changes as shown on the diagram. This is not strictly true, but is sufficiently accurate for the purpose, in view of the other limitations on the accuracy of the figures described below.

The data are calculated on the basis of flooding empty compartments with salt water. The permeability factors used are intended to allow only for structure and fixed articles in the compartments. Consequently if appreciable space is occupied by portable articles such as stores in storerooms or ammunition in magazines, the capacity figures given on the diagram should be correspondingly reduced. If oil is shifted from one tank to another to correct list or trim, the figures for capacity shown on the diagram will be reduced in the ratio of thirty-five to thirty-seven, assuming the density of fuel oil to be thirty-seven cubic feet per ton. Furthermore, the tanks being emptied will probably be not more than ninety-five per cent full.

The figures for list and draft forward and aft are dependent on the capacity figures, and therefore are subject to the same limitations as to accuracy. Furthermore, they are calculated for the ship at "normal" displacement and therefore are exactly correct only for that condition. Even if the vessel entered an action in approximately the "ocean" condition, water taken aboard as a result of damage would change the stability features from those obtaining in that condition, and thus the accuracy of the list and draft data would be still further reduced if they are used for counter-flooding or for shifting liquids already on board to compensate for damage.

Consequently, in view of the above limitations on accuracy, the list figures are given only to the nearest half-degree and the change in draft figures to the nearest inch. The figures should be considered as comparative rather than exact. An example, is worked out on the diagram for shifting liquid already on board. It is worth noting that

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10-6 (b) (cont'd.)

when liquid already on board is used for flooding compartments diagonally opposite, the effect on list and trim is approximately double that obtained by flooding the same compartments from the sea with the same weight of liquid, since the emptied compartments also exert an effect on list and trim.

(c) Stability:-

As stated above, the data on the diagram is calculated for the ship in "ocean" condition, which means that the transverse righting moments are based on the transverse metacentric height (GM) in the "ocean" condition, which for this vessel is 10.34 feet. If this GM has been reduced as a result of damage or otherwise, flooded compartments will produce greater lists than those indicated on the diagram. The list produced by a given inclining moment is inversely proportional to the GM, for small angles and this fact may be utilized to form a rough idea of the GM remaining after damage, or at any other time.

A somewhat more accurate but still very rough method of determining the metacentric height of the vessel at any time when the ship is rolling, may be used by observing the period of roll with a stop watch. The relation connecting the period with the GM is as follows:

$$T = \frac{.22 \times \text{Beam}}{\sqrt{GM}} \quad \text{or,} \quad GM = \frac{K}{T^2} \text{ when } K = (.22 \times \text{Beam})^2$$

Where K is constant, which for this vessel is estimated to be about 56 and T is the time of a half-roll, that is the time in seconds between a maximum on one side to a maximum on the other. The value of the constant K may be more accurately established by observing the period of roll at a time when the GM is approximately known, such as when the ship is about in "ocean" condition, when the GM is 10.34 feet. By placing the time of roll so obtained and the GM in the formula, the value of K may be obtained.

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10-6 (c) (cont'd.)

In observing T, it is best to get the total time of a number of successive half-rolls, such as ten, rather than of a single half-roll, and then divide the total time by the number, in order to average out inaccuracies.

This method is only valid theoretically for free and unrestricted rolling, that is, the natural roll of the ship without outside influences tending to change the time of roll. Consequently, the time should preferably be taken during fairly calm weather, when the roll is not appreciably affected by deep waves.

It must be remembered that these methods of determining the GM give only approximate results, and they should be used only with thorough understanding of the principles involved so that their limitations may be understood. The importance of a thorough knowledge of the general subject of stability in conducting pumping or flooding operations which may affect the stability can not be too strongly emphasized.

For further information concerning Damage Control Bill see PLATE II.