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Tests on Photo-Elastic Investigation of Turret

Openings in Deck Structure.



BY

NAVAL RESEARCH LABORATORY

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Report  
of

FR-1442

Tests on Photo-Elastic Investigation  
of Turret Openings in Deck Structure.

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Prepared by: H. B. Maris, Associate Physicist.

Reviewed by: E. O. Hulburt, Principal Physicist,  
Superintendent, Physical  
Optics Division.

Approved by: H. M. Cooley, Captain, USN, Director.

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ABSTRACT

Studies of the stress distribution surrounding turret openings in a battleship deck have been made by the photo-elastic method for three conditions of loading, with the openings free of any support, with the openings blocked by the turret structure, and with the openings reinforced by the addition of a barbette.

The turret structure increases the maximum shear in the deck slightly without changing the general shear pattern; it decreases the maximum tension by about 25 per cent, but adds about 6 per cent to the total tension in the deck. The barbette structure shifts the region of maximum shear in the deck from the center line of the turrets to regions about 30 degrees fore and aft of the center line with no important changes of maximum shear or tension values.

Hatch openings as studied should be shifted about the width of the openings toward the center line of the ship where they will not be weak points in the deck structure.

Colored photographs of the different types of stress field maps are presented to support the observations and conclusions.

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(a) Authorization

1. This study was authorized by Bureau of Construction and Repair confidential letter NP14-6(RP) of 17 November 1937.

(b) Scope of the Problem

2. The object of the investigation was to determine the stress pattern surrounding turret openings in battleship deck plating when the ship is in hogging condition and to evaluate the importance of the turret and barbette structure in determining this pattern.

CONCLUSIONS

(a) Effect of the Turret Opening

3. The deck loaded while the turret openings were unsupported showed maxima of tension on the transverse center lines of the turrets at the edge of the openings. Measured in terms of a unit load equal to the average load on a section of the deck uninterrupted by an opening the two openings showed maxima of 3.5 for turret 1 and 3.1 for turret 2.

(b) Effect of the Turret in Blocking the Opening

4. The deck loaded while the openings were blocked by the turret structure showed approximately the same maximum stresses for both turrets, 3.8 for shear, 2.5 for tension, and 1.25 for transverse compression.

(c) Effect of the Barbette in Supporting the Opening

5. The deck loaded while the turret openings were supported by a barbette structure showed maximum tensions of about 2.5 on the center line of the turrets. Maxima for shear were found about 30° fore and aft of the center line at the barbette, that is, the edge of the opening, and measured about 2.5. The transverse force on the center line of the turret was a tension at the barbeete of value about 0.4.

(d) Effect of the Hatch Openings on the Strength of the Deck

6. The hatch openings were found to be in lightly stressed parts of the deck where they did not affect its strength in the deck without barbette. The barbette-stiffened deck, however, showed high values of shear in the region of the hatch openings. This made them the weak regions in the deck structure. If these openings were moved a distance about equal to their own width toward the center

deck structure.

## DETAILS OF THE EXPERIMENTAL METHOD AND RESULTS

### (a) Type of Model Used

7. A photo-elastic study was made of the stresses in a model deck made of celluloid 1/4 inch thick with turret and hatch openings as specified in Bureau of Construction and Repair letter NPL4-6(RP) of 17 November 1937. The deck was loaded through tension in the side plating of celluloid 0.18 inch thick as shown in Plate 1a.

### (b) Conditions of Loading

8. Stress studies were made for three different conditions of loading, as follows:

- (1) With unsupported openings the results are given in Plates 2, 3, 4 and 5.
- (2) Opening supported by the turret with results in Plates 6, 7, 8 and 9.
- (3) Openings supported by the barbette as shown in Plate 1 with results in Plates 10, 11, 12 and 13.

### (c) Optical Arrangement

9. The optical arrangement for the photo-elastic study was a little different from the conventional design and is shown in schematic detail in Plate 1, Fig. 2. An image of the source of light a is formed by the condenser lens b on the polarizer c. The polarized light passes through the compensator d and then spreads out to fill the large collimator lens e which is 12 inches in diameter and has a focal length of 10 feet. This long focal length gives a very accurately parallel polarized beam beyond e. The analyzer at g throws a double refraction shadow of the test member f on the screen h. Synchronous rotation of c, d, and g enables the investigator to draw the lines of the isoclinic and isochromatic maps much more accurately than was possible with the prism polarizers.

### (d) Description of the Plates

10. The left side of turret 1 is designated AA' and the right side BB', as shown on Plate 1. The sections through turret 2 are respectively CC' and DD'. Photographs of the section AA' under the different conditions of loading are shown on Plates 2, 6 and 10. The data of these pictures are presented in the P-Q

direction for the principal stresses and stress flow lines for the different types of loading are shown on Plates 3, 7 and 11.

(e) Integrations Performed

11. Stress integrations as required by the letter of authorization were completed for the transverse sections through the center of each turret opening. The results of these integrations are presented in Plates 5, 9 and 13. These plates also include edge stresses for that part of the turret opening near the axis of integration. The stresses surrounding the hatch openings were found to be unimportant for loading conditions (1) and (2) but very important for the opening supported by a barbette. No measurements were made but the problem is discussed in detail.

(f) P-Q Maps

12. Plates 2 and 6 show colored stress photographs of Section AA', Plate 1, stressed respectively without and with a rigid internal disc designed to take the place of the rigid roller path ring of the turret structure. From the similarity of the two pictures we see at once that the presence of the turret does not introduce any important change in the general stress pattern of the deck structure. The P-Q maps of Plates 4 and 8 show that the P-Q value along the edge of the opening is increased about 10 per cent by the presence of the turret structure. This increase represents a large transverse compression equal to about 50 per cent of the tension load. The deck under longitudinal tension deforms to exert a transverse compression on the turret. This compression fore and aft of the center line of the turret has a longitudinal component which adds to the tension stress of the deck, and this component is approximately 6 per cent of the total load. However, the value of the tension near the edge is found by a comparison of Plates 5 and 9 to be decreased about 25 per cent. The increased tension is carried by parts of the deck five feet or more from the opening.

13. Plate 11 was made of a turret opening reinforced with a barbette structure but with no turret support. A comparison of this photograph with Plates 2 and 6 shows that the barbette very materially changes the whole stress pattern of the deck. The great stiffness of the barbette reduces the high shear on the center line of the turrets by introducing high transverse tensions near the barbette, but it introduces new points of high shear about 30° fore and aft of this center line. This shift in the location of the highly stressed region of the deck is of major importance because the hatch openings are now all in the highly stressed part of the deck and are therefore regions of weakness in the deck structure.

14. The different hatch openings were examined for maximum edge stresses. These were found to be equal to about 70 per cent of the maximum stress along the AA' axis for decks without barrette support. They are therefore unimportant for this type of loading. The deck reinforced with the barbettes, however, showed the hatch opening stresses to be much greater than the maximum turret opening stresses. A comparison of Plates 4, 8 and 12 shows that on the first two plates all hatch openings are located in lightly stressed sections of the deck but in Plate 12 the hatch openings are all near the most heavily stressed part of the deck and are therefore an important source of weakness in the deck. No attempt was made to obtain exact measurement of these hatch opening stresses because in the first two cases they were unimportant and in the third case excessive thickness of the barrette gave results which in detail are not applicable to the steel structure. However, in the steel structure just as in the celluloid the hatch openings would be in a highly strained part of the deck, and would therefore be a source of weakness. Plates 11 and 12 show very definitely that a shift of the hatch openings toward the center line of the ship into a more lightly stressed region of the deck would increase the strength of the deck structure by about 100 per cent.

(h) Isoclinic and Stress Flow Maps

15. Plates 3 and 7 show the longitudinal or P tension near the side plates to be so near to parallel to those plates that the transverse or Q force is negligible. Plate 11 gives us a very different picture. The direction of the P stress forms a wide angle with the side plating, more than  $10^{\circ}$ , and since the total force acting from the deck plate on the side plate must be in the plane of the side plate, the Q force must be equal to the P force times the tangent of that angle. Aft of the center line of the turrets the Q force is small. Near the center line it is a little more than 0.1 of P but forward it is in some places more than 0.3 of P. It is possible that a compression of this magnitude might cause buckling of the deck plate.

(i) Integration Values

16. Plates 5 and 9 show the maximum deck stress, tangent to the turret opening, to be approximately three times the stress near the side plating. Plate 13 shows that the drop in P-Q values in Plates 10 and 12 near the center line of the turrets represents large tension values of Q rather than small values of P. The high P-Q values at about 30 degrees fore and aft of the center line of these plates represent high compression or negative values of Q and not high values of P. These are thought to be true indications of the stress conditions in a steel deck and barrette structure; however, detailed measurements of the celluloid model would not be applicable to the steel structure because of the excessive thickness of the celluloid barrette. Therefore no

satisfactory to make more exact measurements, if they are desired, on a steel model.

(j) Summary

17. The deck loaded without turret opening support showed a maximum stress on the center line of number 1 turret equal to 3.5 of the deck load on a deck with no opening. Number 2 turret showed a stress of 3.1. Along each center line a transverse tension developed which reached a maximum value of 0.3 on the same scale at about four feet from the edge of the opening. The deck loaded with the turret openings blocked with a rigid ring showed very nearly the same maximum stress values for the center lines of both turrets. P-Q reached a value of 3.8 and a compression of 1.2 is observed. The deck with turret openings supported by a barbette shows maximum tension values of about 2.5. The outer third of the deck forward of the center line of the turrets is under a transverse compression which reaches a maximum value of about 0.2 at the outer edge. This compression extends inward to the barbette and reaches a maximum value of about 1.0 about 30° forward of the center line. Along the center line the inner two-thirds of the deck is under transverse tension which reaches a maximum value of about 0.4 at the barbette. The deck plating near the hatch openings is subject to very high shearing stresses when the turret openings are supported by a barbette. It is very probable that under these conditions the hatch openings seriously weaken the deck when they are in the position indicate for this study. This defect could be remedied by moving them about the width of the hatches toward the center line of the ship.

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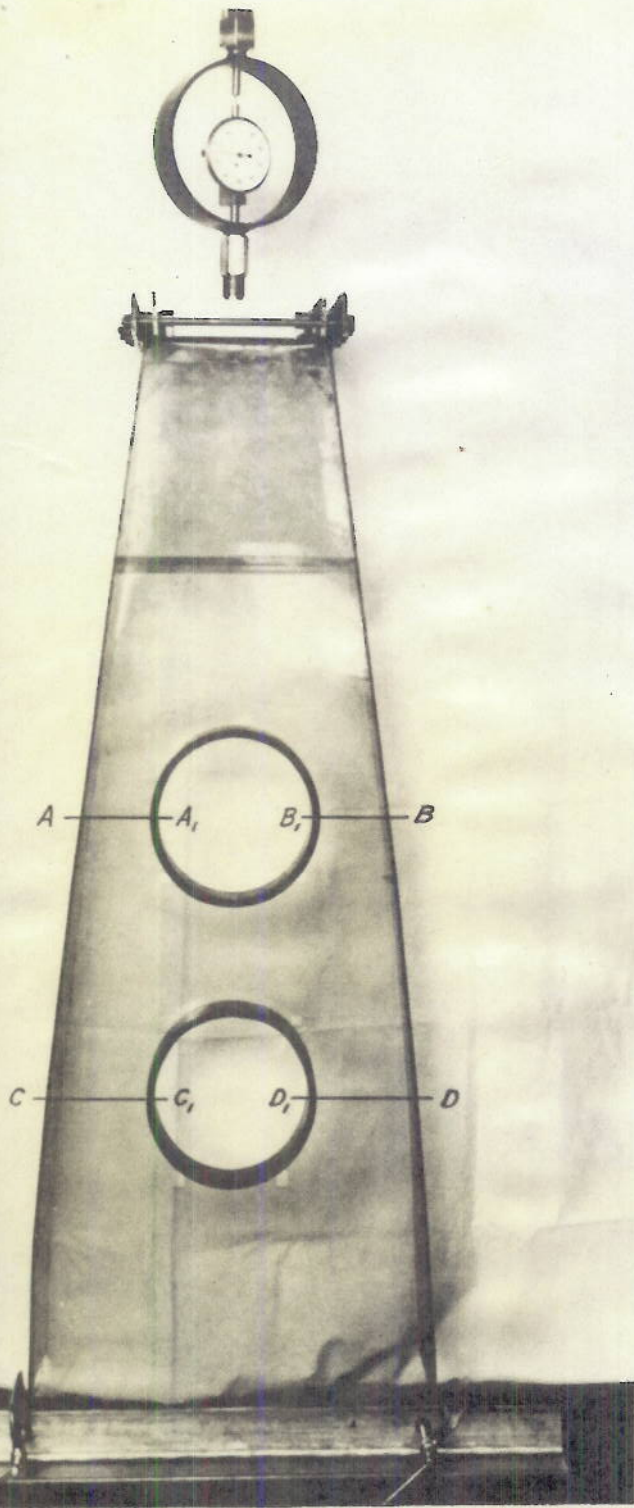


FIG. 1-LOADING FRAME WITH MODEL

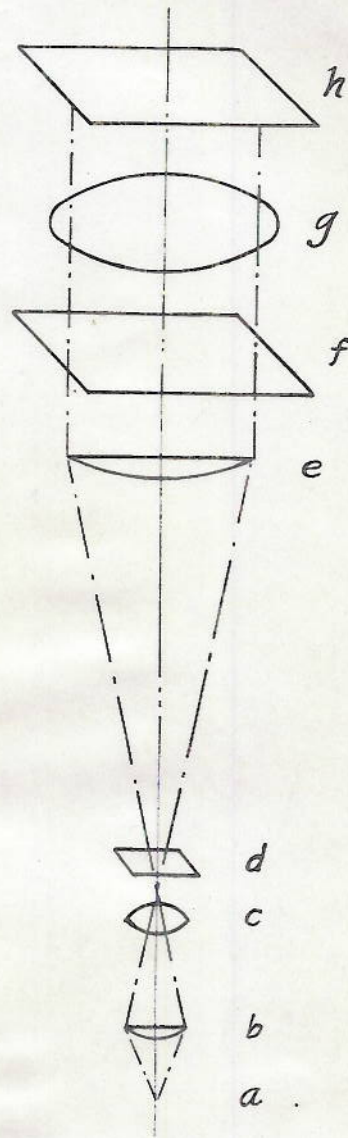
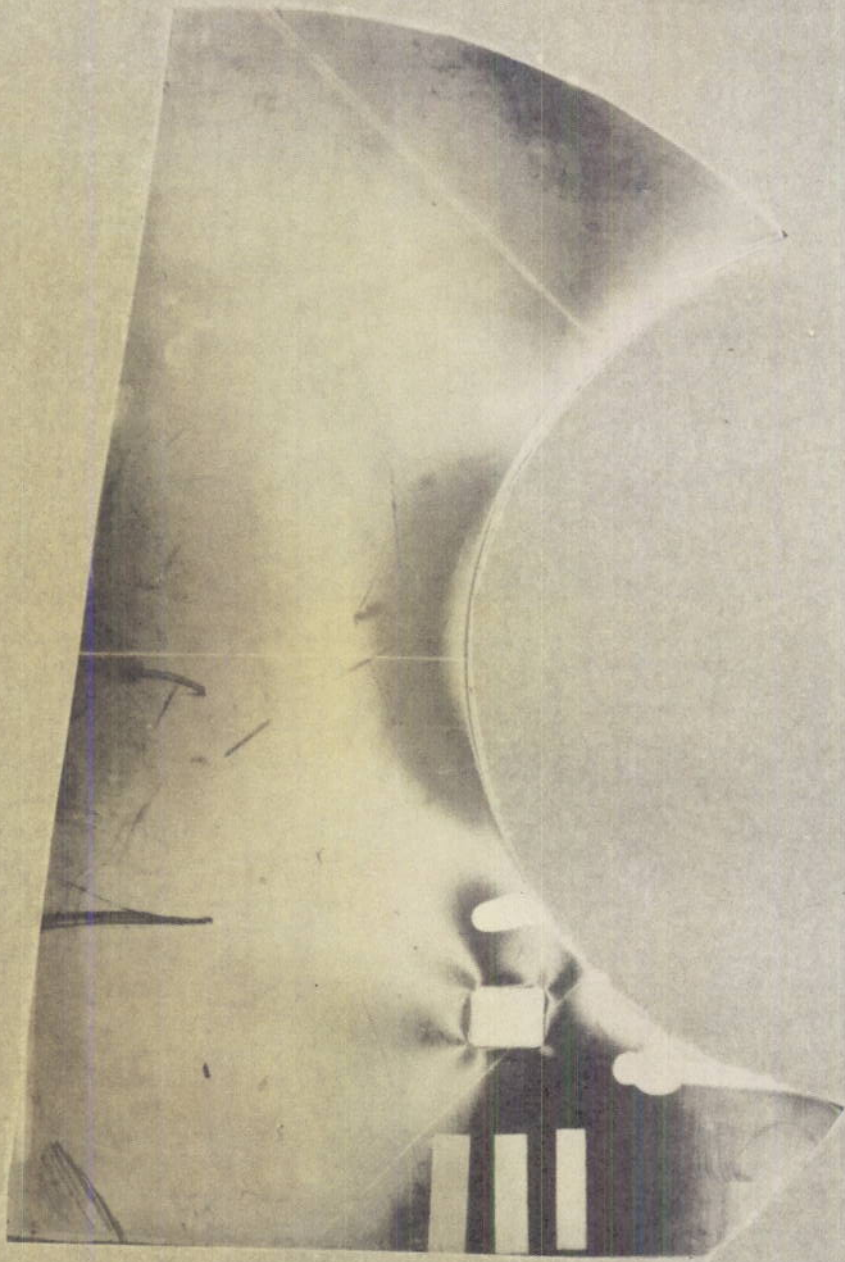


FIG. 2-OPTICAL ARRANGEMENT

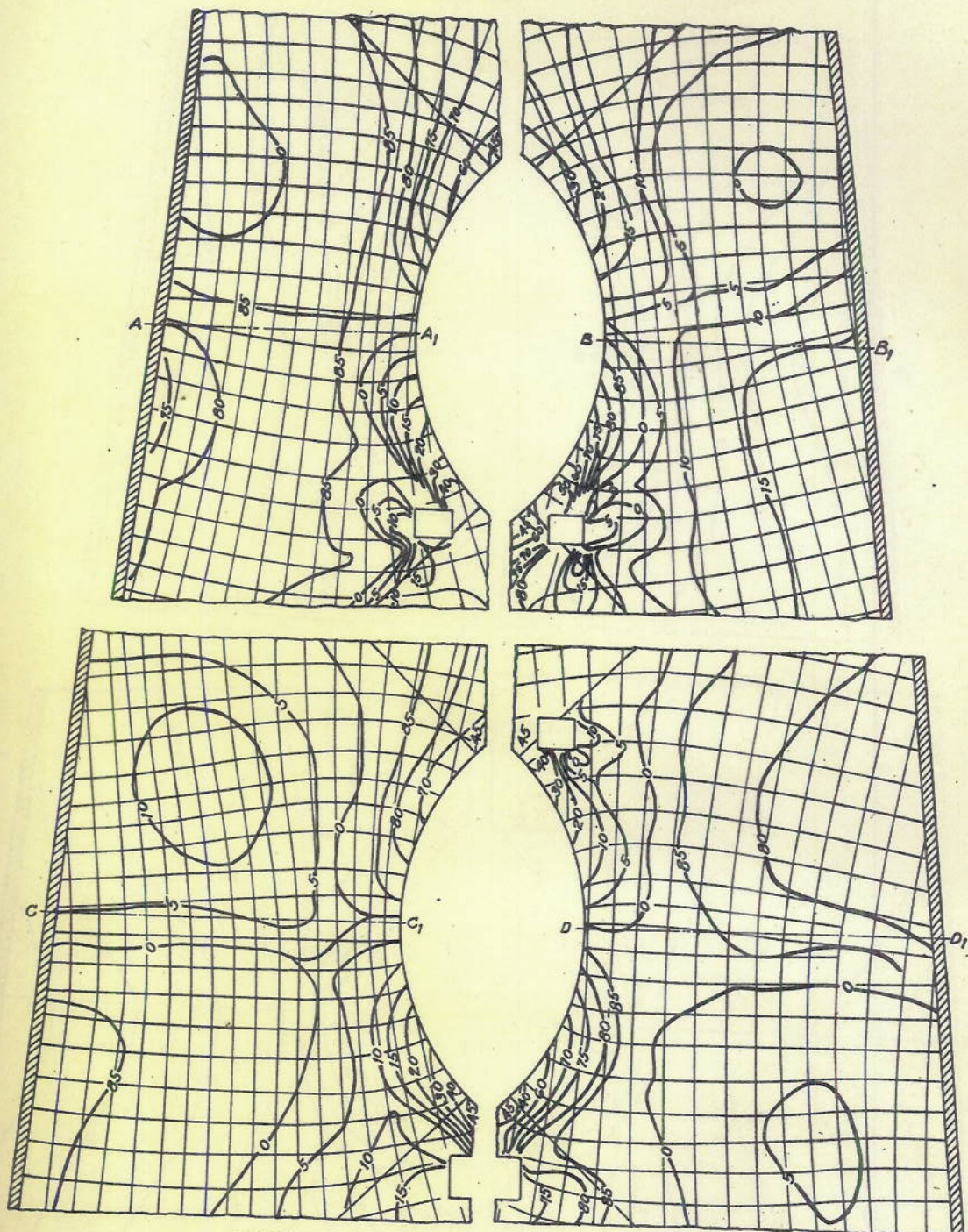
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PLATE 1



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PLATE 2



ISOCLINICS AND FORCE LINE FLOW MAP - FREE OPENING

PLATE 3

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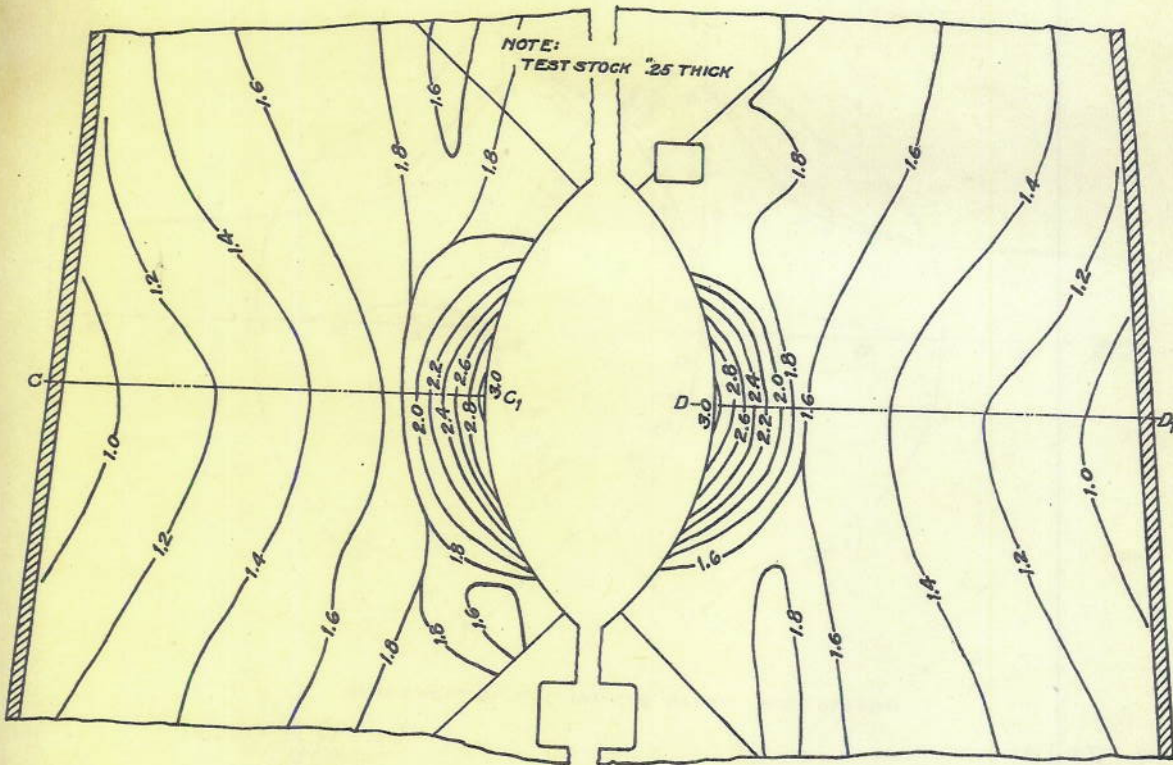
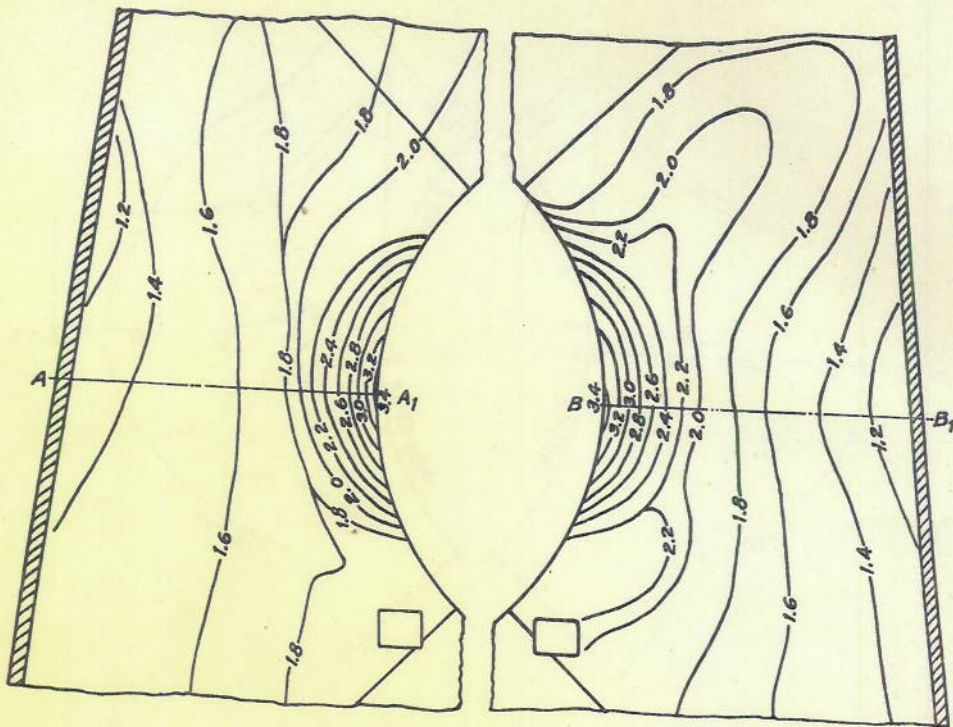
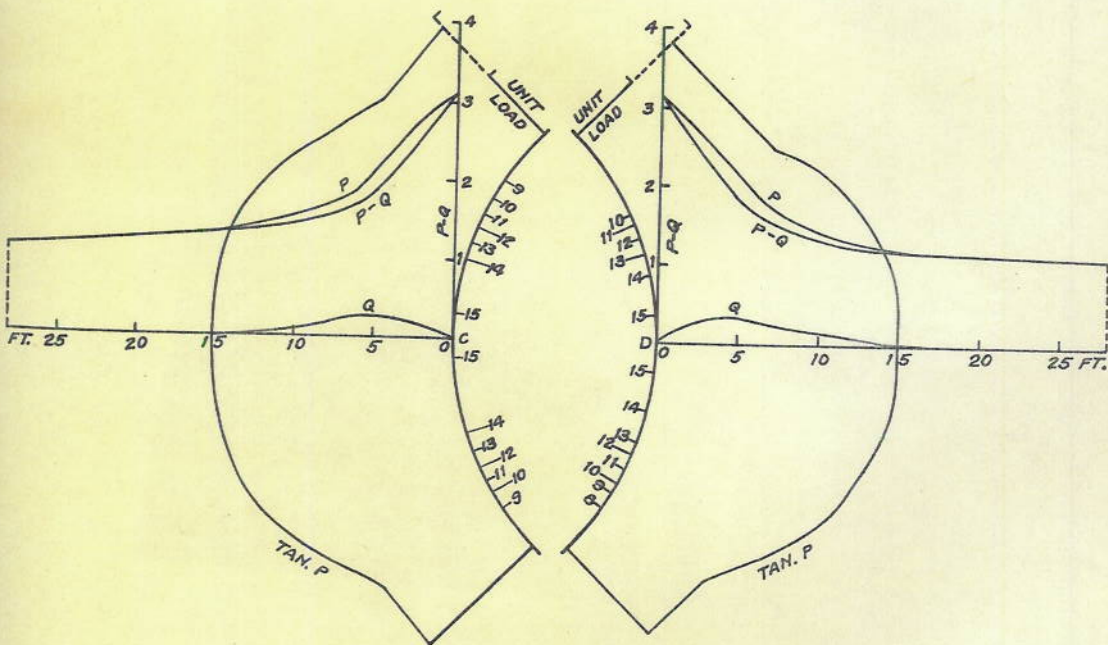
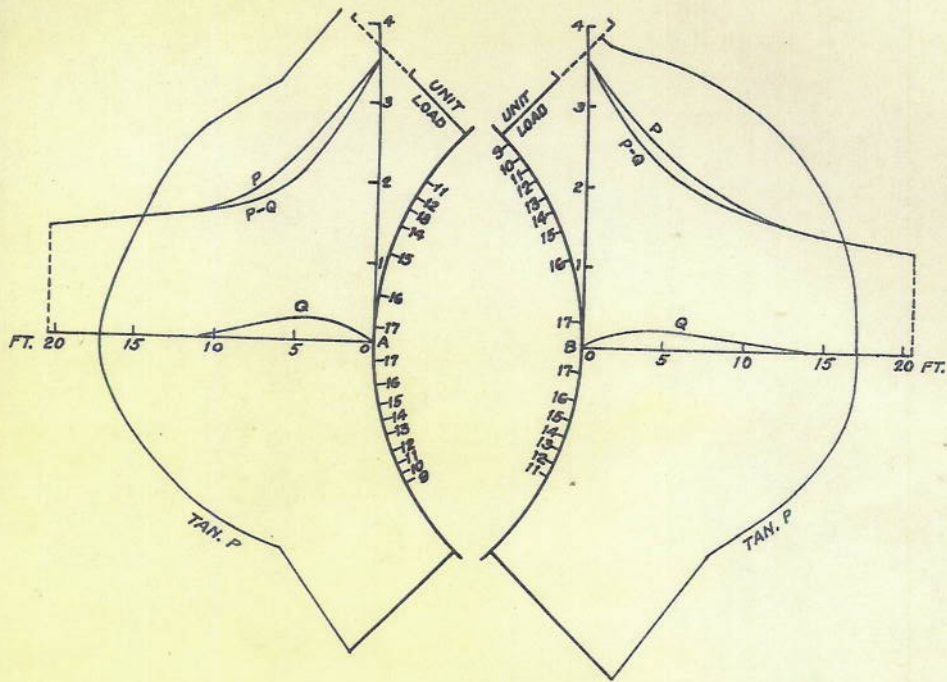


PLATE 4

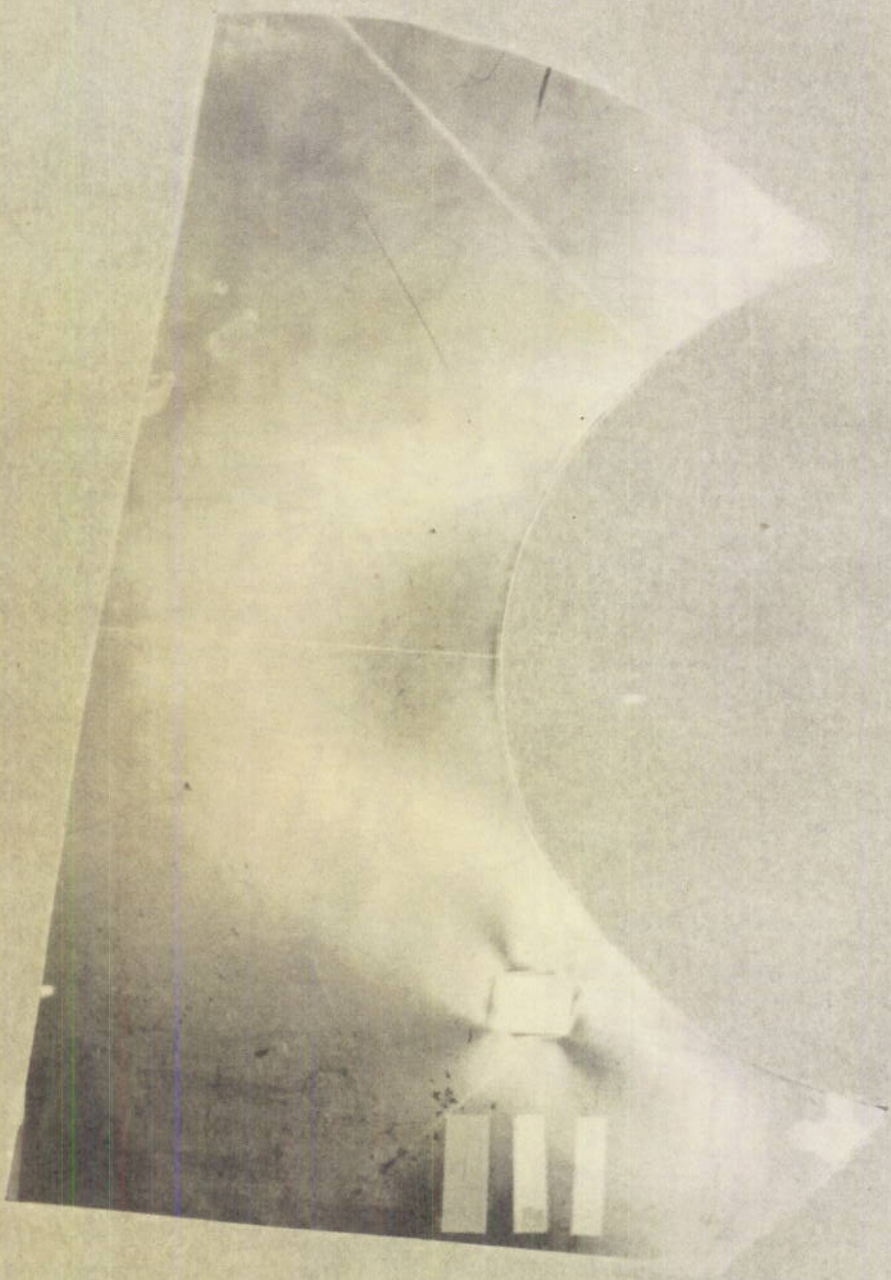
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SCALE PLAT OF P, Q AND P-Q VALUES - FREE OPENING.

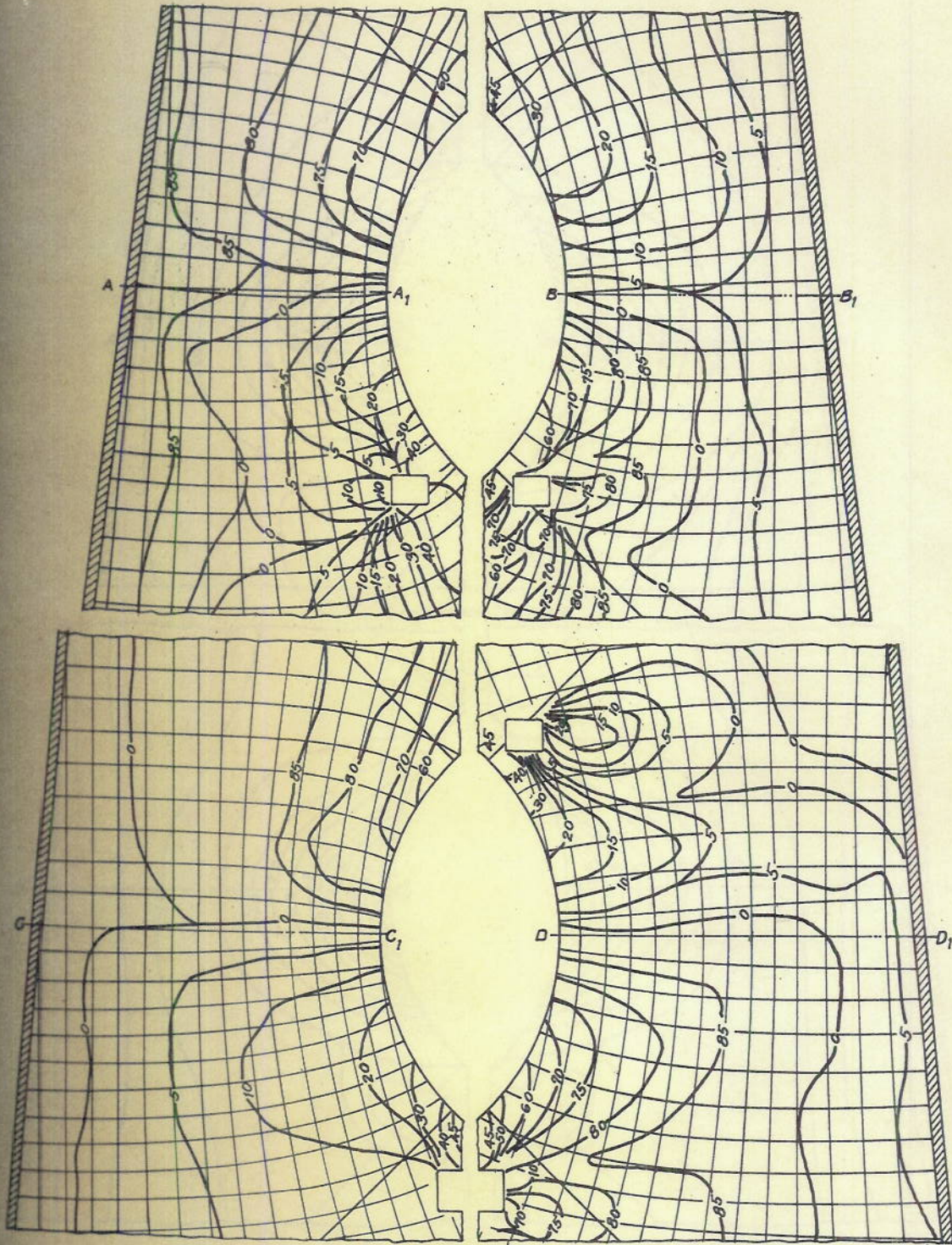
PLATE 5

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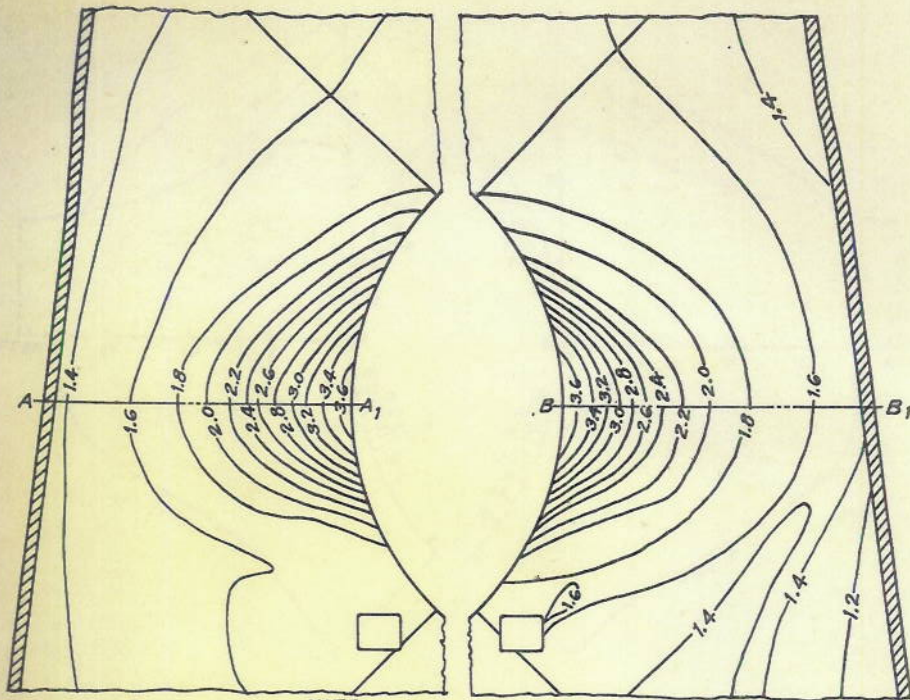
PLATE 6



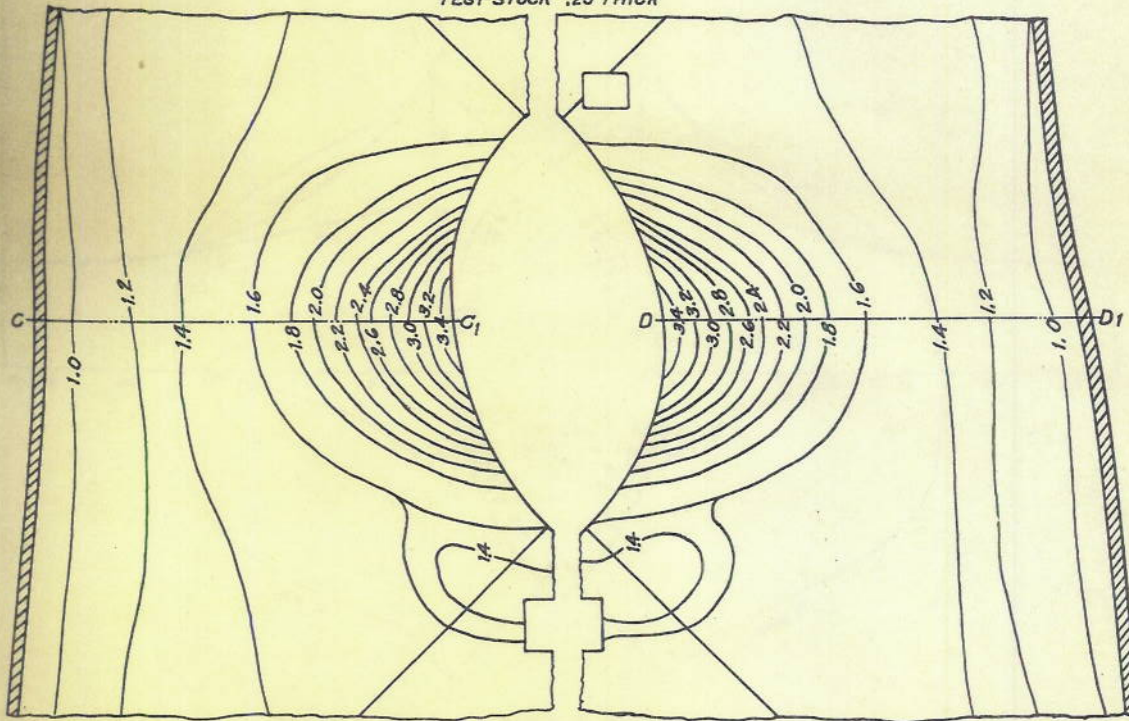
ISOCLINICS AND FORCE LINE FLOW MAP - BLOCKED OPENING

PLATE 7

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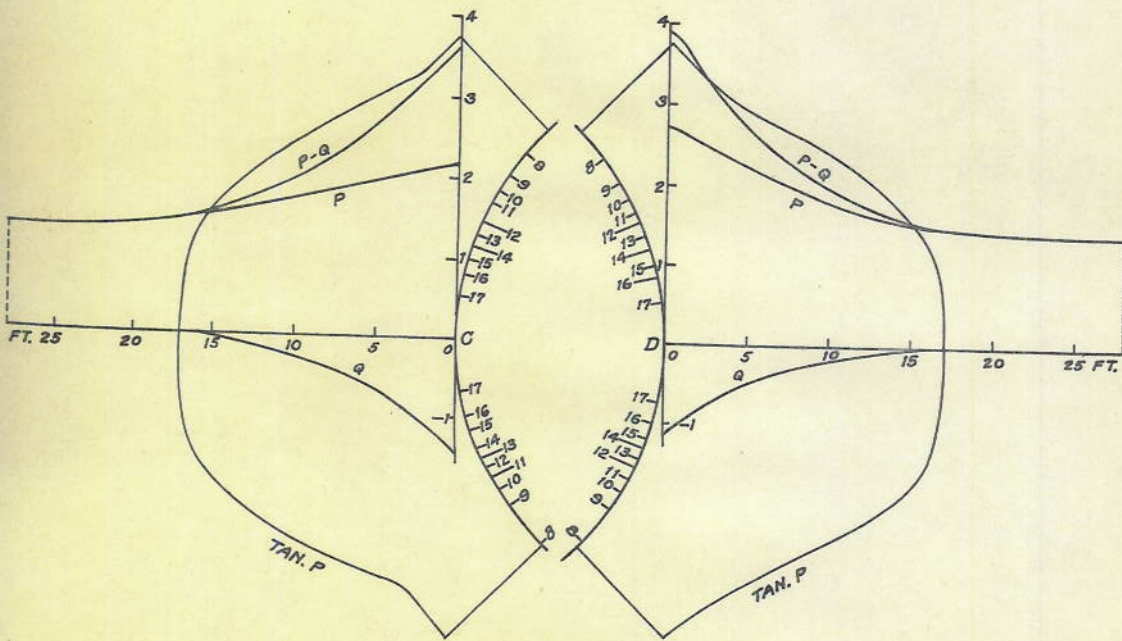
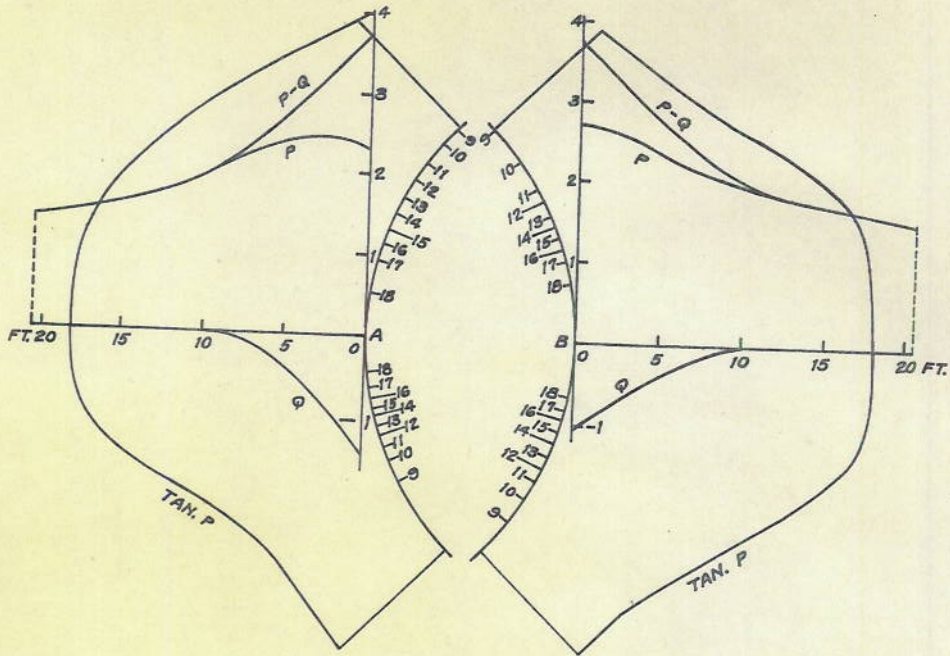
NOTE:  
TEST STOCK ".25 THICK



P-Q MAP--BLOCKED OPENING

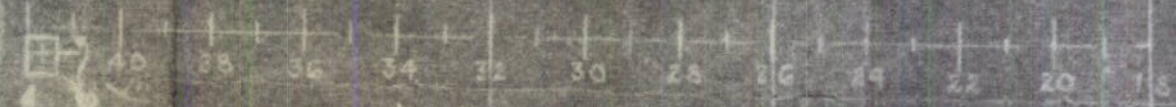
PLATE 6

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SCALE PLAT OF P, Q AND P-Q VALUES--BLOCKED OPENING.

40# SIDE PLATING 6" wide



HATCH 48 56

30# STS 2# STS

40# SIDE PLATING

ENCLOSURE B

SKETCH No. 1

FOR PHOTO ELASTIC STUDY

OF MAIN DECK PLATING

BETWEEN FR. 18 AND 36

SCALE 2" = 1'-0"

0 13 002

SIFIED



NOTE: PULLING FORCE  
 SHOULD BE APPLIED  
 (A) FORWARD AT THE  
 SIDE CENTER  
 (B) AFT UNIFORMLY ON  
 DECK PLATING

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16'-0"  
26'-0"  
(To FCG 4 1/2)

16'-0"  
(To FCG 4 1/2)

Scale  
1/2" = 1'-0"

84'-0"

56' x 52'

HATCH 36" x 54"



105'-8"

84 84 62 30 72 72 54 54 36 36 24 24

15'-6"  
15'-6"

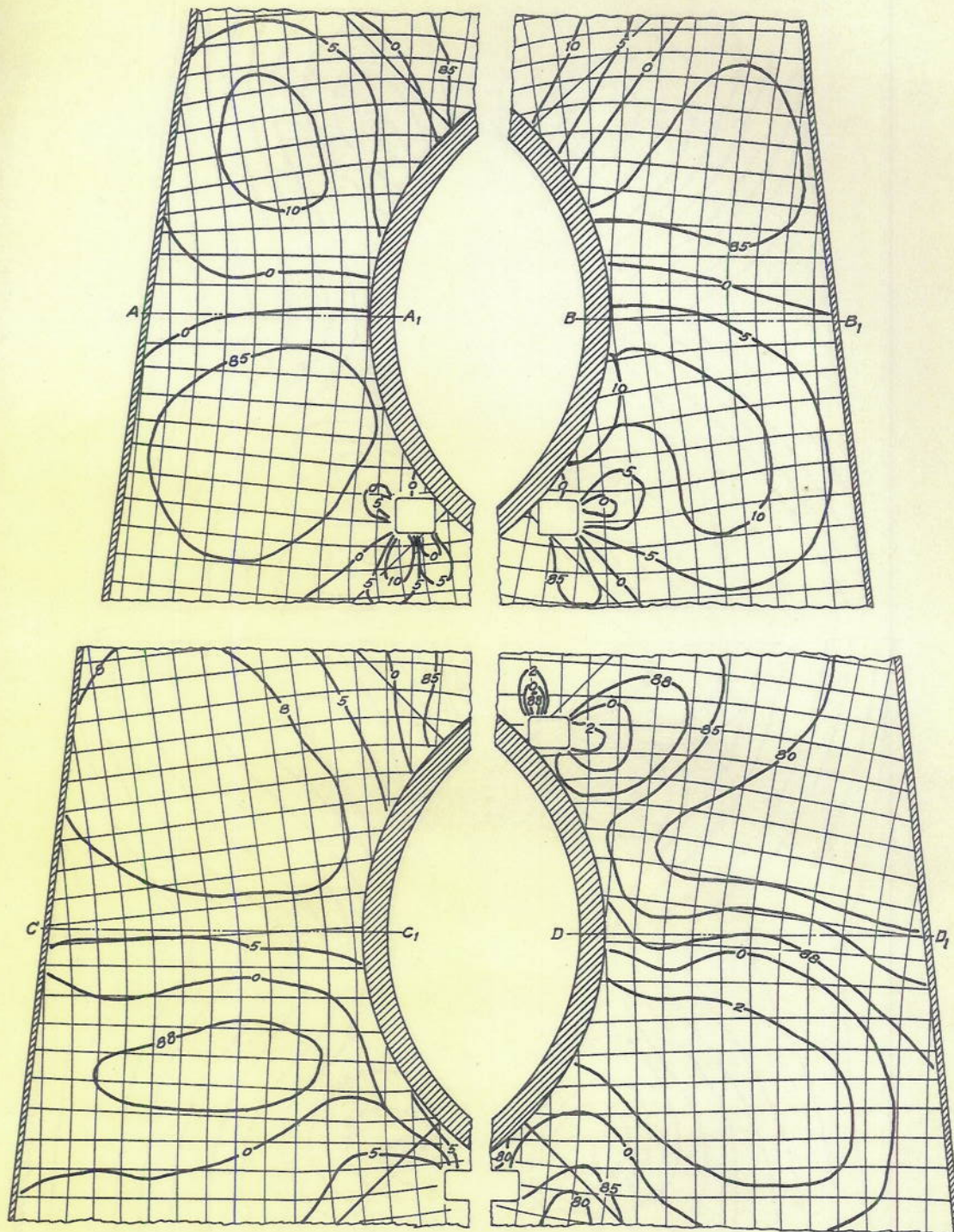
HATCH 36" x 54"

56' x 52'

56'

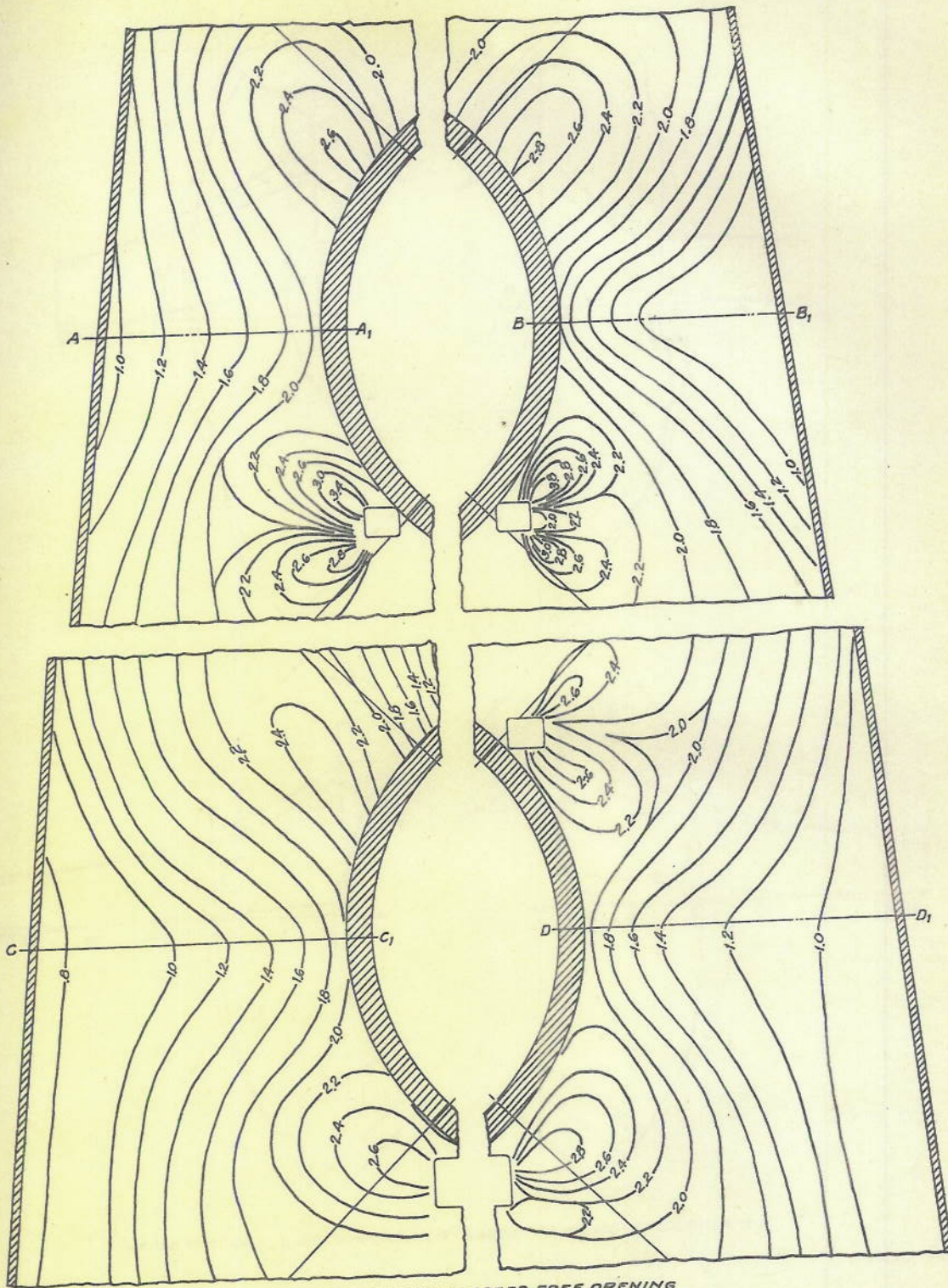
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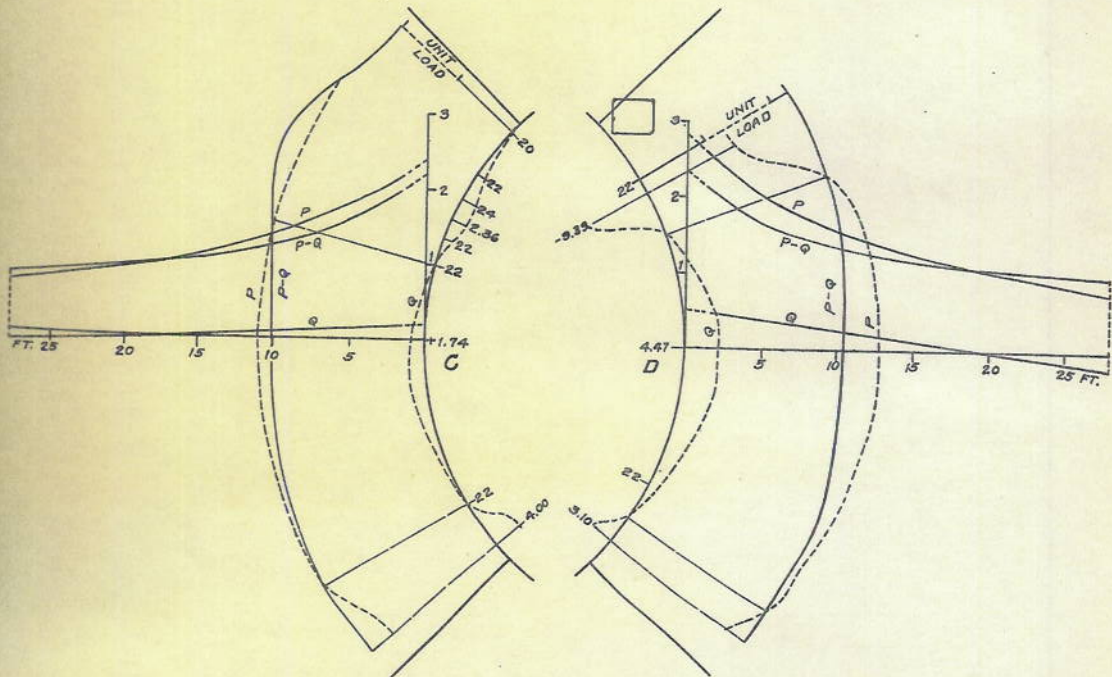
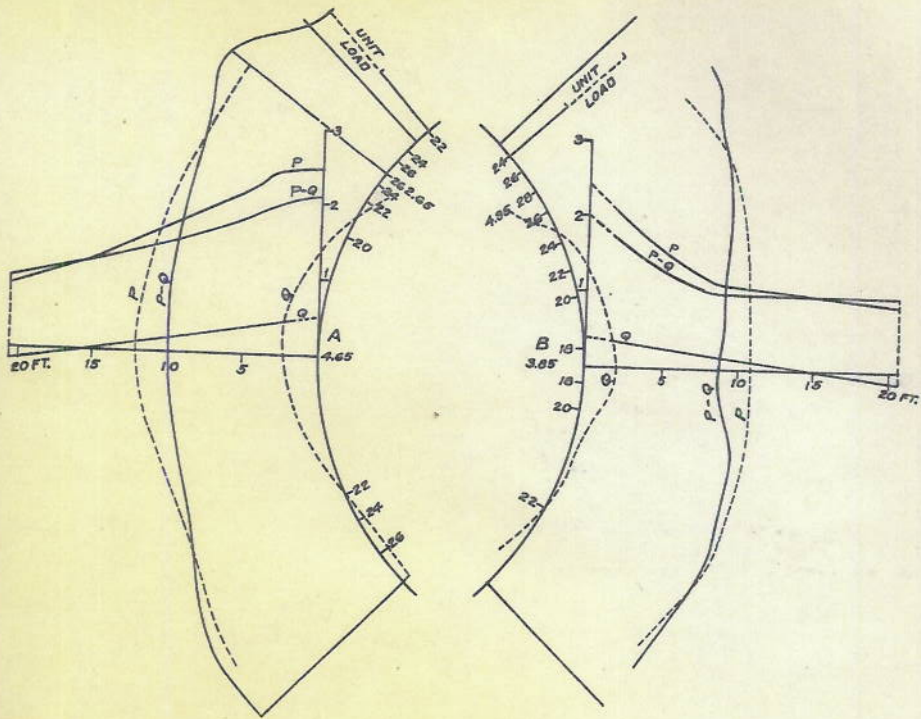
ISOCLINICS AND FORCE LINE FLOW MAP-BARBETTE ADDED-FREE OPENING.

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P-Q MAP-BARBETTE ADDED-FREE OPENING

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SCALE PLAT OF P, Q AND P-Q VALUES-BARBETTE ADDED-FREE OPENING