

**DEPARTMENT OF TRANSPORTATION  
COAST GUARD**

COMMANDANT (MMT-5)  
U.S. Coast Guard  
WASHINGTON, DC 20591

NVIC 3-69  
22 May 1969

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO.3-69

Subject: Z Nomograph Method of Calculating Available CM

1. Purpose. The purpose of this circular is to publish an acceptable short form method of calculating available CM.
2. Background. Section 93.10-1 of the Coast Guard Rules and Regulations for Cargo and Miscellaneous Vessels states, in part, \* \* \* information shall be prepared. \* \* \* and furnished to the Master. \* \* \* This information shall be such that the Master can, for any condition of loading, by rapid and simple process, obtain accurate guidance as to the stability of the vessel \* \* \* This regulation requires the inclusion of a suitable short form for the calculation of a vessel's stability and freeboard in trim and stability booklets for general dry cargo vessels.
3. Discussion. The Z nomograph short form eliminates the need for multiplication and division, thus providing a simple, rapid, and accurate method for calculating available CM.

Many of the present short forms require tedious arithmetical operations as well as considerable averaging to place the cargo in arbitrary layers. Container ships with many cargo layers in addition to sizable deck loads often operate near their required CM in the fully loaded condition, thus a more accurate method is needed to determine the available CM.

The Z nomograph short form method requires additional preparation prior to its approval and issuance to the Master of said vessel. Nonetheless, the end product is easy to use (requires only a straight edge to read the nomographs) and provides a more accurate stability evaluation.

4. Action. Enclosure (1) contains instructions on how to prepare the nomographs for calculating available CM. This method is an acceptable short form method for calculating stability, and may be used in Trim and Stability Book-lets. Enclosure (2) is an acceptable format for the short form part of such a booklet.

The use of the enclosed method is not mandatory since the presentation of stability information in any other simplified form which effectively complies with current regulations is also acceptable.

  
**C. P. MURPHY**  
**Rear Admiral, U. S. Coast Guard**  
**Chief, Office of Merchant Marine Safety**

End: (1) Instructions for the Preparation of the Z Nomograph Method for Calculating Available GM.  
(2) Example Short Form

Dist: (SDL No.88)

A: None

B: n(45); c(10); eg(3); q(6); bdp(1)

C: m(4); 0(2)

D: i(2); k(1)

E: o(2)

F: None

List 112-155

## INSTRUCTIONS FOR THE PREPARATION OF THE Z NOMOGRAPH METHOD FOR CALCULATING AVAILABLE GM

This short form was developed with the following goals in mind:

1. To provide a method for calculating stability which is flexible enough to permit its application to a wide range of vessel and cargo types.
2. To produce accurate results throughout the full range of vessel loading.
3. To present the data in a form which has physical meaning to the user.
4. To eliminate error-prone interpolation.
5. To reduce the arithmetic process to simple addition or subtraction.

### A. PREPARATION OF THE BASIC GM NOMOGRAPH

1. The basic ship in the no cargo condition should include the following items:
  - a. Lightship
  - b. Crew and effects
  - c. Passengers
  - d. Nonconsumable stores
  - e. 2/3 consumable stores
  - f. Lube oil
  - g. Small diesel oil and other miscellaneous small service tanks
  - h. Fixed ballast

The resultant weight, center of gravity, and vertical moment are the operational lightship values to be used in the preparation of the nomograph.

2. Free Surface Deductions - Calculate and take the SLUD of the free surface moments for all tanks as indicated in Table 1.
3. Basic GM - Assume the basic ship KG remains constant for the full range of operating displacements. At various displacement intervals throughout the operational range of displacement, calculate the basic GM according to the following formula:

$$\text{GM basic} = \text{KM} - (\text{KG basic ship} + \frac{\text{Free Surface Moments}}{\text{Displacement}})$$

Tabulate the results and construct a graphic plot of displacement vs basic GM.

### B. PREPARATION OF THE Z NOMOGRAPH FOR THE LOADING ZONES

1. Zones and Levers - Separate cargo spaces and tanks into convenient zones. The criteria for placing a cargo space or tank in a particular zone is the location of the vertical center of

gravity, i.e., values of KG for all cargo spaces or tanks within a zone should be approximately equal. (Obviously, the more zones used, the more accurate is the final GM calculation. Conversely, the more zones used, the more calculation is needed in arriving at the final GM, and the less attractive the Z nomograph method appears. Generally, for a large container ship, one zone is needed per layer of containers, plus one zone for bottom tanks. In break bulk vessels, at least one zone per deck, plus one zone for bottom tanks, and one or two zones for deck cargo are needed.) The center of gravity for cargo spaces or containers is taken at the homogeneous center. The KG of deck cargo is taken at the height of the deck plus 0.6 of the anticipated height of cargo. When working with general purpose ships such as general cargo/vehicle carriers, it is best to establish separate zones for the different cargo categories because the KG for different cargoes may vary widely. Calculate an average KG for each zone. Then calculate the zone lever using the following formula:

$$\text{Zone Lever} = \text{KG}_{\text{basic ship}} - \text{KG}_{\text{zone}} \text{ (avg.)}$$

For example, the zone lever of a typical zone would be found as follows:

KG basic ship - 28.51 feet

<u>Item</u>	<u>Capacity (tons)</u>	<u>KG</u>	<u>Vert. Mom.</u>
Tween Deck	5144.0	28.60	147118
Wash Water Tank	103.6	30.93	3204
Potable Water Tank	40.0	33.50	1340
Upper Trim Tank	<u>308.0</u>	<u>30.78</u>	<u>9480</u>
	5595.6	28.80	161142

Zone 3 lever = 28.51 - 28.80

Zone 3 lever = -0.29 ft

2. Flume Tanks - Since flume tanks have a large free surface correction when operating, and may or may not be used depending upon operating conditions, the flume tanks are best handled as a separate zone. Since the free surface correction varies directly with displacement, a graph of free surface factor vs displacement will provide a handy presentation of data, while the weight or liquid in the tank can be treated as a simple zone weight. (In lieu of the separate zone approach, the flume tank weight may of course be grouped into one of the other zones, depending upon the VCG of the tank.)
3. Stability Factor - The product of the zone lever and the sum of weight in each zone represents a change in the vertical moment of the vessel, which in turn changes the location of the center of gravity. Since the location of the metacenter remains unchanged for a movement of weight, the movement of the center of gravity also represents the change in GM. The change in GM resulting from the weight of cargo or liquid added in a particular zone is called a stability factor, which is determined from the relationship:

$$\text{Stability Factor} = \frac{(\text{Weight in Zone}) \times (\text{Zone Lever})}{\text{total displacement}}$$

The stability factor is calculated for a range of operational displacements taking convenient increments of weight. The results should be presented in tabular form to be useful in the preparation of the Z nomographs.

4. Z Nomograph - The Z nomograph is a simple and practical way of presenting the corrections to GM which are generated by the relocation of weights to their actual zone KG's. Its use eliminates the necessity for multiplication and division, and permits visual in lieu of numerical interpolation. It has the added advantage of linear scales whereby an increment of length representing, say, 100 tons of cargo or 0.1 foot of GM remains the same throughout the range of the scale.

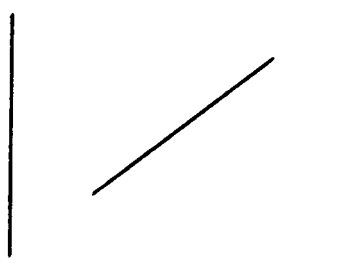
The nomograph solves the equation.

$$\text{Stability Factor} = \frac{(\text{Tons Loaded}) \times (\text{zone lever, or } KG_{bs} - KG_{zone})}{\text{total displacement}}$$

(i.e. change to GM  
of basic ship)

Since KG zone is a step variable, a separate nomograph is required for each zone.

To prepare a Z nomograph lay out two parallel lines and cross with a third line canted at 45° as shown below:



Tons Loaded Scale - The left hand line will be the scale for tons loaded in the particular zone. The calibration of this scale is based upon the following considerations:

- a. The lower intersection is always the ZERO reference point for the scale.
- b. The range of the scale is based upon the anticipated maximum load that can be accommodated in the zone. For example, if a zone consists solely of several tanks the maximum capacity of which totals 2745 tons -- then an appropriate range for the scale would be 0-3000 tons.
- c. The scale divisions are linear and should be chosen on the basis of convenient length of line for reading and the range of the scale. The subdivisions of the scale should be decimal.

Stability Factor Scale - The right hand line will be the scale of stability factors. The calibration of this scale is based upon the following considerations:

- a. The upper intersection is always the ZERO reference point for the scale.
- b. The range of the scale is based on the maximum anticipated stability factor which can be generated for the particular zone. A few slide rule trials, varying X in the following equation, will identify the maximum stability factor:

$$\text{Stability Factor} = \frac{(X_{\text{tonsloaded}}) \times (\text{zonelever})}{(\text{basicshipdispl} + X)}$$

- c. The scale calibration is linear and decimal. The sign of the stability factor must be clearly noted.

Displacement Scale - The canted line will be the scale of displacement. Its calibration is non-linear and is not selected, but derived.

- a. The range should extend from lightship displacement to full load displacement.
- b. The calibration is accomplished by solving the basic equation for a specific set of variables and then using the left and right scales as references to plot the solution, thereby establishing a discrete point on the displacement scale. Additional displacement marks are obtained by repeating this process.

C. PRESENTATION - The calculated data is presented in the Trim and Stability Booklet as follows: (see attached example, enclosure (2))

1. Instruction Sheets (2)
2. Short Form Calculation Sheet including
  - a. Tabulation of cargo or liquids actually loaded, separated into appropriate zones with provisions for the departure and arrival conditions.
  - b. Deadweight Summary Table for departure and arrival conditions. Total tonnage is entered in appropriate zones. Columns should be provided for entering the appropriate stability factor for each zone. The net stability factors in the departure and arrival conditions are determined from the algebraic sum of the positive and negative stability factors.
  - c. Displacement summary for arriving at the total displacement by summing Basic Ship Displacement (a constant) and total deadweight in the departure and arrival conditions.
  - d. Spaces for recording departure and arrival means drafts.
  - e. A stability summary with provisions for entering basic GM, net stability factor, available GM and required GM for the departure and arrival conditions.
3. Basic GM Tabulation Sheet with columns for displacement on the extreme right and left, column of Basic GM, and a column of Mean Draft.
4. Nomographs shall be provided for each zone. (Different nomographs may be provided for the same zone for different cargoes, such as general cargo, vehicular cargo, etc., whenever this added refinement is considered beneficial.)

, MAR 1969

TABLE 1

<u>TANKS</u>	<u>FREE SURFACE</u>
1. Fuel Oil Settlers	Full Slack
2. Fuel Oil Storage Tanks (use one of the following having the largest free surface)	
a. Pair of Double Bottom Tanks	Full Slack
b. Centerline Double Bottom Tank	Full Slack
c. Pair of Deep Tanks	Full Slack
d. Centerline Deep Tank	Full Slack
3. All Other Fuel Oil Double Bottom Storage Tanks	98%-5° Heel
4. All Other Fuel Oil Deep Tanks	98%-5° Heel
5. Fuel Oil and Ballast Tanks (already covered in 2 through 4)	
6. Clean Ballast (pressed up)	0
7. Clean Ballast (if authorized to be carried slack by operating instructions)	See operating inst. for additional slack tanks
8. Fresh Water - for each system, select centerline tank or tank pair as in item 2 and handle the same way	See item 2
9. Distilled Water	Full Slack
10. All Other Fresh Water Double Bottom Tanks	0
11. All Other Fresh Water Deep Tanks	0
12. Peak Tanks	See appropriate system
13. Liquid Cargo Tanks (when a centerline or pair of cargo tanks are authorized slack in the operating instructions treat as in item 2)	Full Slack
14. All Other Liquid Cargo Tanks	98%-5° Heel
15. Flume Tanks	See inst. B-2

## TRIM AND STABILITY BOOKLET EXAMPLE

### OPERATING INSTRUCTIONS FOR TRIM AND STABILITY BOOKLET

Sheet 2 provides a simplified means of determining available GM and draft at various conditions of vessel loading. This sheet is largely self explanatory. After totaling various items of vessel loading as indicated by the loading tables shown, the vessel's draft and available (corrected) GM may be determined in a simple, direct and accurate manner.

The tabular GM on sheet 3 includes an allowance for slack tank free surface for each type of consumable liquid (see operating instruction for table of assumed free surface present and F.O. Tanks 98% full. No additional free surface correction need be made when using this form unless additional tanks are slack, beyond those permitted by instruction no. \_\_\_\_\_ (From instruction page.)  
(free surface moment)

$$\text{GM reduction (due free surface)} = \frac{(\text{free surface moment})}{\text{total displacement}}$$

NOTE: The total displacement computed on sheet 2 will not necessarily agree exactly with the displacement from its mean keel draft because of minor variations between actual and assumed values of items contained in basic displacement.

A GM available less than the GM required indicates insufficient stability. Such a condition may be corrected by ballasting tanks in any zone having a positive stability factor.

### INSTRUCTIONS FOR USE OF SHORT FOBM

1. Enter the long tons of cargo and liquids carried in the various locations, compartments, and tanks in the spaces provided for each in the center and left-hand columns of the form. This breaks down the loading of the ship into the appropriate Zones.
2. Add the tons in each Zone and then enter the total for each Zone in Table I, in the right-hand column of the form.
3. In Table I, add the tons in the Zones to obtain the DEADWEIGHT and then enter this value in the appropriate space in Table II.
4. Add the entries in Table II to obtain the DISPLACEMENT.
5. On sheet 3, lay a transparent straight edge (celluloid triangle, etc.) across the Displacement in the right column and in the left column. At the intersections with the center columns, read off the MEAN DRAFT (which is entered in Table III) and the BASE SHIP GM (which is entered in the appropriate space in Table IV). Note the algebraic sign of the Base Ship GM.
6. Now that the Displacement is established, the Stability Factors in Table I can be completed. Sheets 4 through 9 furnish the information. For example, on sheet 4 (which applies to Zone 1 only), lay a transparent straight edge across the TONS LOADED IN ZONE 1 (left-hand scale) and across the TOTAL DISPLACEMENT (canted scale). At the intersection on the right-hand scale, read the



STABILITY FACTOR for Zone 1. Enter this value in the appropriate space in Table I on the Short Form. Proceed in the same manner for Zones 2 through 6.

7. Calculate the algebraic sum of the Stability Factors in Table I this is the NET STABILITY FACTOR. Enter this value in the appropriate space in Table IV.
8. The algebraic sum of the first two entries in Table IV is the AVAILABLE GM.
9. Repeat steps 1 through 8 for the arrival condition.

SHORT FORM CALCULATION SHEET

ZONE ①

SUPERSTRUC DECK CARGO
TOTAL - ZONE 1

ZONE ②

MAIN DECK CARGO
TOTAL ZONE 2

ZONE ③

TWEEN DECK CARGO
WASH WATER TANK - FWD
FRESH WATER (POW)
UPPER TRIM TANK
TOTAL ZONE 3

ZONE ④

TANK TOP CARGO
LOWER TRIM TANK
TOTAL ZONE 4

ZONE ⑤

SIDE TANK NO 1	1
	2
	3
	4
	5
	6
	6A
	6B
	7
	8
SETTLING TANK NO 9	9
FORE PEAK TANK	
SIDE TRIM TANK	
AFTER PEAK TANK	
TOTAL ZONE 5	

ZONE ⑥

DOUBLE BOTTOM TANK 1	1
	2
	3
	4
	5
	6
	7
	7A
	8
	9
	10
FEED TANK 11	11

I: DEADWEIGHT

ZONE	TONS	STABILITY FAC
1		
2		
3		
4		
5		
6		
DWT		
NET STAB. FACTOR		

II DISPLACEMENT

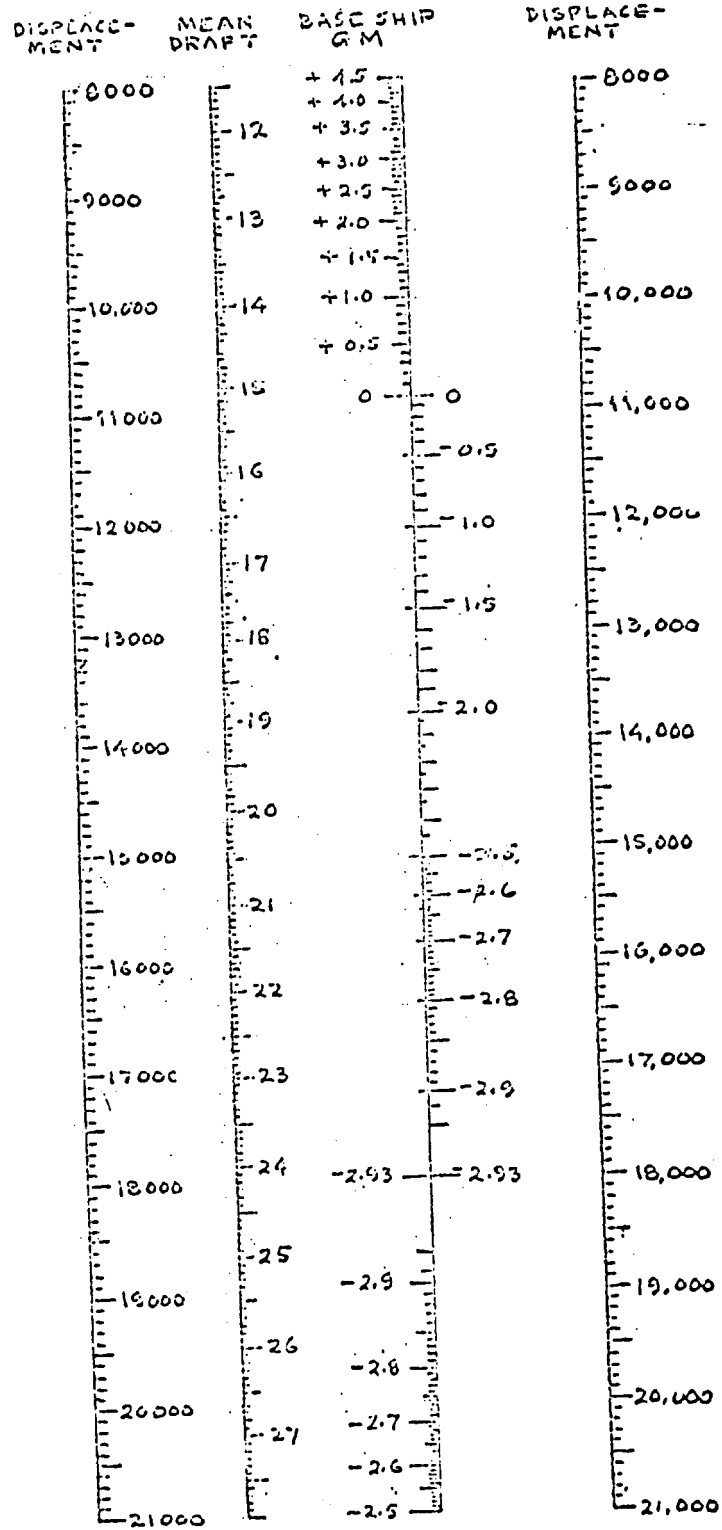
BASE SHIP	74
DEADWEIGHT	
TOTAL DISPLACEMENT	

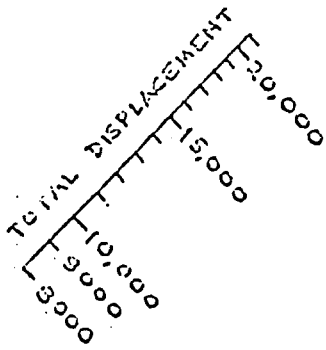
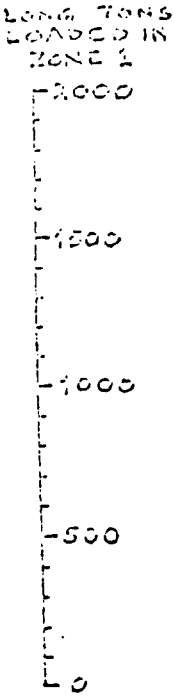
III MEAN DRAFT

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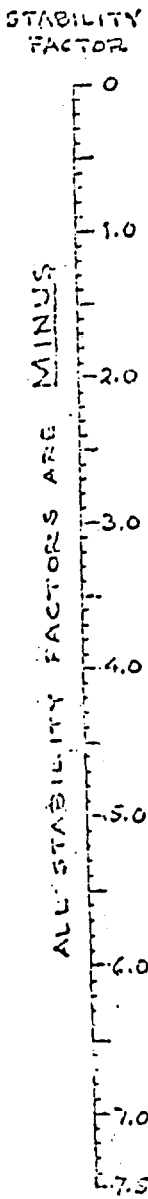
IV G.M

G.M FOR BASE SHIP
NET STABILITY FACTOR
AVAILABLE G.M
REQ'D G.M (SEE SHEET)

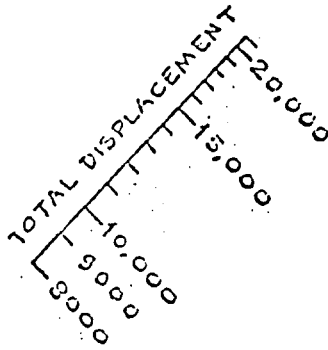
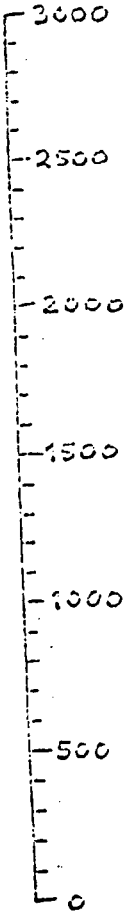




ZONE 1

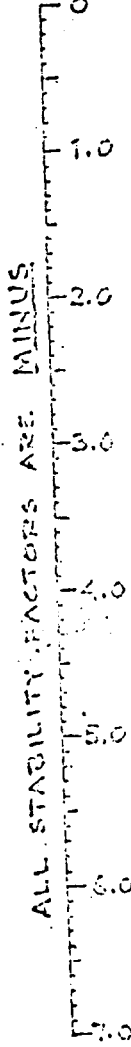


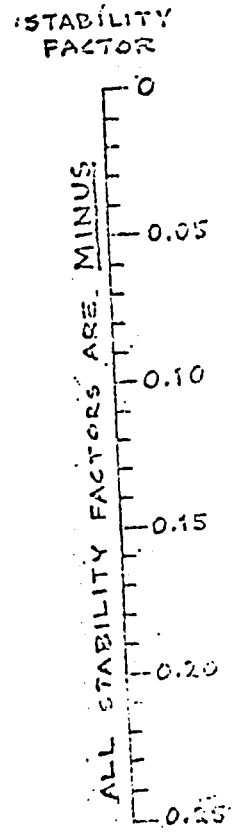
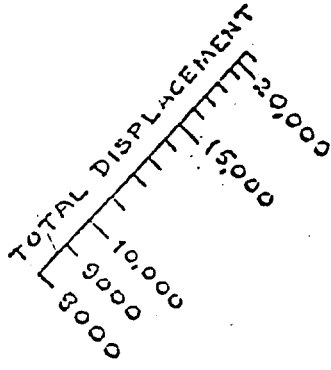
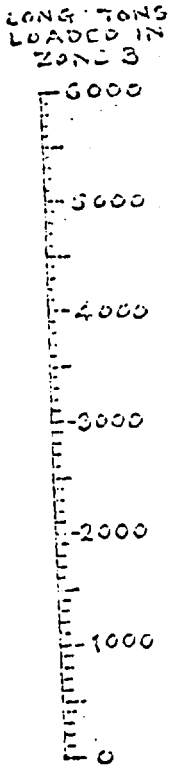
LONG TONS  
LOADED IN  
ZONE 2



ZONE 2

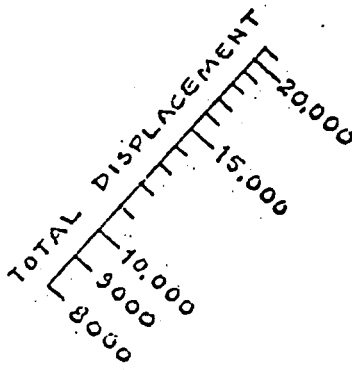
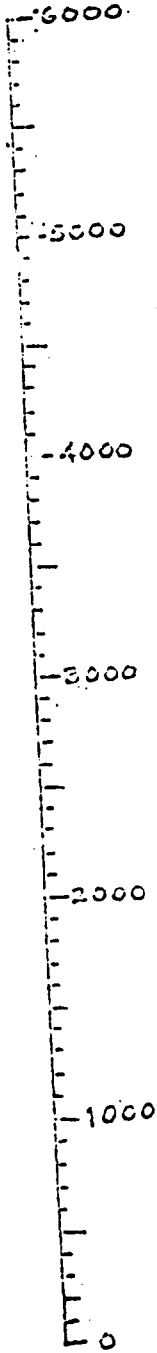
STABILITY  
FACTOR



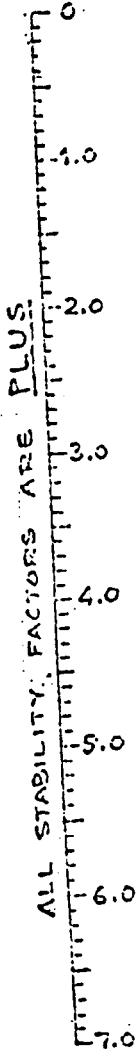


ZONE 3

LONG TONS  
LOADED IN  
ZONE 4

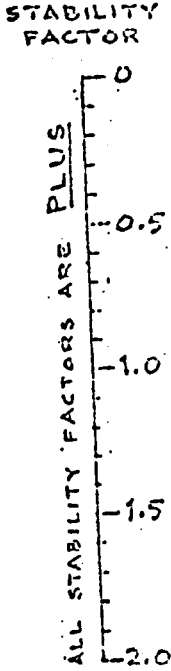
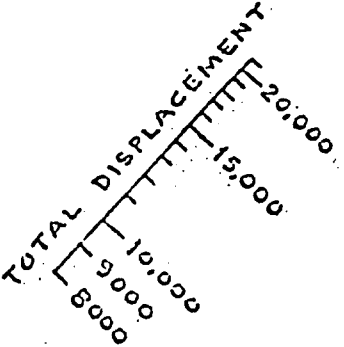
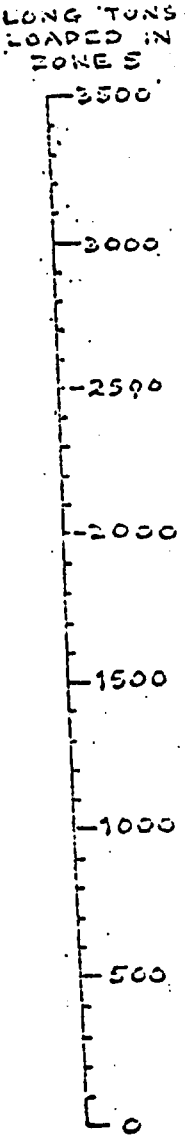


STABILITY  
FACTOR



ALL STABILITY FACTORS ARE PLUS

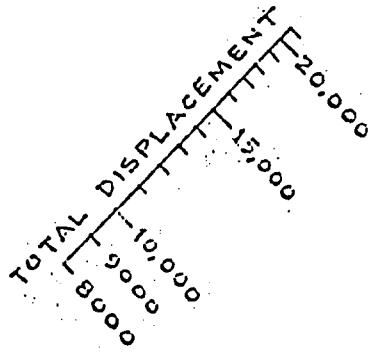
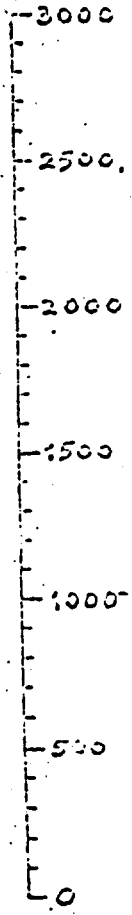
ZONE 4



ZONE 5

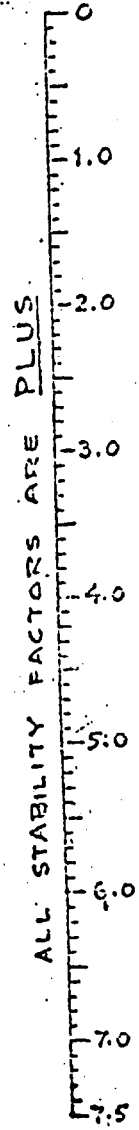


LONG TONS  
LOADED IN  
ZONE 6



ZONE 6

STABILITY  
FACTOR



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