PHOTOGRAPH THIS SHEET

AD-A955 224

DTIC ACCESSION NUMBER

LEVEL

REPORT 821
FIRST INTERIM REPORT ON DEVELOPMENT OF DIVISION AND ARMY FLOATING BRIDGE EQUIPAGE
20 Sept. 43 – 1 May 44

26 May 44

DOCUMENT IDENTIFICATION

INVENTORY

(1)

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☑
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A-1		

DISTRIBUTION STAMP

UNANNOUNCED

DTIC COPY INSPECTED 6

DTIC SELECTE MAR 3 0 1987 S D D

DATE ACCESSIONED

DATE RETURNED

87 3 26 114

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

87 3 26 114

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC

DTIC FORM 70A MAR 86

DOCUMENT PROCESSING SHEET

PREVIOUS EDITION MAY BE USED UNTIL STOCK IS EXHAUSTED.

(UNPUBLISHED CARD) ~~RESTRICTED~~

ATI 97 828

(COPIES OBTAINABLE FROM CADO BY U.S. MILITARY ORGANIZATIONS ONLY.)

U.S. ARMY CORPS OF ENGINEERS, ENGINEER RESEARCH AND DEVELOPMENT LABS., FORT BELVOIR, VA. (REPORT NO. 821)

FIRST INTERIM REPORT ON DEVELOPMENT OF DIVISION AND ARMY FLOATING BRIDGE EQUIPAGE - AND APPENDIXES A-H - 20 SEPT 1943 TO 1 MAY 1944

ROBERT J. SWAIN 26 MAY '44 336PP. PHOTOS, TABLES, DIAGRS, GRAPHS, DRWGS

ARMY MATERIEL (37) 53 13 BRIDGES - DESIGN
INSTALLATIONS (5) 2 4 BRIDGES, PORTABLE

~~RESTRICTED~~

UNCLASSIFIED

[redacted]

ADB 7207
ADF 560265
Declassified

ATI 97828

AD-A955 224

WAR DEPARTMENT

Report 821

FIRST INTERIM REPORT ON DEVELOPMENT OF DIVISION AND ARMY FLOATING BRIDGE EQUIPAGE

20 September 1943 to 1 May 1944

26 May 1944

FOR TECHNICAL INFORMATION ONLY

Does not represent recommendations or conclusions of the Office, Chief of Engineers

TECHNICAL STAFF
THE ENGINEER BOARD
Corps of Engineers, U. S. Army
Fort Belvoir, Virginia

UNCLASSIFIED

Engineer Board, Fort Belvoir, Va.

UNCLASSIFIED

[redacted]

Report 821

FIRST INTERIM REPORT ON

DEVELOPMENT OF DIVISION AND ARMY FLOATING BRIDGE EQUIPAGE

20 SEPTEMBER 1943 TO 1 MAY 1944

Projects BR 473 and BR 474

26 May 1944

Submitted to

THE ENGINEER BOARD

Fort Belvoir, Virginia

and/or

The Chief of Engineers

U. S. Army

Washington, D. C.

FOR OFFICIAL ACTION

by

Robert O. Swain
Captain, Corps of Engineers
Fort Belvoir, Virginia

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, 50 U. S. C., 31 and 32, as amended. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

[redacted]

UNCLASSIFIED

TABLE OF CONTENTS

[redacted]

SYLLABUS

The general trend is toward wider and heavier military equipment. As the present bridging equipage is not adequate to handle such load increases, the Engineer Board was directed to design, develop and test Division and Army Floating Bridges, consistent with limitations placed on weight, transportation, and erection time. This report covers the development completed during the period 20 September 1943 to 1 May 1944.

Three superstructure designs and one ponton design, developed by engineering firms working in conjunction with the Technical Staff of the Engineer Board, have been accepted for test and are being procured.

It is recommended that the designs now under construction be tentatively approved and that engineering tests be conducted in accordance with the proposed plans of this report.

[redacted]

FIRST INTERIM REPORT
DEVELOPMENT OF DIVISION AND ARMY FLOATING BRIDGE EQUIPAGE
20 September 1943 to 1 May 1944

I. SCOPE

1. Scope. The scope of this report covers the development of the Division and Army Floating Bridge Equipage for the period 20 September 1943 to 1 May 1944. Design and procurement data for these bridges are presented in detail. Particular emphasis is placed on the research completed in preparation for the various bridge designs.

II. AUTHORITY

2. Basic Authority. The basic authority for projects BR 473 and BR 474, Division and Army Floating Bridge Equipage, is contained in the second indorsement from the Chief of Engineers to the President, Engineer Board, dated 20 September 1943, file number CE SPENC, subject: Work Order DBR 3102, Development and Requirements of Division and Army Floating Bridges.

3. Amendments to Basic Authority. Increases in widths and capacity were authorized in a letter from the Chief of Engineers to the President, Engineer Board, dated 22 February 1944, file number CE SPENE, subject: Revised Loads and Clearances for Division, Army, and Exceptionally Heavy Bridges (Work Order DBR 3214).

4. Copies of Authority and Directives. Copies of the complete authorization and directives appear in Appendix A.

III. INVESTIGATION

5. Purpose. The purpose of the projects on Division and Army Floating Bridge Equipage is the development of tactical floating bridge equipage which will be lighter in weight, capable of more rapid construction, less vulnerable to attack, and able to sustain heavier loads in higher stream velocities than the present equipment, which is proving inadequate for the heavier vehicles now attached to the Division and the Army. The criteria for these projects are given in the military characteristics in Appendix A.

6. Capacity. The original requirements for capacities of the Division and Army bridges to be developed under these projects specified gross weight and length of track in contact with the ground for

[redacted]

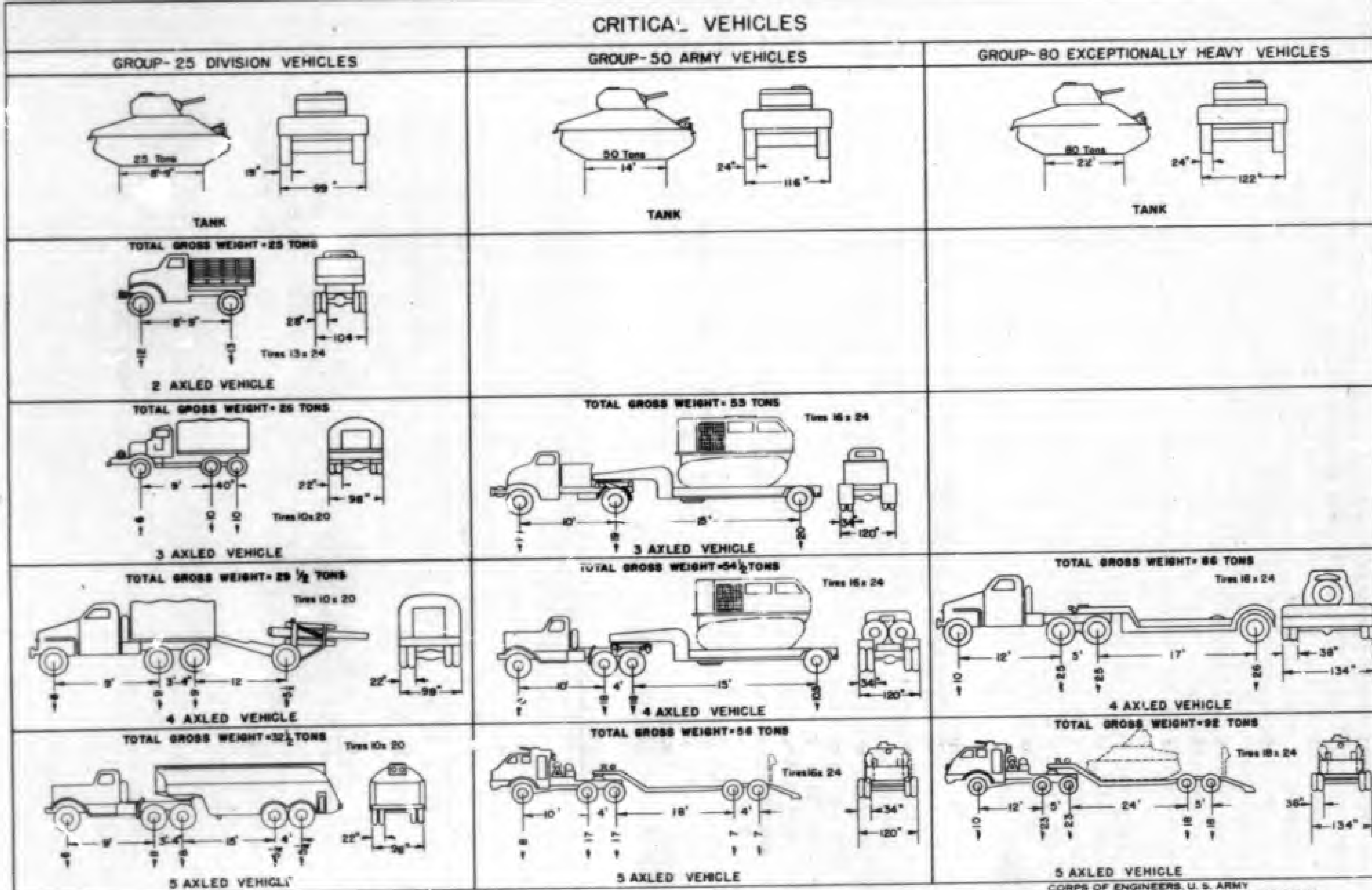
the heaviest tracked vehicles contemplated, and the clear width of roadway required. They were subsequently raised and at present the designed capacities are: Division bridge, 25-ton gross weight (assumed to rest on tracks having 105 inches of ground contact) with a clear roadway width of 128 inches; Army bridge, 50-ton gross weight (assumed to rest on tracks having 168 inches of ground contact) with a clear roadway width of 150 inches. The tanks representing these loads, together with their wheeled equivalents, are shown in Figure 1. Since the capacity of the bridge depends also on the stream velocity and the degree of control under which the vehicle crosses the bridge, the velocity was fixed at 5 mph after careful study of probable areas of operation, and the vehicle was assumed to cross under controlled conditions, one of four traffic categories now under consideration. These proposed categories are: a. Unrestricted; b. Controlled; c. With Caution; d. With Risk. Figure 2 more specifically defines these terms, in this case applied to the reinforced 25-ton ponton bridge.

7. Employment of Consultants. Upon receipt of authority to proceed with the designs of these bridges, an attempt was made to supplement the Technical Staff of the Engineer Board with designers experienced in metals used in airplane construction. The priority of airplane design prohibited obtaining any airplane designers. However, three consulting engineer organizations - two marine and one structural - were invited to submit bids for this work. The facilities of the Engineer Board, both at Fort Belvoir and Yuma, were made available to these consultants prior to the submission of bids. As a result of these negotiations, two organizations - Sparkman and Stephens, New York City; and Howard, Needles, Tammen, and Bergendoff, Kansas City, Missouri - were retained to submit preliminary plans. At a later date, the Allison Steel Company, Phoenix, Arizona, submitted a balk design. Only one firm, Sparkman and Stephens, has undertaken the design for the ponton.

8. Engineering Tests. Preliminary engineering tests of the new equipment have been initiated at the Yuma Test Branch; these consist primarily of experimentation with pontons, rafts, and deck-balk wearing surfaces, utilizing designs submitted by Sparkman and Stephens. It is anticipated that engineering tests of all equipment will be underway during the month of August 1944, and that plans and specifications of the accepted design based on engineering tests can be made available to the Chief of Engineers by the end of 1944. The directive for the engineering tests at Yuma appears in Appendix B.

9. Description of Proposed Superstructure Designs. All three superstructure designs are based on a span of 15 feet and the utilization of the same type ponton. Designs are consistent with the weight, erection time, and transportation limitations covered in the military characteristics.

a. T-1 Superstructure. This design submitted by Howard, Needles, Tammen, and Bergendoff is composed of aluminum balk and chess. A truss balk, 18 inches in depth, with extruded sections for chords and diagonals, has been accepted for use as stringers



Note: These vehicles are hypothetical and do not represent any vehicle in existence.
All axle loads shown are in tons.

FIG. 1

CORPS OF ENGINEERS, U. S. ARMY
THE ENGINEER BOARD, FORT BELVOIR, VIRGINIA

SUBMITTED 27 May 1944 / APPROVED	CRITICAL VEHICLES DIFFERENT TYPES FOR DIFFERENT GRADES OF BRIDGES	DRAWN M.Y.M. DATE 3-27-44	TRACED D.A.H. DATE 5-8-44	CHECKED
		SHEET 1 OF 4 SHEETS		
		M 4848-1		

FIG. 2. TRAFFIC CATEGORIES APPLIED TO 25-TON PONTON BRIDGE (REINFORCED)

(Note: Capacities for this bridge may be further increased by use of bow adapters)

TRAFFIC PASSES	WITH RISK	WITH CAUTION	UNDER CONTROL (Design Condition)	UNRESTRICTED
Position of Vehicle on Roadway	On centerline	On centerline	Anywhere	Anywhere
Speed of Traffic	3 mph. Man guiding in front of vehicle	5 mph	25 mph	35 mph
Spacing of Vehicles	One on bridge	50-yard gap	30-yard gap	Close column
Ponton Freeboard	3 inches	6 inches	6 inches	6 inches
Balk Breaks	5%	Occasional	None	None
Brakes & Gears	Not to be used	Not to be used	Use if necessary	Permitted
Stopping Traffic on Bridge	None	None	Undesirable	Permitted
Capacity in Tank Tons in Current Velocity of 5 mph	42	36	28	15

and in trestle transoms. Four types of balk connectors are proposed: Type R with male and female ends, especially adaptable for breaks in grade where moment transference is not required; Type A for continuity for transference of moment with provision for adjustment in change in grade; Type S for rapid assembly of sections; and the fourth type for use in landing bays with double story balk. Two types of chess have been designed, both of aluminum bases. One type utilizes an aluminum wearing surface; the other, a steel plate wearing surface. The chess are 13 feet 8 inches long, 2 5/8 inches deep, and 11 3/4 inches wide. Under consideration are shorter sections of chess which may be dowled into standard chess to provide for variance of roadway widths from 120 inches to 180 inches. The weight of the balk is approximately 300 pounds; of the all-aluminum chess, 145 pounds. Other design features include:

(1) Removal of bays in multiples of 15 feet.

(2) Removal of damaged pontons, and replacement, without disconnecting the superstructure.

(3) Steel curbs that can be spaced for roadway widths of 120 inches, 128 inches, 150 inches, and 180 inches.

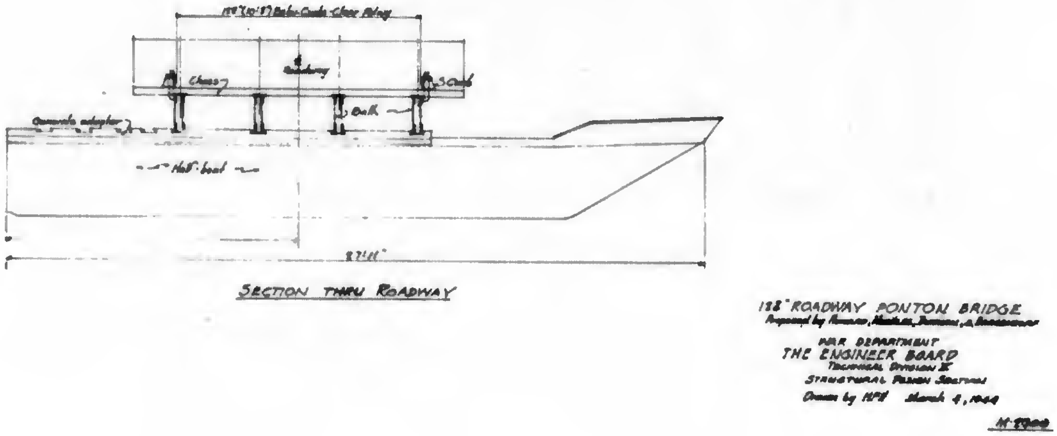
(4) Variable roadway widths.

(5) Diaphragms of various lengths to match balk spacing, permitting rapid bridge assembly.

(6) Erection gauges and hooks to facilitate rapid assembly of floating equipage.

Four balk are required for the Group 25 loading; eight, for the Group 50. Arrangement of this superstructure is shown in Figure 3; design details are given in Appendix C.

b. T-2 Superstructure. The T-2 superstructure designed by Sparkman and Stephens utilizes two extruded aluminum shapes welded together to form a section 15 feet long, 8 inches deep, and 9 inches wide. This design, which is commonly referred to as "deck-balk," provides the floor and stringer systems in single units. The method of construction is similar to placement of the 10-ton and 25-ton ponton balk, except that the deck balk furnishes a complete floor system. Roadway widths are variable, being governed only by the number of the deck-balk used. Several types of wearing surface are proposed, including steel plate, timber, and aluminum. The deck-balk without a wearing surface weighs 180 pounds. The curb is provided by extra deck-balk resting on the floor deck-balk. Arrangement of this superstructure on pontons is shown in Figure 4. Seventeen balk are required for the Group 25 loading, and 20 for the Group 50 loading. Design characteristics are given in Appendix C.



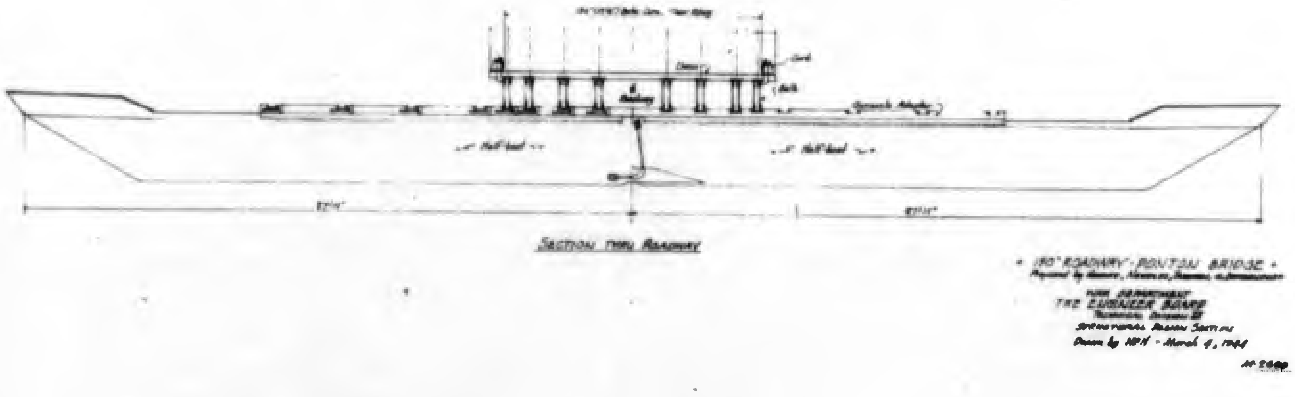


FIG. 3. T-1 SUPERSTRUCTURE. Top: Class 25 loads.
Bottom: Class 50 loads.

c. T-3 Superstructure. This design, submitted by the Allison Steel Company, is comprised primarily of 12-inch aluminum I-beams with balk connectors. The chess and curb will be of a type similar to that proposed for the T-1 superstructure. Eight balk are required for the Group 25 loading, and 12 for the Group 50 loading. Three special balk connectors are now being given consideration for this type of balk. These are shown in Appendix E. Some consideration is being given the use of this balk in units of two. Single balk will weigh approximately 170 pounds, or about 360 pounds made up in double sections connected with struts. Figure 5 shows the proposed design for this type of balk. Appendix C presents the design details.

10. Description of Ponton Design.

a. The ponton was designed with three major characteristics in mind. These are:

(1) A shape to permit efficient flow of water at speeds of 5 mph (7.3 feet per second).

(2) A weight not to exceed approximately 1,200 pounds.

(3) A shape which would permit nesting on the standard two-wheel pole type trailer.

b. The shape of the bow of the ponton was governed by a series of tests in the Vicksburg Model Basin and additional tests under the direction of Sparkman and Stephens at Stevens Institute of Technology. The dimensions of the ponton are: length, 27 feet 11 inches; beam at top, 6 feet 7 inches; beam at bottom, 4 feet 6 inches; depth, 37 5/8 inches. The elliptical-shaped end on approximately a 30-degree angle was found to be the most desirable, having a reasonably high displacement rate plus satisfactory flow characteristics. In order to meet the weight requirements and still have sufficient displacement for the Group 50 Bridge, a half-ponton type was selected. Each half-ponton has a displacement of approximately 20,000 pounds with a 6-inch minimum freeboard. To meet the weight requirements of the completed half-ponton and to have a half-ponton of sufficient ruggedness to withstand the abuses of general use, aluminum alloys were selected for the construction. Although no aluminum pontons have been actually completed, weight calculations indicate that the half-ponton will not exceed a total weight of 1,200 pounds. Preliminary tests indicate a possible lack in stability of the half-ponton and slightly less displacement than might be desirable for rafting. Both of these features can be increased by widening the bottom of the half-ponton without changing the shape of the top. The nesting would be decreased from 25 inches to 11 inches. This change in cross section is explained more fully in Appendix D. The change in cross section would mean an increase of approximately 3,000 pounds in displacement and would raise the stability to the equivalent of the present 10-ton ponton.

c. Present design permits transportation of three half-pontons on a two-wheel pole trailer. Proposed design changes would limit transportation to two half-pontons per trailer. Figures 6, 7, and 8 show the half-ponton, the whole ponton, and the transportation, respectively.

11. Heavy Floating Equipage. While consideration is being given designs of heavy rafts, the development of heavy floating bridge equipage, under project BR 464, is dependent upon receipt of Group 50 equipage. Engineering tests are to be conducted utilizing Group 50 flotation with the H-10 and the Panel Bridge (Bailey Type) superstructures. The latter, however, has a clear roadway limitation which does not make it entirely desirable for the heavier and wider vehicles proposed for Group 80 loading. With the addition of a whole ponton per span in the Group 50 bridge, it is hoped that this reinforcement will permit passage of all Group 80 vehicles.

12. Shore Connections.

a. The shore connections of a floating bridge usually include one of the three following types of construction:

(1) Direct span from the last ponton to shore, as is frequently utilized with a steel treadway bridge.

(2) Combination of an abutment span, a trestle span, and a hinge span, as is usually associated with the 25-ton ponton bridge.

(3) Long landing bays up to 80 feet, as are used in the erection of the Floating Panel Bridge (Bailey Type).

b. The first consideration for shore connections for the Group 25 and Group 50 bridges was centered around trestle spans and long landing bays. Trestle spans submitted with the T-1 and T-2 superstructures were of a conventional design with the added features of being able to erect double stories and to utilize ponton balk for trestle columns and transoms. Long landing bay designs have been submitted by the two consulting engineers and one design by the Technical Staff of the Engineer Board. Current trends include the reduction of the length of long landing bays for shore connections, inasmuch as damage to any one part of such a long span usually consumes considerable time and material for replacement. Under consideration now is a type of jet-pile utilizing trestle columns. It is doubtful whether any decision will be made on shore connections until the engineering tests have been conducted on all designs submitted. Design progress with shore connections is presented in Appendix F.

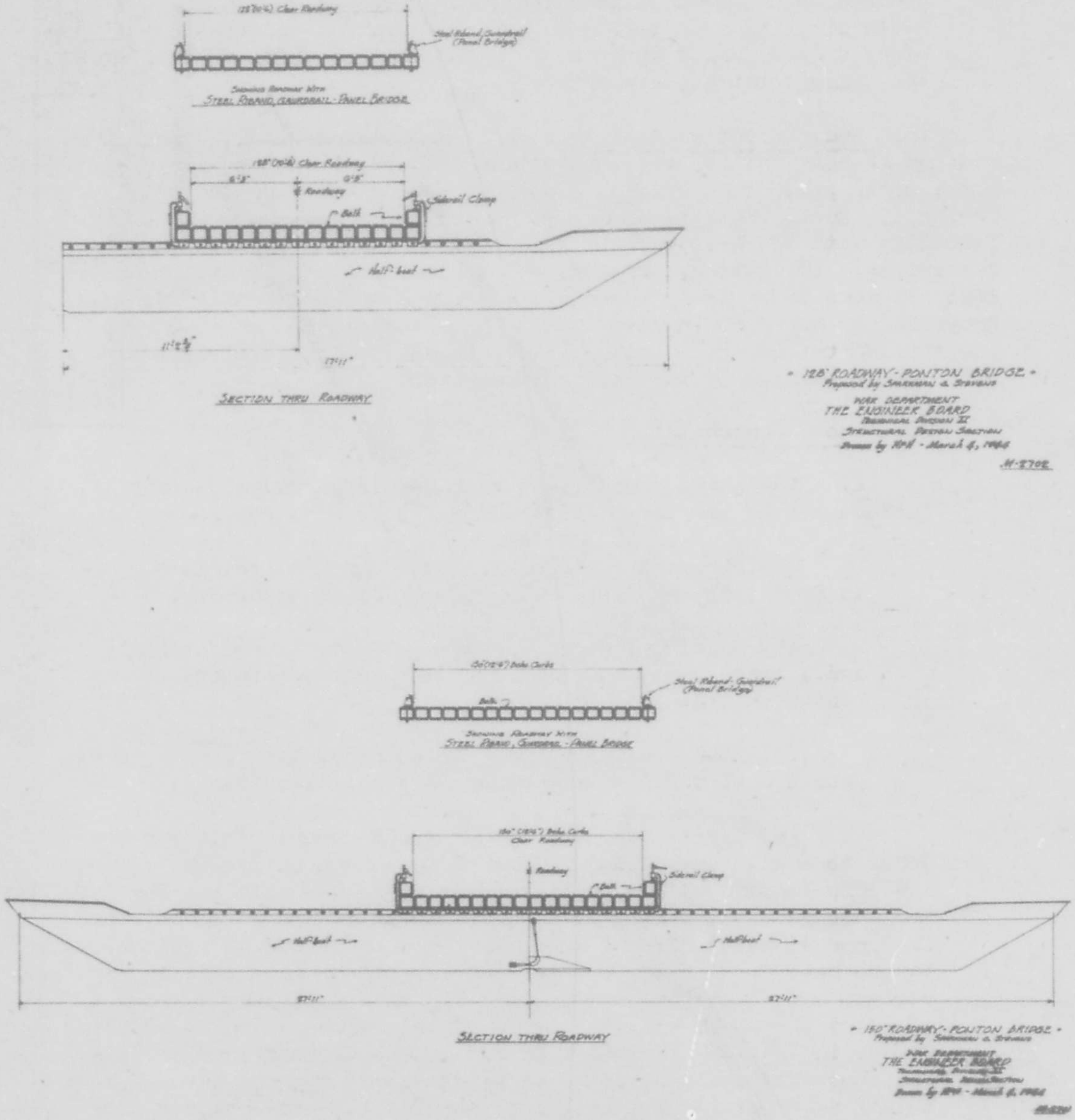


FIG. 4. T-2 SUPERSTRUCTURE. Top: Class 25 loads.
Bottom: Class 50 loads.

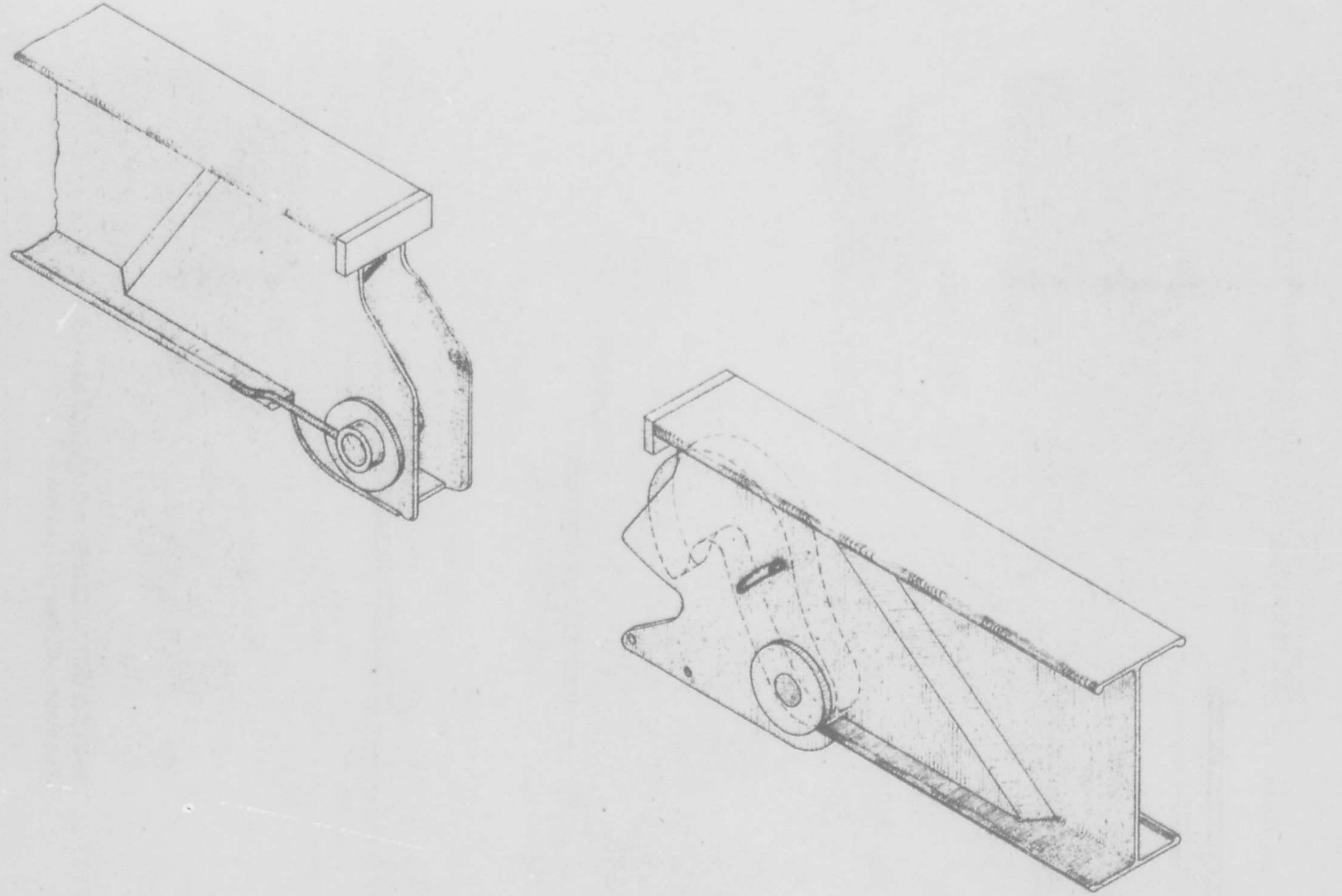


FIG. 5. T-3 SUPERSTRUCTURE

CORPS OF ENGINEERS, U. S. ARMY
THE ENGINEER BOARD, FORT BELVOIR, VIRGINIA

SUBMITTED	BRIDGE EQUIPMENT	DRAWN N. W. B. DATE 3-11-44	TRACED DATE	CHECKED DATE
APPROVED		SHEET 1 OF 1 SHEETS		
		C-5041-1		

Note:- See D-5038-1 for detail [illegible]

FIG. 6. HALF-PONTON

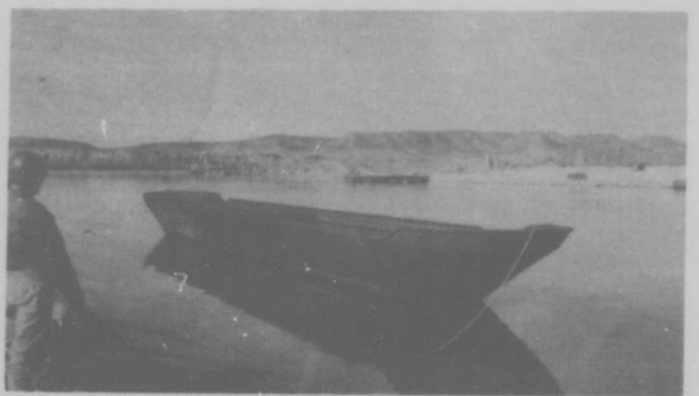


FIG. 7. WHOLE PONTON

FIG. 8. TRANSPORTATION OF THREE HALF-PONTONS

13. Rafts. Several raft tests are underway with the T-2 superstructure and plywood pontons. Preliminary results of these tests indicate that a 5-ponton raft will be required for the Group 25 loading. The original design contemplated a 3-half-ponton raft plus two reinforcing half-pontons for the Group 25 loading. For the Group 50 loading, a 5-whole-ponton or 7-whole-ponton raft is proposed. A series of tests was conducted at Stevens Institute to determine the horsepower required to drive various rafts at various speeds. Results of these tests, together with speed estimates with various marine power sources, are given in Appendix D. These data have not been confirmed by actual test, but are representative and can be presumed to be correct within approximately 10 percent. Consideration is being given a heavy raft design, divorced entirely from Group 50 equipage.

14. Balk and Raft Connectors.

a. In military floating bridges, one of the paramount design problems involved pertains to the development of a balk or raft connector which will allow the rapid assembly of a bridge manually or by means of such mechanical aids as are possible by the 6-ton, 6 x 6, Bridge Truck. Requirements can be expanded into the following characteristics:

(1) The joint shall permit the balk to be separated in any direction.

(2) The joint shall develop full strength of balk.

(3) The joint can be assembled to be used as a hinged part.

(4) Ends of balk shall be interchangeable.

(5) No loose connections are permitted.

b. Experimental model connectors which have been designed to meet the foregoing requirements are graphically presented in Appendix E.

15. Research. The research connected with the design of these bridges consists of two parts:

a. The determination of the most effective relationship between the stiffness of the superstructure and the capacity of the floating supports and the investigation of the various types of superstructure to find the best method of obtaining this required stiffness. An introduction to the factors involved in these problems is presented in Figure 9.

b. Engineering tests on various types of bridges to determine the effect of high stream velocities on their capacity, and the development of a standard group of tests to be applied to future bridges to measure their suitability for military use.

The work accomplished in this research is presented in part in Appendix H.

16. Status of Procurement. As of 1 May 1944, contracts had been made for the procurement and fabrication of materials for 300 feet of each of the three basic superstructure designs, and for plywood and aluminum pontons to provide sufficient flotation for a 240-foot floating bridge. Procurement details, together with the cost data, are given in Appendix G. All metals under procurement are of aluminum alloy (24 and 61ST) and steel. Experimentation is contemplated with two other metals: aluminum alloy with zinc, which has an exceptional strength; and magnesium.

IV. DISCUSSION

17. Procurement. While procurement progress has been handicapped because of the tight scheduling of aluminum, sufficient materials are now in the contractors' hands to proceed with the fabrication of the major parts of each of the three proposed superstructures and with the aluminum pontons.

18. Design. The trends in design are as follows for the various components of the bridge:

a. Pontons. While the single floating support was satisfactory for loads up to about 34 tons (tank loading), the trend for the past two years has been towards the half-ponton, a boat that can be used individually to carry loads up to approximately 25 tank tons and can be joined stern to stern with another half-ponton to carry heavier loads.

b. Superstructure. The three types of superstructure now under consideration provide for erection of bridges for Group 25, Group 50, and Group 80 vehicles. All of these bridges can be widened in the field in the routine manner of erection.

c. Heavy Floating Bridge Equipage. Greater stress is contemplated on traffic control to utilize the Group 60 Bridge to pass vehicles in the Group 80 classification.

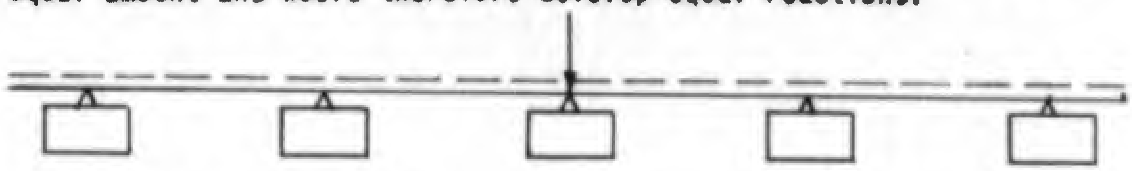
d. Rafts. Raft studies conducted to date indicate the new equipment is superior to existing rafts. Consideration is being given to special rafts for ferrying Group 80 vehicles.

e. Shore Connections. The tendency for shore connections is for spans that can be rapidly replaced in the event of damage.

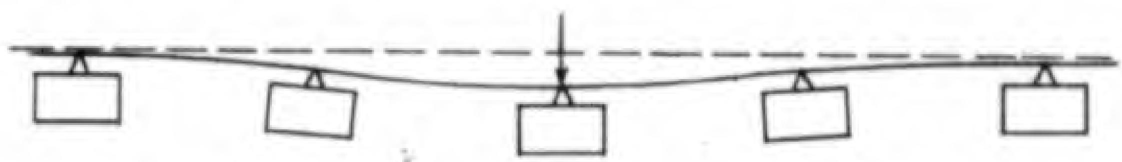
f. Balk and Raft Connectors. Stress is being given to connections between balk and connections between rafts to facilitate erection and the use of bridge bays as ferries.

RELATIONSHIP BETWEEN STIFFNESS OF SUPERSTRUCTURE AND CAPACITY OF PONTONS

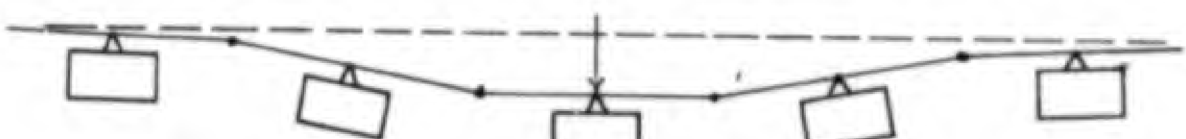
If a ponton bridge could be constructed with a perfectly rigid superstructure, all the pontons supporting it would be submerged an equal amount and would therefore develop equal reactions.



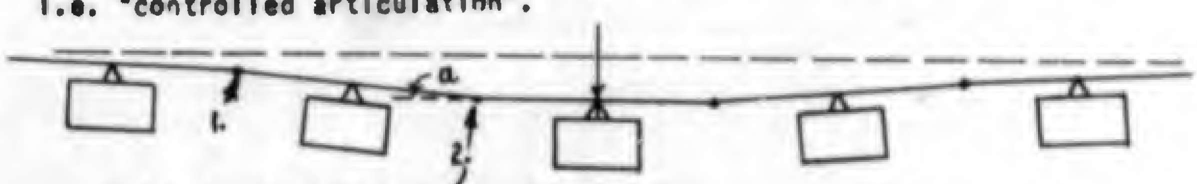
In a bridge in which the joints are rigidly connected, this condition is approached, the deck acting as a continuous beam over a series of supports. This type of construction is undesirable because the end reactions, although they are somewhat reduced, produce excessive bending moments because of their long moment arm.



If articulation, that is a hinge type joint, is introduced into the superstructure between each supporting ponton, the load is carried almost entirely by the ponton directly under the load, the only resistance developed by adjacent pontons being due to their righting or stabelizing moment.



This method of construction is also undesirable, since the individual pontons must have excessively large displacements. Somewhere, between the two extremes, there lies a combination of superstructure and pontons which will have maximum load capacity combined with minimum total weight. This combination can be approached by constructing the articulation so that the joints will lock after a certain amount of rotation, i.e. "controlled articulation".



1. Joint acting as hinge.
2. Joint locked and transmitting positive moment.
"a" = angle of limit of articulation.

FIG. 9

19. Engineering Tests. Engineering tests are now underway and will be in full operation during the month of August.

V. CONCLUSIONS

20. Conclusions. As a result of the investigations conducted to date, it is concluded that sufficient designs have been investigated to furnish a suitable floating bridge for use by infantry and cavalry divisions, and by an army. The work completed represents the initiation of a comprehensive floating bridge program in that the designs under consideration provide for minimum weight, erection time and transportation in addition to variable roadway widths and capacities. It is also concluded that engineering tests will be completed in time to submit plans and specifications based on these tests to the Chief of Engineers during the latter part of 1944.

VI. RECOMMENDATIONS

21. Recommendations. It is recommended that the designs now under consideration be tentatively approved, and that the engineering tests be conducted in accordance with the proposed plans of this report.

Submitted by:

Robert O. Swain,
Captain, Corps of Engineers,
Chief, Bridge Branch.

Forwarded by:

Carl W. Meyer
Colonel, Corps of Engineers,
Director, Technical Division IV.

APPENDIX A

AUTHORITY

Headquarters
ARMY GROUND FORCES
Army War College
Washington, D.C.

1 September 1943

823/60 (1 Sep. 1943) GNENG

SUBJECT: Development and Requirements of Division and Army Floating Bridges.

TO: Commanding General, Army Service Forces, The Pentagon, Washington, D. C. (Attn: Requirements Division and Chief of Engineers).

1. Reference is made to the recent revision of Par. 5, AR 850-15, which is expected to be published in proof form 21 August 1943. This revision materially increases the permissable weights and widths of military vehicles over those for which our standard bridging has been designed. A complete revision, particularly of the floating bridging, is necessary.

2. At present, the reinforced five boat infantry support raft will ferry combat team loads up to a gross of ten tons in a stream of velocity 3.5 miles per hour. The M-3 bridge, fully reinforced will pass eighteen ton tank loads with restricted movement in currents of velocities up to 4.8 ft. per second, but will not pass the four ton truck with trailer and bulldozer in velocities over about one mile per hour. The twenty-five ton heavy ponton bridge, when fully reinforced with metal pontons, will carry a safe load of only thirty tons with restricted movement in a stream of velocity 5 miles per hour.

3. Study of general stream velocities in the United States and possible theatres indicates that 5 miles per hour is the proper velocity for military bridge design and that normal flows seldom exceed 7 miles per hour. Flood flows seldom exceed 11 miles per hour saving in exceptional cases like the Rhine, where by reservoir manipulation the flow may reach 18 miles per hour, or in mountain torrents like the Rhone where 30 miles per hour is reached. The division and army bridge should meet the velocity of 5 miles per hour when constructed normally, and carrying its design load, and meet higher velocities with lighter loads. Tests at Yuma have shown that fully reinforced bridges obstruct the flow and form a water and debris jam, endangering the stability of the structure.

4. Inclosures 1 and 2 outline proposed military characteristics for division and army floating bridges and rafts. If these characteristics are met successfully, eventually these bridges will replace the infantry support raft, the M-3 Bridge and the Heavy Ponton Bridge. The development is such that the existing M-3 and Heavy Ponton Bridge will be first improved by the balk for the new bridge, and eventually, the boats will be replaced by the more flexible and easily transported

(except for the pneumatic float) half boat. The half boat will be less vulnerable than the pneumatic boat and two of them will have more displacement and stability than a heavy ponton boat. Time lost inflating pneumatic floats will be eliminated. Both the British and the Germans have already gone to half boat design. Even after complete conversion, most of the old equipment will be useable for reinforcing, for expedients, and in locations where fast, heavy capacity bridging is not required. Since the troop basis calls for only about one-third of the heavy ponton units and one-half of the light ponton units considered necessary for operations in Europe, it is desirable that the new equipment be developed, procured and issued rather than to stock obsolete equipment.

5. The military characteristics outlined call for the maximum ingenuity in design. It is contemplated that light critical metals will be required both in the balk and in the boats, with first priority probably required in the balk. The justification for this is the tremendous mobility, speed of erection, flexibility and economy of effort gained in the initial crossing of heavy loads. In the division, the tank destroyer weapons will be able to closely support the assault waves. In the Army, the heavy artillery can gain a matter of hours in forward displacement. It is understood that the situation in light metals is improving.

6. It is requested that the Chief of Engineers be directed to prosecute this development immediately, and that the materials necessary for this development be made available to him on a triple A priority.

FOR THE COMMANDING GENERAL:

/s/
C. H. DAY,
Colonel, A. G. D.,
Asst. Ground Adj. Gen.

2 Incls.
No. 1 - Military Characteristics for Army Floating Bridge and Raft
No. 2 - Military Characteristics for Division Floating Bridge and Division Assault Raft.

INTERESTED UNITS: All Army Units, Especially Those Heavier Than 18 Tons Gross, Including Armored Units.

MILITARY CHARACTERISTICS FOR ARMY FLOATING BRIDGE AND RAFT

1. The bridge shall have sufficient capacity to carry the vehicles accompanying an army in the field which meet the weight and width limitations prescribed in AR 850-15 dated August 1943. For a tracked load this weight limit is 38.9 tons gross on an 18 foot track and design of this structure will not attempt to accommodate any combination of vehicles more severe than this. The width limit is 124" for the lower 1 foot of vehicle and 130" above the lower foot.

2. The bridge and raft, constructed normally of two division half boats placed end to end per span of about 15 feet, and desirably with additional divisional balk, shall be capable of carrying safely the maximum load with unrestricted movement in a stream of velocity of 5 miles per hour. In velocities up to 5 miles per hour, the full boat raft shall be propelled by the standard power boat or outboard motors. It shall be capable of operating in greater velocities as a ferry.

3. The bridge and raft shall have a minimum clear roadway width of 144 inches. It is desirable that the divisional bridge chess be used.

4. The raft shall be constructed of component parts of the bridge and shall be useable as an integral part of the bridge. It is desirable that the component parts of this bridge and raft be identical with those of the divisional bridge.

5. The bridge shall be so constructed that it can be erected from transportation on a prepared site in two hours plus 2 feet per minute and reloaded from the water in two hours plus 2 feet per minute. It is desirable that the division bridge be convertable into this bridge in the water with the least amount of time and effort. The raft shall be so designed that it can be unloaded and ready for use, or reloaded from the water, within one hour in blackout.

6. The component parts of the bridge shall be of such weights, design and dimensions that they can be handled easily and quickly by hand, and preferably transported on standard 2½ ton cargo or dump trucks and 2-wheel utility pole type trailers. If possible, the loading should be so designed that a unit of divisional bridge augmented by an additional unit, as nearly identical as possible would result in a unit of army bridge. If necessary, standard ponton semi-trailers shall be used for transportation, but this is undesirable.

7. The characteristics of the pontons shall be the same as for the divisional bridge. They shall be so designed that when rigidly connected back end to back end, they form a full boat ponton for the army bridge.

8. The balk shall be of the articulated light truss or joist type. Preferably they shall be identical with divisional balk.

9. The maximum weight of the bridge shall not exceed 500# per foot. A lesser weight is desirable.

10. The characteristics of maintenance, delineation and smoke equipment and the characteristics of minimum parts and ruggedness are the same as for the division bridge.

INTERESTED UNITS: Infantry Division
Tank Destroyer Battalion

MILITARY CHARACTERISTICS FOR DIVISION FLOATING BRIDGE AND DIVISION ASSAULT RAFT

1. The bridge and raft shall have sufficient capacity to carry the vehicles organically assigned to an infantry or cavalry division in the field which meet the weight and width limitations prescribed in AR 850-15 dated August 1943. For a tracked load, this weight limit is eighteen tons gross on an 18 foot track and the width limit is 96 inches, except for special vehicles, which may be 108 inches.

2. The bridge and raft constructed normally of one half boat per span of about 15 feet shall be capable of carrying safely the maximum load with unrestricted movement in a stream velocity of 5 miles per hour. In velocities up to 5 miles per hour the raft shall be propelled by the standard power boat or outboard motors. It shall be capable of operating in greater velocities as a ferry.

3. The bridge and raft shall have a minimum clear roadway width of 128". It is desirable that the clear width be 144" if other characteristics are not materially altered or weight increased too much by reason of gaining this advantage.

4. The raft shall be constructed of component parts of the bridge and shall be useable as an integral part of the bridge. It is desirable that the components of this bridge and raft be useable in the army bridge and raft.

5. The bridge shall be so constructed that it can be erected from transportation on a prepared site in one-half hour plus 3 feet per minute in blackout and reloaded from water in one hour plus 2 feet per minute. The raft shall be so designed that it can be unloaded and ready for use in about fifteen minutes and reloaded from water in about thirty minutes under blackout.

6. The component parts of the bridge shall be of such weights, design and dimensions that they can be handled easily and quickly by hand, and such that a complete 3 boat floating bay raft can be transported on one standard 2½ ton cargo or dump truck and 2-wheel utility pole type trailer.

7. Each individual streamlined nesting half boat ponton shall have a displacement of about ten tons with 6" freeboard in a current of velocity of about 5 miles per hour and shall weigh not more than about 1200 pounds. It shall be capable of being carried and handled by manpower by 20 to 24 men.

8. The balk shall be of the articulated light truss or joist type.

9. The maximum weight of the bridge shall not exceed 330 pounds per foot. A lesser weight is desirable.

10. The bridge unit shall be equipped with first echelon maintenance equipment designed to prevent the pontons from sinking when strafed by calibres up to 37 mm.

11. Defensive smoke equipment to be issued to the bridge organization to which the bridge is assigned, or to be made an integral part of the bridge itself shall be capable of effectively screening 6 raft and 1 bridge location or 2 bridge locations.

12. Bridge and raft delineation shall be provided by a kit in each bridge unit composed of such items as waterproof radio active buttons and luminous markers necessary to delineate one bridge and two approaches with a minimum of equipment and maintenance.

13. Consistent with the foregoing characteristics, the bridge shall consist of a minimum of parts and shall be sufficiently rugged to withstand rough treatment.

SUBJECT: Development and Requirements of Division and Army Floating Bridges

SPRMD 823 (1 Sept 43) 1st Indorsement WNJ:bfl 6047

Headquarters, Army Service Forces, Washington, D. C. 9 September 1943

To: Chief of Engineers - Attn: Troops Division, Equipment Branch.

1. Attention is invited to the basic communication.

2. The Chief of Engineers will initiate action immediately to develop division and army floating bridges and rafts in accordance with the inclosed military characteristics.

3. It is further desired that this matter be processed through the Corps of Engineers Technical Committee.

4. If high priority is necessary to secure materials for this development, such requests will be submitted, through the Corps of Engineers Priority Officer, to the Director, Production Division, Army Service Forces.

For the Commanding General:

LEE A. DENSON, JR.,
Colonel, General Staff Corps,
Acting Director, Requirements Div.

2 Incls. n/c

/s/
R. M. OSBORNE
Colonel, Field Artillery
Deputy Chief, Development Br.

CE SPENC

Subject: Work Order No. BR 3012, Development and Requirements of Division and Army Floating Bridges.

2nd Ind.

Office, Chief of Engineers, 20 September 1943.

TO: The President, The Engineer Board, FORT BELVOIR, VIRGINIA.

1. The Engineer Board is directed to open a project with the necessary subprojects immediately and to develop as rapidly as possible the subject equipment as described in the basic communication and first indorsement thereto, and in accordance with the inclosed military characteristics.

2. The military characteristics will be processed through the next Technical Committee meeting.

By order of the Chief of Engineers:

/s/
JAMES H. STRATTON
Colonel, Corps of Engineers,
Chief, Engineering Division.

2 Incls. n/c
1 - Military Characteristics for Army Floating Bridge and Raft.
2 - Military Characteristics for Division Floating Bridge and Division Assault Raft.

WAR DEPARTMENT
THE ENGINEER BOARD
CORPS OF ENGINEERS, U. S. ARMY
FORT BELVOIR, VIRGINIA

334.9 27 Oct 1943

Subject: Division Floating Bridge Equipage.

To: Chief of Engineers, U. S. Army
(Attention: Equipment Development Branch,
Engineering Division.)

1. It is requested that project BR 473 be approved for the investigation and development of Division Floating Bridge Equipage.

2. Inclosures "A" and "B" contain the necessary information for the project.

3. This request is in accordance with 2nd indorsement from the Office, Chief of Engineers to the Engineer Board, dated 20 September 1943, Subject: Work Order No. BR 3012, Development and Requirements of Division and Army Floating Bridges.

4. It is requested that expenditure of funds in the amount of $150,000 be authorized to cover the development and procurement of 500 feet of this proposed equipage.

For the Board:

Peter P. Goerz,
Colonel, Corps of Engineers,
Executive Officer.

2 Incls.
Incls. "A" and "B"

INCLOSURE "A"

Project No. BR 473 Division Floating Bridge Equipage

Authority for Initiation of Project:

Second indorsement from Office, Chief of Engineers to the President, Engineer Board, dated 20 September 1943, File Number CE SPENC, Subject: Work Order Number BR 3012, Development and Requirements of Division and Army Floating Bridges.

Purpose of Project.

It is proposed to develop floating bridging equipage which will permit the continuous and uninterrupted passage of Division loads which meet the weight and width limitations prescribed in AR 850-15, dated August 1943.

Military Characteristics:

a. The bridge and raft shall have sufficient capacity to carry the vehicles organically assigned to an infantry or cavalry division in the field which meet the weight and width limitations prescribed in AR 850-15 dated August 1943. For a tracked load, this weight limit is eighteen tons gross on an 18 foot track and the width limit is 96 inches, except for special vehicles, which may be 108 inches.

b. The bridge and raft constructed normally of one-half boat per span of about 15 feet shall be capable of carrying safely the maximum load with unrestricted movement in a stream velocity of 5 miles per hour. In velocities up to 5 miles per hour the raft shall be propelled by the standard power boat or outboard motors. It shall be capable of operating in greater velocities as a ferry.

c. The bridge and raft shall have a minimum clear roadway width of 128 inches. It is desirable that the clear width be 144 inches if other characteristics are not materially altered or weight increased too much by reason of gaining this advantage.

d. The raft shall be constructed of component parts of the bridge and shall be usable as an integral part of the bridge. It is desirable that the components of this bridge and raft be usable in the army bridge and raft.

e. The bridge shall be so constructed that it can be erected from transportation on a prepared site in one-half hour plus 3 feet per minute in blackout and reloaded from water in one hour plus 2 feet per minute. The raft shall be so designed that it can be unloaded and ready for use in about fifteen minutes and reloaded from water in about thirty minutes under blackout.

f. The component parts of the bridge shall be of such weight, design and dimensions that they can be handled easily and quickly by hand, and such that a complete 3 boat floating bay raft can be transported on one standard 2½ ton cargo or dump truck and 2-wheel utility pole type trailer.

g. Each individual streamlined nesting half boat ponton shall have a displacement of about ten tons with 6 inch freeboard in a current of velocity of about 5 miles per hour and shall weigh not more than about 1200 pounds. It shall be capable of being carried and handled by manpower by 20 to 24 men.

h. The balk shall be constructed of steel, aluminum or magnesium alloy and shall be of a section which produces the most economical and efficient design with respect to weight and moment resistance.

i. The maximum weight of the bridge shall not exceed 330 pounds per foot. A lesser weight is desirable.

j. The bridge unit shall be equipped with first echelon maintenance equipment designed to prevent the pontons from sinking when strafed by calibres up to 37 mm.

k. Defensive smoke equipment to be issued to the bridge organization to which the bridge is assigned, or to be made an integral part of the bridge itself shall be capable of effectively screening 6 raft and 1 bridge locations or 2 bridge locations.

l. Bridge and raft delineation shall be provided by a kit in each bridge unit composed of such items as waterproof radio active buttons and luminous markers necessary to delineate one bridge and two approaches with a minimum of equipment and maintenance.

m. Consistent with the foregoing characteristics, the bridge shall consist of a minimum of parts and shall be sufficiently rugged to withstand rough treatment.

INCLOSURE "B"

Project No. BR 473 — Division Floating Bridge Equipage

PLAN FOR DEVELOPMENT

1. It is proposed to design, procure and test 500 feet of floating equipage suitable to carry vehicles organically assigned to an infantry or cavalry division which meet the weight and width limitations set forth in AR 850-15 dated August 1943.

2. This development will cover the design of all component parts of the floating equipage and the redesign or use of existing or new equipage where such use will be economically and technically feasible.

3. It is proposed the Engineering and Service Tests of this equipage will be conducted on the Colorado River in the vicinity of Yuma, Arizona, under the supervision of the Engineer Board.

4. It is proposed to utilize the facilities of the various U. S. Engineer districts, the N.D.R.C. and such consultants as may be necessary to expedite the completion of this development.

5. It is proposed that the test bridge will be equipped with suitable delineation for blackout construction and driving.

6. It is proposed to study the transportation requirements and to incorporate in the design, where practical, features which will utilize present standard transportation facilities to the greatest extent.

7. It is proposed that new equipment specifications as required and a final report based on results of tests conducted will be prepared and submitted to the Chief of Engineers at the conclusion of the test program.

8. The Engineering and Service Tests will require the assistance of troops and special equipment which should be made available both at Yuma, Arizona and at Fort Belvoir, Virginia.

26 October 1943 Approval by Board

CE (27 Oct 43) SPETQ Subject: Division Floating Bridge Equipage.

1st Ind.

ASF, Office, Chief of Engineers, WASHINGTON 25, D. C., 12 November 1943.

To: The Commanding General, Army Service Forces.
(Attention: Development Branch, Requirements Division, Room 4E625, The Pentagon, WASHINGTON, D. C.)

1. Reference is made to 1st Indorsement, dated 9 September 1943, from your office, regarding "Development and Requirements of Division and Army Floating Bridges", authorizing the development of subject equipment in accordance with submitted military characteristics.

2. It is recommended that the change in military characteristics indicated in Inclosure "A", paragraph Military Characteristics, h, regarding balk, be approved. Army Ground Forces (Col. Elliott) has informally approved this change.

3. It is further recommended that the request of the Engineer Board for the expenditure of funds in the amount of $150,000 to cover the development and procurement of 500 feet of this proposed equipage, be approved.

For the Chief of Engineers:

B. L. HARLOE,
Colonel, Corps of Engineers,
Chief, Equipment Branch,
Troops Division.

2 Incls. n/c

Subject: Division Floating Bridge Equipment.

SPRMD 823 (27 Oct 43) 2nd Indorsement WJN:bfl 6047

Headquarters, Army Service Forces, Washington, D. C. 18 Nov 1943

To: Commanding General, Army Ground Forces.

1. Reference is made to your letter dated 1 September 1943, file 823/60 (1 Sept 43) GNENG, subject "Development and Requirements of Division and Army Floating Bridges" wherein it is requested that the Chief of Engineers be directed to develop division and army floating bridges and rafts in accordance with the inclosed military characteristics.

2. Comments or concurrence are requested relative to the recommendations contained in Paragraph 2 and 3, 1st Indorsement.

For the Commanding General:

LEE A.DENSON, JR.,
Colonel, General Staff Corps,
Director, Requirements Division.

2 Incls. n/c

823(27 Oct 43)GNENG 3rd Ind. 22 Nov 1943

HEADQUARTERS ARMY GROUND FORCES, Army War College, Washington, D. C.

To: Commanding General, Army Service Forces (Attn: Director, Requirements Division, Development Branch), The Pentagon, Washington,D.C.

1. Recommend that change in paragraph h, Military characteristics read as follows:

"h. The Balk shall be constructed of metal, preferably of light type such as aluminum, and shall be of a section which produces the most efficient design with respect to weight and moment resistance."

2. The speed of erection of this bridge is directly proportional to the weight of the components, including the balk. The characteristics, for building, of steel balk and aluminum balk are entirely different. Colonel Elliott agreed to the weight and moment characteristics,but does not recall discussion of type of material or economy. Steel should be used only if aluminum proves unworkable or not available.

For the COMMANDING GENERAL:

R. A. MEREDITH
Major, A.G.D.,
Asst. Ground Adj. General

2 Incls n/c

Subject: Division Floating Bridge Equipage

SPRMD 823 (27 Oct 43) 4th Indorsement WJN.ofl
6047

Headquarters, Army Service Forces, Washington, D. C., 26 November 1943.

To: Chief of Engineers - Attn: Troops Division, Equipment Branch.

The request for Project BR 473 "Division Floating Equipage" as indicated in the basic letter, including the military characteristics pertaining thereto as amended by Paragraph 1, 3rd Indorsement, is approved.

For the Commanding General:

/s/
LEE A DENSON, JR.,
Colonel, General Staff Corps,
Director, Requirements Division.

2 Incls. n/c

CE SPENC Subject: Division Floating Bridge Equipage.

5th Ind.

Office, Chief of Engineers, 7 December 1943.

To: The President, The Engineer Board, FORT BELVOIR, VIRGINIA.

Project BR 473 is approved as modified by the preceding 4th indorsement.

By order of the Chief of Engineers:

/s/
B. M. HARLOE,
Colonel, Corps of Engineers,
Chief, Engineering and
Development Division.

2 Incls. n/c
#1 - Incl. "A"
#2 - Incl. "B"

WAR DEPARTMENT
THE ENGINEER BOARD
CORPS OF ENGINEERS, U. S. ARMY
FORT BELVOIR, VIRGINIA

334.9 27 Oct 1943

Subject: Army Floating Bridge Equipment.

To: Chief of Engineers, U. S. Army.
(Attention: Equipment Development Branch, Engineering Division.)

1. It is requested that project BR 474 be approved for the investigation and development of Army Floating Bridge Equipage.

2. Inclosures "A" and "B" contain the necessary information for the project.

3. This request is in accordance with 2nd indorsement from the Office, Chief of Engineers to the Engineer Board, dated 20 September 1943, Subject: Work Order No. BR 3012, Development and Requirements of Division and Army Floating Bridges.

4. It is requested that expenditure of funds in the amount of $150,000 be authorized to cover the development and procurement of 500 feet of this proposed equipage.

For the Board:

Peter P. Goerz,
Colonel, Corps of Engineers,
Executive Officer.

2 Incls.
Incls. "A" and "B"

INCLOSURE "A"

Project No.BR 474 — Army Floating Bridge Equipage

Authority for Initiation of Project.

Second indorsement from Office, Chief of Engineers to President, Engineer Board, dated 20 September 1943, File Number CE SPENC, Subject: Work Order Number BR 3012, Development and Requirements of Division and Army Floating Bridges.

Purpose of Project.

It is proposed to develop floating equipage which will permit the continuous and uninterrupted passage of Army loads which meet the weight and width limitations prescribed in AR 850-15 dated August 1943.

Military Characteristics:

a. The bridge shall have sufficient capacity to carry the vehicles accompanying an army in the field which meet the weight and width limitations prescribed in AR 850-15 dated August 1943. For a tracked load this weight limit is 38.9 tons gross on an 18 foot track and design of this structure will not attempt to accommodate any combination of vehicles more severe than this. The width limit is 124 inches for the lower 1 foot of vehicle and 130 inches above the lower foot.

b. The bridge and raft, constructed normally of two division half boats placed end to end per span of about 15 feet, and desirably with additional divisional balk, shall be capable of carrying safely the maximum load with unrestricted movement in a stream of velocity of 5 miles per hour. In velocities up to 5 miles per hour, the full boat raft shall be propelled by the standard power boat or outboard motors. It shall be capable of operating in greater velocities as a ferry.

c. The bridge and raft shall have a minimum clear roadway width of 144 inches. It is desirable that the divisional bridge chess be used.

d. The raft shall be constructed of component parts of the bridge and shall be usable as an integral part of the bridge. It is desirable that the component parts of this bridge and raft be identical with those of the divisional bridge.

e. The bridge shall be so constructed that it can be erected from transportation on a prepared site in two hours plus

2 feet per minute and reloaded from the water in two hours plus 2 feet per minute. It is desirable that the division bridge be convertible into this bridge in the water with the least amount of time and effort. The raft shall be so designed that it can be unloaded and ready for use, or reloaded from the water, within one hour in blackout.

f. The component parts of the bridge shall be of such weights, design and dimensions that they can be handled easily and quickly by hand, and preferably transported on standard 2½ ton cargo or dump trucks and 2-wheel utility pole type trailers. If possible, the loading should be so designed that a unit of divisional bridge, augmented by an additional unit, as nearly identical as possible would result in a unit of army bridge. If necessary, standard ponton semi-trailers shall be used for transportation, but this is undesirable.

g. The characteristics of the pontons shall be the same as for the divisional bridge. They shall be so designed that when rigidly connected back end to back end, they form a full boat ponton for the army bridge.

h. The balk shall be constructed of steel, aluminum or magnesium alloy and shall be of a section which produces the most economical and efficient design with respect to weight and moment resistance.

i. The maximum weight of the bridge shall not exceed 500 pounds per foot. A lesser weight is desirable.

j. The characteristics of maintenance, delineation and smoke equipment and the characteristics of minimum parts and ruggedness are the same as for the division bridge.

INCLOSURE "B"

Project No. BR 474 — Army Floating Bridge Equipage

PLAN FOR DEVELOPMENT

1. It is proposed to design, procure and test 500 feet of floating equipage suitable to carry vehicles assigned to the Army in the field as set forth in AR 850-15 dated August 1943.

2. This development will cover the design of all component parts of the floating equipage and the redesign or use of existing or new equipage where such use will be economically and technically feasible.

3. It is proposed the Engineering and Service Tests of this equipage will be conducted on the Colorado River in the vicinity of Yuma, Arizona under the supervision of the Engineer Board.

4. It is proposed to utilize the facilities of the various U. S. Engineer districts, the N.D.R.C. and such consultants as may be necessary to expedite the completion of this development.

5. It is proposed that the test bridge will be equipped with suitable delineation for blackout construction and driving.

6. It is proposed to study the transportation requirements and to incorporate in the design, where practical, features which will utilize present standard transportation facilities to the greatest extent.

7. It is proposed that new equipment specifications as required and a final report based on results of tests conducted will be prepared and submitted to the Chief of Engineers at the conclusion of the test program.

8. The Engineering and Service Tests will require the assistance of troops and special equipment which should be made available both at Yuma, Arizona and at Fort Belvoir, Virginia.

26 October 1943 Approved by Board

CE (27 Oct 43) SPETQ   Subject: Army Floating Bridge Equipment.

1st Ind.

ASF, Office, Chief of Engineers, WASHINGTON 25, D. C., 12 November 1943.

To: The Commanding General, Army Service Forces.
(Attention: Development Branch, Requirements Division, Room 4E625, The Pentagon, WASHINGTON, D. C.)

1. Reference is made to 1st Indorsement, dated 9 September 1943, from your office, regarding "Development and Requirements of Division and Army Floating Bridges", authorizing the development of subject equipment in accordance with submitted military characteristics.

2. It is recommended that the change in military characteristics indicated in Inclosure "A", paragraph Military Characteristics, h, regarding balk, be approved. Army Ground Forces (Col. Elliott) has informally approved this change.

3. It is further recommended that the request of the Engineer Board for the expenditure of funds in the amount of $150,000 to cover the development and procurement of 500 feet of this proposed equipage, be approved.

For the Chief of Engineers:

B. M. Harloe,
Colonel, Corps of Engineers,
Chief, Equipment Branch,
Troops Division.

2 Incls. n/c

Subject: Army Floating Bridge Equipment.

SPRMD 823 (27 Oct 43) 2nd Indorsement WJN:bfl
6047

Headquarters, Army Service Forces, Washington, D. C. 18 Nov 1943

To: Commanding General, Army Ground Forces.

1. Reference is made to your letter dated 1 September 1943, file 823/60 (1 Sept 43) GNENG, subject, "Development and Requirements of Division and Army Floating Bridges" wherein it is requested that the Chief of Engineers be directed to develop division and army floating bridges and rafts in accordance with the inclosed military characteristics.

2. Comments or concurrences are requested relative to the recommendations contained in Paragraph 2 and 3, 1st Indorsement.

For the Commanding General:

LEE A. DENSON, JR.,
Colonel, General Staff Corps,
Director, Requirements Division.

2 Incls. n/c

823(27 Oct 43)GNRQT-10/61839 3rd Ind.

HEADQUARTERS ARMY GROUND FORCES, Army War College, Washington, D. C.

TO: Commanding General, Army Service Forces, ATT: Director, Requirements Division, Development Branch.

1. Recommend that change in paragraph h, military characteristics, read as follows:

"h. The balk shall be constructed of metal, preferably of light type such as aluminum, and shall be of a section which produces the most efficient design with respect to weight and moment resistance."

2. Paragraph 3, 1st Indorsement, is concurred in.

For the COMMANDING GENERAL:

R. J. DELACROIX
Major, A. G. D.,
Asst. Ground Adj. General.

2 Incls. n/c

Subject: Army Floating Bridge Equipment.

SPRMD 823 (27 Oct 43) 4th Indorsement WJN:bfl
6047

Headquarters, Army Service Forces, Washington, D. C. 15 Dec 1943

To: Chief of Engineers - Engineering and Development Division.

The request for Project BR 474 "Army Floating Bridge Equipage" as indicated in the basic letter, including the military characteristics pertaining thereto as amended by Paragraph 1, 3rd indorsement, is approved.

For the Commanding General:

HENRY P. WESTPHALINGER,
Colonel, General Staff Corps,
Acting Director, Requirements Division.

2 Incls. n/c

CE SPENC 5th Indorsement

Office, Chief of Engineers. 17 December 1943

To: The President, The Engineer Board, FORT BELVOIR, VIRGINIA.

Project BR 474 is approved as modified by the preceding 4th indorsement.

By order of the Chief of Engineers:

B. M. HARLOE,
Colonel, Corps of Engineers,
Chief, Engineering and
Development Division.

2 Incls: n/c
Incls "A" and "B"

WAR DEPARTMENT
Office of the Chief of Engineers
Washington

CE SPENE
400.1 (BR 473, 474) R&D

22 February 1944.

Subject: Revised Loads and Clearances for Division, Army and Exceptionally Heavy Bridges. (Work Order No. DBR-3214.)

To: The President,
The Engineer Board,
Fort Belvoir, Virginia.

1. Reference is made to a 2nd Indorsement by this office dated 20 September 1943, subject: "Work Order No. DBR-3012, Development and Requirements of Division and Army Floating Bridges", a 2nd Indorsement dated 15 September 1943, subject: Work Order No. DBR-3003, Development and Requirements of Exceptional Heavy Floating Bridges", and a letter from this office dated 22 September 1943, subject: "Work Order No. DBR-3009, Design of Fixed Bridges". In this and subsequent correspondence between this office and the Engineer Board, the loads established for Division, Army and Exceptional Heavy Bridges were respectively 18 tons, 39 tons and British Class 70 or 62 tons whichever produces maximum stress.

2. At a conference in the office of G-4, Army General Staff, 19 February 1944, called to discuss the effect on bridging of vehicles exceeding the limitations of AR 850-15 as regards width and/or weight, certain changes were proposed.

3. It is now desired to design the bridges mentioned in paragraph 1 above, for heavier loads, which are to be as follows:

For Division Bridges	25 Tons
Army Bridges	50 Tons
Exceptional Heavy Bridges	80 Tons

4. The minimum clear width of roadway, between curbs, will be 10'-8" (128") for the Division Bridge, and 12'-6" (150") for the Army and Exceptional Heavy Bridges.

5. Informal discussions have been held with AGF and ASF and agreement on the increased loads and clearances as above outlined has been reached. Appropriate action is to be taken immediately, in anticipation of the formal directive which Army Ground Forces is preparing. This directive contemplates revision of AR 850-15 and will change the military characteristics for all Division, Army and Extra Heavy Load Bridges and rafts.

6. It is directed that bridges now being designed, or to be designed in the future, agree with the requirements set forth in paragraphs 3 and 4 above and that all details of design be prepared in accordance therewith.

7. It is desired that the Division and Army Bridges be placed on a high priority.

By order of the Chief of Engineers:

/s/
B. M. Harloe,
Colonel, Corps of Engineers,
Chief, Engineering and
Development Division.

APPENDIX B

ENGINEERING TEST PROCEDURE

Technical Division IV
Engineer Board

BR 473
BR 474

15 March 1944

DIRECTIVE FOR THE ENGINEERING TEST OF
DIVISION, ARMY, AND HEAVY FLOATING BRIDGE EQUIPAGE

To: Chief, Yuma Test Branch

I. GENERAL.

A. Purpose. The purpose of this directive is to form a basis for a comprehensive engineering test to determine the best-suited design for Division, Army, and Heavy floating bridge equipage. While this directive concerns certain bridge designs developed through the Technical Staff of the Engineer Board and its consultants, it is not proposed to limit engineering tests to those designs whose submission has been made prior to the date of this directive.

B. Scope. It is directed that engineering tests be made and detailed reports submitted on the individual units, component parts and completed bridge assemblies of designs submitted by and/or through: Technical Division IV; Howard, Needles, Tammen & Bergendoff; and Sparkman & Stephens.

C. Military Characteristics.

1. Each completed bridge will be tested for conformance with the military characteristics as established by Army Ground Forces for Division, Army, and Heavy floating bridges, with the following changes: The weight classifications to 25, 50, and 80 tons respectively and widths to 128, 150, and 150 inches.

2. In addition to the above-mentioned military characteristics, the following military characteristics originating from Technical Division IV of the Engineer Board will be considered in this test.

a. The minimum clear span between the first ponton and shore shall be 25 feet.

b. Minimum length of a test floating bridge shall be 100 feet (hinge to hinge only).

c. The clear water surface for all bridges shall be 40 percent of floating portion of the bridge (under load).

d. The floating portion of the bridge shall be so designed and constructed as to permit expeditious removal of floating bays to warrant passage of river traffic and debris.

e. The superstructure of the bridge shall be so designed and constructed as to permit the easy removal or replacement of a ponton.

f. The hinge span connections shall be so designed to permit a 10-ft. fluctuation of the water level.

g. It is desirable that the bridge be so designed as to permit its construction from both the near and far side banks.

h. If gunwale adaptors are integral part of balk fasteners and anchor, ponton gunwale adaptors shall be removable.

i. Pontons shall be adaptable for use with outboard motors.

j. Raft connectors shall be so designed as to permit easy connection and removal.

k. Method of anchoring or guying bridge shall not retain debris.

D. Desirable Features. Any combinations of bridging equipment now in use or submitted for those engineering tests which might be composed of desirable features for new bridging equipment shall be reported to Technical Division IV for consideration and necessary action. It is the intent of this directive to encourage the use of any facilities which would create better design.

II. ENGINEERING TESTS.

A. Component Parts.

1. Pontons. (Unless otherwise noted these tests are to include both half ponton and double ponton)

a. Determine

(1) Most desirable centerline of the bridge on the ponton.

(2) Exact weight and center of gravity.

(3) Requirements and best method for

(a) Loading and unloading

(b) Handling

(c) Transporting

(4) Adaptability of ponton for use with outboard motor.

(5) Suitability of outboard motor bracket.

(6) Practicability and adequacy of joining or disjoining pontons.

(a) Stern to stern.

(b) As raft.

(7) Ponton freeboard at various loads in various currents.

(8) Reaction to heavy loads by strain gage tests.

(9) Component parts of ponton repair kit.

(10) Effect of weather, salt air, water, sand, mud, and grit on ponton.

(11) Need for tie between gunwales to provide for heavier loads.

(12) Most suitable placement of pontons in bridge with particular consideration toward construction in series of floating bays.

b. Check

(1) Facility of changing gunwale adaptors (cleared)

(2) Adequacy of ponton when grounded (aluminum only

c. Subject pontons to failure tests.

d. Test rowing of pontons in various currents.

2. Balk.

a. Determine

(1) Yield point of balk by strain gage measurements

(2) Exact weight and dimensions.

(3) Requirements and best method for

(a) Handling

(b) Transporting

(4) Minimum number of balk permissible for various live loads when the balk is placed upon fixed supports.

(5) Effect of salt air, water, mud, sand, grit, and weather on the material and movable parts of the balk.

(6) Effect of rubber-tired and metal-tracked traffic on deck-balk (removable wearing surfaces).

(7) Articulation of various balk.

b. Observe structural tests to be conducted by the following:

(1) Alcoa Research Laboratory

(2) California Institute of Technology

c. Subject balk to failure test.

3. Trestles

a. Determine

(1) Maximum loads and spans for trestles designed by Sparkman & Stephens, and Howard, Needles, Tammon & Bergendoff.

(2) Utility, if any, of present 10- and 25-ton trestle for the proposed bridge.

(3) Maximum slope permissible with trestle.

(4) Exact weights and dimensions.

(5) Requirements and best methods for

(a) Erecting

(b) Handling

(c) Transportation

(6) Effect of salt air, water, mud, sand, grit, and weather on the material and movable parts of trestle.

b. Subject trestles to failure tests.

4. Abutments. Determine

a. Best-suited abutment and abutment sill with particular reference to moving landing bay.

b. Need for surfacing approach road with road expedients.

5. Curb. Determine

a. Effect of impact of both rubber-tired and tracked vehicles on positive siderail.

b. Resistance of tank and wheel vehicles to mounting curb.

c. Ease of placement.

d. Exact weight.

e. Requirements and best method for

(1) Handling

(2) Transporting

6. Balk Connectors

a. Determine

(1) If balk connectors will develop full strength of balk.

(2) Whether balk connectors permit easy and rapid release of sections of the floating bridge.

(3) Use of balk connectors as raft connectors.

(4) Effect of salt air, water, mud, sand, grit, and weather on the material and movable parts of the balk connectors.

(5) Facility of balk connectors in blackout operation.

b. Subject balk connectors to failure tests.

7. Balk Anchors (Fasteners). Determine

a. Ease of placement.

b. Effect of weather, sand, grit, mud, water, and salt air on material and movable parts.

8. Gunwale Adaptor. Determine

a. Ease of removal and replacement.

b. Effect of weather, sand, grit, mud, water, and salt air on material and movable parts.

9. Chess.

a. Determine

(1) Effect of rough handling (throwing off truck).

(2) Life of wearing surface.

(3) Effect of salt air, water, sand, grit, mud, weather on material and movable parts.

(4) Requirements and best method for

(a) Handling

(b) Transporting

(5) Necessity for replaceable wearing strip.

b. Subject chess to failure tests.

10. Long Landing Bay.

a. Determine

(1) Ease of placement

(2) Live load capacities.

(3) Maximum permissive grade.

(4) Minimum ponton requirements for floating support.

(5) Effect of weather, sand, grit, mud, water, and salt air on material and movable parts.

(6) Requirements and best method for

(a) Handling

(b) Transporting

b. Subject landing bay to failure test.

B. Bridge.

1. Determine

a. Interchangeability of all parts.

b. Facility of pre-assembling sections of bridge.

(1) Mechanical equipment needed to handle.

(2) Means of transporting to bridge site.

c. Facility of using other type floats under superstructure.

d. Facility of using any superstructure on pontons.

e. Minimum requirement of clear water surface under bridge.

f. Minimum clear water required between first ponton and water edge necessary to secure flotation.

g. Torsional resistance in deck.

h. Live load capacities for 25, 50, and 80-ton loads in velocities from 0 to 8 ft/sec.

(1) Sparkman & Stephens design.

(2) Howard, Needles, Tammen & Bergendoff design.

(3) Howard-Allison design.

(4) Type IV balk design.

(5) Any combination of the above.

(6) Any design developed during test.

i. Limitations on vehicles exceeding posted classification.

j. Practicability of building from both ends.

k. Exact dimensions and weights.

(1) Roadway

(2) Width

(3) Length

l. Erection time.

m. Effect of weather, sand, grit, mud, water, and salt air on material and movable parts.

n. Equipment required for assembly and installation.

o. Convertibility of different type bridges.

p. Components of repair and maintenance kits.

q. Difficulty of making connections in surf, current, and rough water.

r. Method of anchoring to facilitate maintenance of bridge in flooded stream carrying debris.

s. Water level adaptation.

2. Subject all structures to failure tests.

C. Rafts. Determine

1. Maximum load capacity in streams of varying stream velocities.

2. Ability to be propelled by outboard motors or utility power boats in varying stream velocities.

3. Facility of use as ferries.

4. Dimensions.

5. Requirements and best method for

a. Loading and unloading.

b. Handling.

6. Adaptability as integral part of bridge.

7. Need for raft connecting lever strip.

8. Ease of connecting rafts of 45 and 60 foot lengths.

D. Transportation. Determine

1. Vehicles required to transport bridge.

2. Equipment needed to facilitate loading and unloading.

III. REPORTS REQUIRED.

A. Weekly --Report current testing in regular weekly report.

B. Final (In form of Engineer Board Formal Report) - To include

1. Details of

a. Individual units.

b. Component parts.

c. Bridge assemblies.

d. Any unusual or interesting problems arising during test.

2. Comparison of final results with tests of the 25-ton ponton bridge with steel balk and widened (150") Panel Bridge.

3. Photographs (still and motion) which may be published of

a. Individual units.

b. Component parts.

c. Bridge assemblies.

/s/
Carl W. Meyer
Colonel, Corps of Engineers
Director, Technical Division IV.

APPENDIX C

PLANS OF MAJOR DESIGNS

NOTE

Original prints of the drawings contained in this appendix are contractors' drawings and have been reproduced and included in the report for what information may be gained in spite of the fact that some of the drawings could not be reproduced satisfactorily.

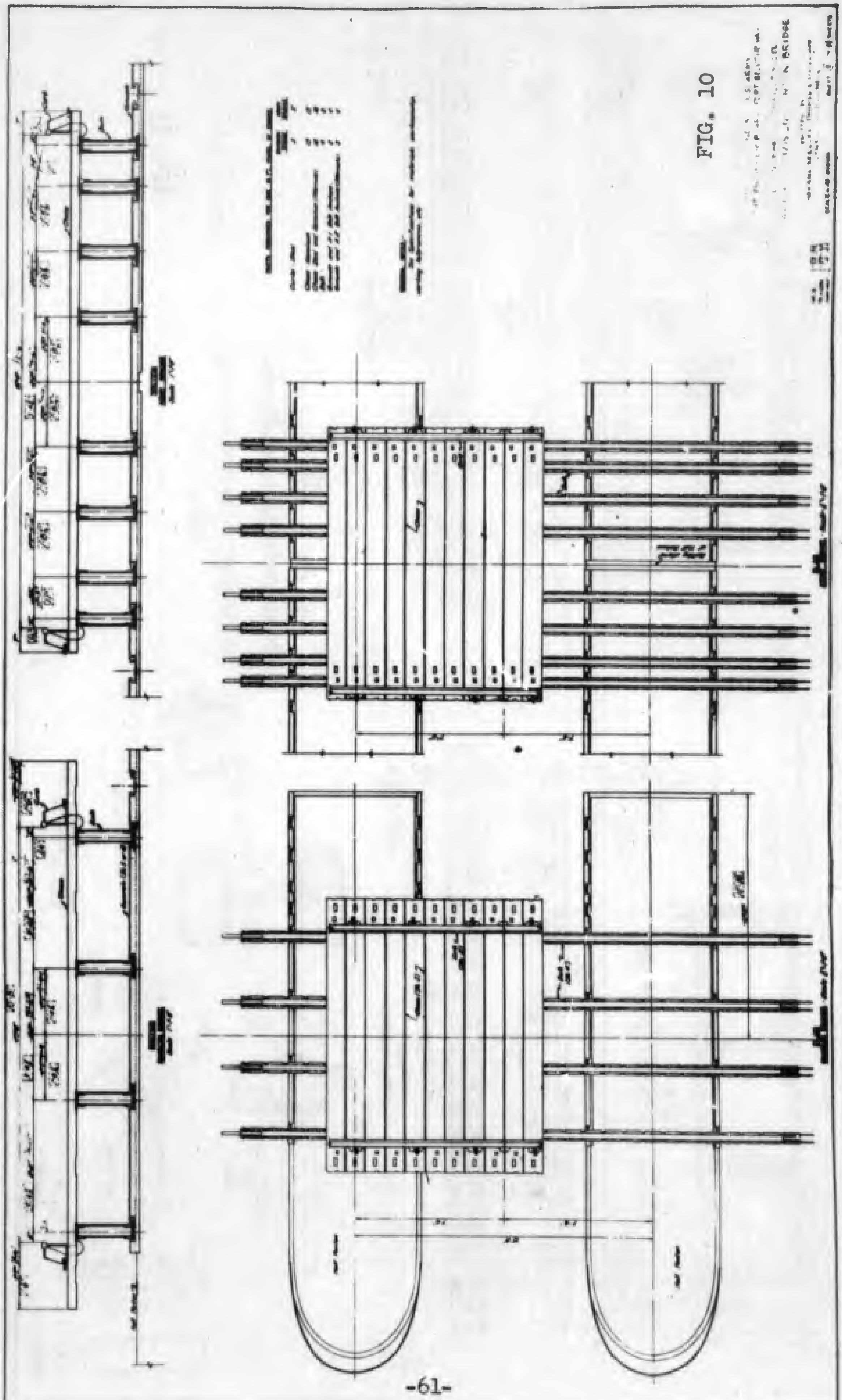


FIG. 10

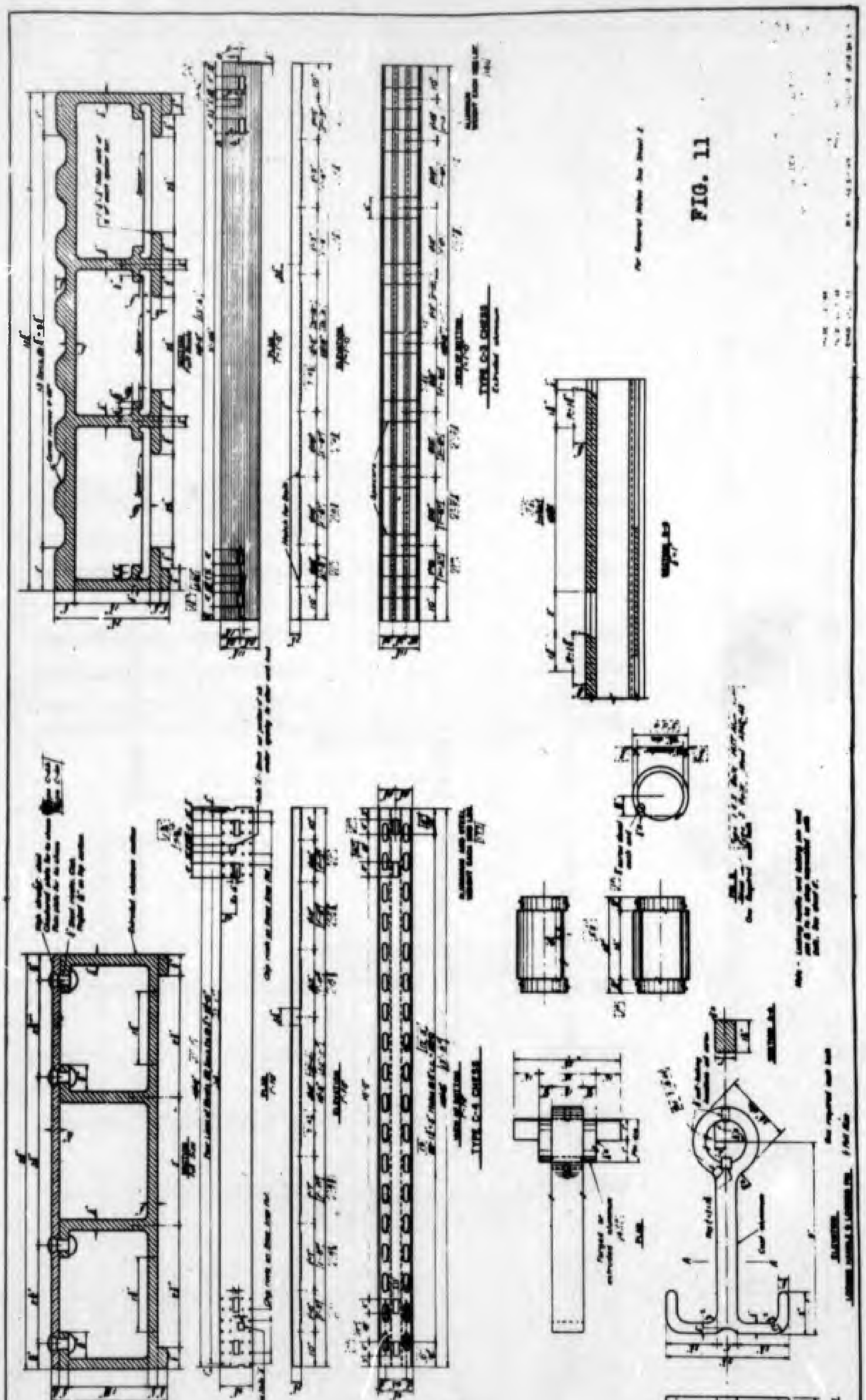


FIG. 11

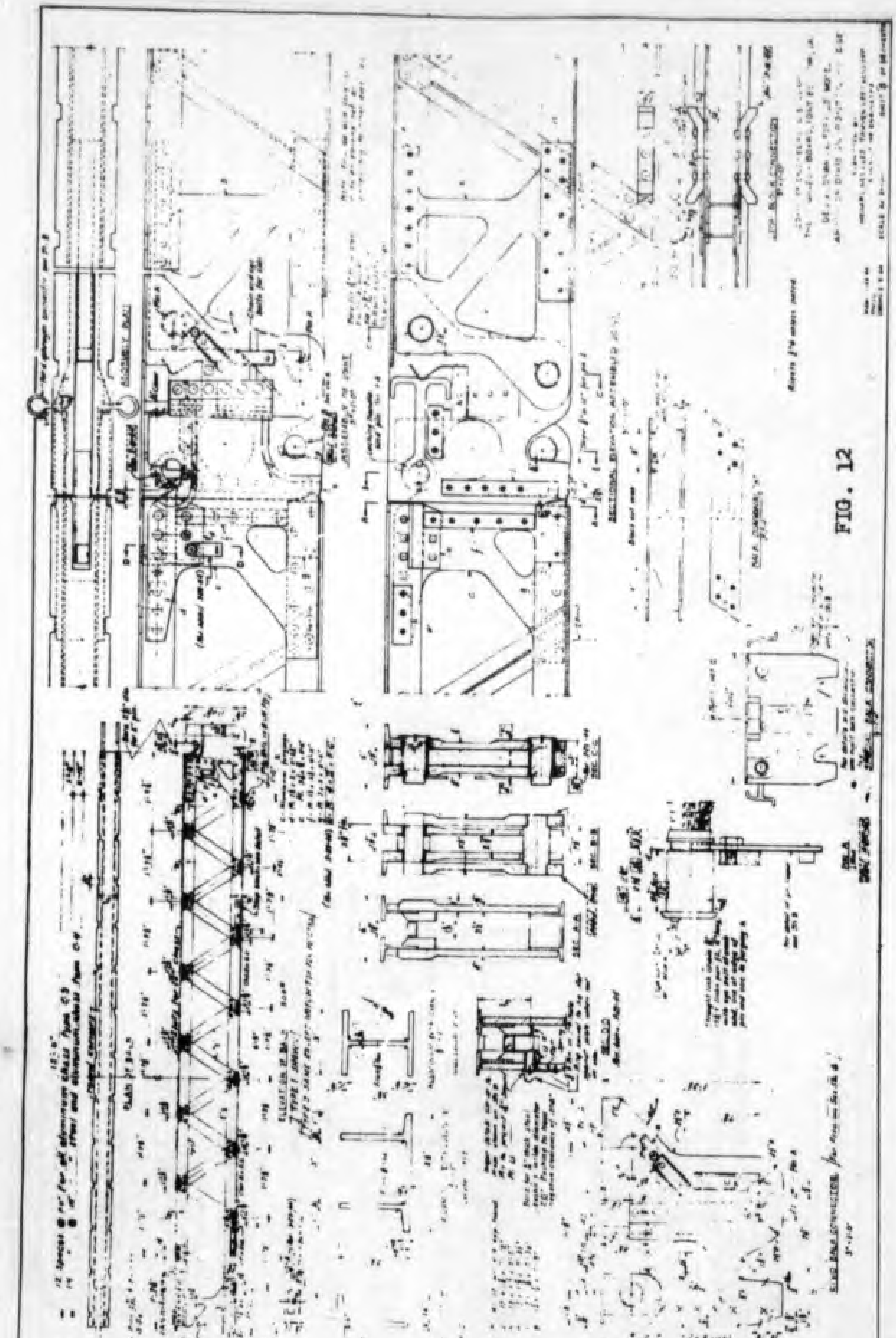


FIG. 12

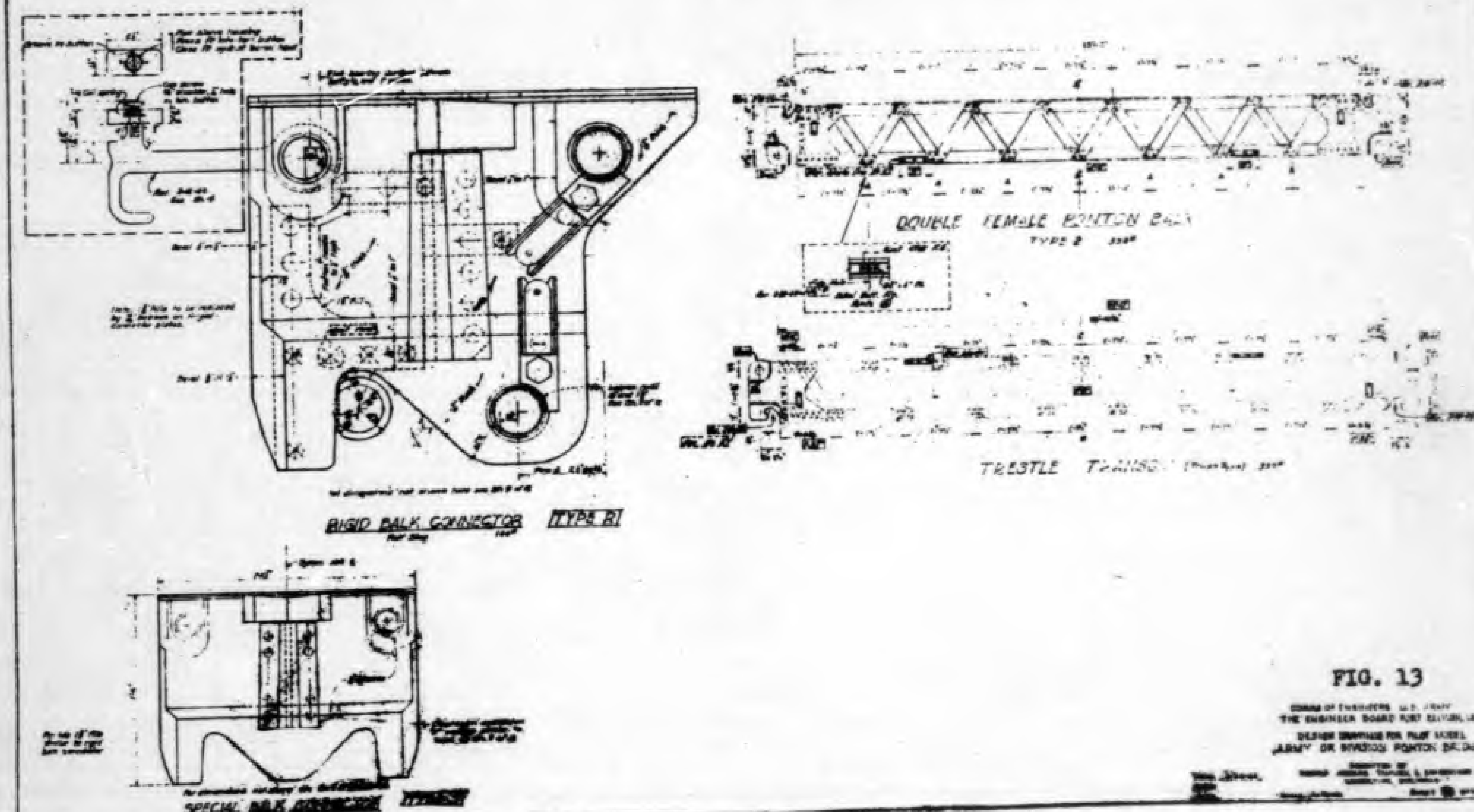

DOUBLE FEMALE PONTON BALK
TYPE 2
TRESTLE
RIGID BALK CONNECTOR
TYPE R1
SPECIAL BALK CONNECTOR
CORPS OF ENGINEERS U.S. ARMY
THE ENGINEER BOARD FORT BELVOIR, VA.
DESIGN DRAWINGS FOR PILOT MODEL
ARMY OR DIVISION PONTON BRIDGE

FIG. 13

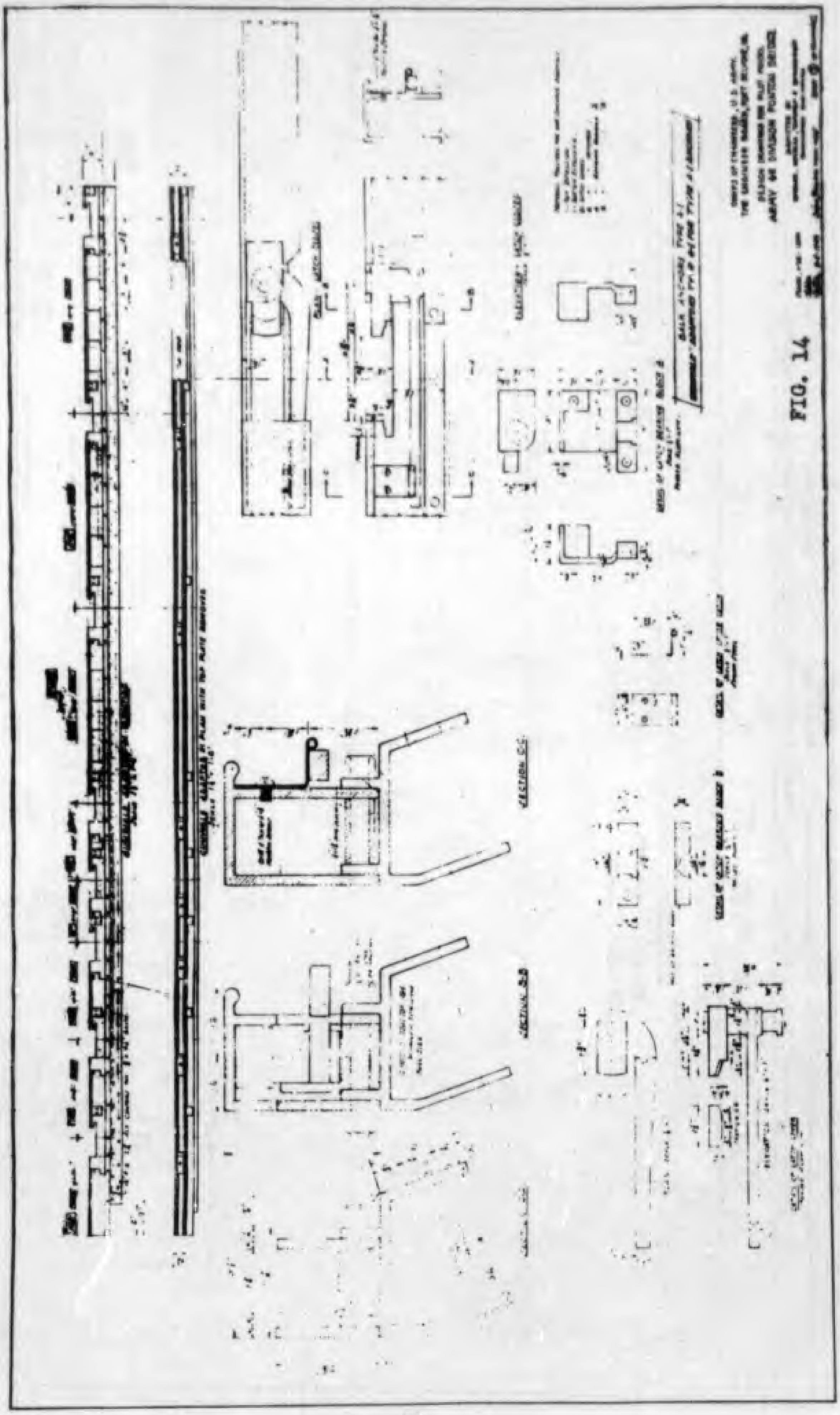


FIG. 14

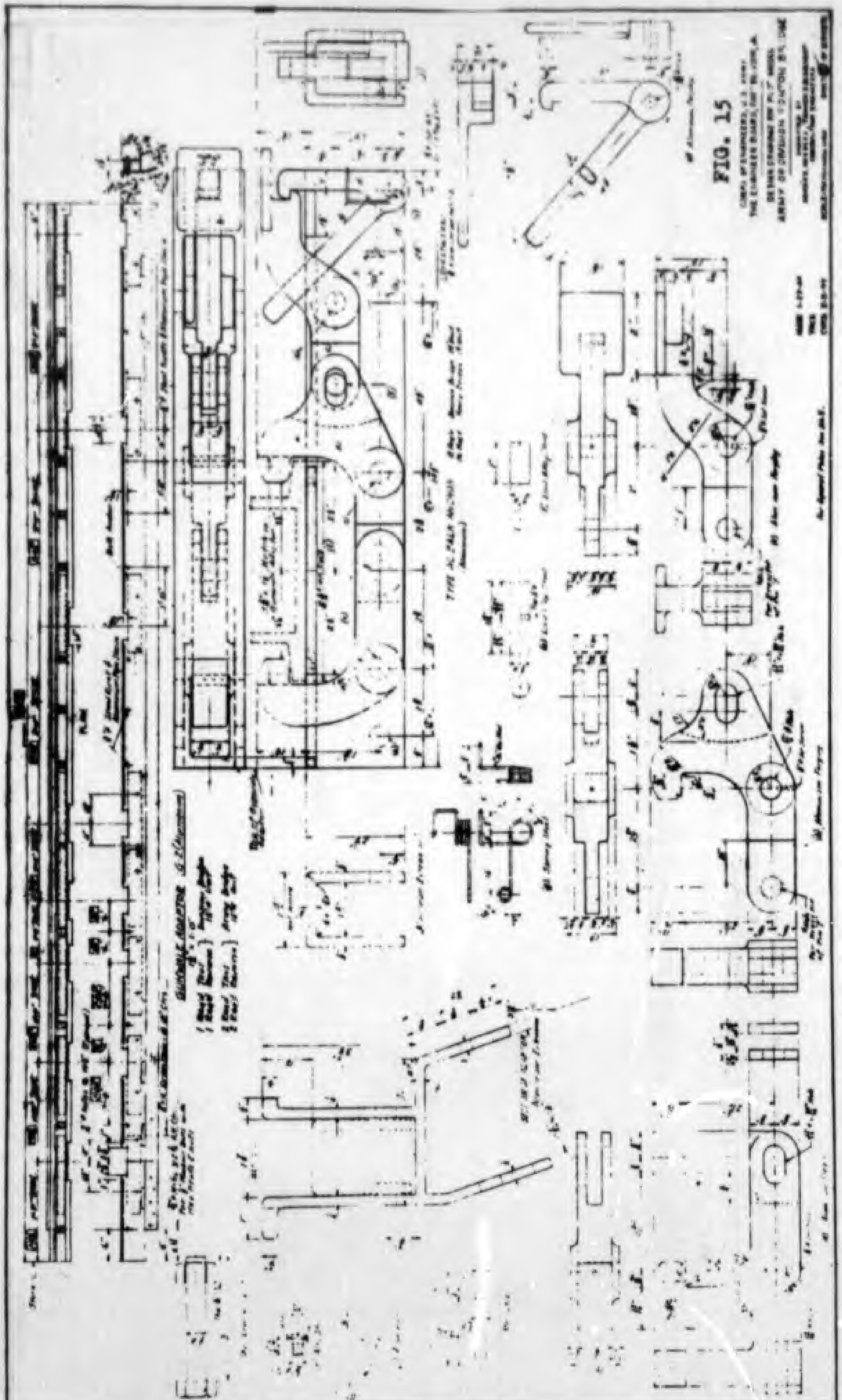


FIG. 15

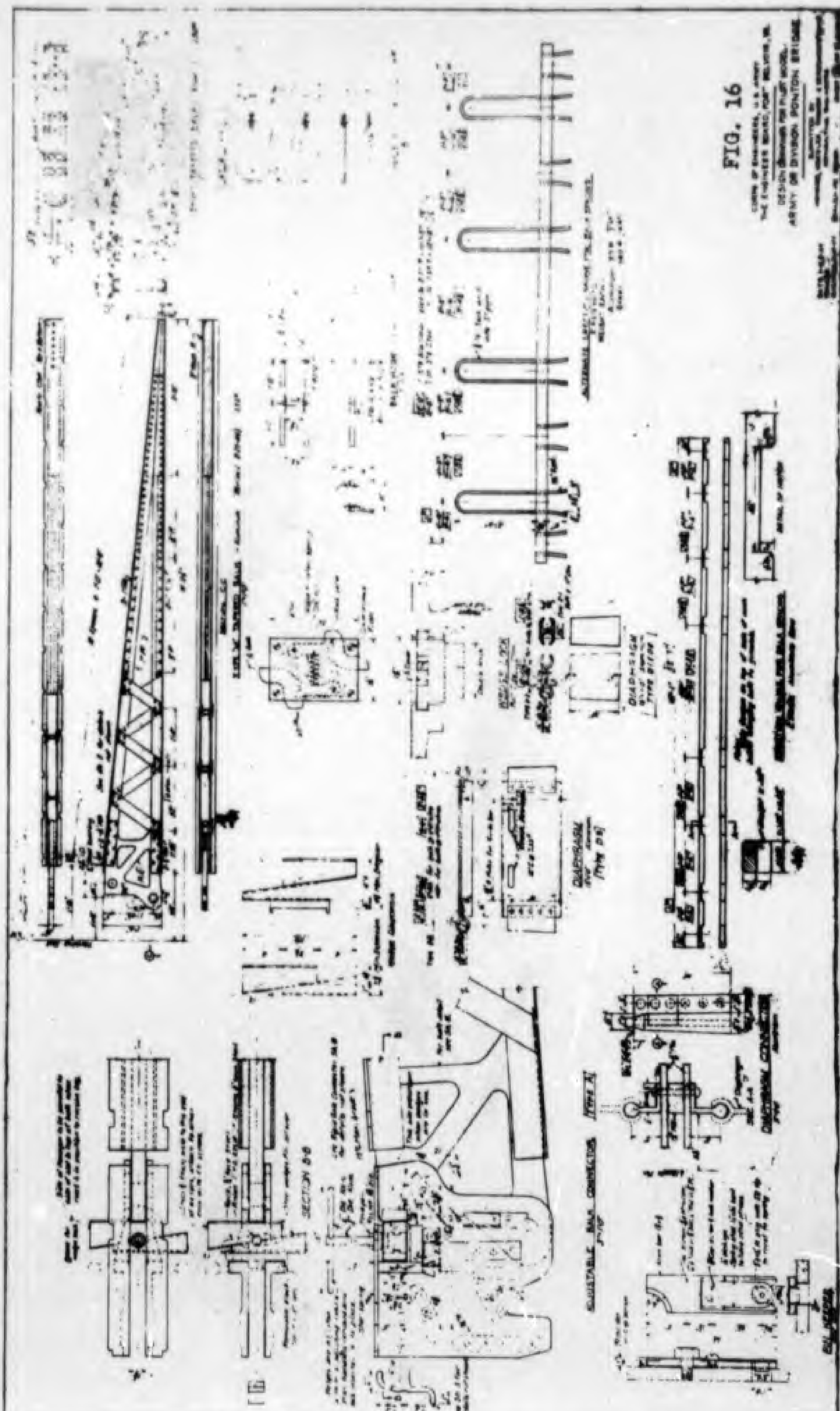


FIG. 16

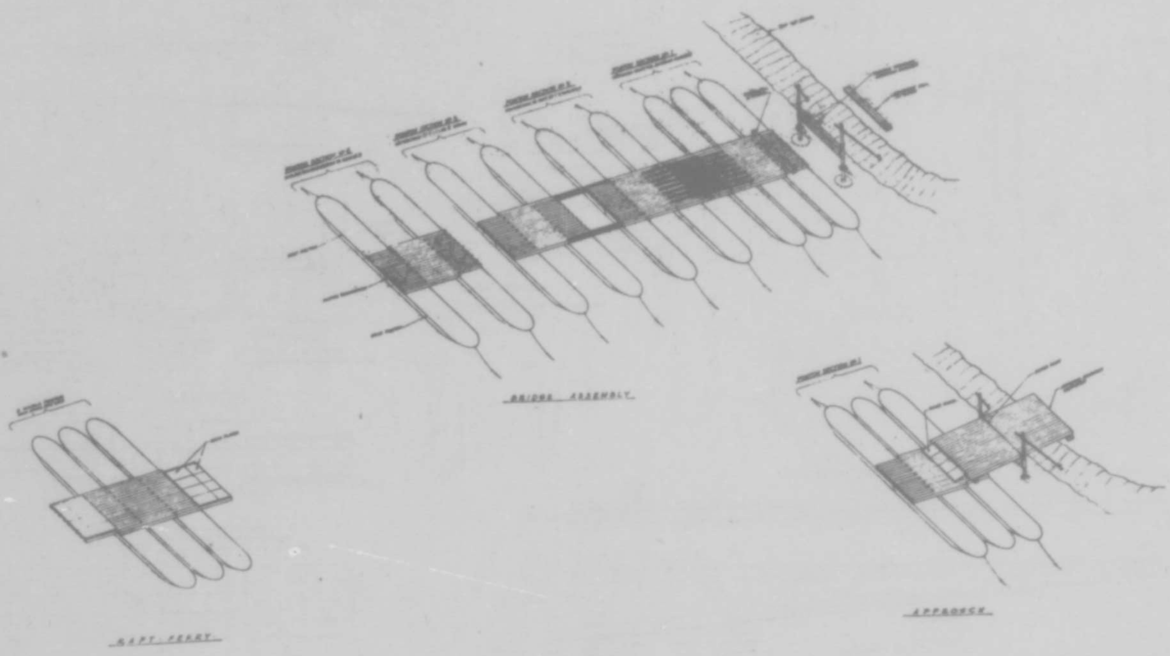
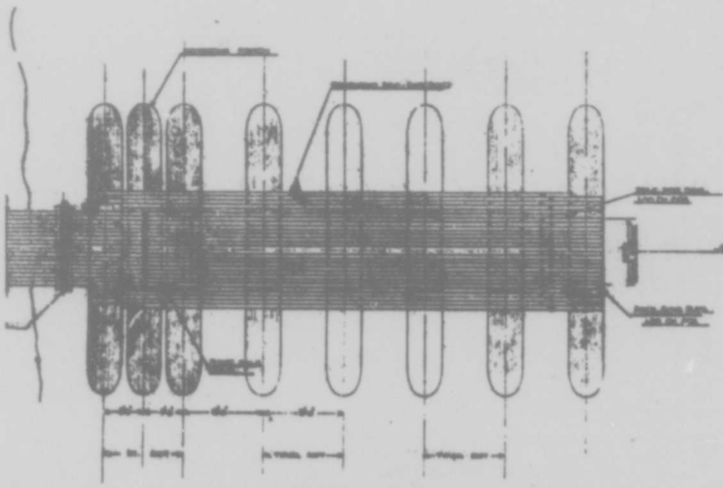
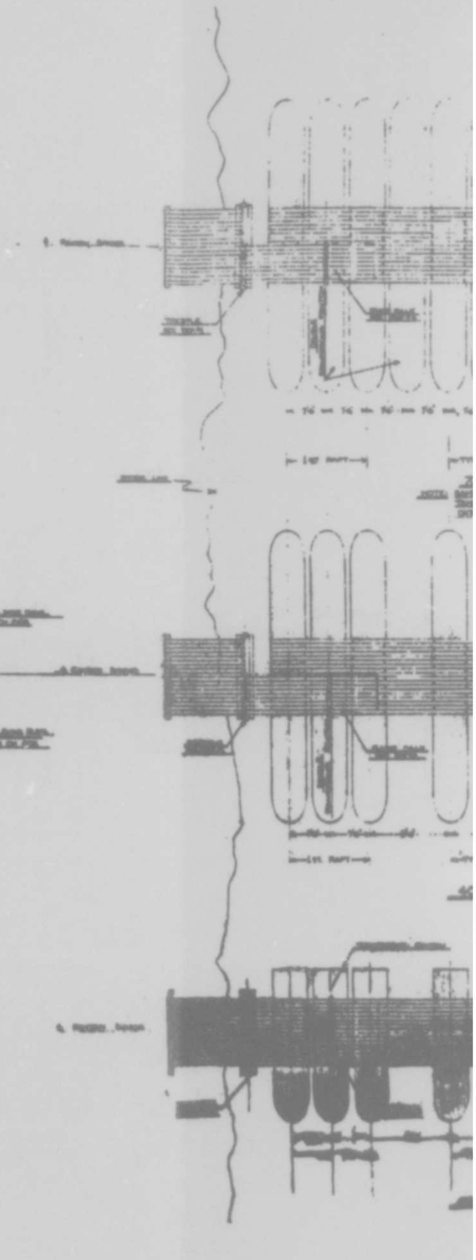


FIG. 17



50 TON PONTON BRIDGE



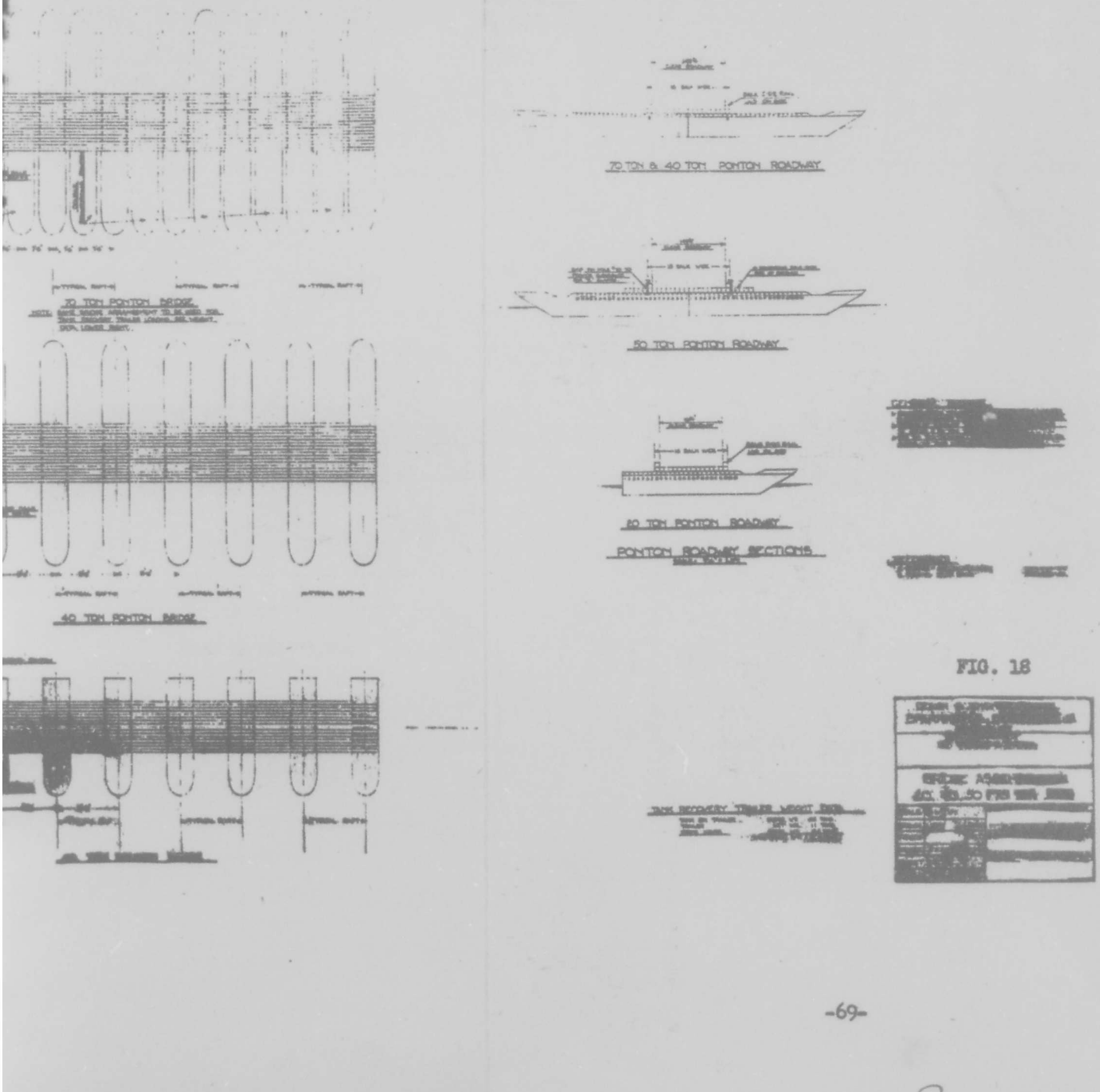
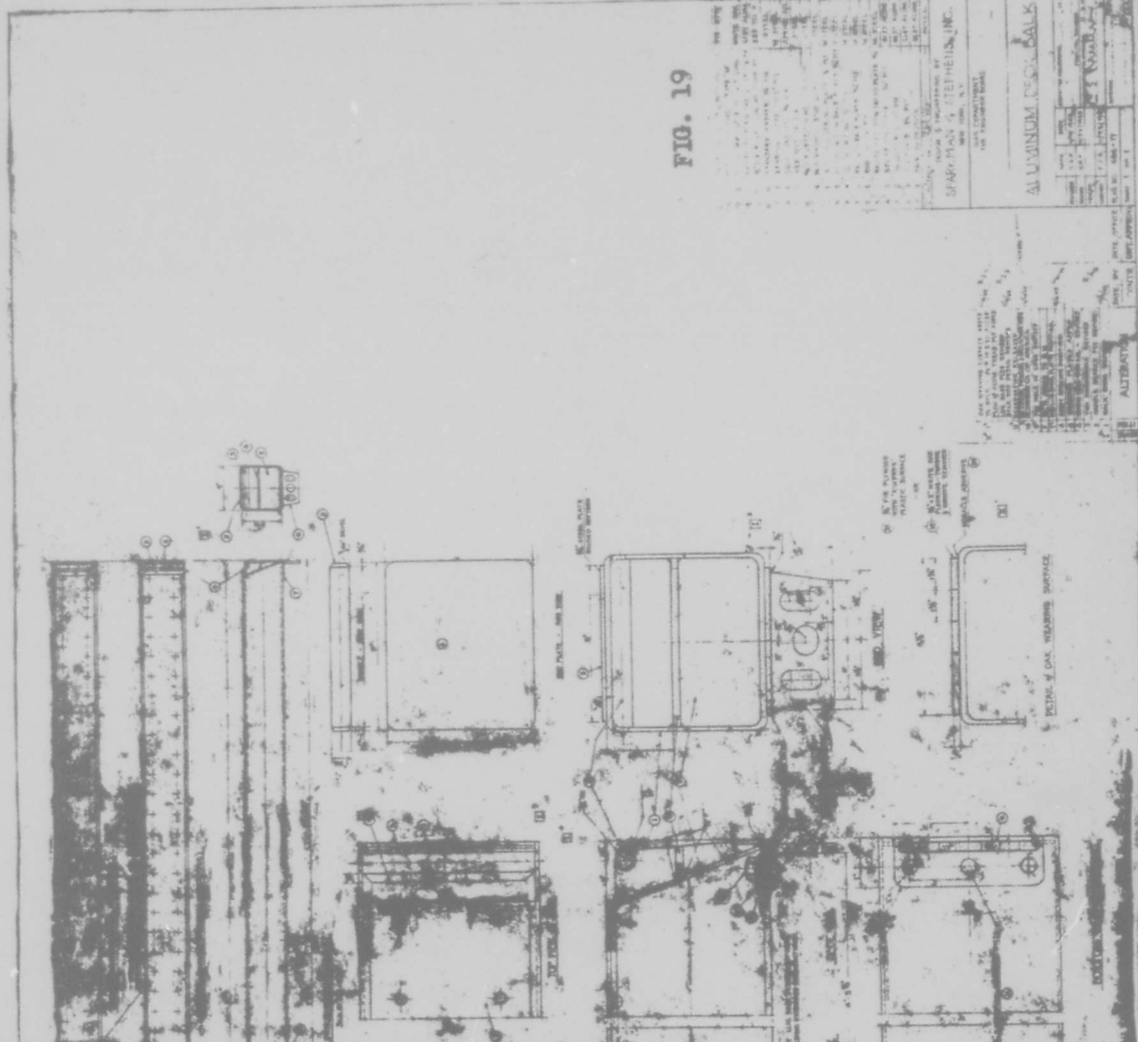
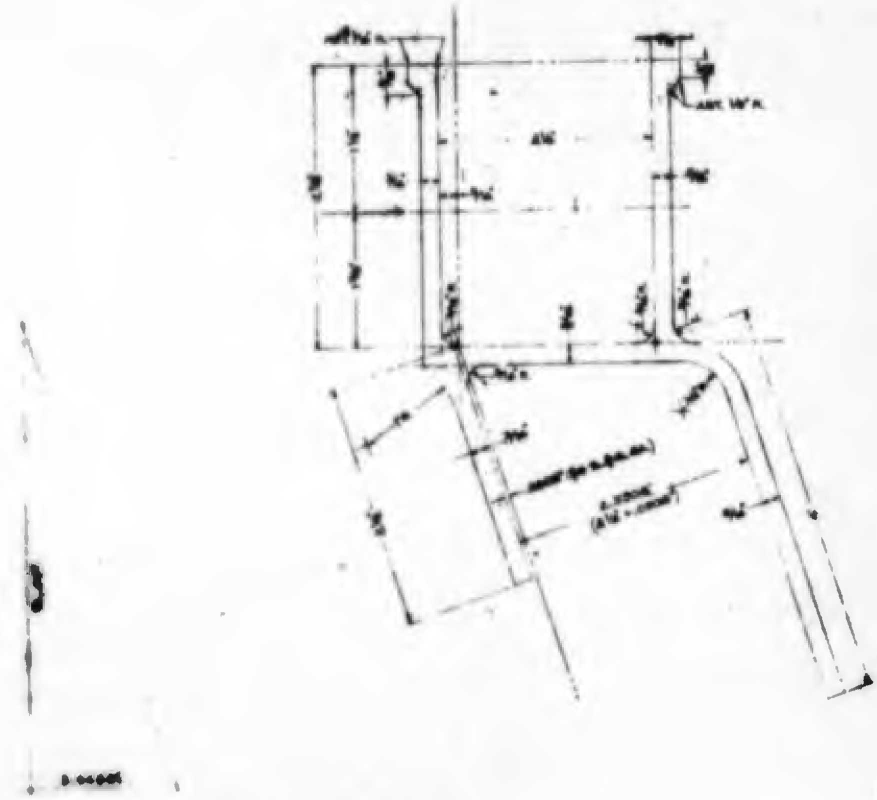

70 TON PONTON BRIDGE
40 TON PONTON BRIDGE
70 TON & 40 TON PONTON ROADWAY
50 TON PONTON ROADWAY
60 TON PONTON ROADWAY
PONTON ROADWAY SECTIONS

FIG. 18

FIG. 19


ALUMINUM DECK BALK
SPARKMAN & STEPHENS, INC.
NEW YORK, N.Y.
ALTERATIONS
DETAIL of OAK WEARING SURFACE
END VIEW
BOTTOM VIEW AT INTERIOR LUG
SECT C-C
BEARING PLATE
DETAIL of CORE POINT ALUMIN. RIVET



MATERIAL – 61S-T AL. ALLOY
AREA OF SECTION – 2.919 SQ. INS.
WEIGHT PER LIN. FT. – 3.433 LBS.
LENGTH PER PIECE – 22 FT.
WEIGHT PER PIECE – 75.526 LBS.

FIG. 20

DRAWING [illegible]

REVISED GUNWALE SECTION

ALUMINUM HALF PONTON

SCALE FULL SIZE.

[illegible] INC.

[illegible]

[illegible]

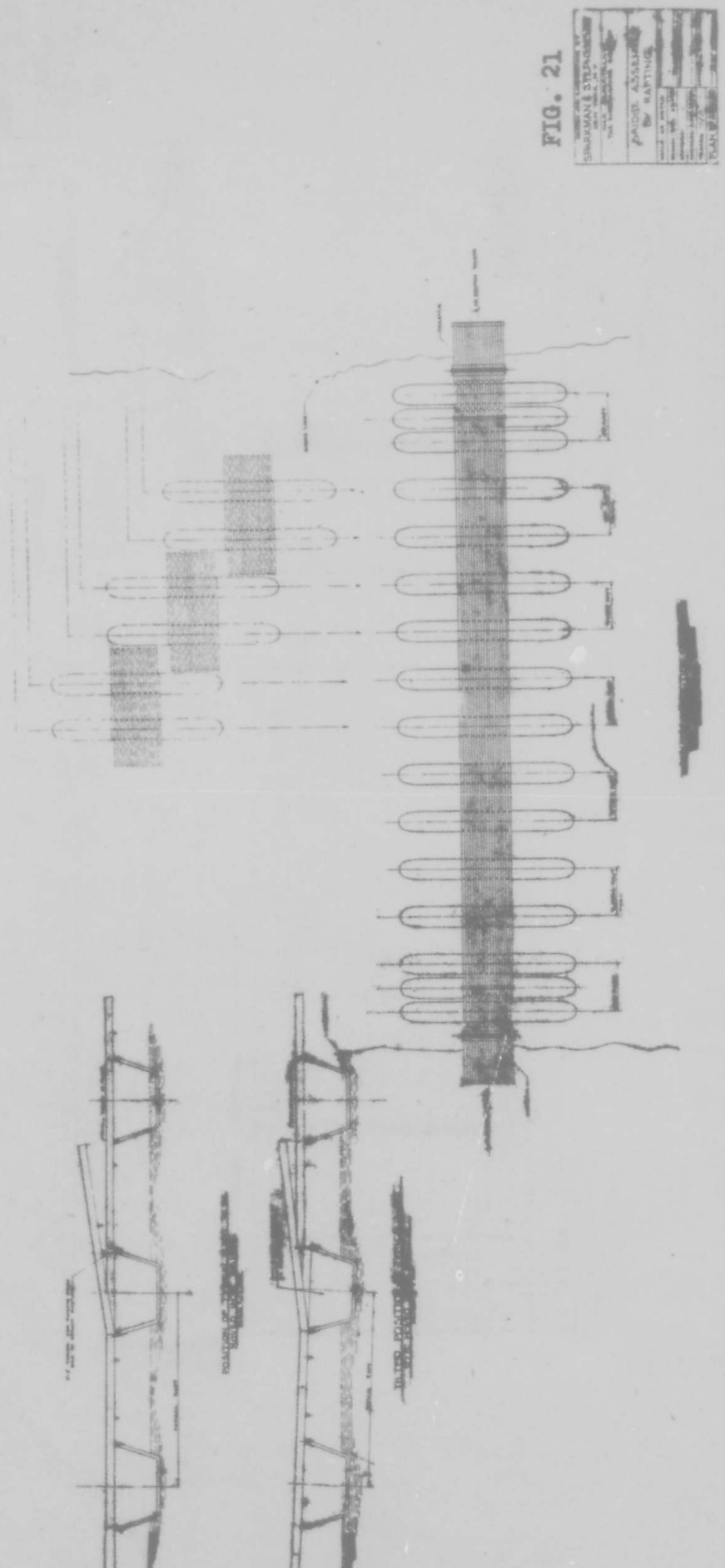


FIG. 21

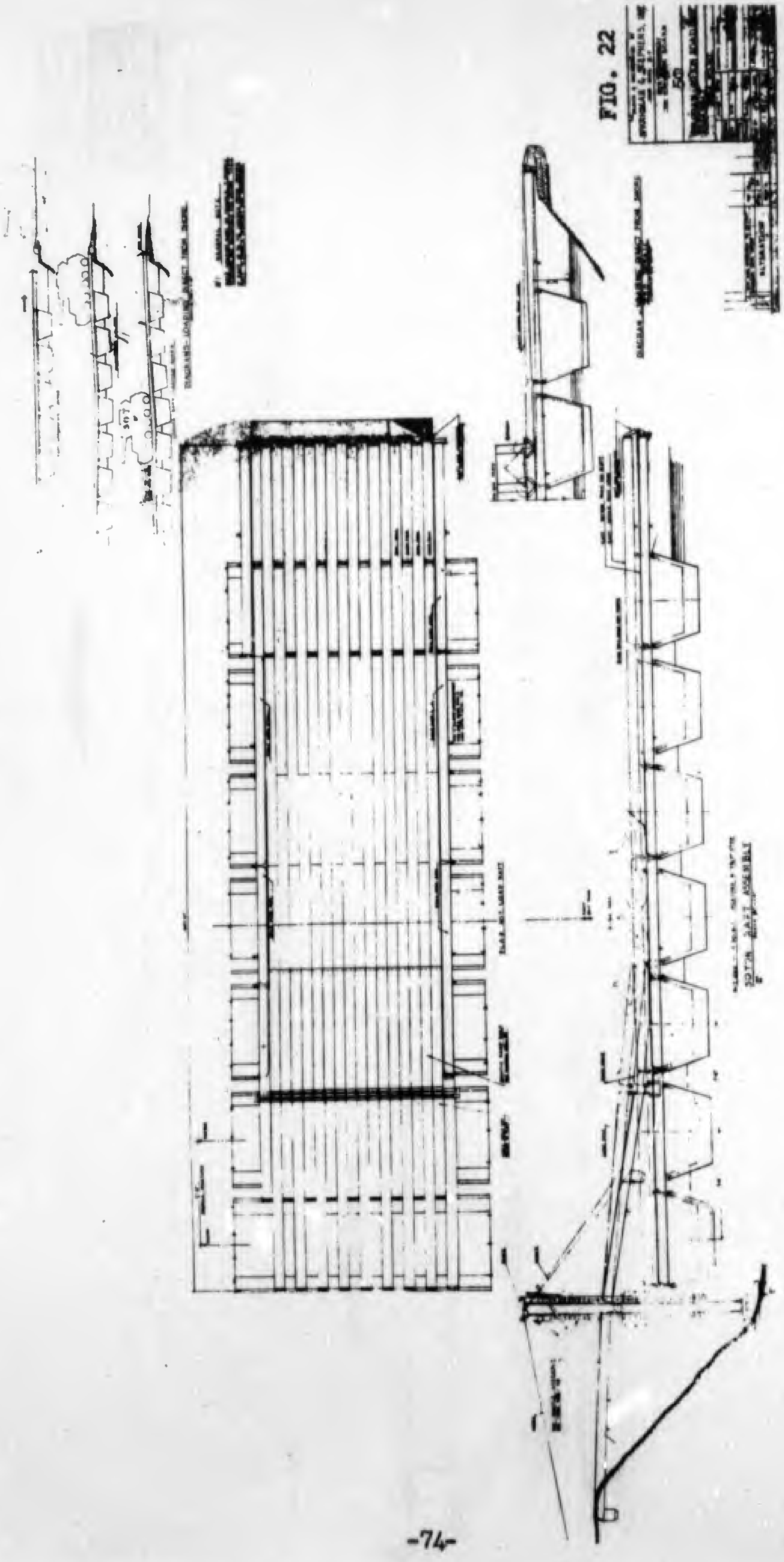
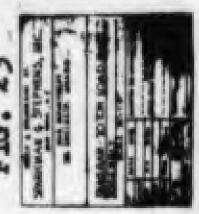
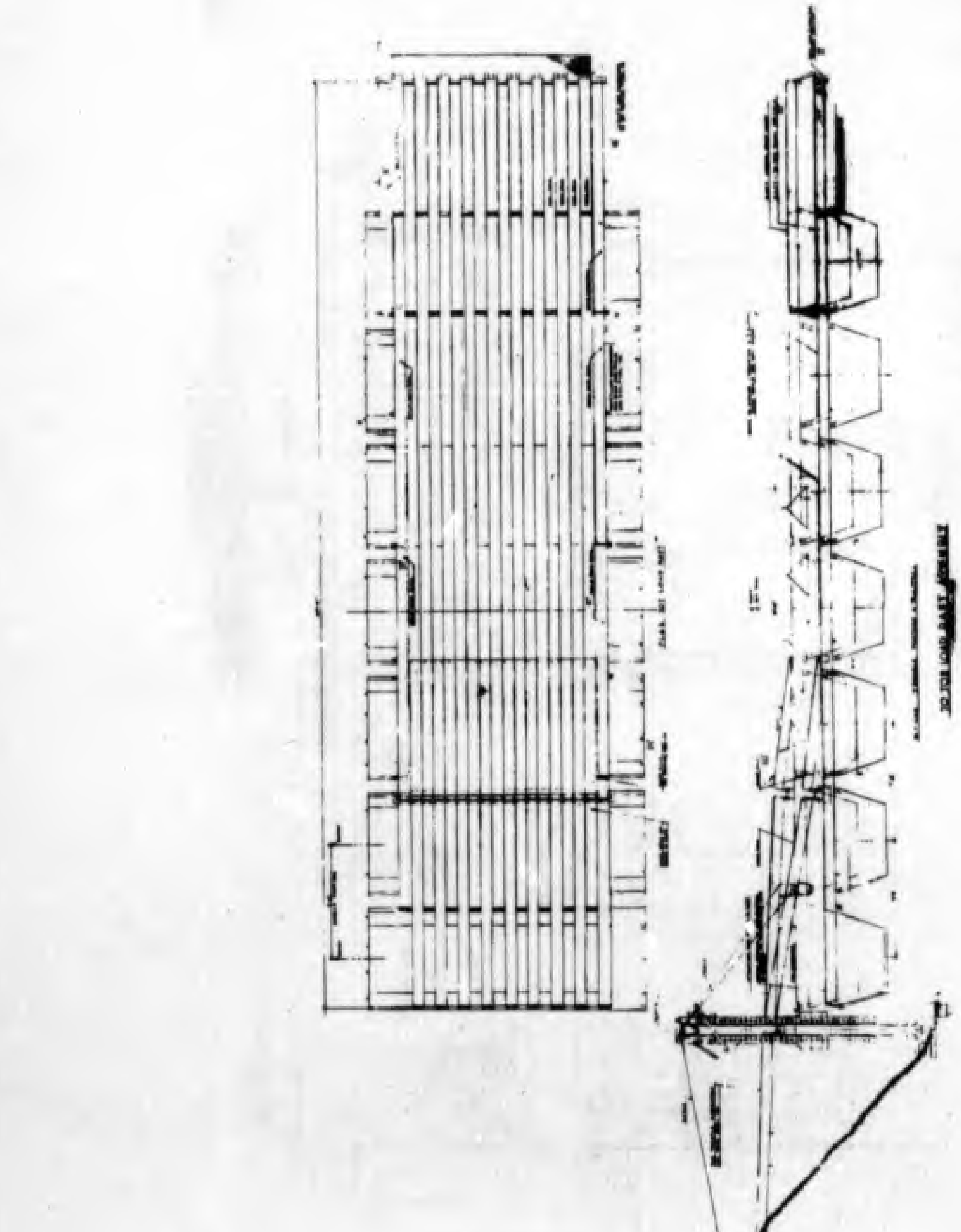


FIG. 22

FIG. 23





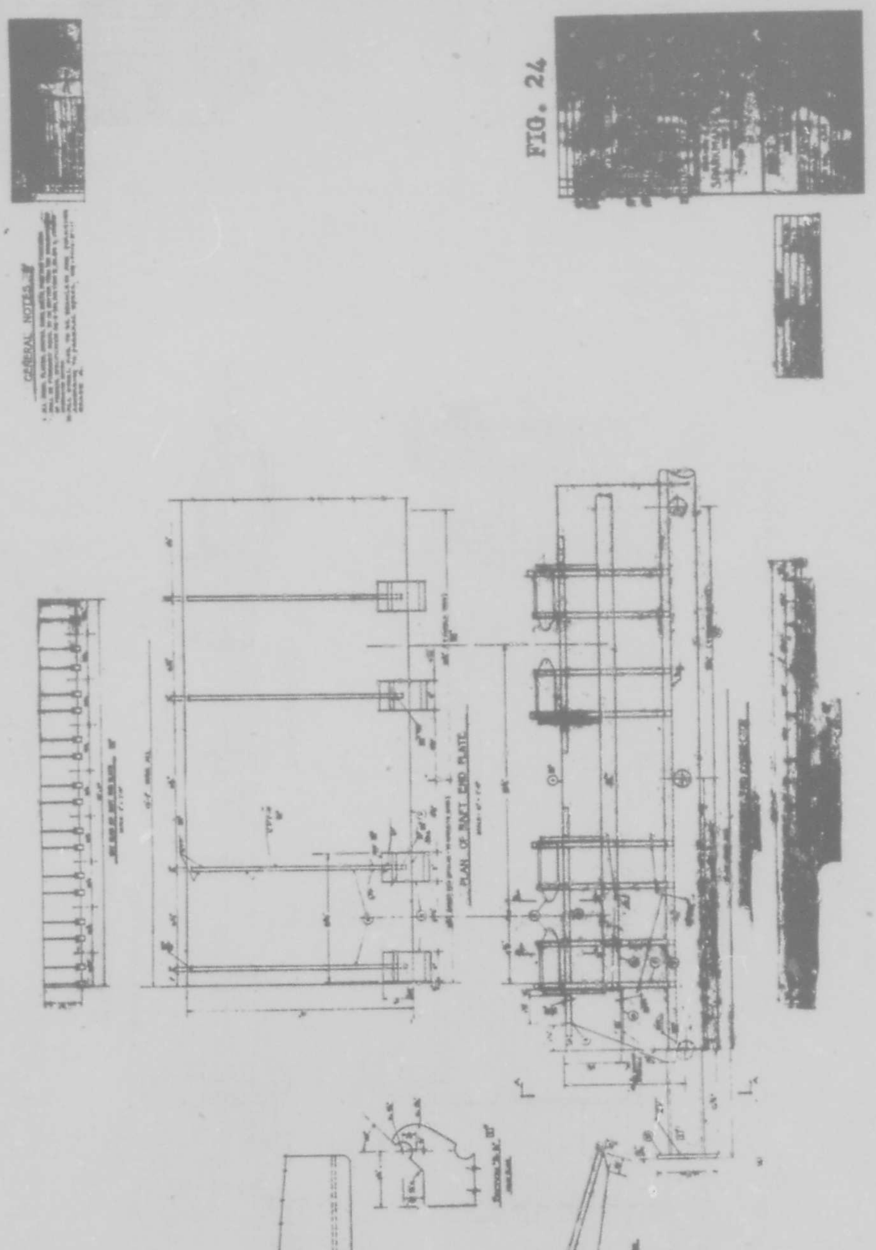
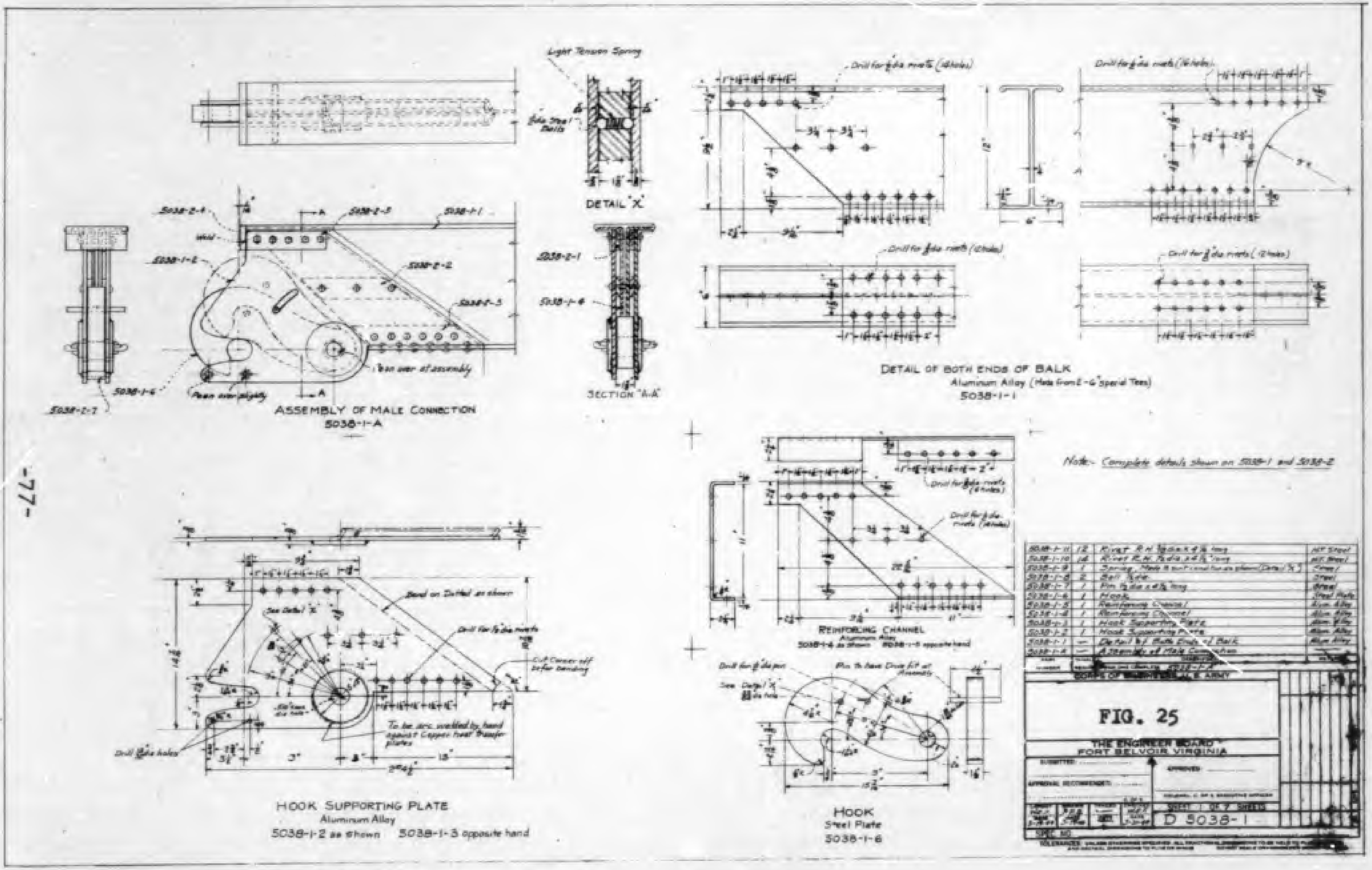


FIG. 24


ASSEMBLY OF MALE CONNECTION
5038-1-A
DETAIL "X"
SECTION "A-A"
Light Tension Spring
DETAIL OF BOTH ENDS OF BALK
Aluminum Alloy (Made from 2 - 6" Special Tees)
5038-1-1
Note:- Complete details shown on 5038-1 and 5038-2
REINFORCING CHANNEL
HOOK SUPPORTING PLATE
Aluminum Alloy
5038-1-2 as shown 5038-1-3 opposite hand
HOOK
Steel Plate
5038-1-6
FIG. 25
THE ENGINEER BOARD
FORT BELVOIR VIRGINIA
D 5038-1

APPENDIX D

PONTON STUDIES

Item	Page

Ponton Design Plans

Ponton Development

Item	Page

Item		Page

NOTE

Original prints of the drawings in Figures 26 through 32 are contractors' drawings and have been reproduced and included in the report for what information may be gained in spite of the fact that some of the drawings could not be reproduced satisfactorily.

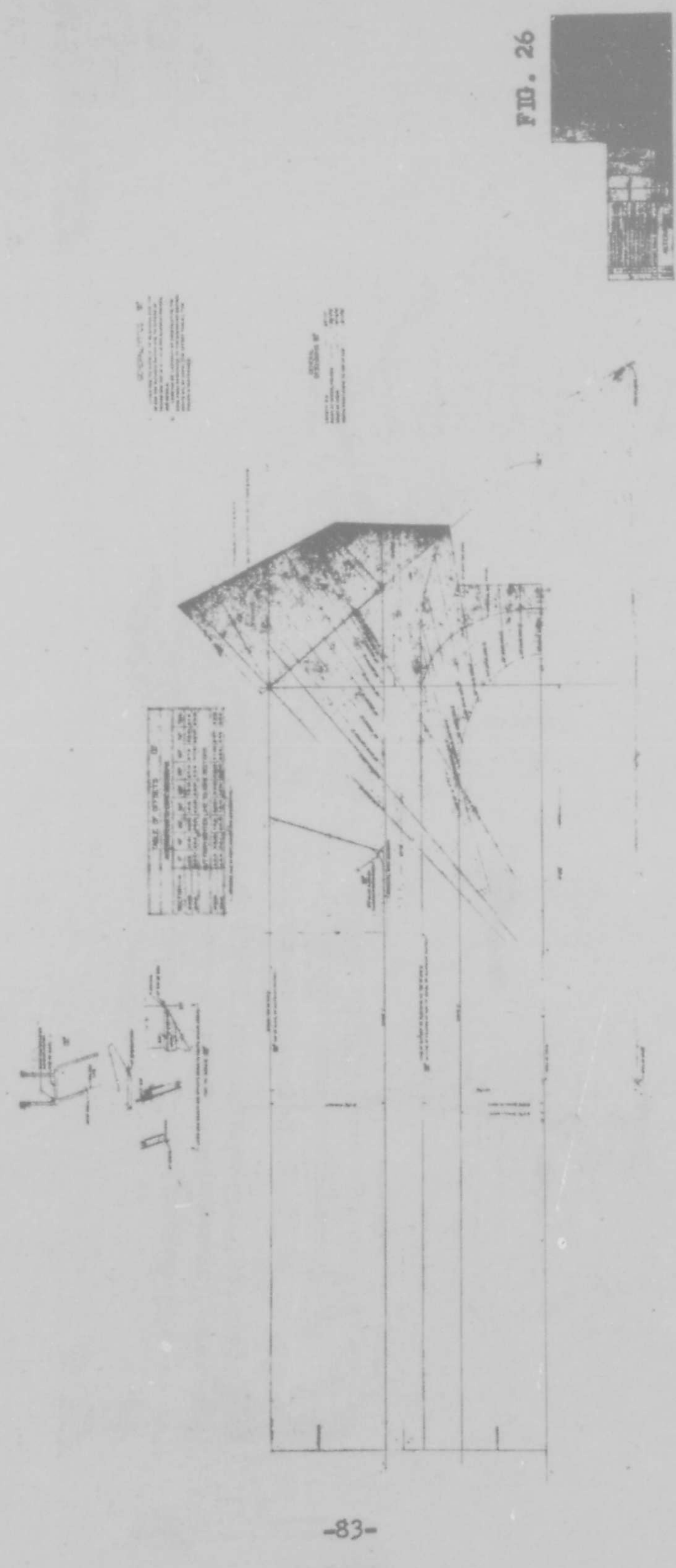


FIG. 26

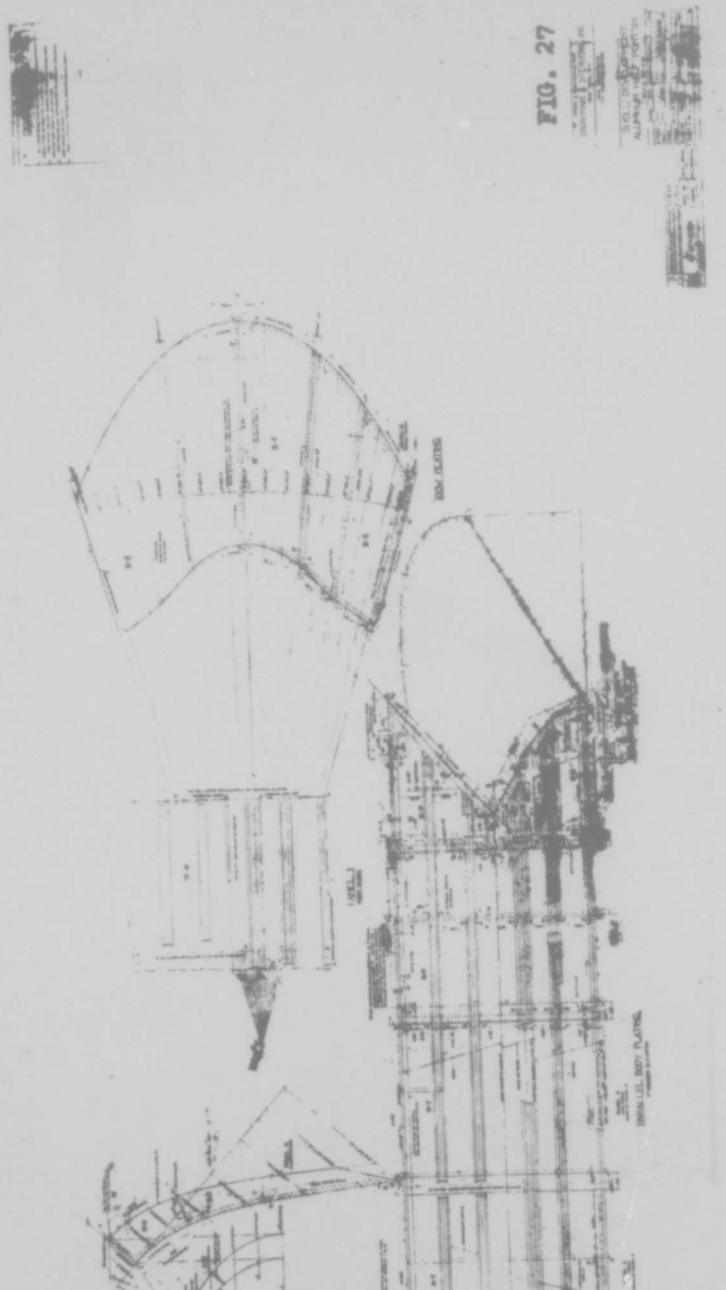
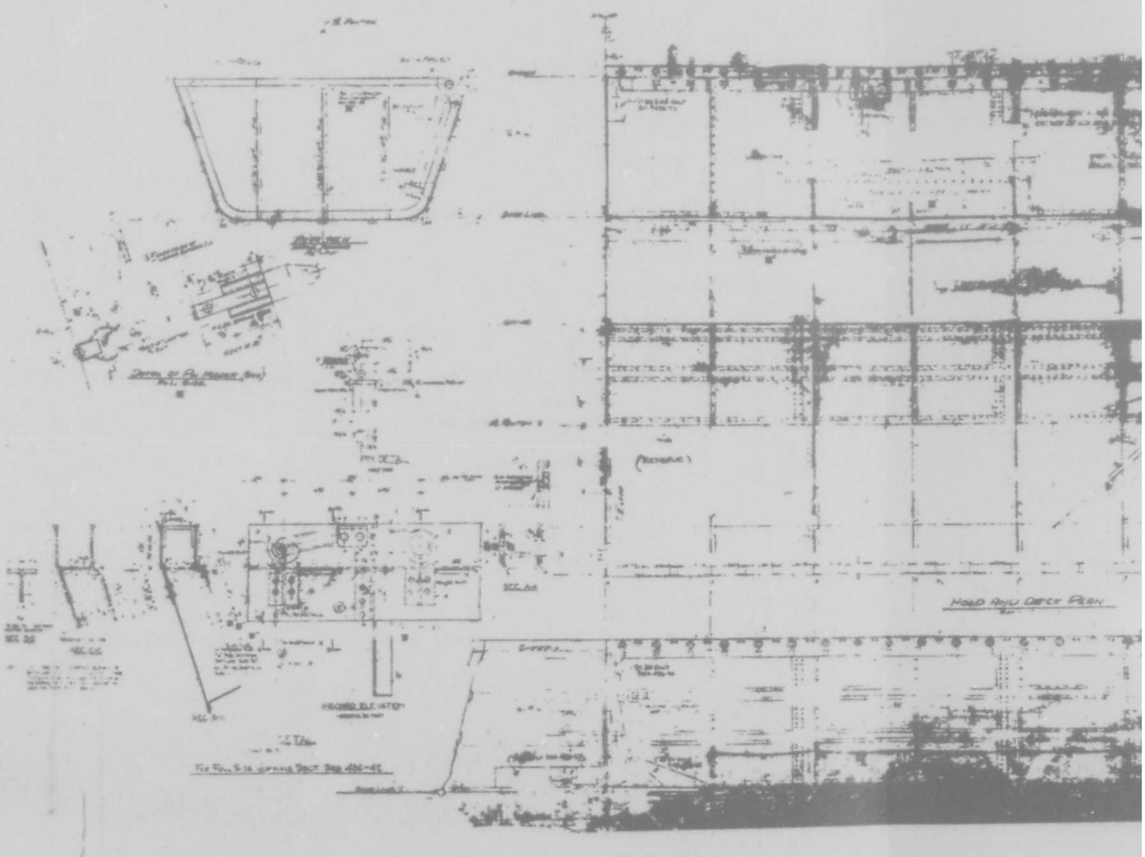


FIG. 27


HOLD AND DECK PLAN

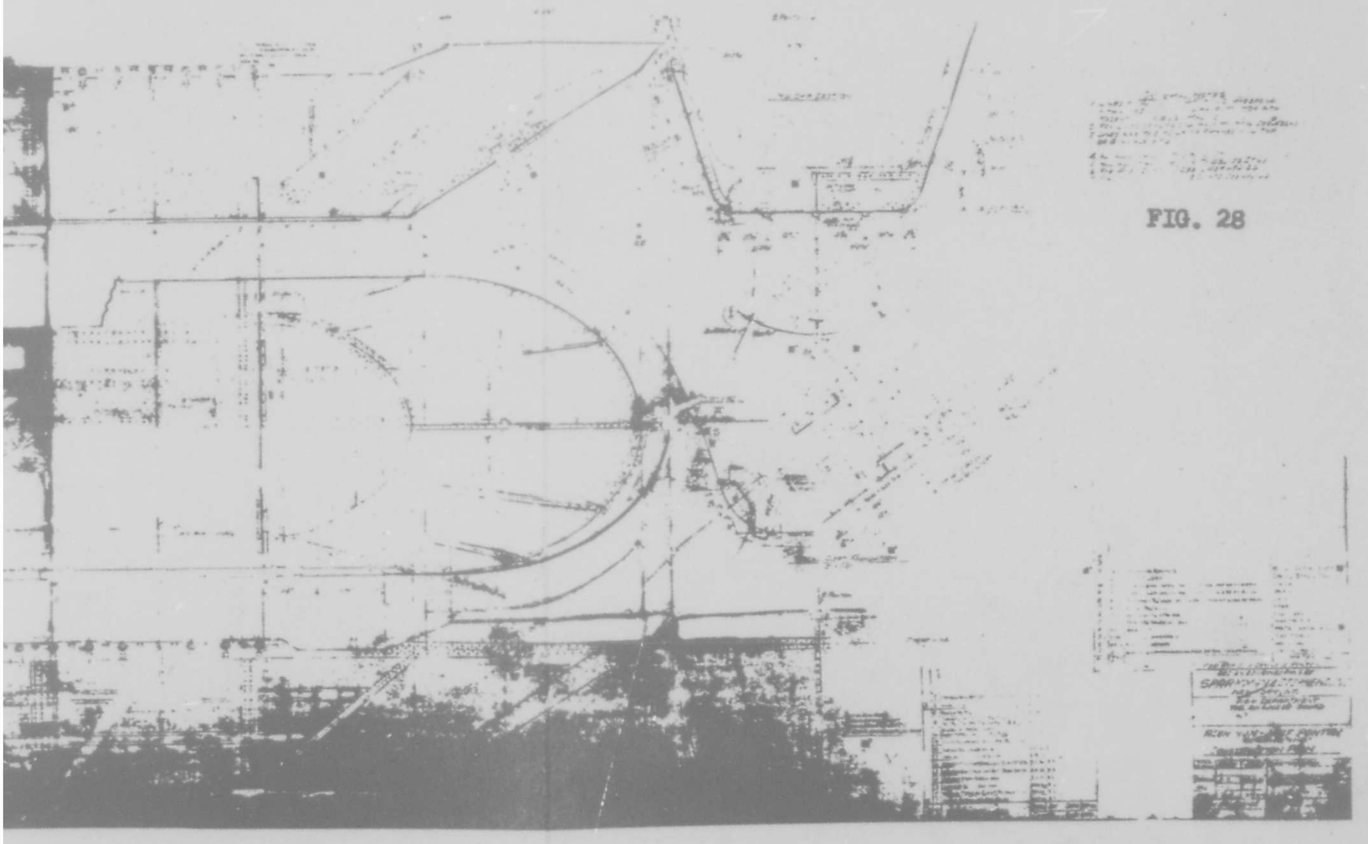
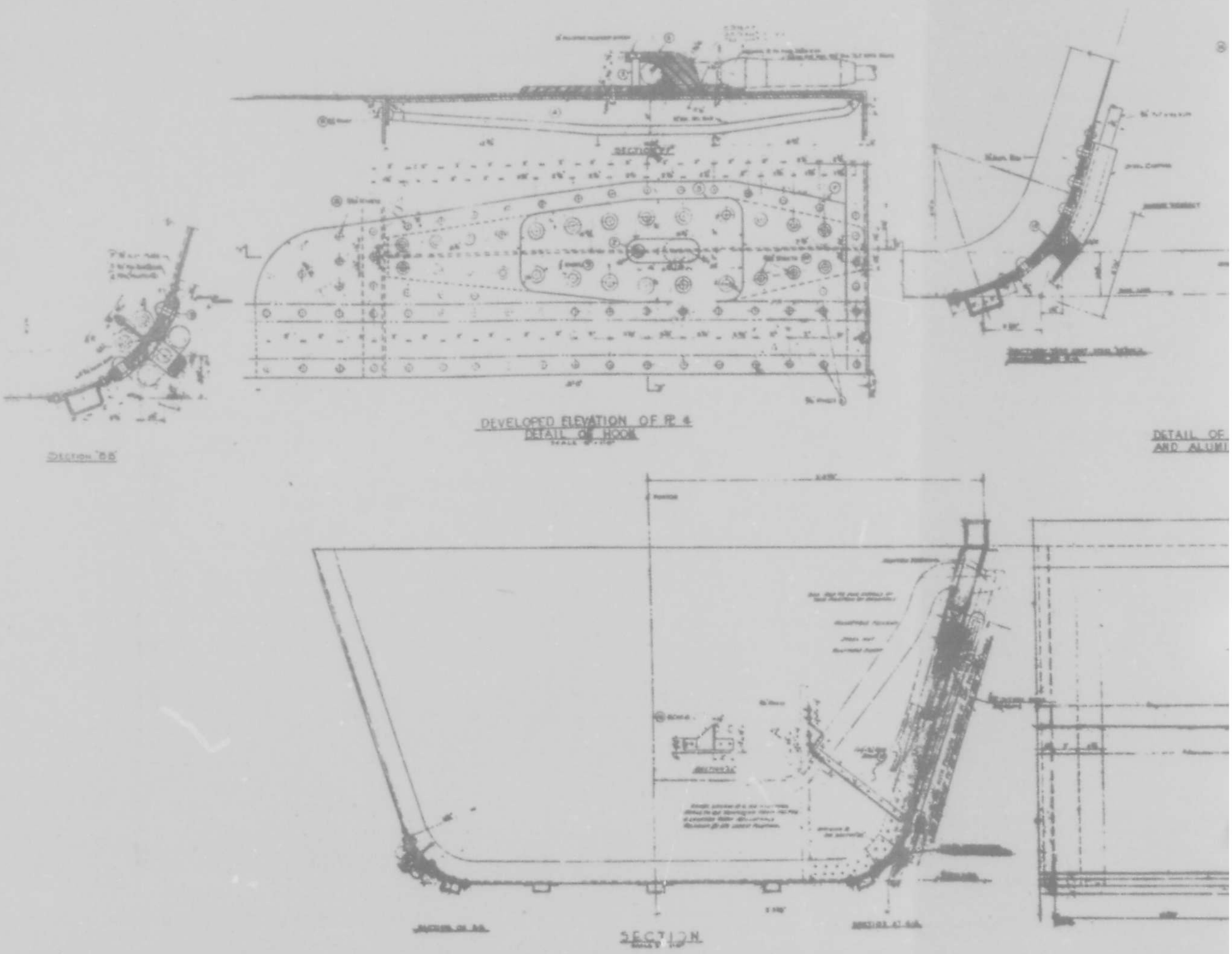


FIG. 28

2


SECTION "BB"
DEVELOPED ELEVATION OF PL 4
DETAIL OF HOOK
DETAIL OF
AND ALUMI
SECTION

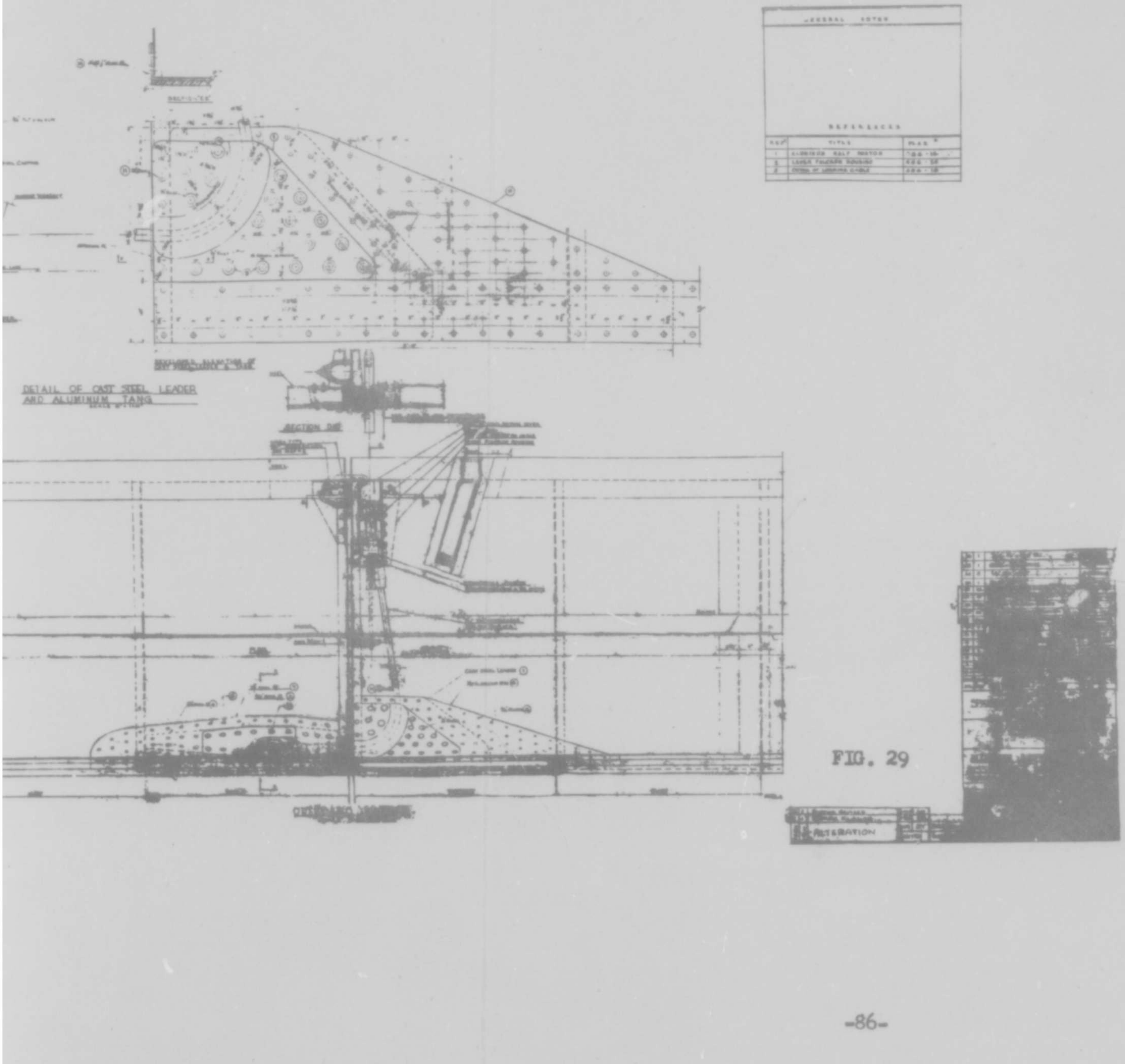

GENERAL NOTES
REFERENCES
DETAIL OF CAST STEEL LEADER
AND ALUMINUM TANG
SECTION
ALTERATION

FIG. 29

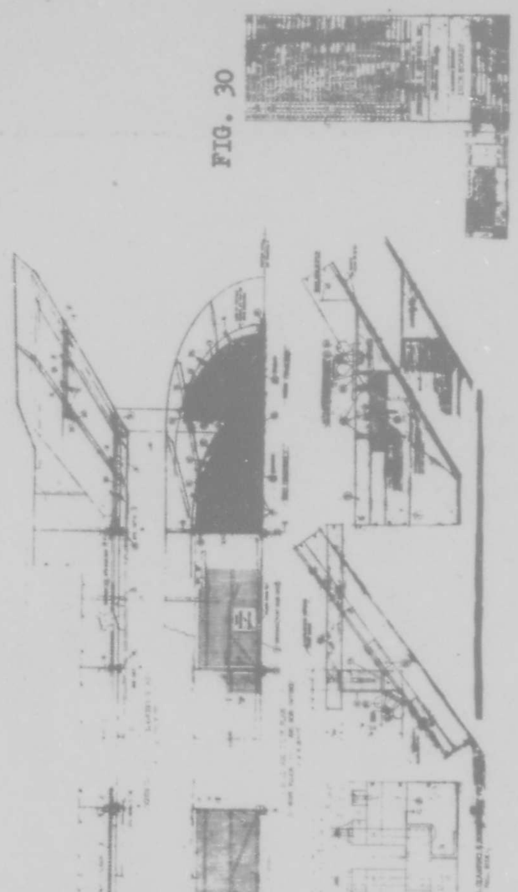


FIG. 30

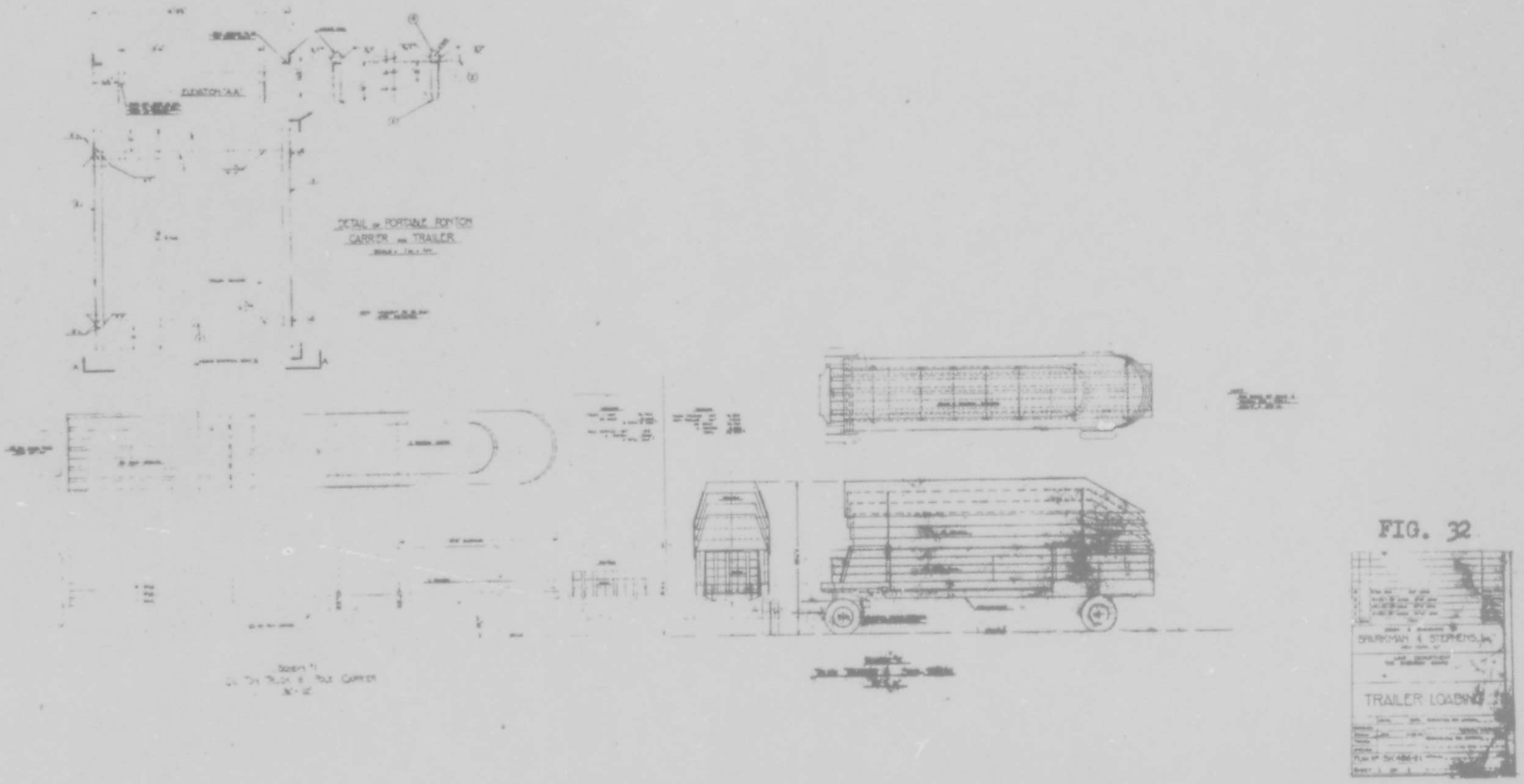

ELEVATION "AA"
DETAIL OF PORTABLE PONTON
CARRIER AND TRAILER
TRAILER LOADING

FIG. 32

GENERAL COMMENTS ON PONTONS

Prepared by Carl Clement, Major, C. E.

Part I

1. <u>General Description</u>. A ponton is a boat used for the support of a deck structure on which various loads may be floated across water. A ponton is not generally used by itself, but is only one of a series of piers or supports under a deck designed to distribute a load to each of the piers. In military use, the primary function of a ponton is as a bridge pier to provide a support to the superstructure or deck by the displacement of water. Since the ponton is required to float, and since it may be required to have varying displacements, its shape is necessarily concerned both with the rate of displacement, which allows it to give a varying degree of support to the superstructure, and with the flow of water around it. In addition to the basic function of acting as a bridge pier, the ponton may be used in varying operations where it forms a part of the floating support of the raft. It may also be used as an individual boat for the transportation of personnel and light loads. The construction of a ponton is necessarily affected by the type of deck which is to be used in conjunction with it, and by the loads implied from the deck into the ponton.

In general, three types of construction are used in pontons. These types are as follows:

<u>a</u>. An open or channel shaped boat of rigid construction.

<u>b</u>. Deck box construction of rigid type.

<u>c</u>. Pneumatic construction, or non-rigid type.

Each type of ponton has certain definite advantages over the other, and may be used only in conjunction with the type of bridge structure for which it was designed. In the past in ponton design, it has generally been accepted that the ponton would form a part of the bridge structure and would transmit loads from one beam to another through the boat. However, the more modern conception is that the boat should be a floating support only, and that the loads implied by the superstructure will be absorbed totally in the superstructure or in adapters between the boat and the superstructure. This last general plan of design makes it possible to utilize one design of ponton under any type of superstructure. Each of the two major factors in the shape of the ponton and the structural design of the ponton are discussed in the sections below.

2. <u>Shape of the Ponton</u>. As described briefly above, there are several factors governing the shape of a ponton. More explicitly, these factors may be listed as follows:

a. The amount of draft increase required for a given pier effect as a moving load passes over the bridge.

b. Speed of the water flowing past the bridge.

c. The width of the ponton is limited by the length of the unit bridge beam.

d. The width of the ponton may be limited by transportation requirements.

e. Weight of the ponton affects the desired final displacement.

f. Dead weight of the bridge deck affects the amount of final displacement.

g. Length of the ponton is most frequently governed by the transportation requirements.

h. Attachment of the bridge deck to the ponton requires that the top of the sides be horizontal and parallel to the center line of the ponton, at least the width of the bridge deck.

i. In the case of pneumatic floats, the shape of the float is limited to combinations of cylinders because of construction difficulties.

Of the factors listed above, no one in particular can be designated as more important than any of the others. All must be blended with each other to provide for the maximum efficiency of the finished ponton. Each of the factors is discussed in detail below.

3. Draft. In the design of any ponton, one of the first items to consider is the draft. Because the boat itself has weight and the bridge deck over the boat has an initial dead weight, the initial displacement of the boat can be estimated. Thus, the equipment draft of a proposed design can also be estimated. Above the initial draft, the boat must have a useable draft which will be governed primarily by the flexibility of the bridge deck. As a load, such as a vehicle, moves across a floating bridge, the deck bends, forming a low point approximately under the vehicle and causing each boat in turn to settle into the water until it provides its maximum pier effect or support to the bridge deck. It is obvious that the amount of flexibility of the bridge deck is governed by the elastic limit of the material used for the deck beams and consequently the increase in draft of any boat will be set by the amount of deflection in the beam. Draft above this point will not be useable within the safe limits of the bridge deck. Therefore, for the accurate design of a ponton, the designer must know the maximum amount of deflection in the deck and how many pounds of support is required by the deck when it is deflected its maximum rate. This figure represents the useable displacement of the boat and the amount of increase in draft in which this displacement must

be obtained. Therefore, the area of the water plane which is governed by the length and the width will be fairly well defined. It is also apparent that the actual depth of the boat will be the initial draft plus the useable draft, plus a safe amount of freeboard for the current and wave height anticipated.

4. Speed of Flow. The speed of flow of current past a ponton is of vital importance in the design and the shape of the forward portion of the ponton. The speed of flow may be attained under two conditions: (1) by the flow or current of the river passing a given bridge site, and (2) by the use of a ponton in a raft or ferry, where the raft is propelled by a power boat or similar source through the water. It is normally anticipated that this rate of flow will be at least 7 feet per second for a boat in a bridge and that when used in a raft the rate of flow may be increased to 10 feet per second. The shape of the bow or front of the ponton should be such as to permit the minimum bow wave consistent with the maximum displacement for a given length in order that the boat will be no longer and no heavier than necessary. The shape of the bow wave must be such that the increase in height of the water line as the water flows past the ponton is at a minimum. In other words, when the boat is traveling through the water, the freeboard at the bow and at other critical points back of the bow shall remain as nearly as possible equal to the static freeboard when the boat is in still water. This requirement of shape is analogous to that of any ship where it is desired to utilize a minimum of power to drive the ship at some given speed. Therefore, the same laws that govern the design of a ship may also be applied to the design of a ponton bow. It is apparent that the smaller the wave, the less power is being used in the development of the wave, and consequently the pull on an anchor line might be materially reduced, as would be the power required to drive a raft constructed from pontons.

In some instances, the design of the front of a ponton has been square or blunt like a box in order to provide the maximum displacement in the least possible length. This would be a satisfactory form if the water were always still. However, current must be taken into consideration. It can be shown that the angle that a square front makes with the water's surface materially affects the shape of the bow wave and power required to move that plane through the water. As described in a report by the Vicksburg Model Basin, it is apparent that if a plane makes an angle of 30 degrees with the water's surface, the bow wave will be considerably smaller than if the plane were at 90 degrees to the water's surface. The relation of the angle of the plane to the height of the wave formed when the current velocity is 7.32 feet per second is shown in Figure 33. The use of a flat plane on the front of a ponton would affect somewhat the difficulties of construction of a boat as compared to a pointed or rounded shape, the flat plane being the easiest form of construction.

Further model studies at Vicksburg and at Stevens Institute of Technology have shown that if the shape of the boat in plan view of the waterline section is rounded, as well as the front being sloped, a still further improvement in the shape of the bow wave can be made. From these studies it appears that the maximum or extreme deviation from the square box which is practical is a bow whose angle to the water is 30 degrees and which in plan view is elliptical, the major axis being twice the width of the boat and the minor axis being equal to the width of the boat. The elliptical shape must be retained from the deck to the bottom in order to obtain the desired result.

The shape of the ponton bow can be further defined by describing the distribution of displacement throughout the length of the boat. If, for instance, the length is divided into an equal number of parts and a line erected perpendicular to the base line at each division point, and this vertical line be defined in length by the area of the cross section below the water line at that point, a curve may be drawn through each of the points thus obtained, which will be known as the "curve of areas." If this curve is rectangular in shape as it would be for a square box, it would indicate that the water meets an abrupt change in flow and consequently a great deal of turbulence would be expected. If, on the other hand, this curve started tangent to the base line, increased to a maximum, and then declined again, it would indicate that the change of the flow of the water is gradual and done in an orderly mathematical way. Consequently, little turbulence would be expected. Years of experimentation by naval architects have proved this to be true. This experience has further indicated that if the shape of the curve of areas approximates a versine curve or a trochoid, the optimum efficiency in the formation of the bow wave and the power required to drive that shape through the water will be had. Based on this information and further model studies to determine the maximum displacement which could be crowded into a given shape and still permit reasonable flow, the elliptical bow on a 30-degree angle appears to be a reasonable answer.

The shape of the boat after the bow section is necessarily restricted to cylindrical shape in which the elements of the cylinder are parallel to the long axis of the boat, so as to provide a constant width at the deck line for attachment of the superstructure, and also to provide maximum of displacement for a given beam length and draft. The shape of the cross section to provide the maximum draft would be rectangular. However, if a nesting boat is selected, the sides must of a necessity have an outward slope to permit the nesting feature, with a consequent loss of displacement and stability.

5. Beam. The beam or width of the boat is controlled by two factors: (1) the length of the unit bridge beam, and (2) the maximum width defined by transportation requirements. The width being governed by the length of a unit bridge beam, it has generally been accepted that the boat would be a small percentage narrower than half the length or one third of the length of a given bridge beam in order that a beam

could be permitted to pass over two boats or three boats. This is illustrated diagrammatically in Figure 34.

6. Length. It is first necessary to satisfy the conditions of displacement in a ponton. It has been shown above that the cross section of a ponton is controlled by the bridge deck in that the useable draft is controlled by the deflection of the deck, while the width of the boat is controlled by the length of the bridge spans. Consequently, to obtain a given displacement, the length is the only factor which may be varied. It may be found that the length so determined will be greater than transportation facilities will readily permit. It is therefore necessary sometimes to divide the ponton into two or more sections. This condition is illustrated in the American 25-ton half-boat type ponton, the British Mark V ponton, which is in three sections, and the German ponton, which is in two sections. The two-sectioned ponton has also been adopted for the design of the ponton for the Division-Army Bridge, and is the type undergoing tests at the present time. Dividing the ponton into length sections makes it possible to utilize one given design boat for a bridge of varying capacity and to utilize one single form of transportation for bridges of varying capacities.

7. Weight of the Ponton. The weight of the ponton is important for two reasons:

a. The weight of the ponton affects the initial draft of the boat, and must be determined with reasonable degree of accuracy before a final design can be completed.

b. It is desirable to have a lightweight ponton so that it may be handled by manpower to and from its transportation at the bridge site. In every case, the weight of the boat must be such as to permit rugged design with sufficient strength to carry the loads imposed upon it with a reasonable degree of safety.

8. Bridge Deck Adapters. As pointed out above, it is necessary to maintain a straight section of ponton immediately below the bridge deck in order to permit design of suitable attachments for connecting the boat to the bridge deck. The most modern and utilitarian conception of attachment of the boat to the deck is to utilize an adapter for each type of deck which might be used on a given ponton, thus permitting that ponton to be used with any bridge deck with the minimum change to the boat.

9. Pneumatic Float Shapes. Because a pneumatic float is constructed of a non-rigid fabric, the shape of the tube or section which is inflated will tend to be a circular in cross section. This tendency must be recognized in the preparation of the design. The cylinder with rounded or dome-shaped ends is a geometrical form which may be satisfactorily used. A torus or dome is another geometrical form which may be effectively used. The above paragraphs have

shown that a ponton must of necessity have length in order to provide the displacement required by the bridge deck. Consequently, a pneumatic float must be of the same general design involving length. The cylinder then becomes the ideal geometrical form for a unit cell shape. The draft of a float has also been discussed and it has been shown that a useable draft of a given amount must be considered. Therefore, the diameter of a cylindrical tube becomes fairly well defined. In order to obtain the necessary displacement then, a series of tubes side by side and having a diameter consistent with the draft requirements of the bridge deck mark the first step in the design of a pneumatic float. The length will be defined by the amount of lateral stability of the finished bridge and the required total displacement of the individual float. The ends of the float will of necessity be of circular shape in planned view. As most floats consist of two or more tubes, it is desirable to use half a torus to connect the two outside cylindrical tubes. Experience has shown in most instances that three cylindrical tubes are sufficient and make a satisfactory designed float with sufficient stability within itself to be used as an individual boat. The relation of draft and beam work out most satisfactorily with three cylinders across the width of the boat. Little opportunity is afforded for radical design shapes of the bow of the pneumatic float. However, the torus or rounded section at the end of the float proves quite effective. Experimentation has shown that by setting the torus at an angle at the water plane, varying degrees of effect can be exerted upon the water flow. In general, an angle of 15 to 20 degrees has been found satisfactory.

10. Stability of an Individual Ponton. A ponton is sometimes used as an individual boat. In this condition it must be sufficiently stable longitudinally and transversely to be safe for operation by semi-experienced personnel. If a group of men in the boat should suddenly move from one side to the other, the boat should be stable enough to prevent its taking water over the gunwale or totally capsizing. Stability of an individual boat will be governed largely by the width of the boat at the top or gunwale. It will be controlled further by the shape of the cross section. Stability of an individual boat is generally measured by the length of the righting arm in feet. It may also be spoken of in terms of foot pounds of righting moment, which would be obtained by multiplying the displacement in pounds by the length of the righting arm in feet. Figures 48 and 49 show the relationship of the center of gravity to the center of buoyancy and method of determining the length of the righting arm.

When the boat has a quantity of water in it, it becomes less stable unless that water is definitely controlled. Controlled water may increase the stability of a given boat.

The ponton designed for use with the Division Army Bridge has a cross-sectional form which is of lower stability than the 10-ton or 25-ton ponton. Figure 46 gives a detailed comparison of the stability of each of the three boats when they are empty or dry.

Figure 47 gives a comparison of the boats when 6 inches of water are present in the bottom of each boat. The Division Army Bridge Ponton is of low stability in each case. Its stability with 6 inches of water present is almost negligible. However, if the water in the bottom is controlled by a single longitudinal bulk head, as shown in Figure 50, the stability is greatly improved and is greater than either the 10-ton or 25-ton ponton. This addition to the Sparkman and Stephensdesigns is a marked improvement. A report of an actual test conducted at the yard of the builder (Henry B. Nevins, Inc.), which is contained in the succeeding section of this appendix, shows the improvement in stability resulting from installation of a center line or longitudinal bulkhead.

The two boats constructed at the Engineer Board shops have center line bulkheads forming a tight inner floor, as shown diagrammatically in Figure 51. This is a step further toward free water control and improved stability. When water is present, the action of the floor is to restrain movement of the free water and to make the water work as useful ballast.

Part II

11. Plywood Ponton for Division-Army Bridge. Sparkman and Stephens, Incorporated, naval architects and designers, were commissioned to develop a design of a ponton for the Division-Army Bridge as a part of a contract to submit a complete design for the bridge.

In general, planning the development of this ponton was to be in two forms:

a. A plywood ponton which could be constructed quickly in sufficient quantity to permit test, and

b. An aluminum ponton to be considered as a final design advantage of minimum weight consistent with maximum strength and desired ruggedness, and it would be considered as the production model boat.

The approximate dimensions of the ponton were developed by Sparkman and Stephens in conjunction with the development of the bridge deck system of their design. Consequently, the rate of displacement, the maximum beam of the boat, and the draft of the boat were controlled by a single bridge deck design. The cross section of the boat was materially defined by a nesting feature which required that the boats be nested to within at least 12 inches and less if possible. The shape of the bow of the ponton resulted from initial tests at Vicksburg Experimental Station, plus a more detailed model study conducted at Stevens Institute of Technology. The general shape of the ponton is shown in Figures 36 to 40. It will be noted that the elliptical bow was utilized and that the rake angle of the bow is approximately 30 degrees, as described in paragraph 4 of Part I.

Since the design of the ponton for use with the wide variation of loads required by the bridge made it necessary to utilize a boat capable of being extended in length to at least twice the basic length, the half-boat plan was adopted. For the connector system between the boats, the contractor was asked to investigate various methods of connection in addition to the pin type connector previously investigated by the Engineer Board on the 25-ton steel half-ponton and the M-2 Assault Boat. In the development of the connector, the most promising design appeared to be a cable arrangement attached to one half-ponton with the slack taken up in the other by a lever system and screw. The cable connector had the advantage over the pin connector in that the half-pontons did not have to be directly against each other before the action could be completed. The cable connector provided a mechanical means of drawing the two half-pontons into final position. The decision was made after investigating several types of connectors to install a cable connector on the first test half-pontons built.

Twenty-six plywood pontons were contracted for with Henry B. Nevins, Inc., to be used in the initial tests of the bridge. Upon completion of the first four half-pontons, a test was conducted to determine the effectiveness of the connector system, the general strength of the pontons, the general form of the bow wave, and such other pertinent details as might be discovered in the conduct of the basic tests. These tests were conducted at City Island, New York, on the 28th February 1944. A report of the tests is inclosed. The general conclusions of the report were that the connector system was not quite strong enough and that certain modifications would have to be made before the pontons could be considered satisfactory for continued test in the bridge. This modification was made, and the pontons were delivered to the Yuma Test Branch for further test.

12. Aluminum Ponton. During construction of the plywood pontons, the construction plan for the final aluminum pontons was completed in sufficient detail to permit assigning of the contract to Lord and Burnham, Incorporated, of Irvington, New York, for the construction of four aluminum pontons. These were essentially the same shape as the plywood pontons with the exception that the radius at the chine was six inches where on the plywood pontons the radius was approximately 1½ inches. The design for the aluminum pontons has been modified from time to time as a result of the tests conducted on the plywood pontons and as a result of difficulties of forming the material into the desired shapes.

13. Engineer Board Design of Plywood Ponton. At the same time, the design of the aluminum ponton and construction of the initial plywood pontons was being accomplished, a third structural design was carried on at the Engineer Board in the form of a plywood ponton having the same shape as the other two pontons but differing in

structure alone. The plywood ponton constructed by the Engineer Board is designed to permit a minimum of weight in plywood construction and to represent a completed design which can be utilized in the event of shortages of lightweight materials such as aluminum for the construction. Several attached photographs show the general construction plan of the ponton designed by the Engineer Board and constructed in the Engineer Board shops. It will be noted that elimination of weight has been accomplished through lightening holes and the reduction of sections to the minimum size consistent with ruggedness.

14. Tests. Upon arrival of the first pontons at the Yuma Test Branch, several tests were conducted to check design figures. The first test conducted was to check the displacement curve for the new ponton against the calculated curve for displacement. In this test it was found that the half-ponton checked very closely with the designed displacement up to a draft of 29 inches. However, when two half-pontons were connected together it was found that the displacement at a given draft measured at the center of the ponton was greater than the calculated amount. This discrepancy can be accounted for in two ways:

a. The draft of the ponton was apparently measured at the center or connector.

b. No freeboard or draft was measured at the ends of the ponton. As the load is applied, a certain amount of slack or articulation is taken up in the cable, permitting the ponton to bend in the middle. Consequently, the draft at this point is greater than it should be for the actual displacement of the ponton. It will be necessary to make corrections for the trim of each half-ponton in order to utilize the calculated displacement curve at a given draft. This particular feature of articulation in the connection is peculiar to the cable type joint, as there is an initial amount of slack which can be taken up, and the tautness of the cable is dependent entirely upon the judgment of the personnel connecting the half-pontons. However, in the pin connecting system the articulation is limited by the clearance of the pin in the holes and would remain constant for any given pair of half-pontons over any load range.

In general, it has been found that the cable connector is sufficiently strong and sufficiently well attached to the ponton to provide an adequate connecting system for any load which may be imposed by a bridge deck. However, it is known that the cable connector is not sufficiently strong to withstand the bending moment of a concentrated load directly over the transom of a ponton and the ponton is sunk by such concentrated load to the gunwale.

A second type hinge connector has been designed and is being installed on the plywood pontons being constructed at the Engineer Board shops.

A third type connecting system operating with a tension bolt at approximately the chine location will be installed on four half-pontons constructed by Henry B. Nevins, Inc. Completion of tests with the three types of connectors will provide additional information to that now available and should make it possible to select a very satisfactory type connector system.

Part III

15. Outboard Motor Brackets. In testing rafts for the Division Army Bridge, it is considered desirable to include a number of outboard motor tests to determine the propulsion characteristics of these motors and to determine the most satisfactory means of mounting outboard motors on the ponton. An adjustable bracket was designed for the Johnson Model POLR 22-hp full-reversing motor, which is the present standard motor issued with the 10-ton, 25-ton, and Infantry Support Raft equipment. This bracket was designed particularly for use on the curved or elliptical end of the ponton. Because of the 20-inch adjustment necessary for proper functioning of the motor, the bracket is necessarily heavy and bulky. No actual tests have been conducted with the outboard motor bracket for the Johnson POLR motor.

A second type bracket was designed for use with the Johnson type POK motor to mount the motor on either the square transom of the boat or the side of the boat between the gunwale adapter and the bow combing. No tests have been made with this bracket. A third bracket of similar appearance to the bracket for the POK motor was designed and constructed for mounting of the modified storm boat motor on the side of the ponton. This bracket was fabricated in both right and left hand forms so that two motors may be attached to one ponton. A fourth type bracket was designed in both right and left hand forms for mounting the Evinrude Light-4 outboard motor which is 17 inches longer than standard shape. Four Evinrude Light-4 outboard motors were purchased for test with rafting equipment for the Division-Army Bridge. Figures 62, 63, and 64 show in diagrammatical form several proposed methods of propulsion using outboard motors for rafts of the Division-Army Bridge.

16. Power Required for Various Rafts. In making power applications to the proposed new Division and Army rafts, several tests were conducted on various sizes of rafts (Figure 60) at various displacements in the Stevens Institute of Technology towing pan to determine the various horsepowers required to drive the rafts at various speeds. The results of these tests are shown in Figures 58 and 59. As a means of comparison, the 5-ponton 25-ton raft was towed with the 25-foot Twin-Screw Utility Power Boat, and the effective horsepower required to pull the raft was determined at various speeds. It was noted that the new ponton requires considerably less power at speeds of four to six miles per hour than does the older 25-ton raft. These figures are still to be borne out by actual test of the Division-Army raft equipment. However, the model tests indicate that speeds obtained with standard marine propulsion equipment such as the 22-hp outboard motor and the standard Utility Power Boat will be higher than have been experienced with the 25-ton ponton equipment, and will probably be better than those experienced with the 10-ton equipment.

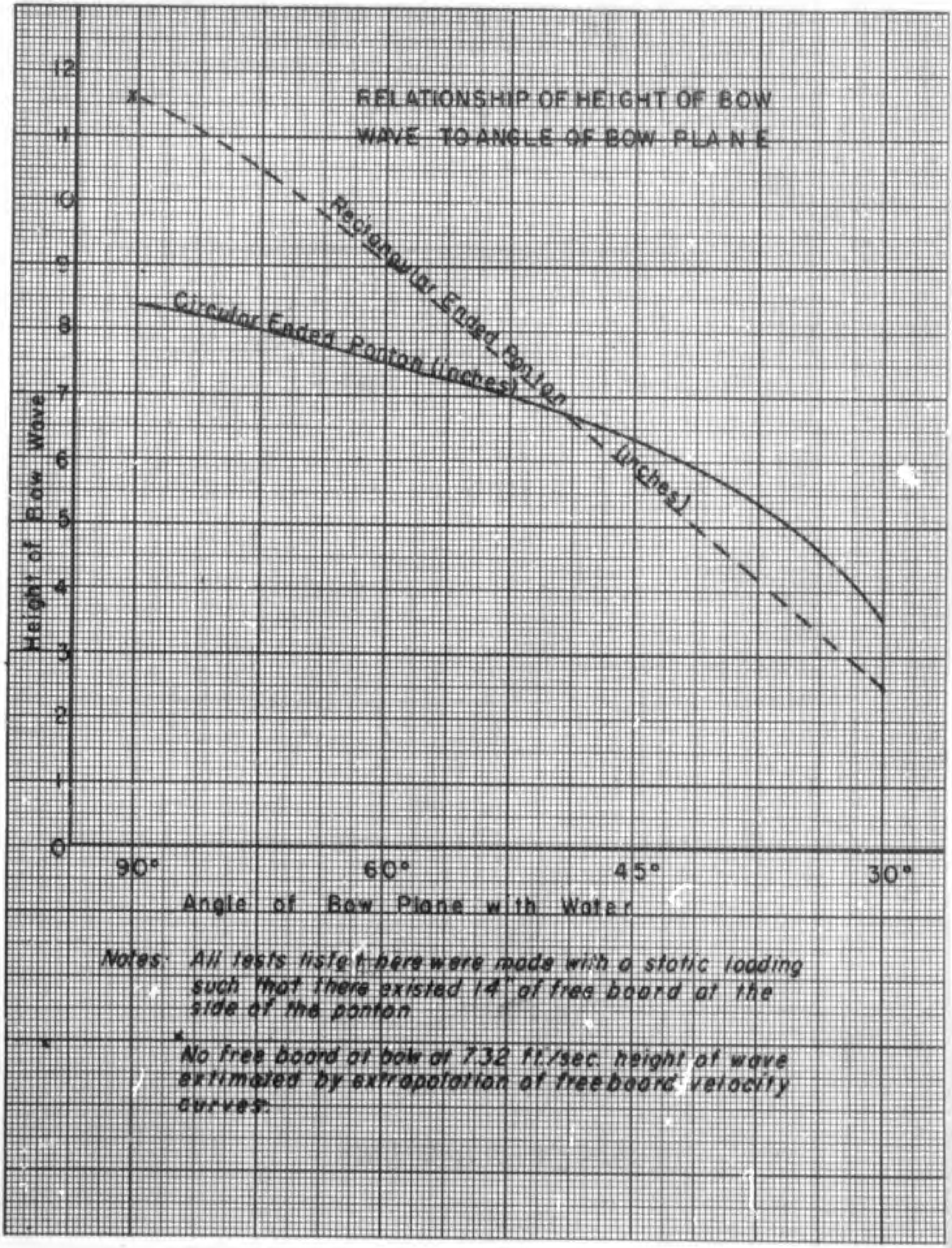
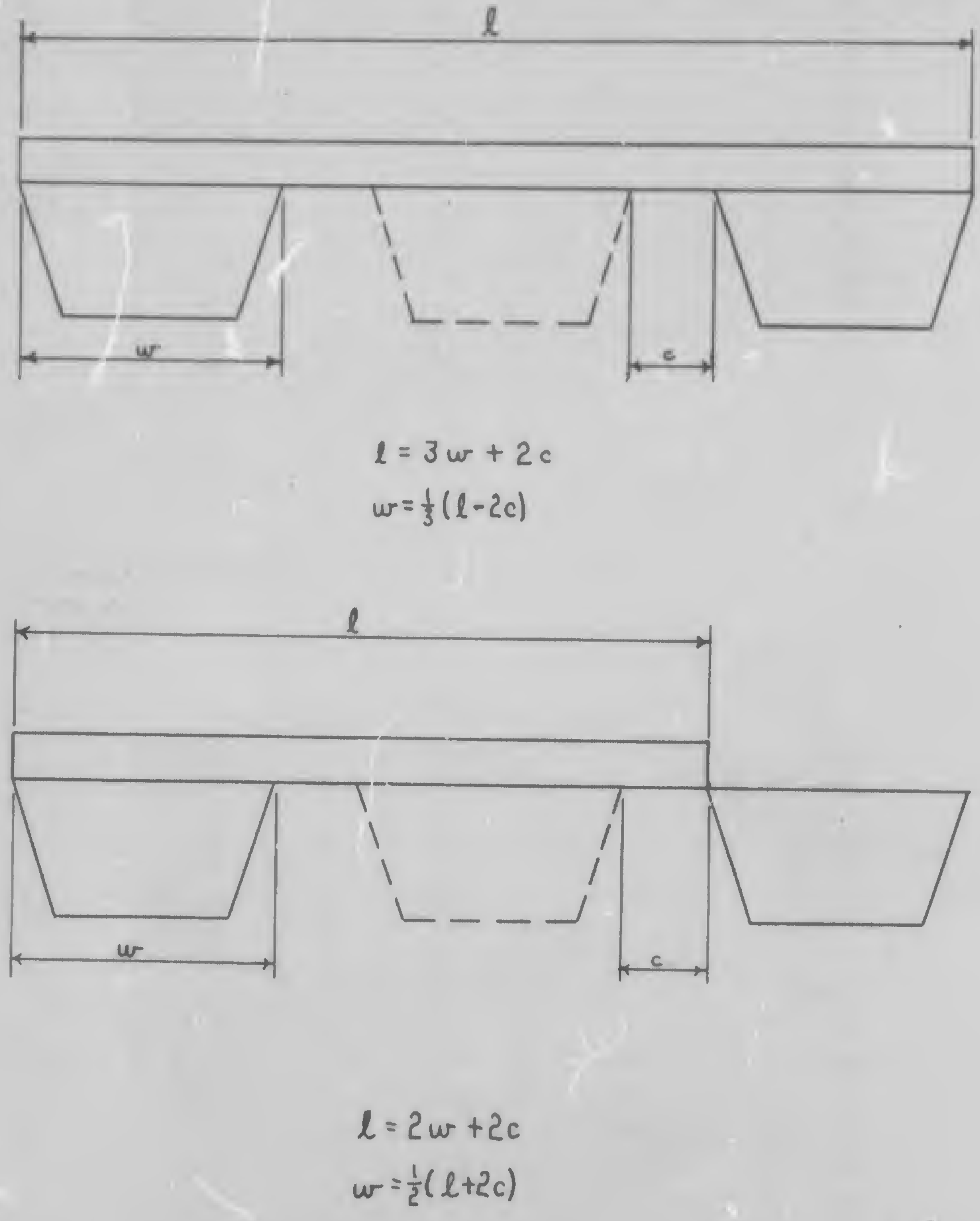

RELATIONSHIP OF HEIGHT OF BOW
WAVE TO ANGLE OF BOW PLANE
Rectangular Ended Ponton (inches)
Circular Ended Ponton (inches)
Height of Bow Wave
0
1
2
3
4
5
6
7
8
9
10
11
12
90°
60°
45°
30°
Angle of Bow Plane with Water
Notes: All tests listed here were made with a static loading such that there existed 14" of free board at the side of the ponton
* No free board at bow at 7.32 ft./sec. height of wave estimated by extrapolation of free board velocity curves.

FIG. 33



ARRANGEMENT
OF
BEAMS OVER PONTONS

FIG. 34

FIG. 35. FRAMING OF PLYWOOD PONTON. General view of the framing of a plywood ponton before installation of fan type framing in the bow.

FIG. 36. BOW FRAME. Another view of bow framing.

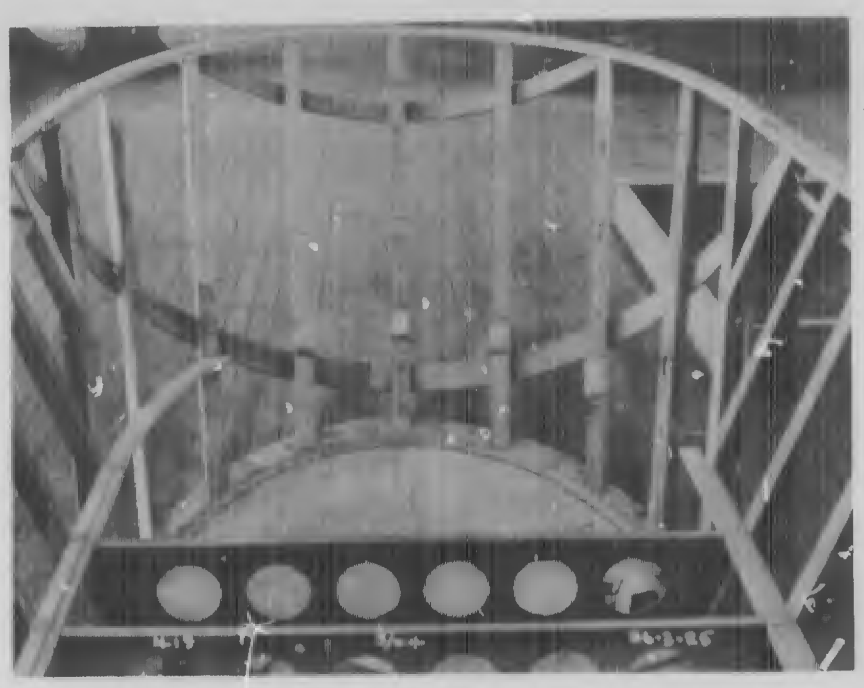


FIG. 37. LOCATION OF BUTT STRAPS. Fan type framing in the bow with butt straps in place for attachment of plywood skin.

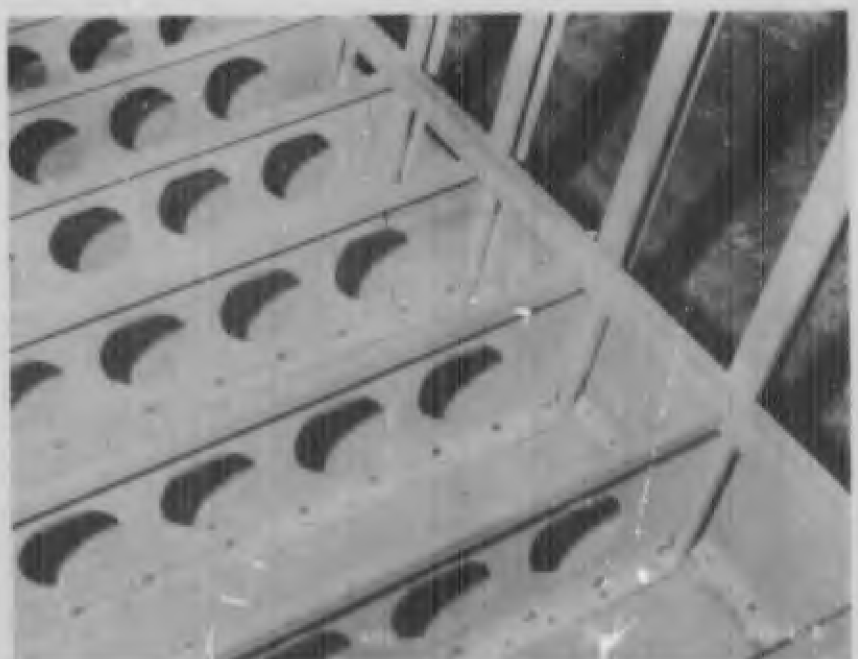


FIG. 38. FRAMING AT CENTER OF PONTON. Close-up view of framing and center portion of ponton showing the heavy floor beam and rigid attachment of the T-shaped side frame to the floor. Note that plywood angles are used for attachment of the frame to the skin to save weight. Fastenings or rivets and all joints are glued for additional strength.

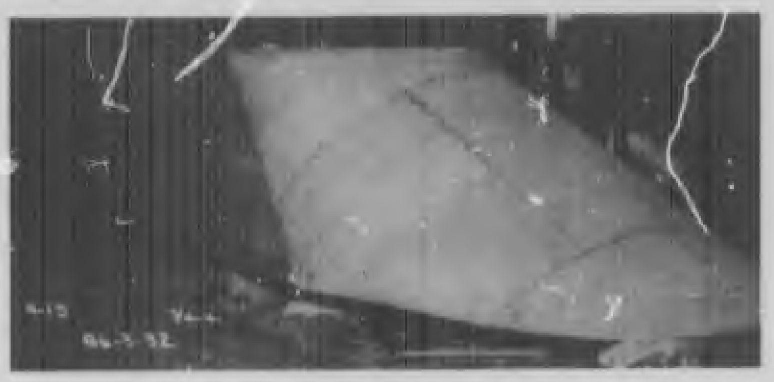


FIG. 39. GENERAL VIEW OF BOW. The bow section of a plywood ponton being constructed in the Engineer Board shops. Note that all joints are of riveted construction.

FIG. 40. GENERAL VIEW OF STERN. The stern of a plywood ponton constructed in the Engineer Board shops. This view shows how the chine skid is utilized as a strength member in formation of the joint between side and bottom.

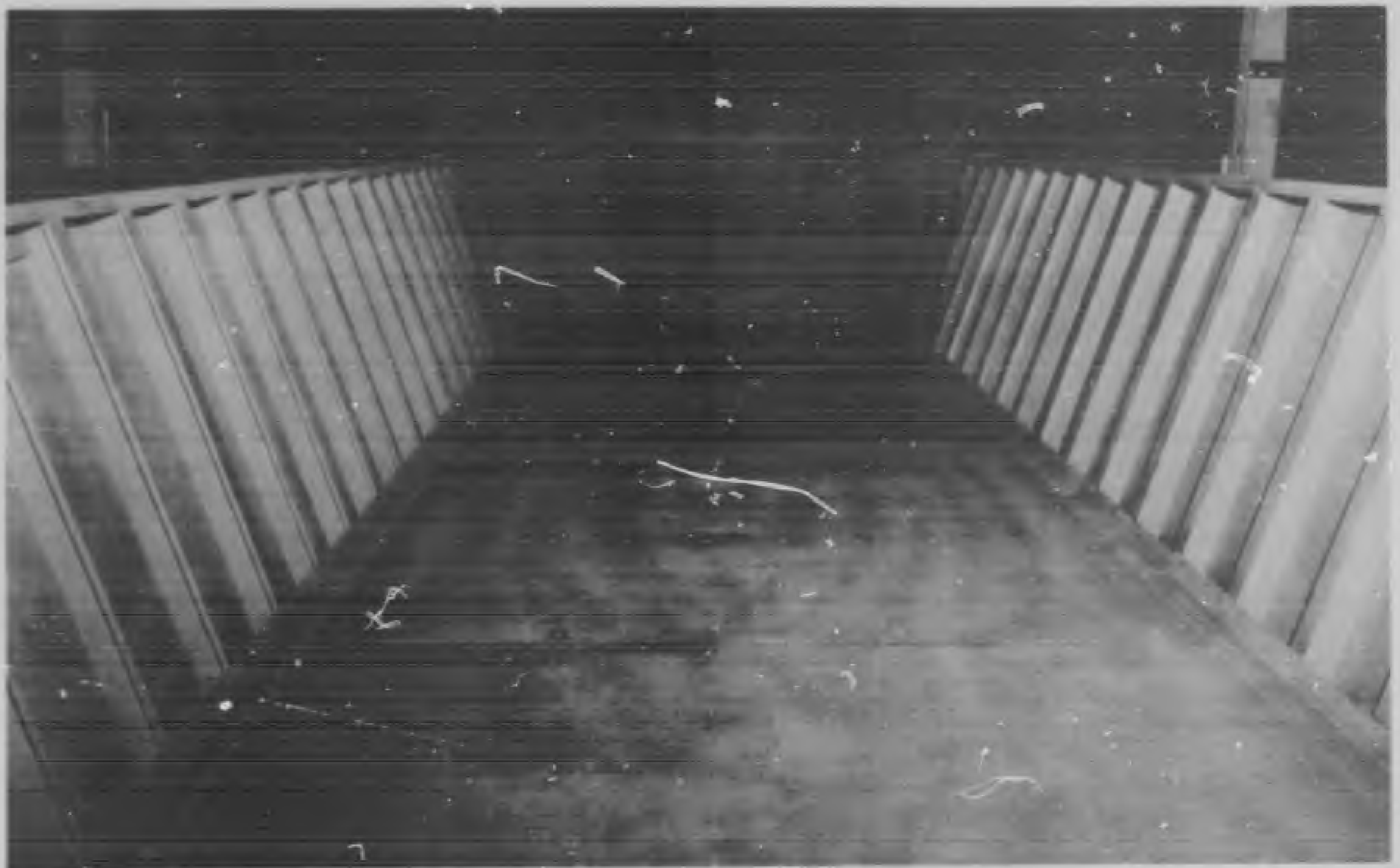


FIG. 41. INTERIOR VIEW OF PLYWOOD PONTON SHOWING FLOORING. Interior of a plywood ponton fabricated in the Engineer Board shops. Note the floor, which is watertight except at the sides. This feature adds greatly to the control of free water and the stability of the ponton when water is present inside.

FIG. 42. ALUMINUM FOLDING HANDLE IN FOLDED POSITION. Nine handles are located on each side of the ponton. Respacing after preliminary test may permit 10 handles, which will be sufficient to carry either the aluminum ponton or the plywood ponton fabricated in the Engineer Board shops.

FIG. 43. ALUMINUM FOLDING HANDLE IN CARRYING POSITION. This handle supersedes the original rope handle which was found unsatisfactory in the preliminary test.

FIG. 44. DETAIL VIEW OF HINGE. View shows the lower hinge connection on the plywood ponton fabricated in the Engineer Board shops. The hinge is of welded construction bolted to the ponton by means of a large tang plate.

Ponton Characteristics

CHARACTERISTIC	1 Sparkman & Stephens Plywood Ponton	2 10 Ton Aluminum Model 1938 Ponton D1660-1	3 10 Ton Ponton M II D2256-1	4 10 Ton Ponton M II Half Boat Type D2416-1	5 25 Ton Ponton Alum Model 1940 D1726-1	6 25 Ton M II Steel D2257-1	7 25 Ton Steel Half Boat Type D2417-1	8 25 Ton Aluminum Half Boat Type D4323-1
LENGTH	27' 11"	28' 0"	27' 5"	27' 5"	32' 9"	33' 0"	34' 5/8"	34' 5/8"
BEAM AT DECK	6' 7 5/8"	5' 6 3/4"	5' 6 1/2"	5' 6 1/2"	6' 6 3/4	6' 7"	6' 11 1/2"	6' 11 1/2"
BEAM AT BOTTOM	4' 6"	5' 3 3/4"	5' 6 1/2"	5' 6 1/2"	6' 5"	5' 7"	6' 11 1/2"	6' 11 1/2"
DEPTH AMID SHIP	3' 1 5/8"	32"	32"	32"	40"	40"	40"	40"
DEPTH BOW	3' 10 5/8"	36"	36"	36"	45"	45"	50 9/16"	50 3/8"
DISPLACEMENT-LIGHT	1700 #	1600 #			2700 #	4200 #	5100 #	3000 #
" 15" FREE	13600 #	11880 #	11801 #	12771 #	25062 #	25269 #	25444 #	25265 #
" 6" FREE	21000 #	18780 #	18728 #	19792 #	34838 #	35145 #	35227 #	35050 #
BLOCK COEFFICIENT	58.6 %	72 %	71.6 %	77.7 %	77.7 %	77.8 %	71.6 %	71 %
PRISMATIC COEFFICIENT	69.6 %	72 %	71.6 %	77.7 %	77.7 %	77.8 %	71.6 %	71 %
CONSTRUCTION MATERIAL	Plywood	Aluminum	Steel	Steel	Aluminum	Steel	Steel	Aluminum
STABILITY (TRANSVERSE)	Poor	Fair	Fair	Fair	Good	Good	Good	Good
" " 6" Free Water Inside	Longitudinal Bulkhead Good	Poor - Fair	Poor - Fair	Poor - Fair	Fair	Fair	Fair	Fair
REMARKS	Very Good Bow Form for Speeds of	Reasonable Bow Form for Speeds	Same as No. 2	Same as No. 2	Same as No. 2	Same as No. 2	Moderately Good Bow form for	Same as No. 7
	5-8'/Sec. Displacement and Stability can	up to 4'/Sec. Poor Form at					Speeds up to 7'/Sec.	
	be increased by widening bottom	higher Speeds.						
	without effect on Wave form.							

Note:- Block Coefficient = Displacement #/ Length x Beam x Depth x 62.4
Prismatic " = Displacement #/ Area Midship Section x Length x 62.4   All Percentages Shown Above are for 6" Freeboard

FIG. 45

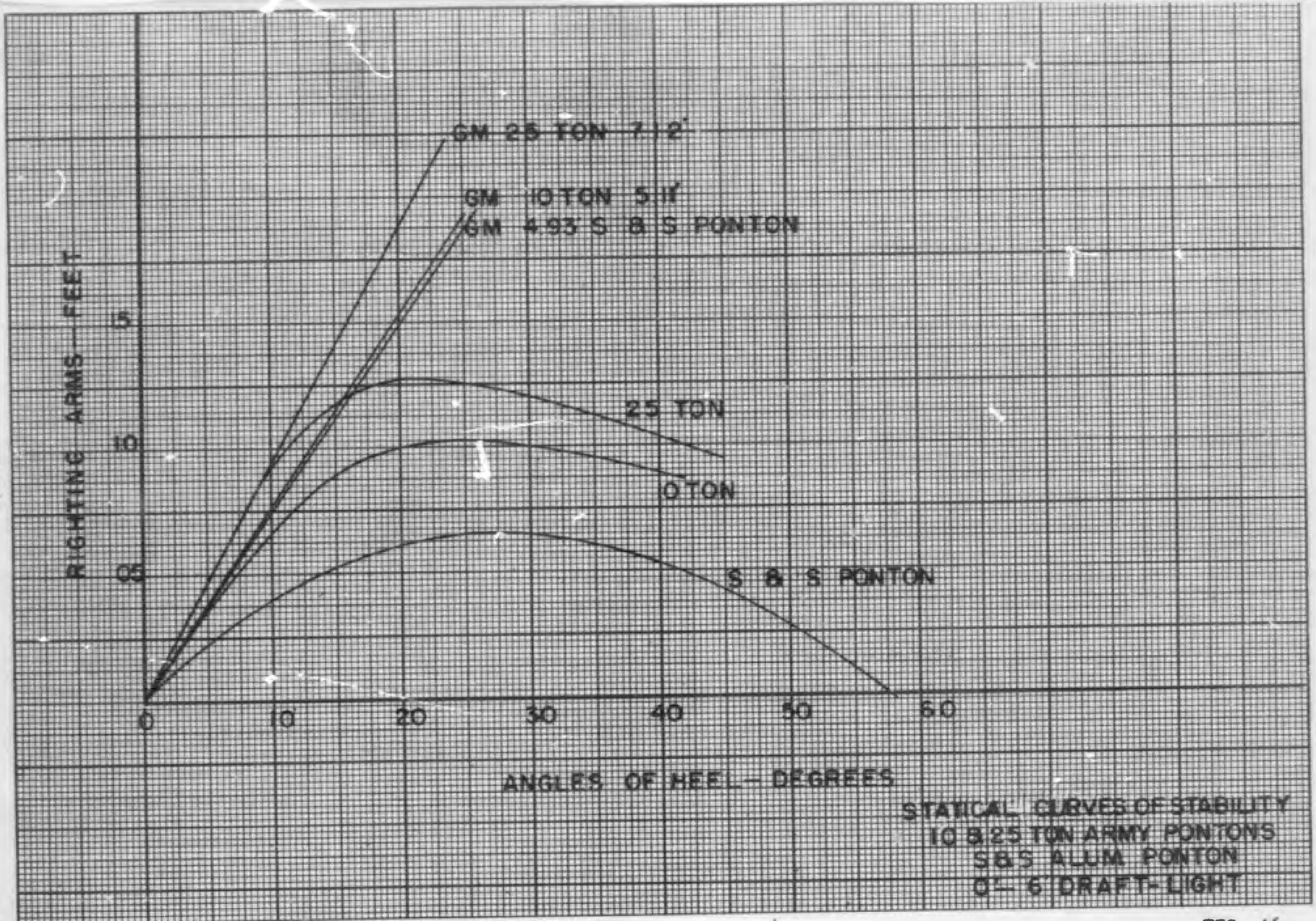

GM 25 TON 7.12'
GM 10 TON 5.11'
GM 4.93 S & S PONTON
25 TON
10 TON
S & S PONTON
RIGHTING ARMS — FEET
1.5
1.0
0.5
0
10
20
30
40
50
60
ANGLES OF HEEL — DEGREES
STATICAL CURVES OF STABILITY
10 & 25 TON ARMY PONTONS
S&S ALUM PONTON
0'-6" DRAFT-LIGHT

FIG. 46

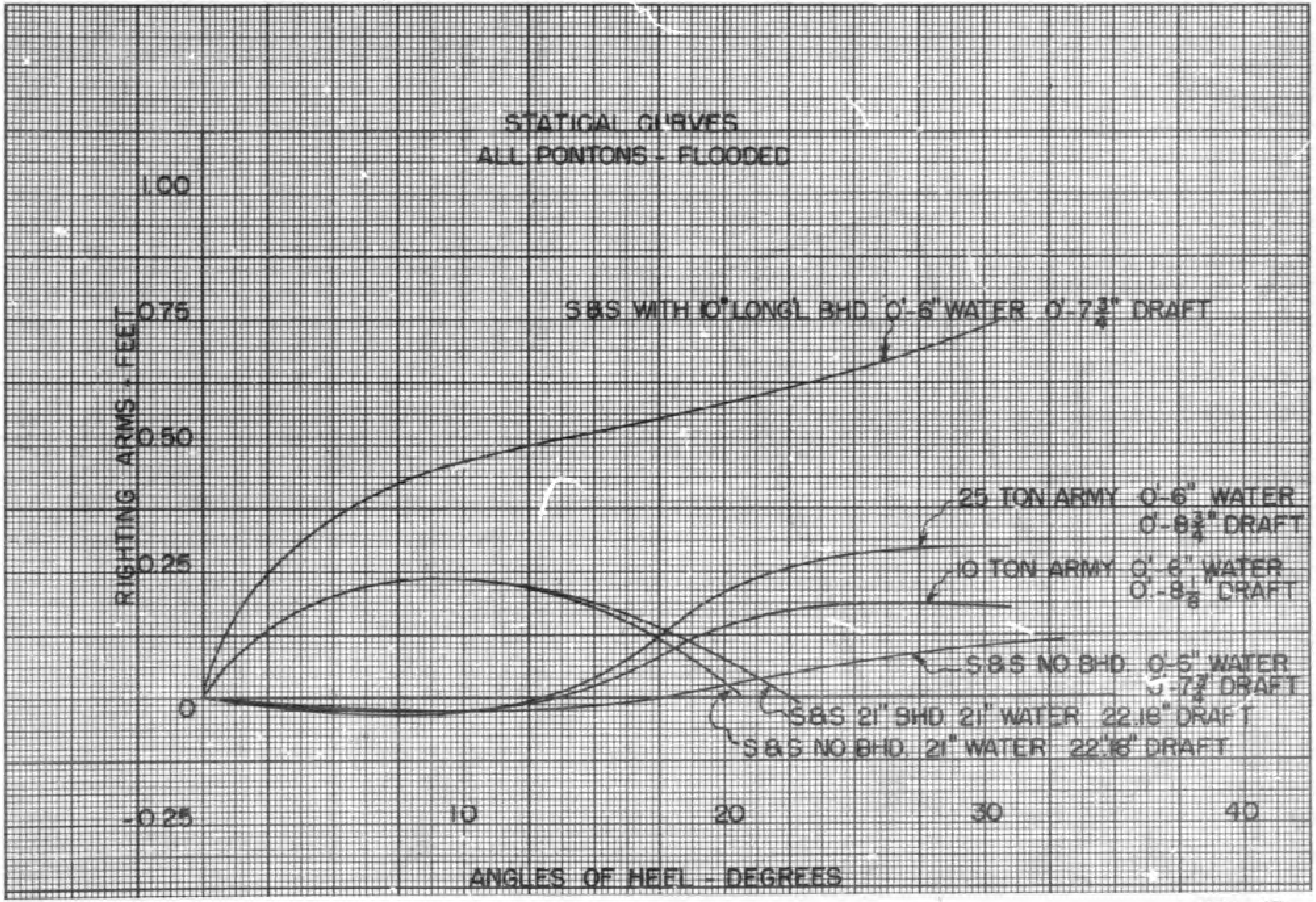
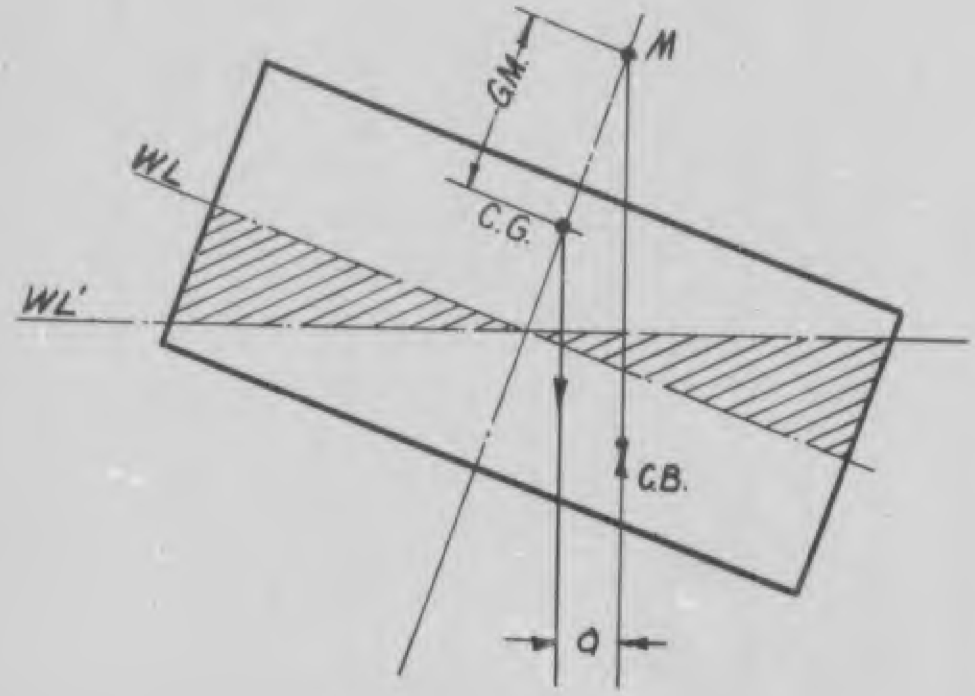

STATICAL CURVES
ALL PONTONS - FLOODED
S&S WITH 10" LONG'L BHD 0'-6" WATER 0'-7$\frac{3}{4}$" DRAFT
25 TON ARMY 0'-6" WATER
0'-8$\frac{3}{4}$" DRAFT
10 TON ARMY 0'-6" WATER
0'-8$\frac{1}{8}$" DRAFT
S&S NO BHD 0'-6" WATER
0'-7$\frac{3}{4}$" DRAFT
S&S 21" BHD 21" WATER 22.18" DRAFT
S&S NO BHD 21" WATER 22.18" DRAFT
RIGHTING ARMS - FEET
1.00
0.75
0.50
0.25
0
-0.25
10
20
30
40
ANGLES OF HEEL - DEGREES

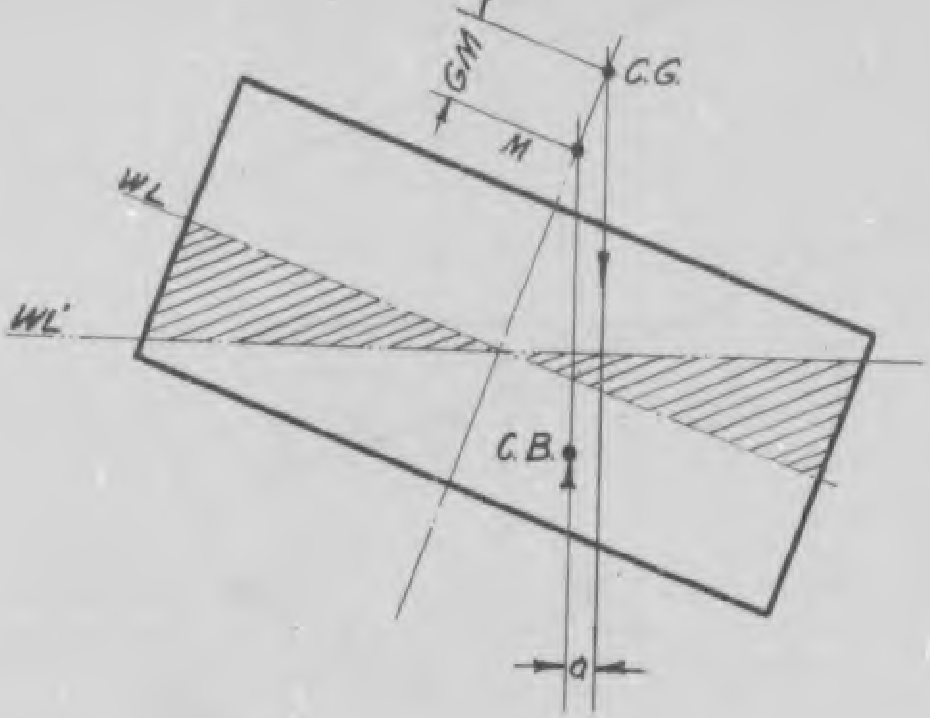
FIG. 47



CG = Center of Gravity
CB = Center of Bouyancy
M = Meta Center
GM = Meta Centric Height
a = Righting Arm

NOTE: A Vessel is said to be Stable as long as M is above CG and the Righting Arm is Positive.

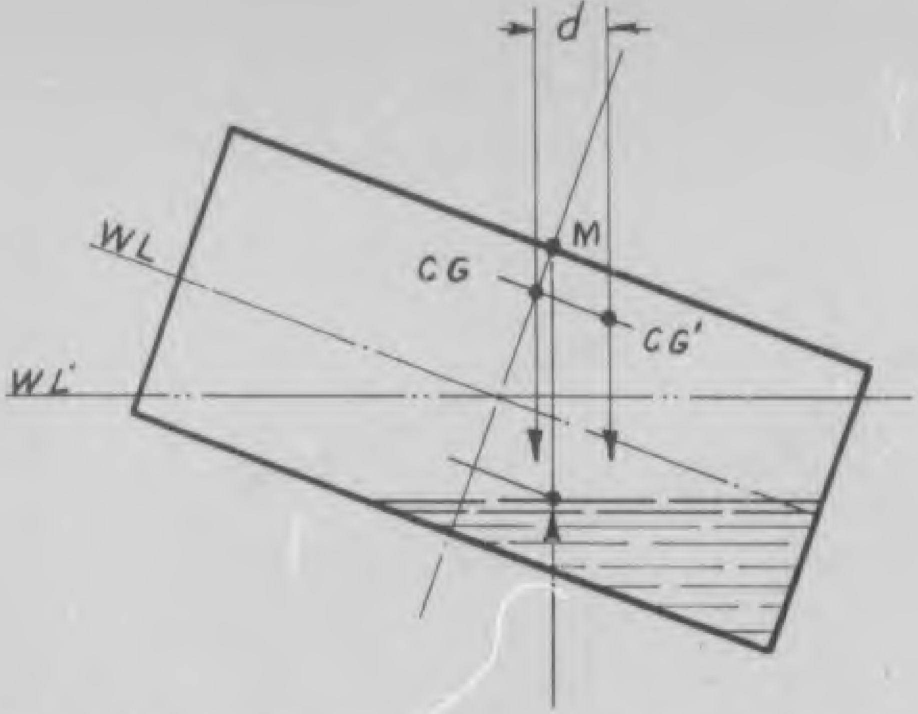
FIG. 48



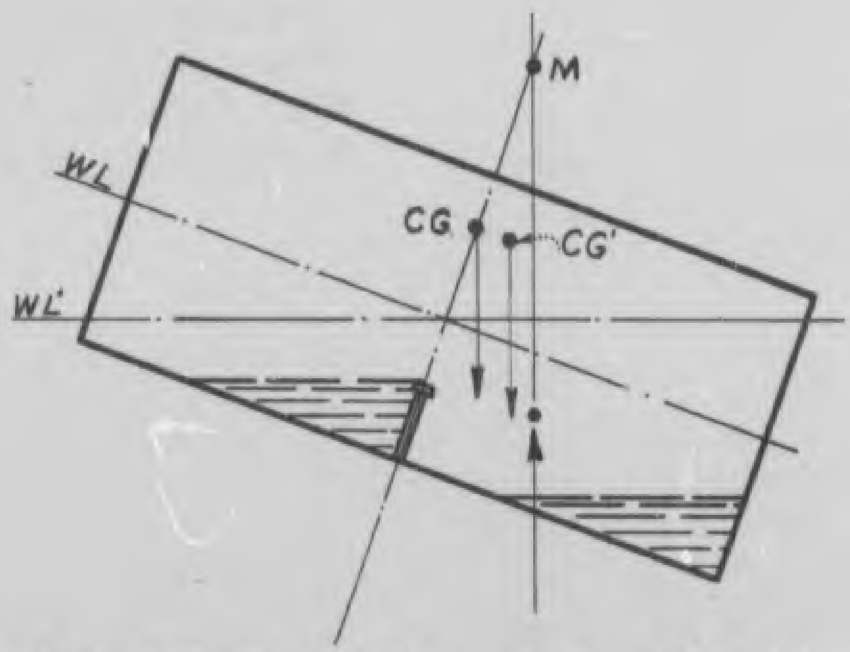
NOTE: A Vessel is said to be Unstable When CG is Above M and the Righting Arm Becomes Negative or an Upsetting Arm.

FIG. 49

A4878-4

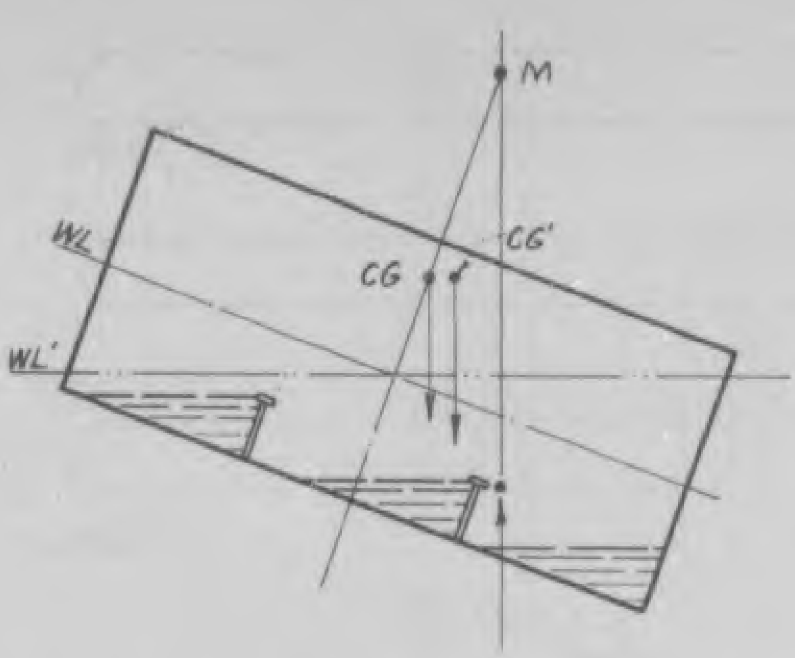


Free Water in a vessel may cause it to be Unstable When Heeled because of a Transverse Change in Center of Gravity from CG to CG' or Distance "d".

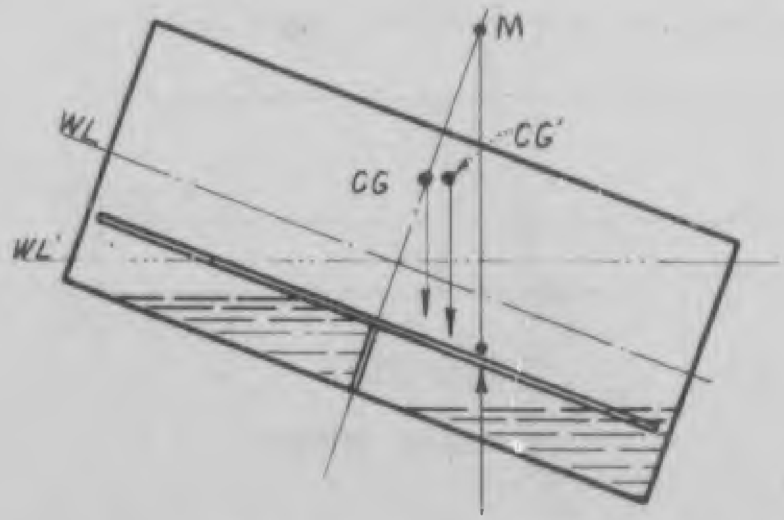


A Longitudinal Bulk Head adds Considerably to Stability when free Water is Present in a Vessel.

FIG. 50

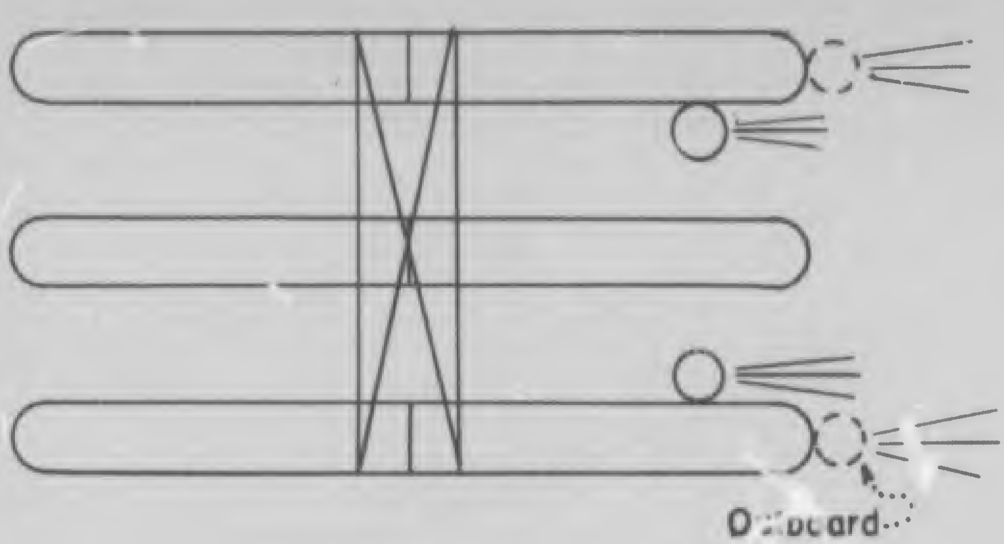


Two Longitudinal Bulkheads will add More to Stability When free Water is Present by Further Control of Water. It is Possible for such a condition to be More Stable Than a Light Boat Because the Center of Gravity of the Boat with Water in Would be Lowered.



Addition of a Watertight Floor on Top of one or More Longitudinal Bulkheads is Optimum Control of Free Water to Gain Stability.

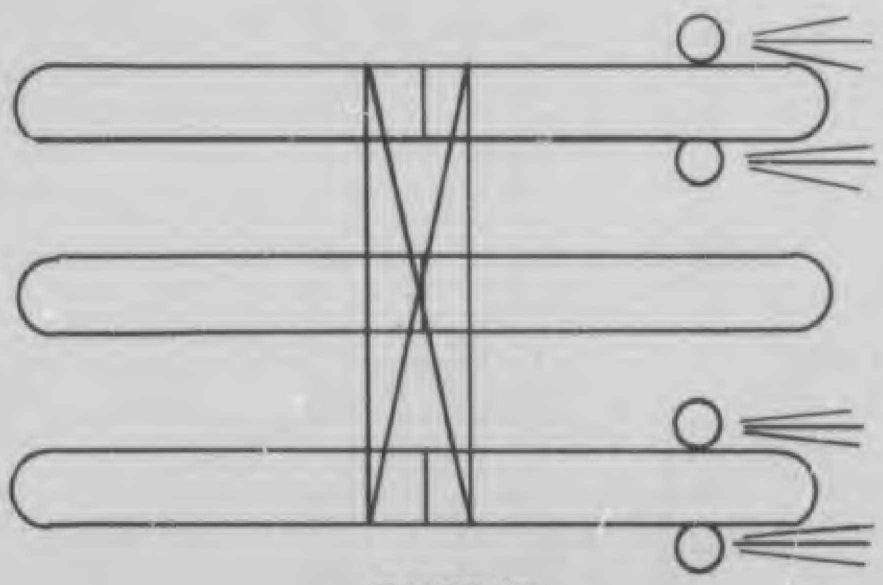
FIG. 51



TYPE I

2 Outboard Motors

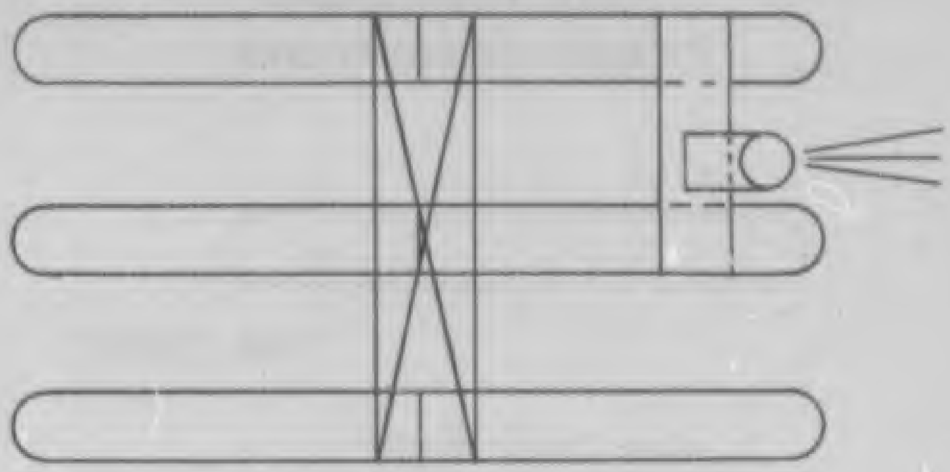
Dotted symbol shows former location of motors.
Solid symbols show the proposed new locations.



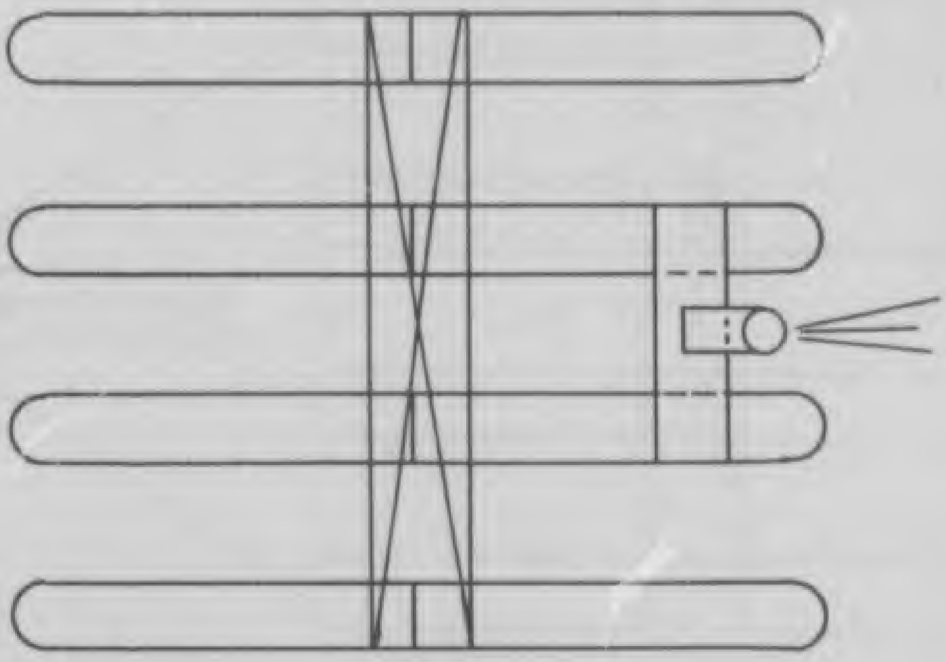
TYPE II

4 Outboard Motors

FIG. 52



TYPE III



TYPE III a

HEAVY DUTY OUTBOARD
MARINE PROPULSION UNIT

FIG. 53

TYPE IV PREPULSION
INBOARD OUTBOARD UNIT

To Make Power Boat

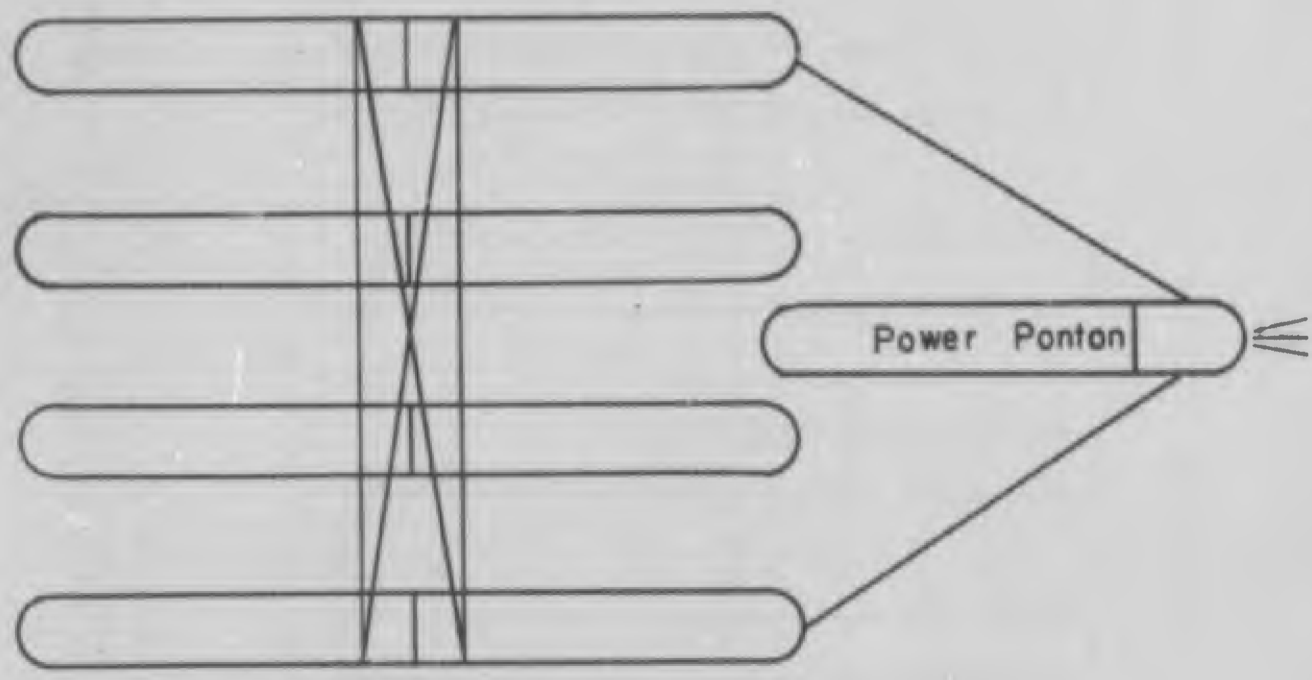


FIG. 54

FIG. 55. STERN VIEW OF POWER ADAPTER. Stern views of two types of power adapters studied in model tests. The adapter to the left was found more effective and the pilot model is being constructed in accordance with this model.

FIG. 56. SIDE VIEW OF POWER ADAPTER ATTACHED TO MODEL HALF-PONTON. The power adapter is 9 feet 9 inches long and has the same cross section as the half-ponton.

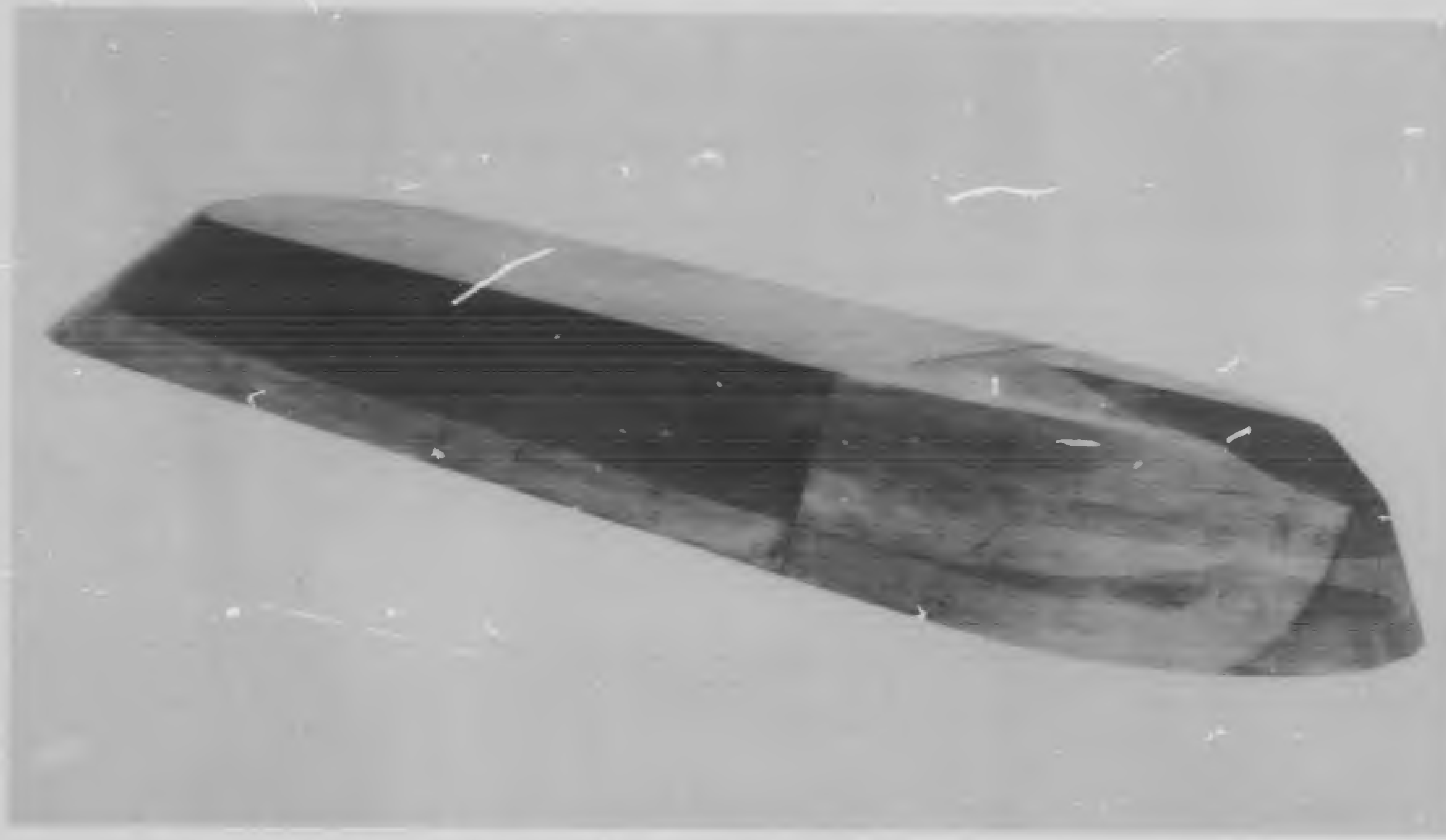


FIG. 57. POWER ADAPTER ATTACHED TO HALF-PONTON. View shows power section adapted to a half-ponton to make the half-ponton into a power boat. This view gives a perspective view of the propeller tunnel and general proportion of size of the power unit as compared to the ponton.

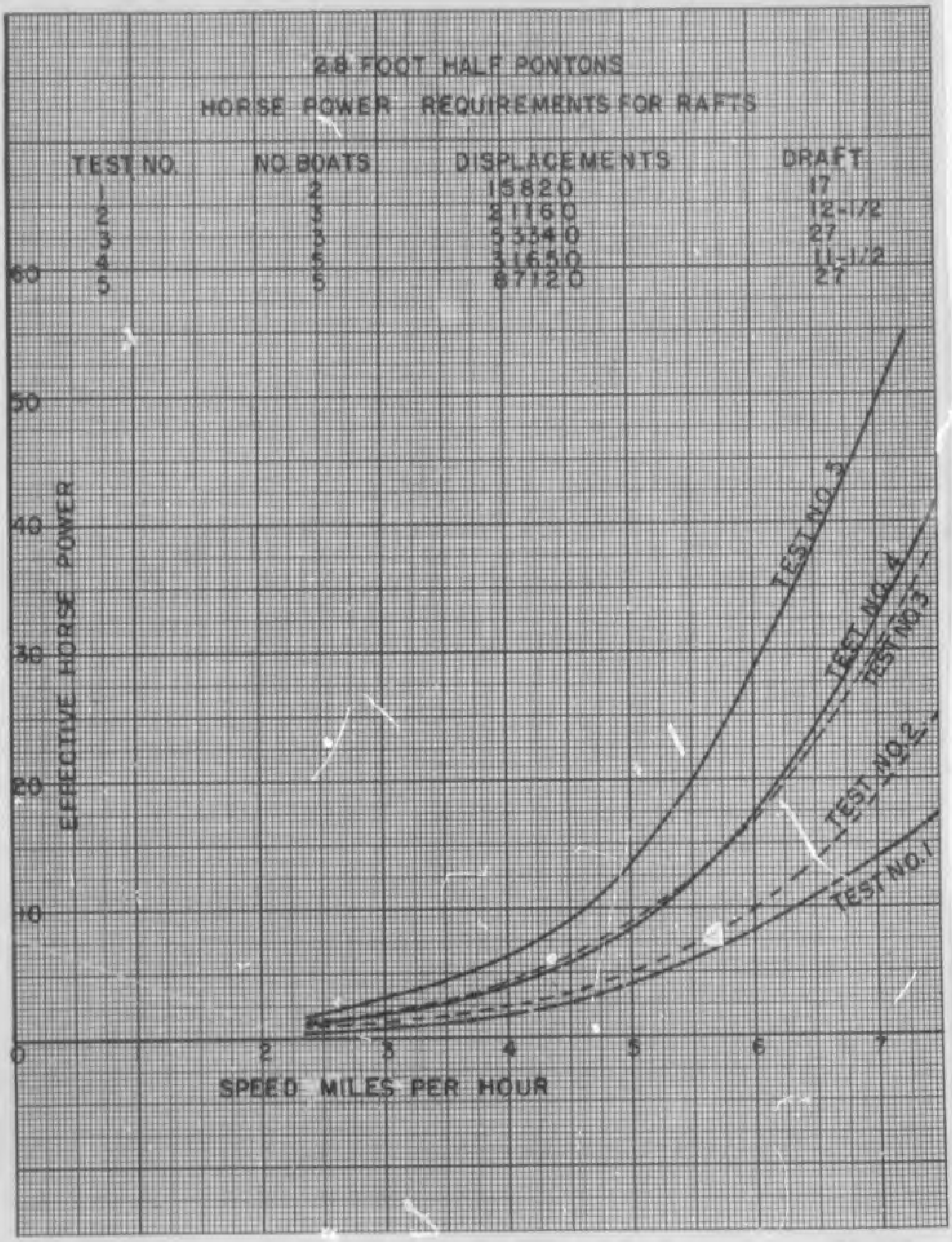

28 FOOT HALF PONTONS
HORSE POWER REQUIREMENTS FOR RAFTS
TEST NO. NO. BOATS DISPLACEMENTS DRAFT
1 2 15820 17
2 3 21160 12-1/2
3 3 53340 27
4 5 31650 11-1/2
5 5 87120 27
EFFECTIVE HORSE POWER
SPEED MILES PER HOUR
TEST NO. 5
TEST NO. 4
TEST NO. 3
TEST NO. 2
TEST NO. 1
0
10
20
30
40
50
60
2
3
4
5
6
7

FIG. 58

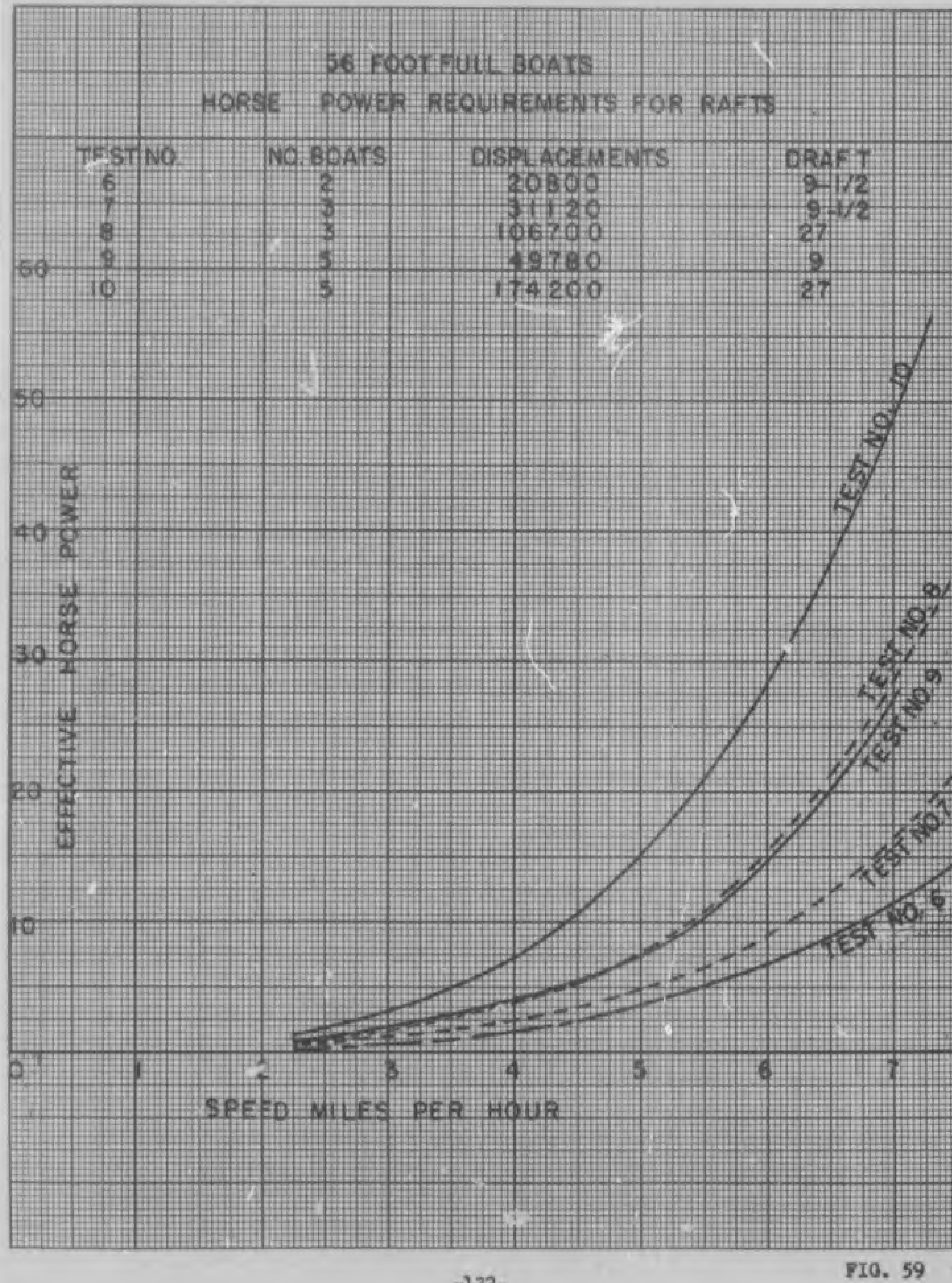

56 FOOT FULL BOATS
HORSE POWER REQUIREMENTS FOR RAFTS
TEST NO. NO. BOATS DISPLACEMENTS DRAFT
6 2 20800 9-1/2
7 3 31120 9-1/2
8 3 106700 27
9 5 49780 9
10 5 174200 27
EFFECTIVE HORSE POWER
SPEED MILES PER HOUR
TEST NO. 10
TEST NO. 8
TEST NO. 9
TEST NO. 7
TEST NO. 6
0
10
20
30
40
50
60
1
2
3
4
5
6
7

FIG. 59

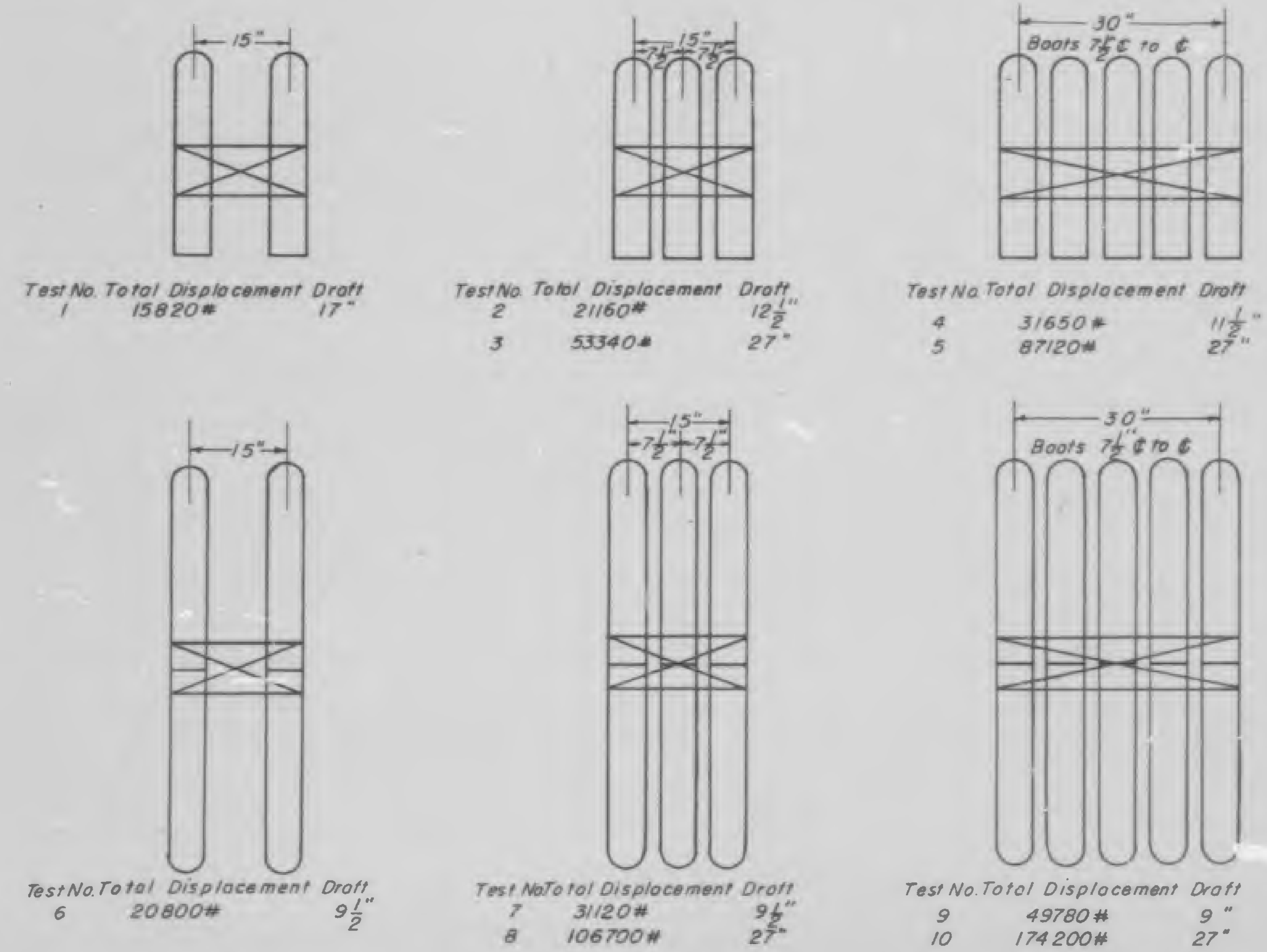

15"
Test No. Total Displacement Draft
1 15820# 17"
15"
7½"
7½"
Test No. Total Displacement Draft
2 21160# 12½"
3 53340# 27"
30"
Boots 7½" ℄ to ℄
Test No. Total Displacement Draft
4 31650# 11½"
5 87120# 27"
15"
Test No. Total Displacement Draft
6 20800# 9½"
15"
7½"
7½"
Test No. Total Displacement Draft
7 31120# 9½"
8 106700# 27"
30"
Boots 7½" ℄ to ℄
Test No. Total Displacement Draft
9 49780# 9"
10 174200# 27"

FIG. 60

CHC/rp
1 March 1944

MEMORANDUM To: Colonel Meyer

Subject: Connector Tests, Plywood Pontons.

1. It was the purpose of the test described below to determine the strength and efficiency of the cable type ponton connector as applied to the plywood half-ponton constructed by Henry B. Nevins, Incorporated. It was the second purpose of the test to determine whether the boats could be easily and quickly connected to each other by means of this type connector and whether any special instructions, tools, or other devices would be required for the connection of the boats while waterborne. It was also the purpose of the test to determine the general wave formation around the bow of the boat when being towed at various speeds.

2. The tests described below were carried out at the yard of Henry B. Nevins, Incorporated, City Island, New York, on 28 February. Present at the tests were the following:

Mr. Olin J. Stephens, Sparkman and Stephens, Inc.
Mr. Gilbert G. Wyland, Sparkman and Stephens, Inc.
Mr. Wilson, Lord and Burnham, Inc.
Mr. Henry B. Nevins, Henry B. Nevins, Inc.
Major Carl H. Clement, Engineer Board.

3. Four half-pontons were used for the test. These boats were connected together in two pairs to form two full pontons which were placed parallel to each other and on approximately 14' centers. Four beams were placed across the gunwales of the boats in similar fashion to balk. Two beams were on each side of the center joint between the boats. At the end of each pair of beams a platform was constructed where lead ballast could be loaded as required. The attached drawing shows the general arrangement of the test lay-out and position of the loads applied.

4. The tests were carried out on the elevator platform which could be lowered into the water to any desired depth. This made it possible to partially support the pontons or to make them fully waterborne as it might be desired during time of loading.

5. The following general weights were noted at the beginning of the test:

Weight of individual half-ponton -- 1,691 lbs.

Weight of deck and four load platforms - - - - - - - - - - -- 2,900 lbs.

Total weight - four boats and
load platforms - - - - - - - - - - - 6,664 lbs.

5. Loads were applied to the four platforms as described above, and the freeboard of the boats measured at bow, center, and stern, to determine the amount of deflection of the boats as the load was increased. The attached table shows the readings as taken during tests. It will be noted that the deflections became smaller as the tension in the cable connectors increased and all form of slack was taken up. The amount of deflection obtained does not seem great for the type connector and the type of load applied.

6. The two boats were placed in the water and several methods of connecting them investigated. It was found that two men could easily accomplish the operation. When bringing boats stern to stern with one man in each boat it was easy to lift up the upper pins by shifting the weight of the individual in the boat. Attachment of the cable to the hook was not difficult. It was found that the cable could not be stretched tight enough by using the lever alone. However, the screw adjustment for the lever fulcrum provided a means of tightening the cable and adjusting its final tension. The best method for connection of two boats appeared to be lowering of the fulcrum point to the minimum for easy attachment of the cable to the lever. After forcing the lever into the last notch, the screw take-up was tightened to bring the boats into final adjustment.

7. Between Trial No. 5 and Trial No. 6, a considerable leak developed in the chine of No. 1 boat at the point of attachment of the cable anchor. The leak did not prevent the completion of Trial No. 6. After Trial No. 6 the boats were removed from the water and thorough inspection made of all connections. The No. 1 boat showed failure in the chine because of the bending taking place in the cable anchor plate and attachment tang. The bending of this plate is caused by the eccentric loading of the cable anchor hook. Inspection of the two hatches of the No. 2 boat indicated that while no wood failure occurred, the tang plates had been bending a small degree and failure probably would have resulted by additional loading.

8. No other failures or leaks were observed in the boats. A tow test was made with two boats coupled end to end to form a single large ponton. This boat was ballasted to a total displacement of 14,200 pounds. At rest, the following freeboard readings were noted:

Bow	Center	Stern
28"	19"	29"

The boat was towed with a small power boat using a 50' tow line. No facilities were available for accurate timing, but it was estimated that the speed of the tow boat and ponton could be brought up to better than 6 miles per hour or approximately 9' per second. Freeboard readings were made while traveling at this speed. It was found that the bow wave reached the underside of the sheer plank, which by subtraction gives a remaining freeboard of approximately 15" forward. The crest of the secondary wave occurred at a point approximately 16' aft of the bow. At this crest measuring from the top of the steel gunwale, the freeboard was 16". It was noted that the boat towed easily and that the shape of the front was such that turbulent water or waves would not be troublesome even though the freeboard were lower than at the time of the test. Several general observations of the boats were made during the tests. These are as follows:

a. The handrail is not of sufficient length to permit enough men to gather around the boat to carry it. The length of the handrail cannot be materially increased and still be of a practical nature. If, however, the aluminum boats do not exceed approximately 1,100 pounds in weight, it is believed that this length handrail will be adequate.

b. Cleats. The four cleats located near the bottom of the boat appeared to be of sufficient size for anchor ropes. It was noted that their attachment to the boat might be too light. One boat was picked up by a crane with a four part bridle attached to these cleats. Some bending took place in the cleat base, and as a result it was decided to increase the thickness and consequently the strength of this base. If correctly attached, these four cleats provide an excellent point for lifting the boat with a crane.

c. Bow chocks. The bow chocks designed for the plywood boat extend above the combing outline and consequently are vulnerable and might be broken off during loading or unloading or handling the boats on dry land. It is believed that this design is improved in the aluminum ponton. The design of the chock and its ability to hold a rope in place appears satisfactory.

d. Connector Lever. The connector lever operated satisfactorily as originally designed. However, several small improvements could be made so that the lever can be more easily located in the desired position. A booster lever was tried and found to work very satisfactorily. However, it is an additional piece, and it is believed that certain small modifications can be made to the basic lever so that the booster lever would not be needed.

e. The small pins used in the top connection between the two boats are not fully satisfactory, since it is impossible to get a good handhold on the top of the pin for its removal. A modification can easily be made to take care of this detail.

9. Conclusions. The following conclusions are drawn as a result of the tests:

a. The connector system as tested is not satisfactory.

b. Modifications can be made to the connector system which it is believed will render more satisfactory.

c. Shape of the bow and water flow around it at various speeds appears to be satisfactory.

d. Connection of one boat to another is simple and direct in principle. It can be accomplished by two men.

e. The four cleats are located satisfactorily but the cleat base should be strengthened.

Carl H. Clement, Jr.
Major, Corps of Engineers
Assistant Chief, Bridge Branch

2 Incls.
Sketch
Table

Trial No.	Displacement No. 1 Boat	Displacement No. 2 Boat	Boat No. 1			Boat No. 2			Remarks
			Bow	Center	Stern	Bow	Center	Stern	
1.	0	0	47-1/2"	42"	48"	47-1/2"	41-3/4"	48"	Boats resting on level platform.
2.	5,800	5,600	41-3/4"	35"	42-1/2"	42"	35"	42"	5 men in No. 1 Boat 4 men in No. 2 Boat
3.	10,432	10,432	33"	27"	35-1/2"	33"	27-1/2"	36"	No leaks
4.	19,232	19,232	31"	23"	32"	30"	24"	32"	No leaks
5.	26,300	26,000	26"	17-1/2"	26-1/2"	25-1/2"	18"	28"	Leak at lever fulcrum, No. 2 Boat
6.	32,000	32,000	23-1/2"	14"	25"	23"	13-1/2"	24"	No. 1 Boat leaking badly at chine.

FIG. 61. LOCATION OF WEIGHTS APPLIED TO PONTONS DURING CONNECTOR TESTS. Note that four points of application, each independent of the other, were used for loading.

FIG. 62. PONTON CONNECTOR TEST SHOWING PLACEMENT OF THE WEIGHT ON EACH HALF-PONTON. Note the small block in the gunwale to properly distribute the load into the gunwale.

FIG. 63. TOWING TEST. A full boat being towed at approximately 6 miles per hour. Ballast - 14,200 pounds. Minimum freeboard - 19 inches at center.

FIG. 64. TOWING TEST. The same ponton as above being towed at approximately 6 miles per hour. Freeboard measurement as indicated by the man with the white stick showed a minimum freeboard of 16 inches due to the secondary wave.

FIG. 65. TOWING TEST. Head-on view of ponton at speed of 6 miles per hour showing formation of bow wave and ample remaining freeboard.

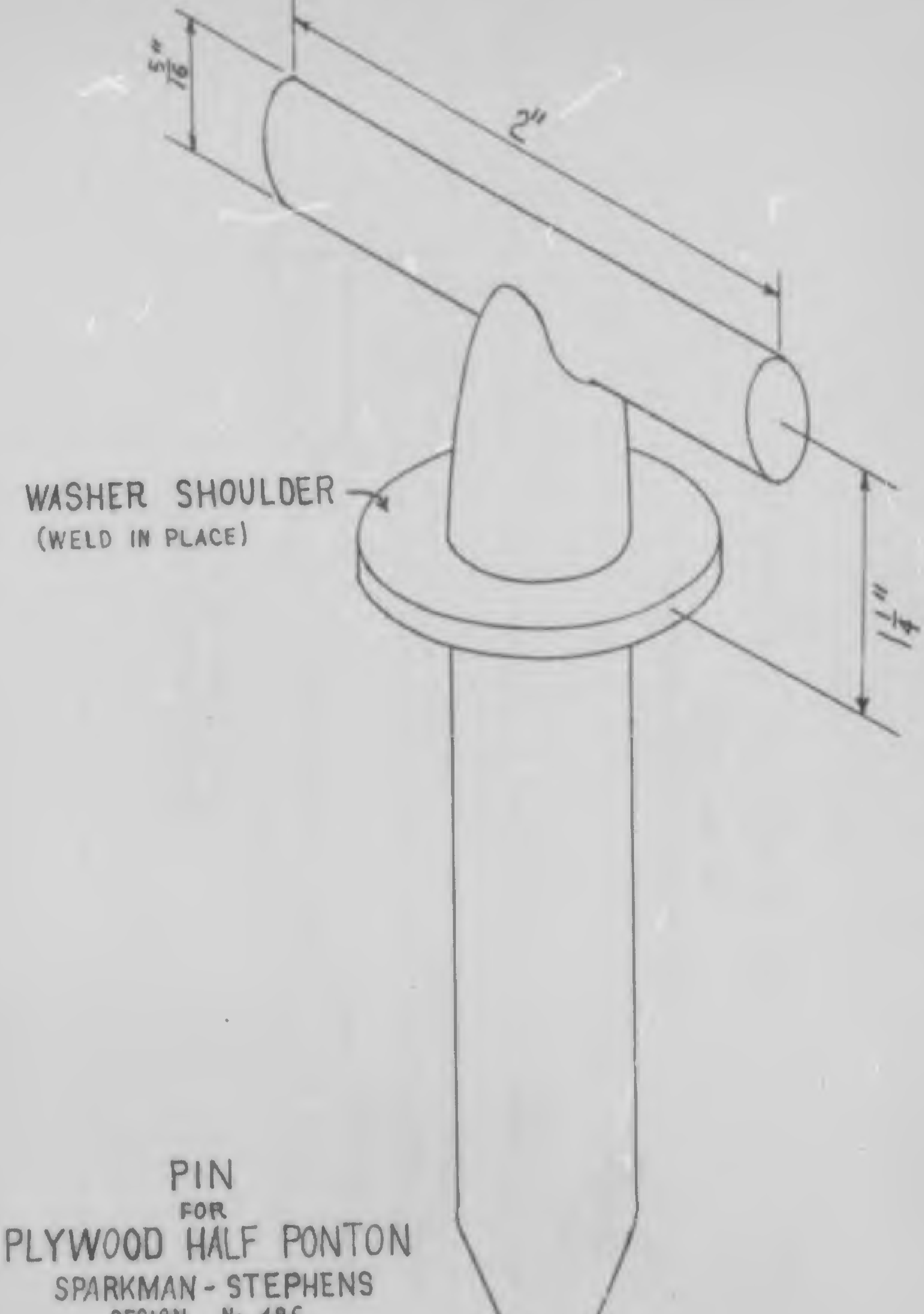
FIG. 66. CABLE CONNECTOR AFTER TEST. Note that bedding compound has been squeezed out around bolt heads due to bending of the cable anchor plate to which the cable is attached. This is a weakness in the connector but can be eliminated by addition of back-up plate on the inside and through-bolts instead of screws.

FIG. 67. METHOD OF LIFTING PONTON. Lifting a plywood ponton weighing 1,691 pounds using a 4-part bridle around the four cleats in the boat. This is a satisfactory method of lifting providing the cleat bases are stiffened somewhat.

FIG. 68. LOADING TEST. General view showing loading test applied to Sparkman and Stephens ponton at the yard of Henry B. Nevins on 28 February.

FIG. 69. BOW VIEW DURING CONNECTOR TEST. View of bow of Sparkman and Stephens ponton during connector tests. Displacement approximately 32,000 pounds. Freeboard to the top of coaming - 23 inches.

FIG. 70. GENERAL VIEW OF CONNECTOR TEST. Another general view of the bow of a ponton during connector tests. The ponton has a displacement of 32,000 pounds as shown.



PIN
FOR
PLYWOOD HALF PONTON
SPARKMAN - STEPHENS
DESIGN No. 486

FIGURE 71

Tow Test Plywood Ponton

of

Henry B Nevine. Inc City Island N.Y.

28 Feb 1944

Displacment - 14,200 Pounds.

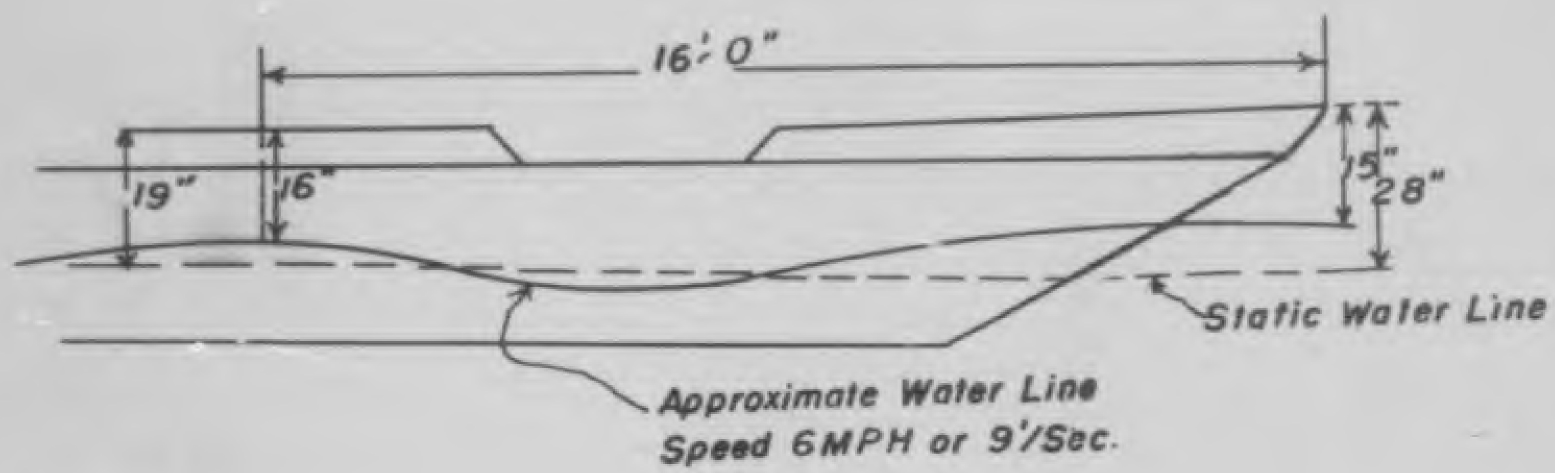
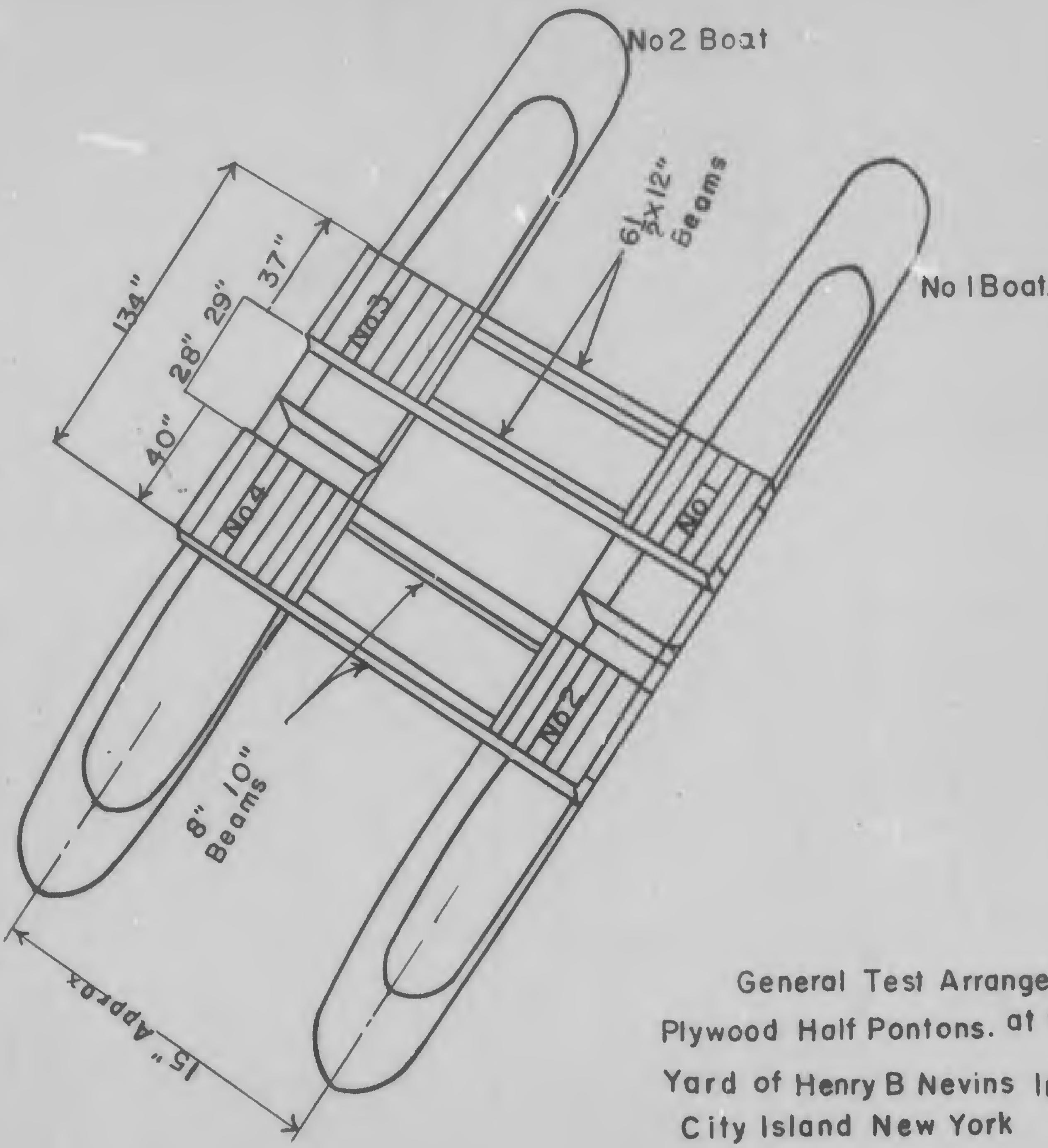


FIGURE 72



General Test Arrangement
Plywood Half Pontons. at the
Yard of Henry B Nevins Inc.
City Island New York

FIGURE 73

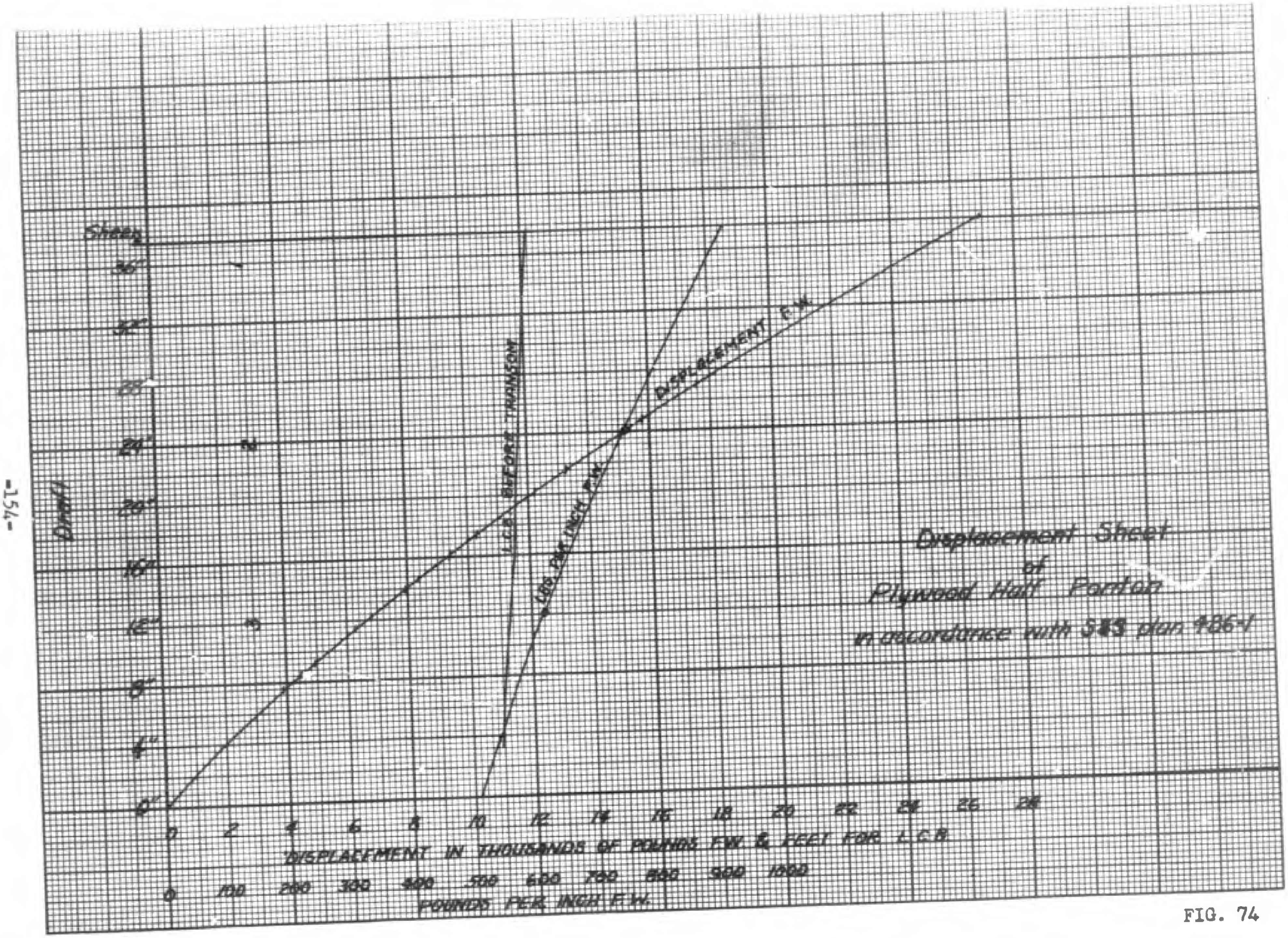

Displacement Sheet
of
Plywood Half Ponton
in accordance with S&S plan 486-1
DISPLACEMENT F.W.
L.C.B. BEFORE TRANSOM
LBS. PER INCH F.W.
Draft
Sheer
36"
32"
28"
24"
20"
16"
12"
8"
4"
0"
1
2
3
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
DISPLACEMENT IN THOUSANDS OF POUNDS F.W. & FEET FOR L.C.B.
0 100 200 300 400 500 600 700 800 900 1000
POUNDS PER INCH F.W.

FIG. 74

Model Studies of Pontons and Pneumatic Floats Conducted By

U. S. Waterways Experiment Station,

Vicksburg, Mississippi

1. In February, 1944, the U. S. Waterways Experiment Station completed a comprehensive report describing the results of a series of model studies performed for the Engineer Board. The purposes of the studies were as follows:

a. To develop an attachment on the bow of the present 25-ton ponton.

b. To determine the optimum bow shape of future pontons to be constructed.

c. To study the most effective methods of anchorage.

d. To investigate the up-stream bow shape of the pneumatic type float.

All tests were conducted in a 4-foot wide flume with flow maintained at a depth equivalent to 20 feet in the prototype. The pontons were built to the linear scale of 1 to 8.

2. In the development of an attachment for the bow of the present 25-ton ponton, a series of different shapes were investigated and compared as to their simplicity of construction, hydraulic efficiency, and ease of transportation. It was concluded that the Type 10 attachment, a vertical plane 12 inches high across the front of the ponton, is the most practical type. Other shapes did not prove to be particularly more effective in control of the water, and all were either harder to build or not readily transported.

3. For the determination of the optimum bow shape of future pontons, a series of tests were proposed on several variations of three basic bow forms, plus three unrelated forms, as follows:

a. A flat plane set at an angle to the water.

b. A cylindrical surface of circular cross section set at an angle to the water.

c. A cylindrical surface of elliptical cross section set at an angle to the water.

d. Several unrelated forms.

In the tests actually conducted, the cylindrical surfaces were only roughly approached; i.e., the circular and elliptical shapes were maintained only in plan, the front or raked portion of the ponton still consisting of a flat plane. This series of tests showed that the simple or scow-shaped bow with raked fore section was the most desirable, and that streamlining in the plan view only did little to increase the hydraulic efficiency. (Study of the proposed compound curve bow shapes at Stevens Institute of Technology show them to have marked advantages. The report of this work is on file at the Engineer Board.)

4. While conducting the tests on the standard 25-ton ponton, additional tests for comparative purposes were made with the British Mark V ponton and the German ponton. As a result of these tests, ponton equipment will be modified so that the bow section will consist of a flat plane set at an angle of 30 degrees with the plane of the water and will have a gunwale higher than that of the rest of the ponton to prevent water entering the ponton when excessive bow waves develop.

5. In the study of pneumatic floats, it was found that turning up the end section effected a considerable improvement in hydraulic efficiency over that of a float whose bottom was all in one plane. This is illustrated in one of the attached photographs.

6. A complete report on these tests is on file at the U. S. Waterways Experiment Station, Vicksburg, Mississippi, and at the Engineer Board, Fort Belvoir, Virginia. Some of the tables and illustrations of this report are included here to show the nature of the experiments.

TABLE 1

Model Study of Pontons and Pneumatic Floats

COMPARISON OF AVERAGE MINIMUM FREEBOARD
VELOCITY RELATIONSHIP

Ponton Loaded to 14-Inch Freeboard on Side in Still Water

Velocity Ft/Sec	American 25-Ton Ponton		Revised American Ponton		German Ponton		British Ponton Mark V		Pneumatic Float Type #1	
	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side
1	18.6	14.0	22.8	15.9	15.9	22.6	15.7	15.9	25.9	14.0
2	17.8	14.0	22.4	15.8	15.8	22.5	15.4	15.9	25.6	14.0
3	17.0	14.0	21.8	15.7	15.8	22.4	12.9	15.8	24.8	13.9
4	16.1	13.8	21.0	15.6	15.7	22.2	12.2	15.7	24.4	13.8
5	14.9	13.6	19.8	15.5	15.5	21.8	11.2	15.6	21.5	15.6
6	13.5	12.9	18.2	12.8	15.2	21.3	9.7	15.1	19.2	15.1
7	11.1	11.9	16.5	12.1	12.5	20.3	7.8	12.2	16.8	12.4
8	8.1	10.7	15.9	11.1	11.6	18.9	5.5	11.0	15.9	11.1
9	5.8	9.4	11.5	9.8	10.4	17.1	2.5	9.4	9.1	8.6
10			8.5	8.5						
Ponton Loaded to 10-Inch Freeboard on Side in Still Water										
1	14.5	9.8	18.5	9.9	19.0	10.0	9.7	9.9	21.9	10.0
2	13.8	9.6	18.0	9.8	18.9	9.9	9.1	9.9	21.5	10.0
3	12.8	9.4	17.4	9.6	18.7	9.8	8.5	9.8	20.5	10.0
4	11.5	9.1	16.5	9.5	18.3	9.7	7.3	9.6	19.0	10.0
5	9.7	8.8	15.5	9.2	17.9	9.5	5.8	9.3	17.2	9.9
6	7.6	8.3	13.7	8.8	17.2	9.1	3.8	8.8	15.0	9.5
7	5.0	7.6	11.6	8.1	16.3	8.4	1.5	8.1	12.3	8.3
8	1.6	6.8	8.9	7.1	14.8	7.5			8.1	5.8
9					12.2	6.5				
Ponton Loaded to 6-Inch Freeboard on Side in Still Water										
1	10.7	5.8	14.7	5.9	14.8	5.8	5.6	6.0	17.9	6.0
2	10.1	5.7	14.0	5.8	14.6	5.7	5.1	5.9	17.3	6.0
3	9.1	5.6	12.9	5.7	14.2	5.6	4.5	5.8	16.2	6.0
4	7.5	5.3	11.4	5.7	13.6	5.6	3.2	5.7	14.7	5.8
5	5.2	4.7	9.5	5.5	12.7	5.5	1.5	5.5	12.8	5.4
6	2.1	5.7	7.3	5.2	11.5	5.2			10.1	4.2
7					9.6	4.7			5.6	1.2
8										
9										

FIG. 75

TABLE 2

Model Study of Pontons and Pneumatic Floats

AVERAGE MINIMUM FREEBOARD ON SIDE

Ponton Loaded to 14-Inch Freeboard on Side in Still Water

American 25-Ton Ponton			Revised American Ponton			German Ponton			British Ponton Mark V			Pneumatic Float Type M3		
Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches
1.13	14.96	14.00	1.13	10.40	13.90	1.13	12.00	13.92	1.13	6.40	13.82	1.13	8.00	[illegible]
3.00	14.96	14.00	2.88	10.40	13.61	3.00	13.60	13.82	2.77	6.40	13.82	3.00	8.00	13.92
5.06	14.96	13.63	5.06	12.00	13.42	5.20	10.40	13.63	5.01	8.00	13.54	5.06	8.00	13.54
7.18	7.60	11.62	7.18	12.80	11.88	7.35	12.40	12.10	7.27	12.40	11.90	7.40	10.00	12.00
9.95	15.20	8.26	8.71	19.20	10.25	9.36	18.00	9.98	8.94	16.80	9.50	8.48	11.20	10.08
			10.46	20.00	7.37							9.22	13.60	6.82
Ponton Loaded to 10-Inch Freeboard on Side in Still Water														
1.13	10.40	9.60	1.13	10.40	9.81	1.13	12.00	9.89	1.13	8.00	9.79	1.13	8.00	[illegible]
3.20	10.40	9.21	3.00	10.40	9.62	3.00	12.00	9.89	3.00	8.00	9.79	3.00	8.00	10.00
4.81	10.40	9.12	5.20	11.20	9.35	4.88	12.40	9.60	5.20	9.20	9.31	5.26	6.40	9.79
7.27	8.80	7.48	7.87	12.00	7.51	7.35	13.80	7.97	7.35	13.60	7.87	7.27	8.00	7.30
8.94	14.40	6.05	8.71	16.00	6.16	9.22	20.00	6.54				8.54	14.80	4.51
Ponton Loaded to 6-Inch Freeboard on Side in Still Water														
1.13	14.40	5.46	1.13	12.00	5.85	1.13	9.60	5.95	1.13	6.80	5.86	1.13	7.20	6.00
3.00	14.40	5.56	2.88	12.00	5.66	3.08	9.60	5.95	3.00	6.80	5.86	3.00	6.96	6.00
4.58	11.20	5.18	5.20	13.60	5.47	3.95	9.60	5.86	4.75	8.00	5.57	5.20	6.80	5.20
5.90	6.40	4.13	6.90	16.00	4.70	5.08	12.80	5.97	6.00	10.00	4.42	7.13	10.40	0.19
6.70	6.80	2.90				6.00	14.40	5.10						
						7.18	14.00	3.94						

FIG. 76

TABLE 3

Model Study of Ponton and Pneumatic Floats

COMPARISON OF AVERAGE MINIMUM FREEBOARD

VELOCITY RELATIONSHIP

Ponton Loaded to 14-Inch Freeboard on Side in Still Water

Velocity Ft/sec	Type 1		Type 2		Type 3		Type 4		Type 5		Type 6		Type 7		Type 8		Type 9		Type 10		Type 11		Type 12	
	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side	Bow	Side
1	18.6	14.0	18.7	15.9	18.6	15.7	18.8	16.9	18.8	15.9	18.8	14.2	18.8	14.0	18.9	14.6	19.0	14.0	30.7	14.2	25.0	14.0	22.8	15.8
2	18.4	14.0	18.2	15.8	18.5	15.7	18.6	15.7	18.4	15.9	18.6	14.1	18.6	14.0	18.4	14.0	18.8	15.8	29.8	14.2	24.6	15.8	22.4	15.8
3	17.8	14.0	17.5	15.6	18.3	15.6	18.1	15.4	17.9	15.9	18.3	14.0	18.2	15.9	17.8	14.6	18.1	15.6	29.0	14.1	24.1	15.6	22.2	15.7
4	16.9	15.9	17.4	15.4	17.2	15.3	17.1	15.1	17.1	15.8	17.8	15.9	17.5	15.6	16.9	15.7	17.4	15.4	28.1	14.0	25.3	15.4	21.8	15.6
5	15.6	13.8	14.8	15.0	15.7	13.8	15.4	13.8	15.7	15.4	17.4	15.6	16.6	15.1	15.6	13.3	16.4	15.1	26.9	15.6	22.1	13.0	21.2	15.5
6	14.0	13.0	13.0	12.4	13.7	12.1	13.4	12.5	13.9	12.8	14.7	13.2	15.5	12.4	13.8	12.5	15.2	12.7	[illegible]	13.0	20.5	12.4	16.8	13.1
7	12.1	13.3	10.8	11.6	11.5	11.3	11.1	12.3	11.8	11.5	12.0	12.6	14.5	11.7	11.4	11.3	13.6	12.2	23.1	11.9	17.4	11.6	18.0	12.4
8	10.8	12.8	8.9	10.8	9.1	10.5	8.7	11.8	9.4	10.0	15.2	[illegible]	13.0	10.9	8.7	9.7	11.8	11.5	20.1	10.7	21.0	10.7	15.1	11.2
9	8.0	12.5	6.3	9.8	6.7	9.8	6.2	11.1	6.1	8.5	14.3	11.8	11.8	10.0	5.8	7.9	9.0	10.5	15.9	9.4	13.6	9.6	14.2	9.8
10	5.6	11.8					5.5	10.6	2.8	[illegible]	15.3	[illegible]					[illegible]	9.1	8.8	9.1	10.9	8.5	8.2	8.2
10.5																	4.5	8.2			9.6	7.9		
Ponton Loaded to 10-Inch Freeboard on Side in Still Water																								
1	14.3	9.9	14.5	10.0	14.8	10.0	14.6	9.9	15.0	9.9	14.8	10.0	14.6	10.0	14.6	9.9	14.8	10.6	26.0	9.8	20.5	10.0	19.1	9.9
2	14.5	9.8	13.9	9.8	14.8	10.0	14.3	9.9	14.9	9.8	14.7	10.0	14.4	9.9	14.3	9.8	[illegible]	9.7	[illegible]	[illegible]	20.6	10.0	18.8	9.8
3	13.8	9.8	13.0	9.5	14.1	9.9	13.8	9.9	14.2	9.7	14.4	[illegible]	14.0	[illegible]	13.6	9.7	13.9	9.8	24.8	9.5	19.4	9.9	18.5	9.7
4	12.8	9.9	11.8	9.7	13.0	9.8	12.6	9.8	12.8	9.4	13.8	9.5	13.4	9.5	12.6	9.2	15.1	9.5	23.5	9.2	18.3	9.7	17.4	9.6
5	11.4	9.8	10.4	8.9	11.5	9.4	11.2	9.6	11.0	9.1	13.2	9.1	12.3	9.1	11.1	8.6	11.9	9.1	21.8	8.9	16.7	[illegible]	16.1	9.4
6	[illegible]	9.4	8.6	8.5	9.7	8.9	9.2	9.2	8.8	[illegible]	12.5	[illegible]	10.9	8.5	9.4	8.0	9.9	8.8	19.7	8.4	14.7	8.6	14.4	8.9
7	8.1	8.6	6.7	7.9	7.7	8.2	6.8	8.4	6.1	7.7	11.4	8.0	9.3	7.9	7.6	7.3	7.5	7.8	17.5	7.7	12.5	7.6	12.4	8.2
8	6.0	7.7	4.4	7.2	5.5	7.5	4.4	7.4	3.3	6.3	10.1	7.3	7.6	7.2	5.6	6.8	4.7	6.8	15.8	6.8	10.2	6.4	10.2	7.5
9	3.1	6.8	1.8	6.5	2.9	6.9	1.8	6.2			7.9	6.6	5.7	6.5	3.5	5.8	1.7	5.2			7.9	5.1	7.9	6.7
Ponton Loaded to 6-Inch Freeboard on Side in Still Water																								
1	10.7	5.9	10.7	5.8	10.8	6.0	10.8	5.9	11.0	5.9	[illegible]	5.9	10.5	6.0	10.6	6.0	10.5	10.7	28.4	5.6	16.7	6.0	14.9	5.9
2	10.3	5.8	10.0	5.7	10.6	6.0	10.5	5.9	10.6	5.8	10.8	5.9	10.3	6.0	10.1	5.9	10.4	6.0	22.1	5.6	16.4	6.0	14.6	5.8
3	9.5	5.8	9.2	5.5	9.8	5.9	9.4	5.8	9.9	5.9	10.6	5.9	9.8	5.8	9.3	5.8	9.8	5.9	21.1	5.6	15.7	5.9	13.9	5.7
4	8.8	5.8	8.0	5.1	8.8	5.8	7.8	5.6	8.7	5.7	10.0	5.8	9.0	5.5	4.1	5.6	8.9	5.8	[illegible]	5.4	14.7	5.7	12.8	5.6
5	6.8	5.6	6.4	4.6	7.5	5.6	5.8	5.4	6.9	5.3	9.1	5.7	7.8	[illegible]	6.5	5.4	7.3	5.4	17.4	4.9	13.0	5.1	11.5	5.2
6	5.8	5.1	4.2	3.8	6.0	5.3	3.5	4.6	4.5	4.5	7.6	5.5	6.4	4.6	4.5	4.9	5.3	4.7	14.5	3.8	10.8	4.1	9.9	4.6
6.5	4.4	4.8																						
7	3.2	4.1	1.6	2.6	4.3	4.9	1.2	3.8			5.9	4.7	4.6	3.6	2.1	4.1	3.2	3.5			8.3	2.3	7.8	3.4
8																								

FIG. 77

TABLE 7

Model Study of Pontons and Pneumatic Floats

AVERAGE MINIMUM FREEBOARD ON SIDE

Ponton Loaded to 14-Inch Freeboard on Side in Still Water

Type A Design			Type B Design			Type C Design			Type D Design		
Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches
1.13	5.60	13.73	1.13	4.00	13.82	1.13	5.60	13.92	1.13	8.00	14.00
3.00	6.40	13.54	3.00	5.60	13.63	3.00	5.60	13.63	3.14	8.00	13.92
3.85	6.40	12.77	4.81	6.40	12.86	5.43	6.40	12.10	5.06	8.80	13.44
5.06	8.80	12.10	6.00	8.40	11.81	7.35	10.00	9.70	7.44	14.40	10.66
6.00	10.00	11.14	7.35	9.60	9.31	8.80	13.60	7.30	9.22	20.80	8.54
7.35	11.20	9.70	7.86	11.60	7.87						
8.02	12.00	8.26									
Ponton Loaded to 10-Inch Freeboard on Side in Still Water											
1.13	4.80	9.79	1.13	4.00	9.79	1.13	5.60	9.89	1.13	8.00	9.70
3.00	6.00	9.31	3.20	5.60	9.70	3.00	6.40	9.60	3.20	8.00	[illegible]
4.10	8.40	8.83	4.88	5.60	9.50	5.32	6.00	7.30	5.01	7.20	9.12
5.20	8.40	8.16	7.35	11.20	6.72	7.35	10.00	4.90	7.35	12.40	7.20
6.22	11.60	7.68				7.61	10.40	4.42	8.02	14.40	7.20
7.35	12.80	6.24									
Ponton Loaded to [illegible]-Inch Freeboard on Side in Still Water											
1.13	4.00	5.95	1.13	5.60	5.76	1.13	4.80	5.95	1.13	8.00	[illegible]
2.88	[illegible]	[illegible]	3.00	5.60	5.46	2.88	6.40	5.76	3.00	8.00	[illegible]
3.85	8.00	4.90	4.52	9.60	5.29	3.45	4.00	5.28	3.95	[illegible]	[illegible]
4.81	8.80	4.32	5.01	7.20	[illegible]	[illegible]	6.40	4.32	[illegible]	11.20	[illegible]
[illegible]	11.20	3.74	6.42	9.60	3.84	[illegible]	[illegible]	3.84	5.78	9.60	[illegible]

FIG. 78

TABLE 7 (Continued)

Model Study of Pontons and Pneumatic Floats

AVERAGE MINIMUM FREEBOARD ON SIDE

Ponton Loaded to 14-Inch Freeboard on Side in Still Water

Type E Design			Type F Design			Type G Design			Type H Design		
Velocity Ft/Sec	Distance From Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance From Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance From Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance From Bow on Side in Feet	Observed Average Freeboard in Inches
1.13	6.40	13.92	1.13	5.60	13.73	1.13	6.40	13.73	1.13	8.00	13.82
3.20	6.40	13.63	3.00	5.60	13.44	3.14	6.40	13.63	3.14	4.40	13.54
5.32	6.40	12.38	5.06	6.40	12.29	4.81	7.20	12.86	5.06	8.00	12.77
7.18	8.80	8.92	7.35	11.20	9.22	7.27	10.80	10.66	7.27	12.00	11.04
8.80	12.00	5.57	8.09	12.00	7.50	8.94	13.20	8.26	9.62	11.40	9.12
Ponton Loaded to 10-Inch Freeboard on Side in Still Water											
1.13	6.40	9.79	1.13	6.40	9.60	1.13	8.00	9.89	1.13	8.00	9.88
3.00	6.40	9.76	3.00	6.40	9.41	3.00	6.00	9.60	3.14	10.40	9.41
5.01	7.60	8.95	5.06	8.40	8.06	4.67	6.40	9.22	5.06	8.00	8.83
6.70	9.60	6.72	6.70	8.80	6.54	7.27	11.20	5.66	7.35	12.80	6.33
									7.52	4.80	6.14
Ponton Loaded to 6-Inch Freeboard on Side in Still Water											
1.13	6.40	5.86	1.13	8.00	5.95	1.13	8.00	5.95	1.13	8.00	5.95
3.14	6.40	5.66	3.20	8.00	5.86	3.00	8.00	5.86	3.20	8.00	5.86
4.95	7.20	5.09	4.02	6.40	5.47	4.10	6.40	5.66	4.81	11.20	5.66
6.00	9.60	4.42	5.06	7.20	5.18	5.78	7.20	4.42	6.00	8.80	4.32
			5.90	8.00	4.61						

FIG. 79

TABLE 7 (Continued)

Model Study of Pontons and Pneumatic Floats

AVERAGE MINIMUM FREEBOARD ON SIDE

Ponton Loaded to 14-Inch Freeboard on Side in Still Water

Type I Design			Type J Design			Type K Design			Type L Design		
Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches	Velocity Ft/Sec	Distance from Bow on Side in Feet	Observed Average Freeboard in Inches
1.13	8.00	13.92	1.13	8.00	13.92	1.13	9.20	13.63	1.13	8.00	13.82
3.00	8.00	13.44	3.39	8.80	13.63	3.00	8.80	13.63	3.00	8.80	13.82
5.20	8.00	12.67	5.06	9.60	12.50	5.26	8.40	12.00	4.95	8.80	12.67
7.55	10.40	10.08	7.55	10.40	8.54	7.55	12.40	9.89	7.52	[illegible]	[illegible]
9.08	17.60	7.39	8.94	11.40	5.18	8.71	14.40	8.45	9.08	12.40	8.54
Ponton Loaded to 10-Inch Freeboard on Side in Still Water											
1.13	8.00	9.89	1.13	8.00	[illegible]	1.13	9.60	9.70	1.13	8.00	[illegible]
3.44	8.00	9.21	3.20	8.80	9.70	3.00	9.60	9.70	[illegible]	8.00	9.60
5.20	8.00	8.36	5.67	9.60	8.26	[illegible]	9.60	9.31	[illegible]	[illegible]	8.84
7.55	12.00	3.55	7.27	12.00	4.49	7.55	11.20	5.76	7.55	12.00	5.86
									7.52	12.00	5.66
Ponton Loaded to 6-Inch Freeboard on Side in Still Water											
1.13	8.00	5.95	1.13	8.00	5.95	1.13	8.00	5.95	1.13	8.00	5.95
3.00	8.00	5.76	2.88	8.00	5.76	3.44	8.80	5.76	2.88	8.00	5.86
4.38	8.00	5.30	4.33	10.80	5.47	4.16	9.60	5.30	4.33	8.00	5.66
6.00	10.40	4.70	5.67	9.60	4.99	6.00	10.40	3.94	6.00	10.40	4.90

FIG. 80

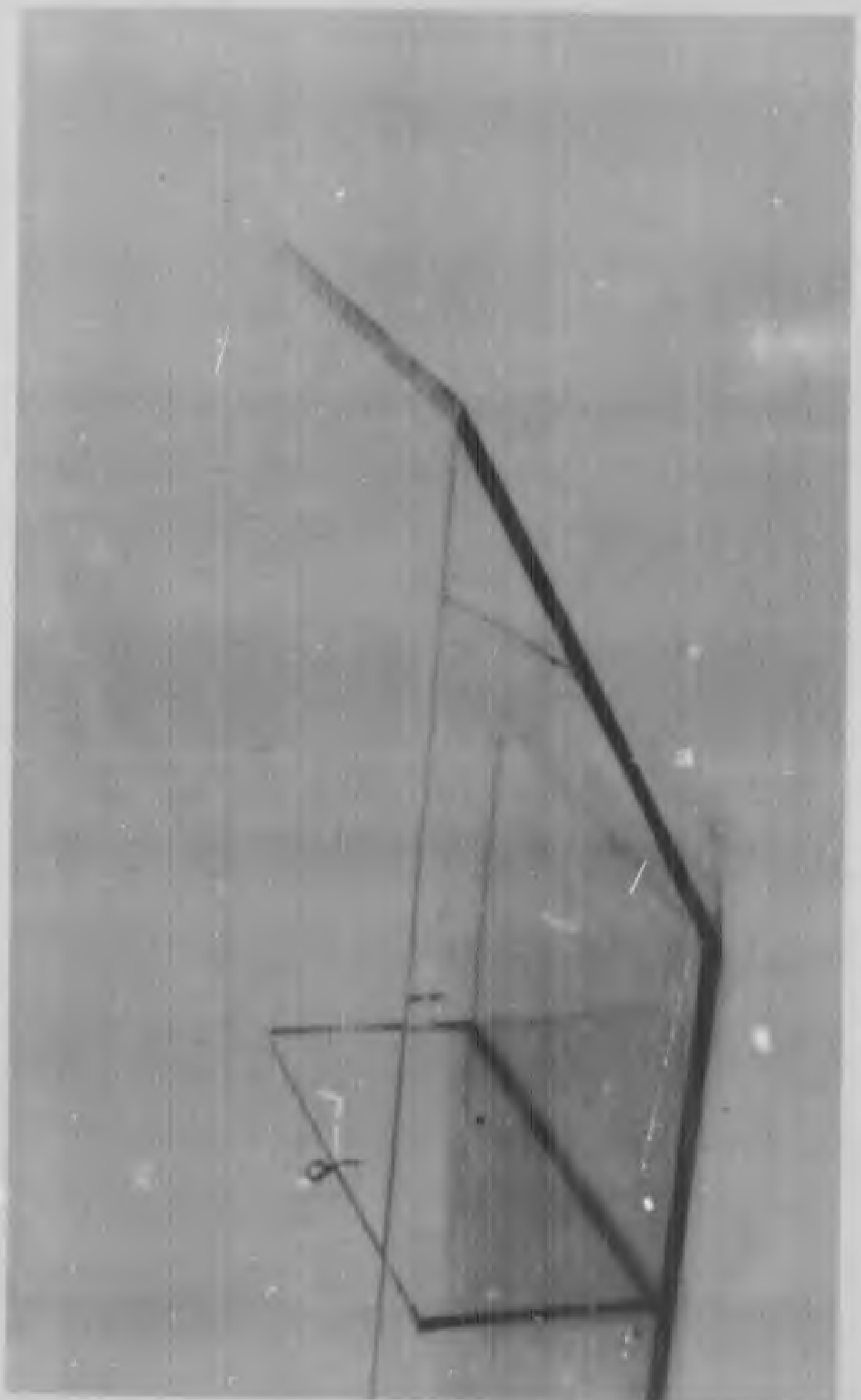


FIG. 81. DETAILS OF NEW PONTON - TYPE D DESIGN

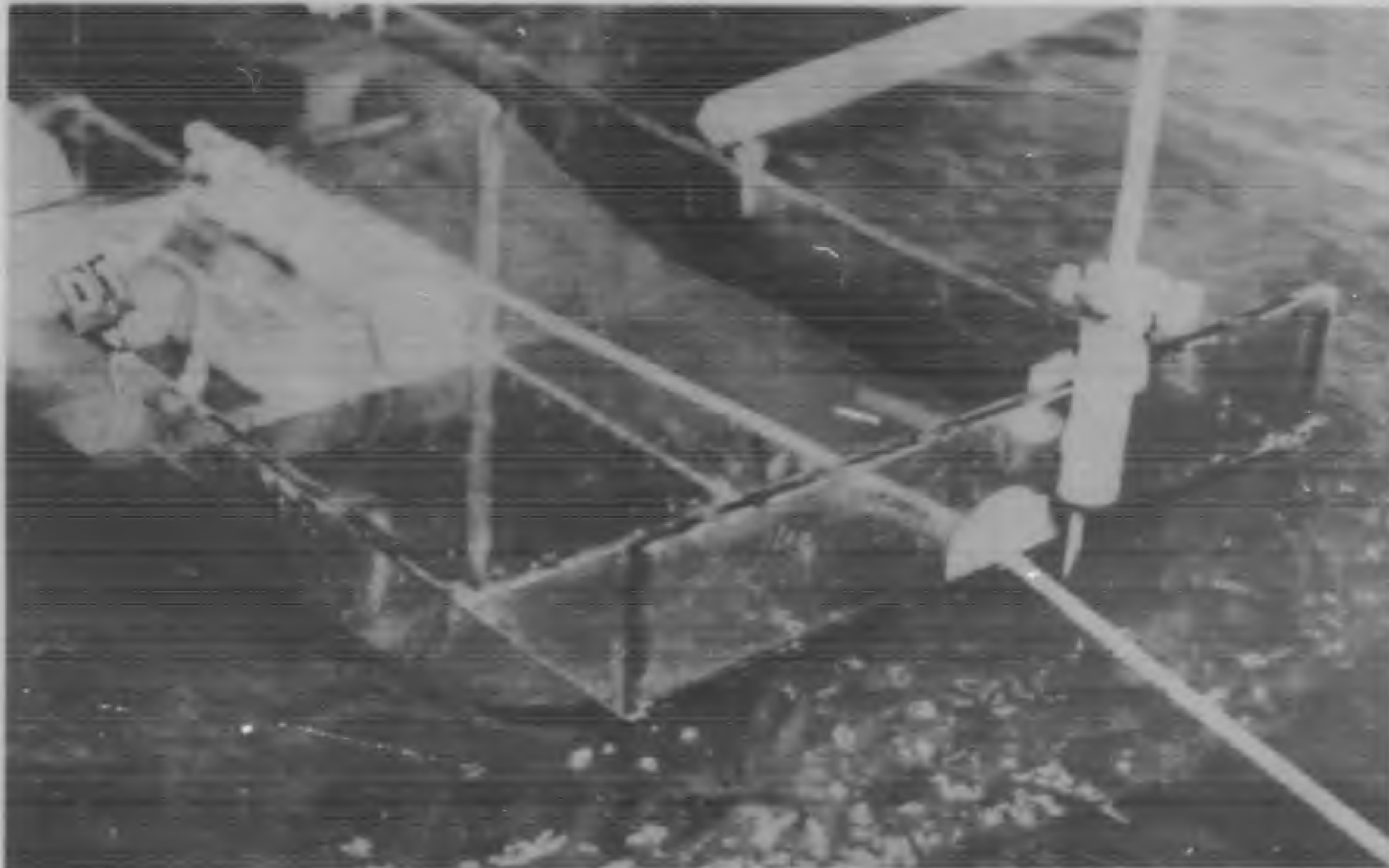


FIG. 82. FLOW CONDITIONS FOR NEW PONTON - TYPE D DESIGN. Freeboard for velocity of 7.35 feet per second and 10-inch loading. Bow - 2.[illegible]2 inches; side - 7.20 inches.

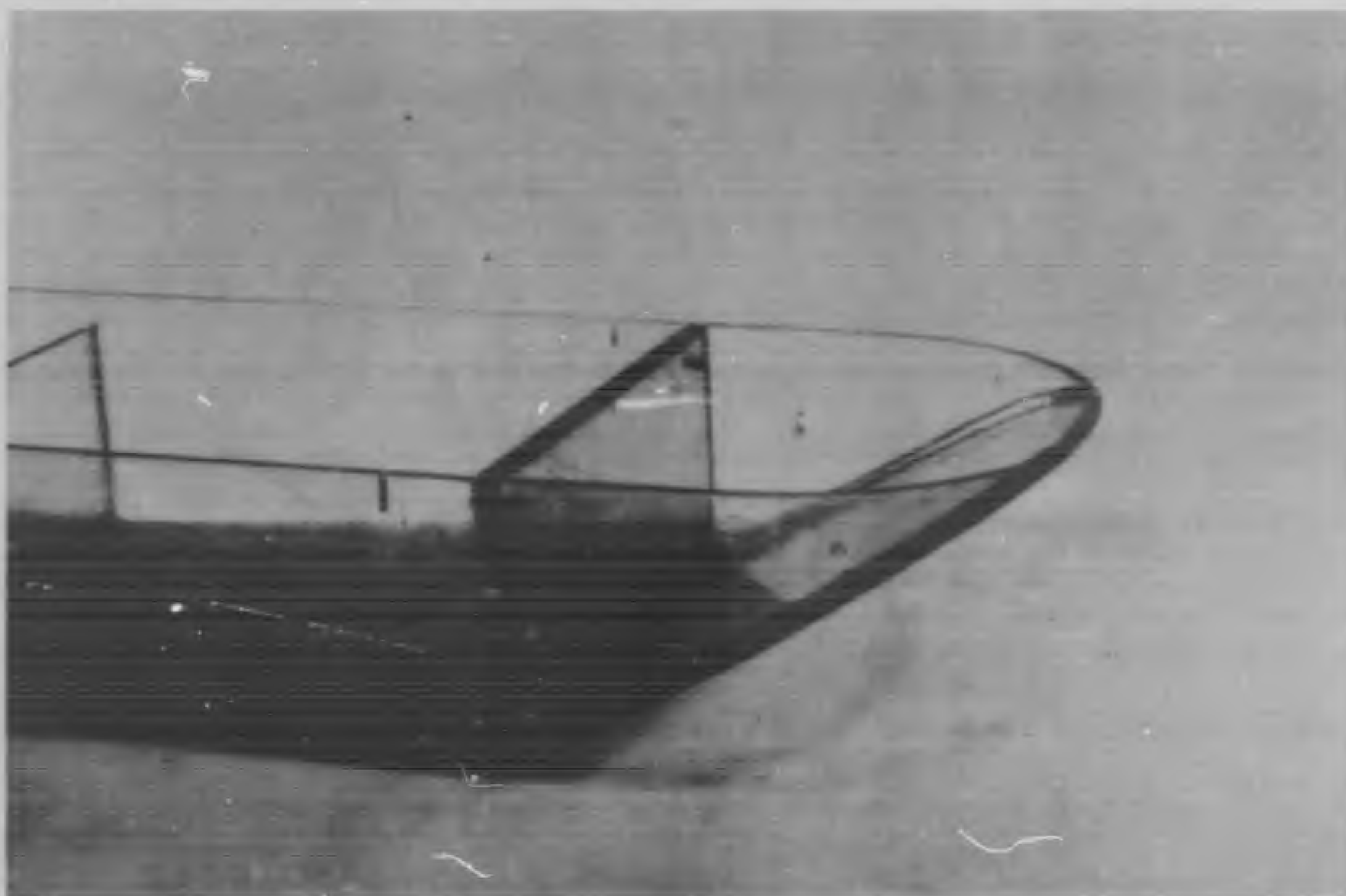


FIG. 83. DETAILS OF NEW PONTON - TYPE H DESIGN

FIG. 84. FLOW CONDITIONS FOR NEW PONTON - TYPE H DESIGN. Freeboards for velocity of 7.35 feet per second and 10-inch loading. Bow - 2.11 inches; side 6.33 inches.

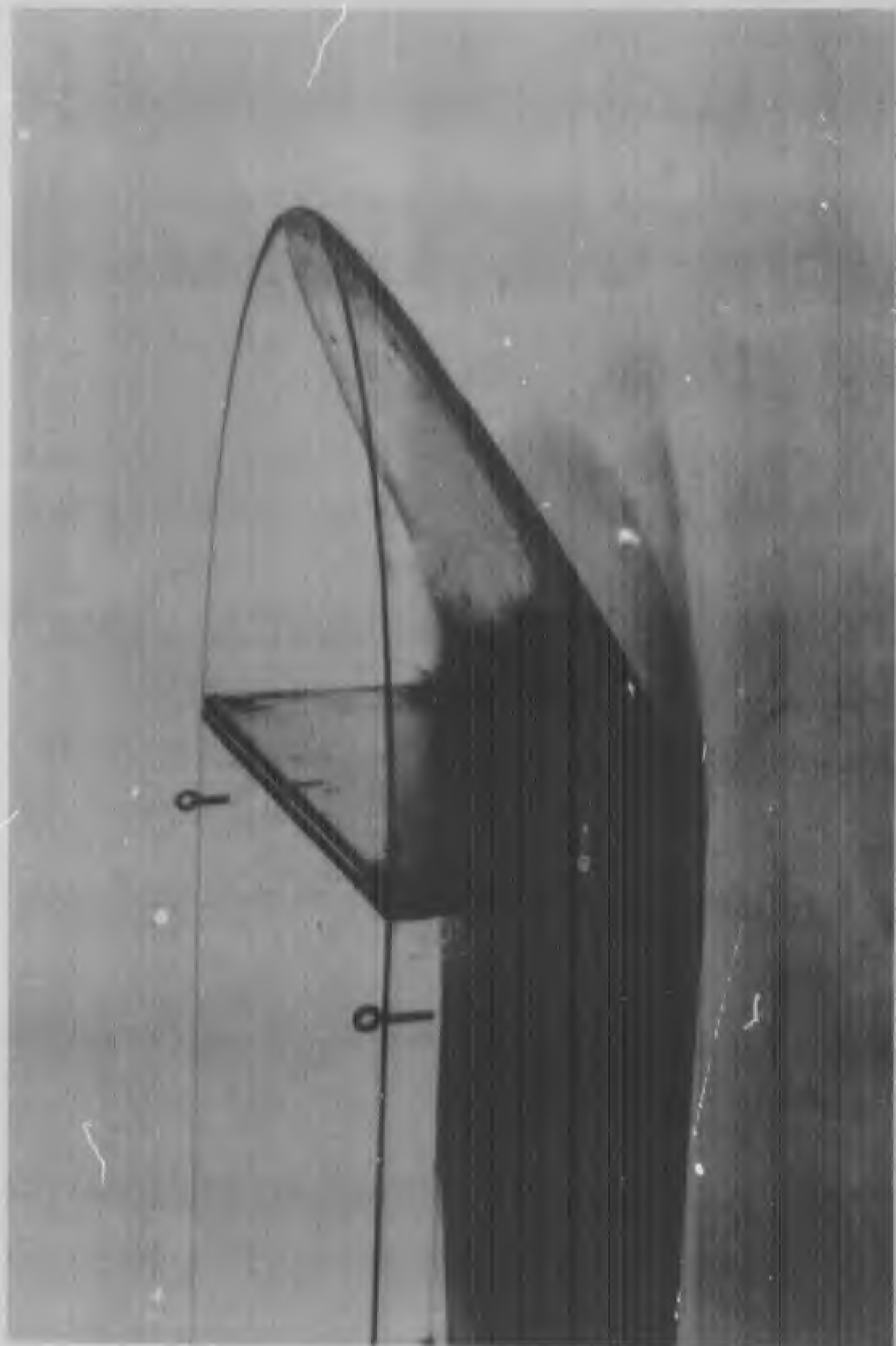


FIG. 85. DETAILS OF NEW PONTON - TYPE L DESIGN

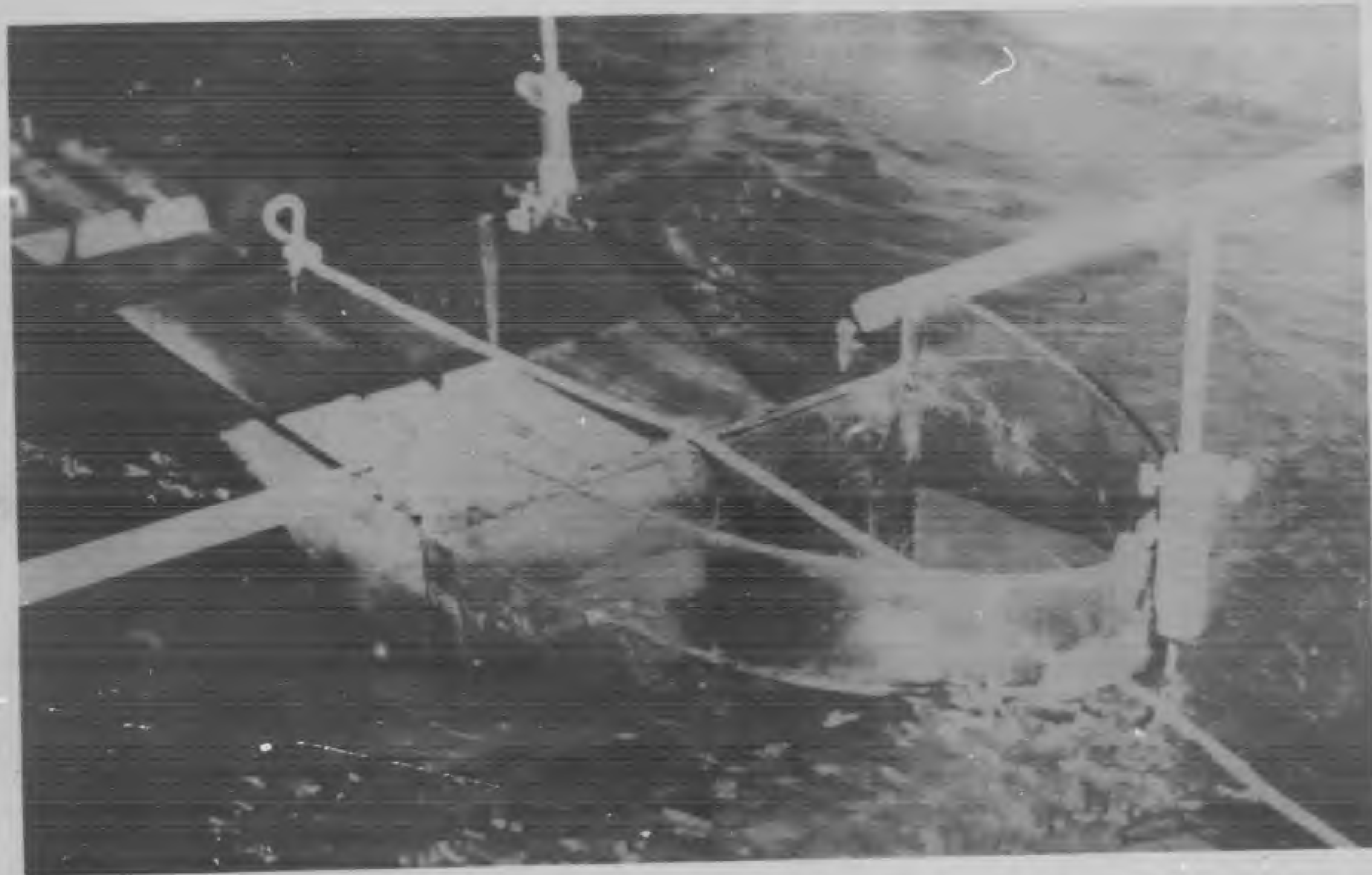


FIG. 86. FLOW CONDITIONS FOR NEW PONTON - TYPE L DESIGN. Freeboards for velocity of 7.35 feet per second and 10-inch loading. Bow - 0.00 inch; side 5.86 inches.

FIG. 87. FLOW CONDITIONS FOR AMERICAN 25-TON PONTON. Average freeboards for velocity of 7.3 feet per second and 10-inch loading. Bow - 4.25 inches; side - 7.50 inches.

FIG. 88. DETAILS OF NEW PONTON - TYPE 2

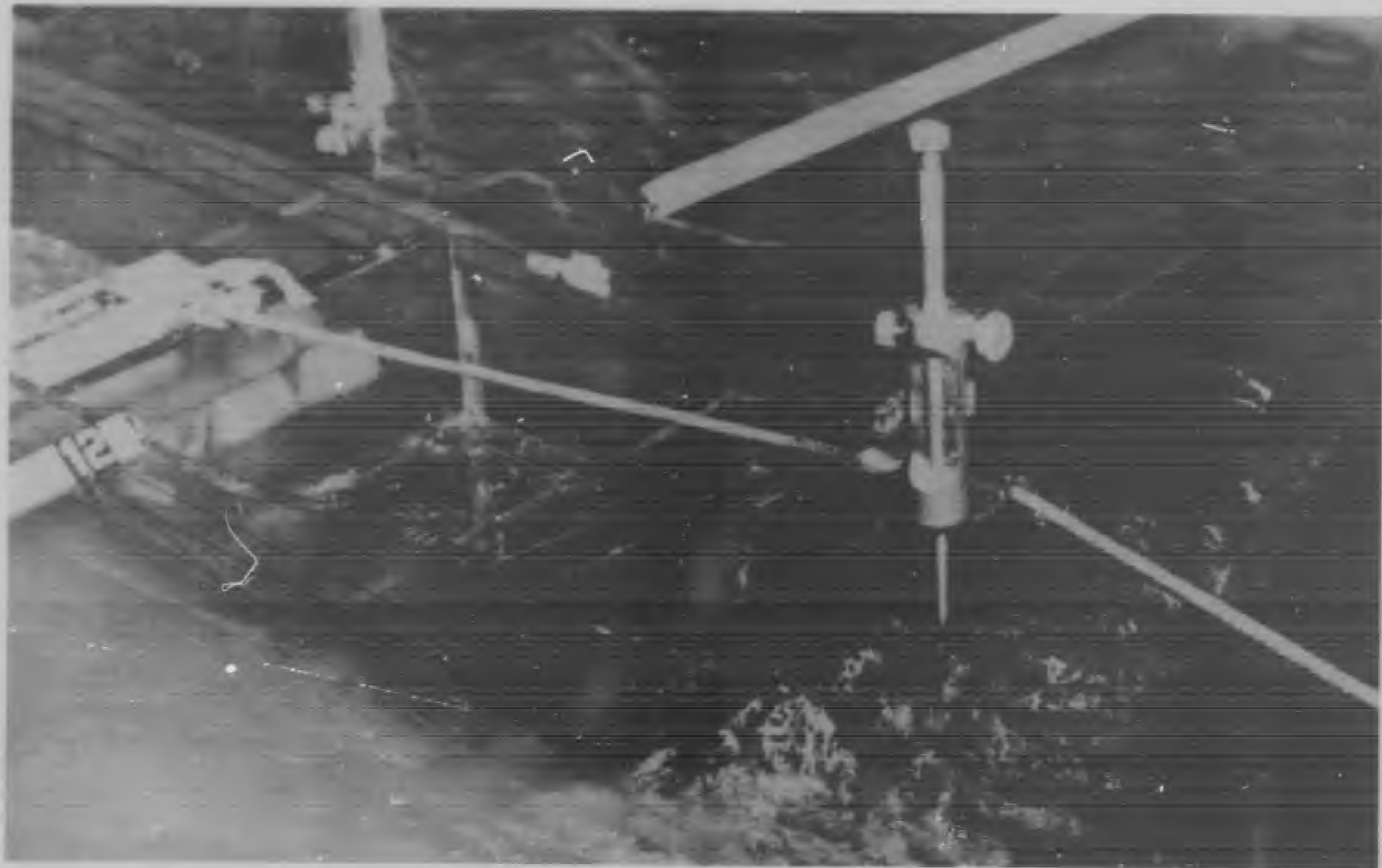


FIG. 89. FLOW CONDITIONS FOR NEW PONTON - TYPE 2. Freeboards for velocity of 7.08 feet per second and 10-inch loading. Bow - 8.06 inches; side - 8.83 inches.

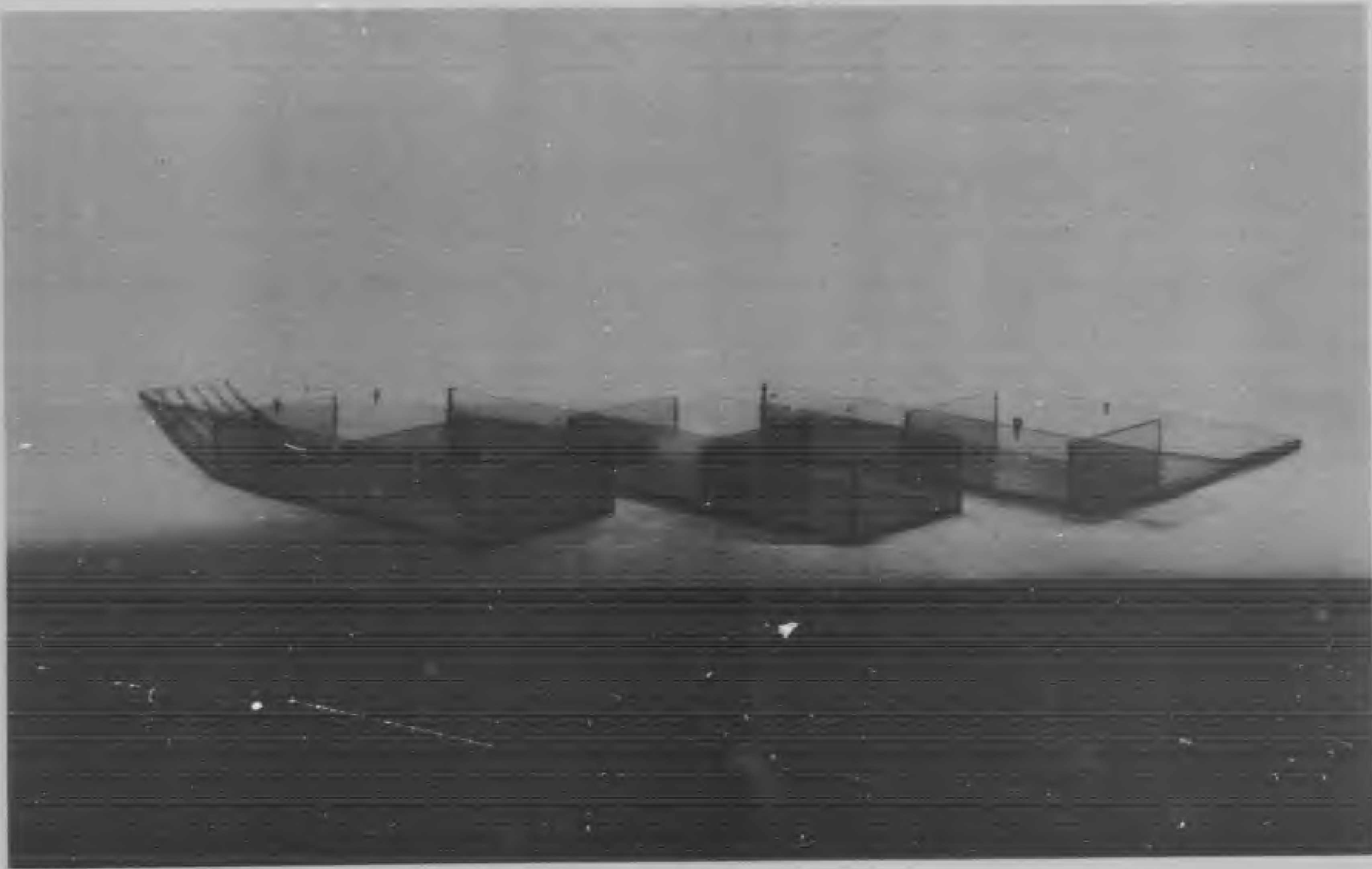


FIG. 90. DETAILS OF BRITISH PONTON, MARK V

FIG. 91. FLOW CONDITIONS FOR BRITISH PONTON, MARK V. Freeboards for velocity of 7.3 feet per second and 10-inch loading. Bow - 0.77 inch; side - 7.87 inches.

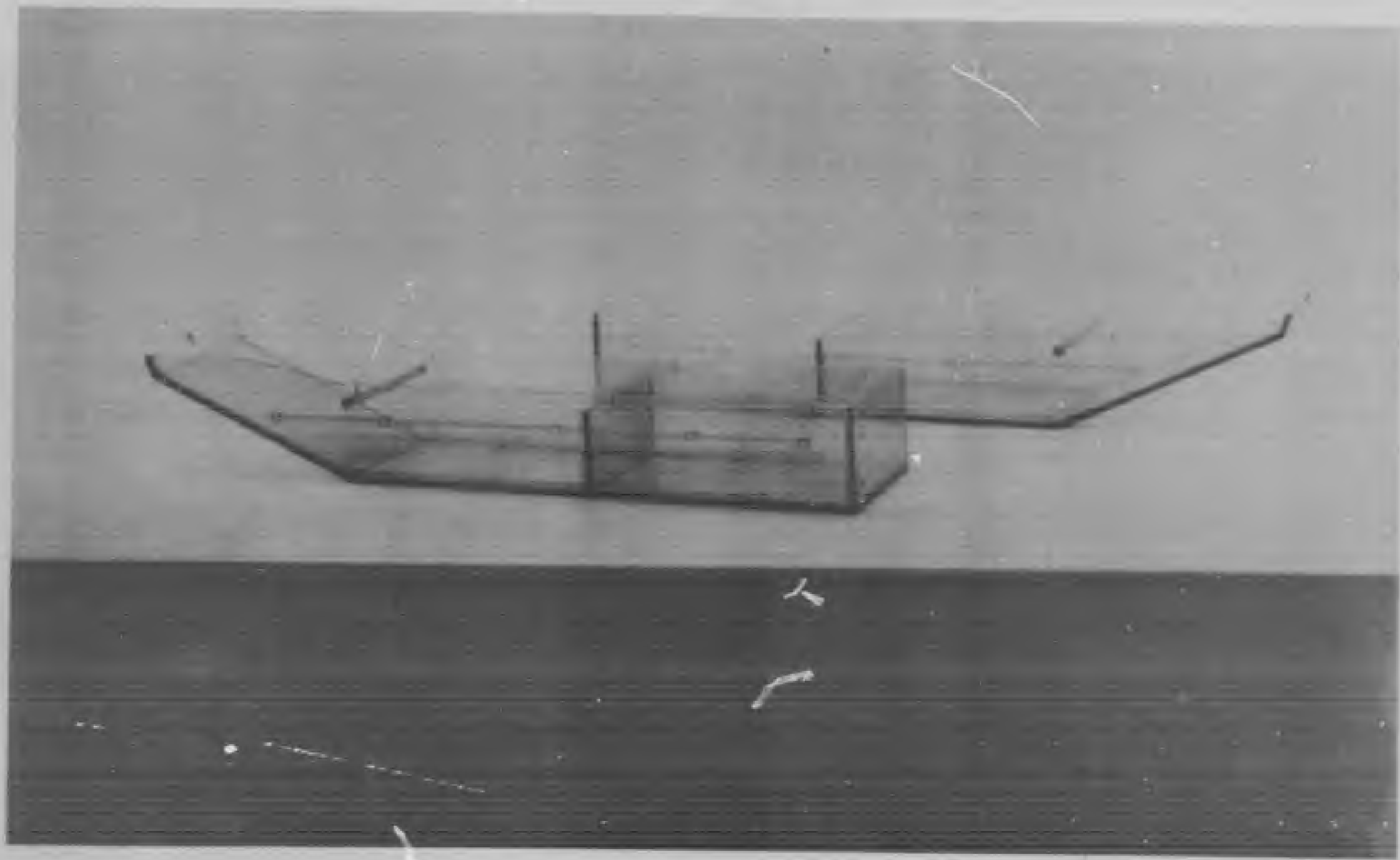


FIG. 92. DETAILS OF GERMAN PONTON

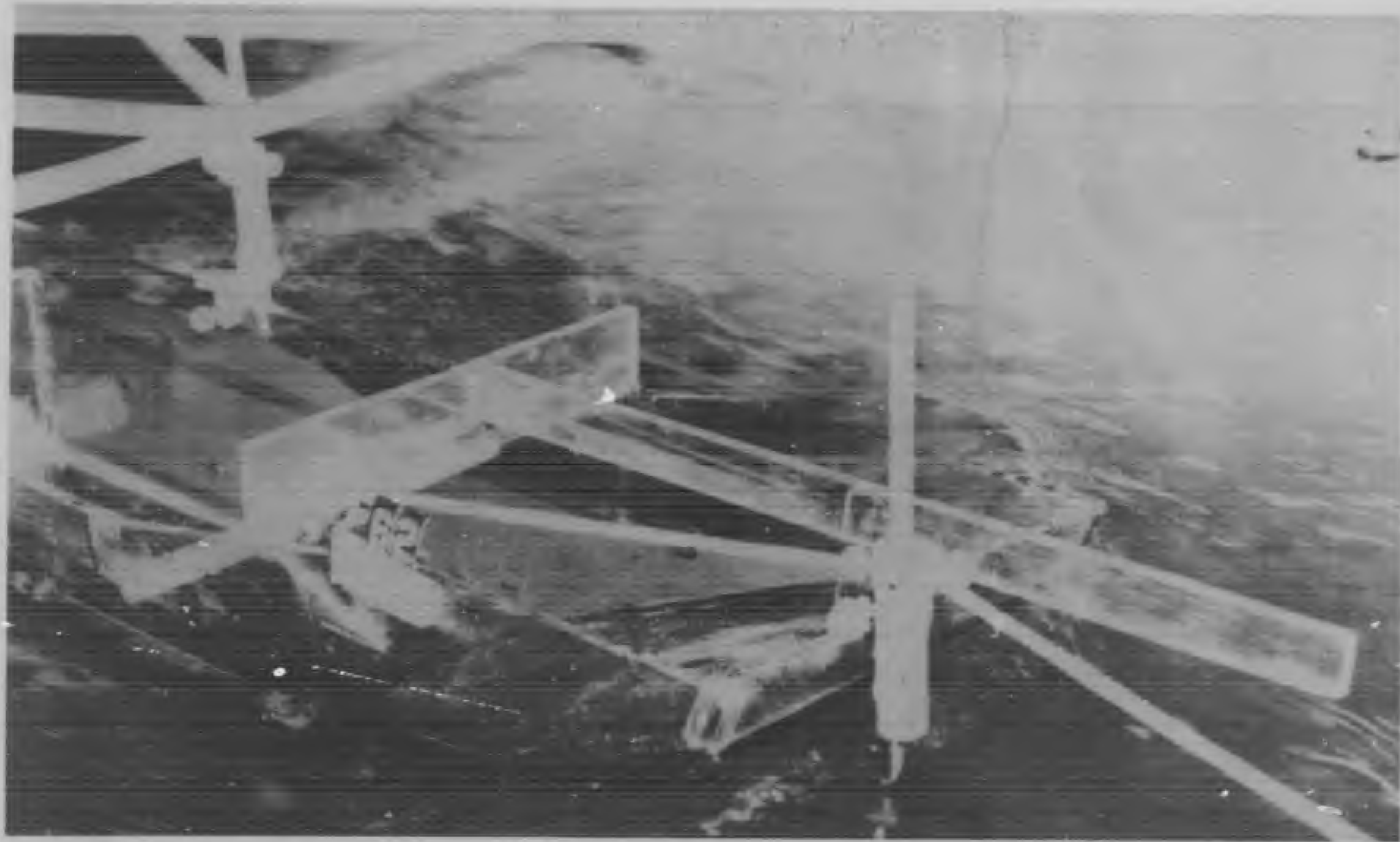


FIG. 93. FLOW CONDITIONS FOR GERMAN PONTON. Freeboards for velocity of 7.35 feet per second and 10-inch loading. Bow - 15.9 inches; side - 8.0 inches.

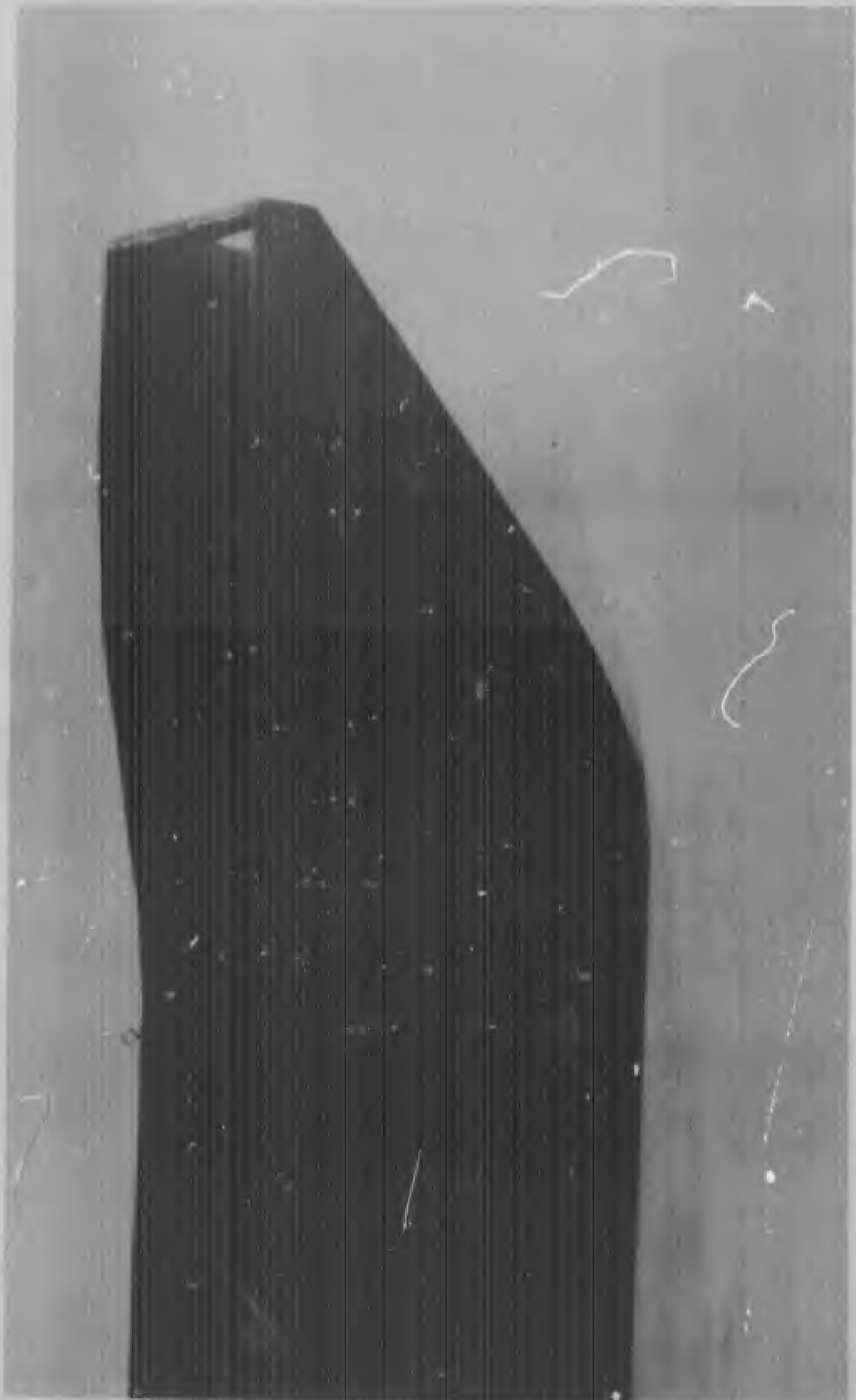


FIG. 94. DETAILS OF THE REVISED DESIGN PONTON

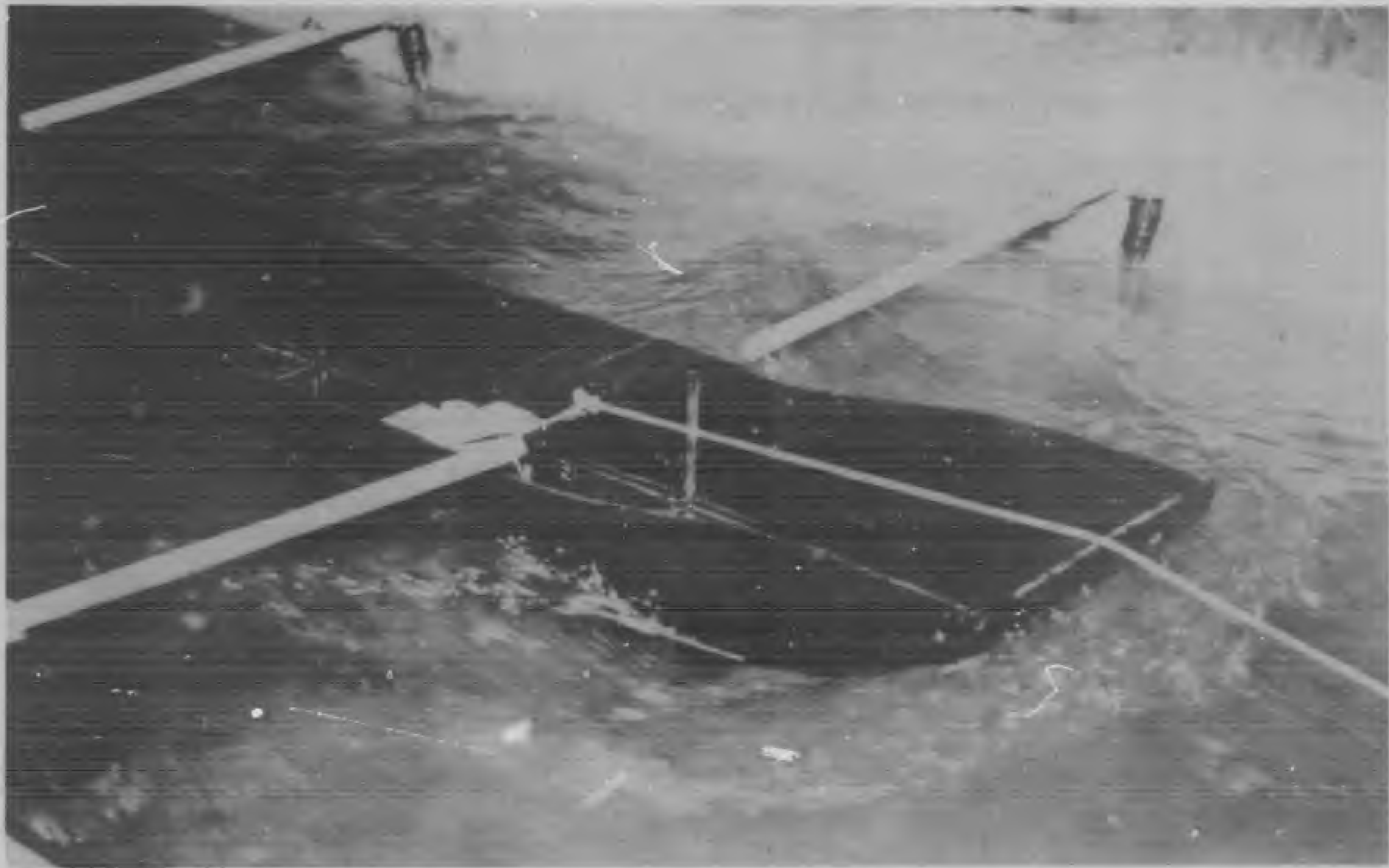


FIG. 95. FLOW CONDITIONS FOR REVISED DESIGN PONTON. Average freeboards for velocity of 7.3 feet per second and 10.75-inch loading. Bow - 12.10 inches; side - 8.26 inches.

FIG. 96. DETAILS OF AMERICAN M-1 TYPE PNEUMATIC FLOAT

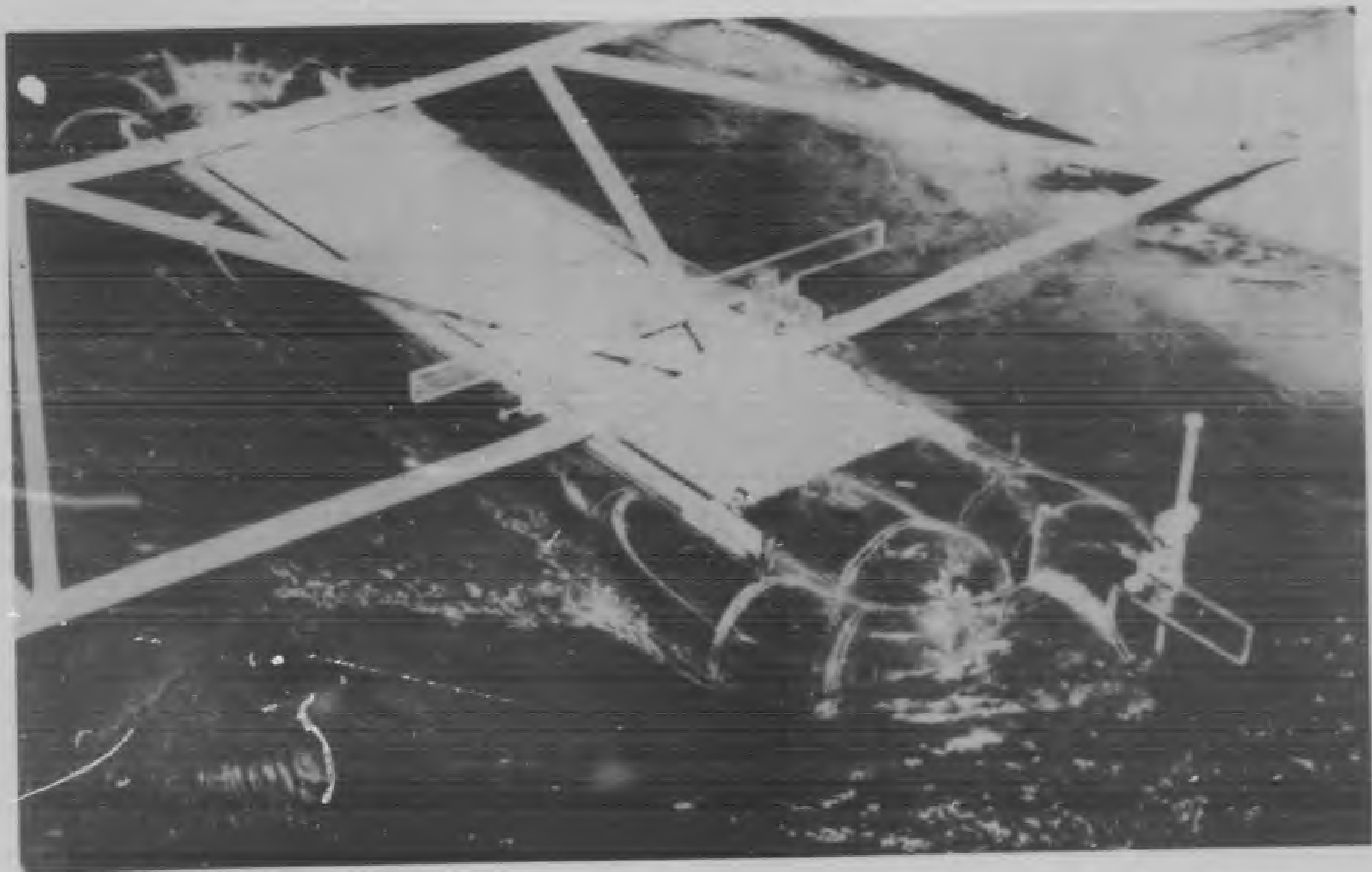


FIG. 97. FLOW CONDITIONS FOR AMERICAN M-1 TYPE PNEUMATIC FLOAT. Freeboards for velocity of 7.27 feet per second and 10-inch loading. Bow - 11.7 inches; side - 7.3 inches.

APPENDIX E

BALK AND RAFT CONNECTORS

BALK:

This balk connector has been designed to be used with a standard 8-inch WF 17# beam.

CONNECTOR FEATURES:

The balk can be separated in any direction.
Loose parts consist of two pins.
It can be assembled to be used as a hinged joint.
Ends of balk are not interchangeable.
Articulation can be provided for in pin holes.

CONNECTOR OPERATION:

To assemble the balk, their ends are brought opposite one another. The two locking pins are removed from their carrying holes, thereby allowing the swinging links to be turned to a horizontal position.

The balk are shifted until holes are alined then the pins are inserted to lock the unit together. Note that one lug on the locking pin is used to prevent the link from turning, thus developing shear, while the other lug receives tension or compression under an imposing moment. The shear lug holes has been elongated to prevent stress from being developed in the tie plate used to connect the shear lug and the locking pin.

The balk connection can be changed from a moment joint to a hinge joint by removing lower locking pin and turning free link back into the balk.

Connector assembled as a moment joint.

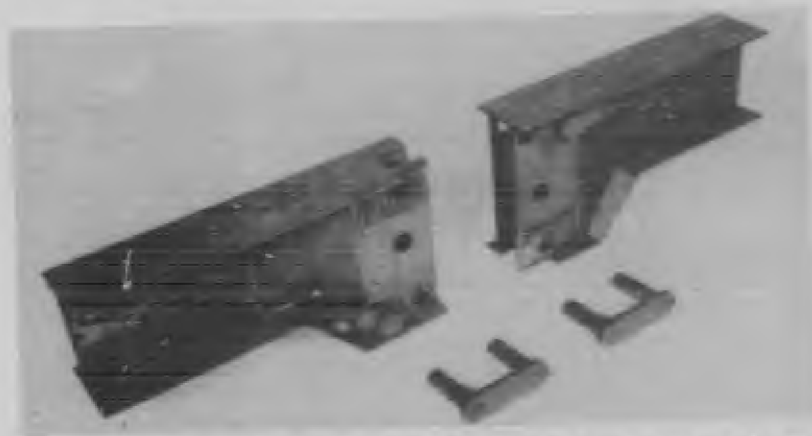
Connector assembled as a hinged joint.

FIG. 98. E-1 8-INCH WF CONNECTOR, TYPE I

Connector assembled as a moment joint. Note the use of spring retaining clips to hold the locking pins in place.

When links are turned into balk ends, locking pins and lugs may be placed in carrying holes provided for this purpose.

Locking pins and shear lugs have been removed and balk are separated longitudinally without turning links into balk ends. Links are tapered to aid in making a connection.



Locking pins and shear lugs are removed and links are turned into balk ends by operating link handles. Balk are now free to be separated in any direction.

FIG. 99. E-1 8-INCH WF CONNECTOR, TYPE I

BALK:

This balk connector has been designed to be used with a 10-inch Channel at 15.3#.

CONNECTOR FEATURES:

The joint will only permit the balk to be separated longitudinally.

It cannot be used as a hinged joint.
Ends of balk are not interchangeable.
Loose parts consist of one pin.
Articulation can be provided for in pin holes.

CONNECTOR OPERATION:

To assemble balk, balk ends are brought together so that yoke ended balk engages lugs on adjoining balk, Pin holes are alined and locking pin is inserted.

The balk proper is formed of two channels which are separated by folding type diaphragms. For transporting, the channels are folded together.

Balk alined for joining. Note that channels of adjoining balk are not in direct alignmont after being assembled.

FIG. 100. E-2 BALK CONNECTOR

BALK:

This balk connector has been designed to be used with a 10-inch 15# Beam.

CONNECTOR FEATURES:

The joint will only permit the balk to be separated longitudinally.
It cannot be used as a hinged joint.
Ends of balk are interchangeable.
Loose parts consist of two pins.
Articulation can be provided for in pin holes.

CONNECTOR OPERATION:

The balk connector is joined by first placing the balk end to end and then alining the pin holes. The two locking pins are inserted and the balk are locked together.

The balk proper is formed of two I-beams which are separated by folding type diaphragms. For transporting, the I-beams are folded together.

Balk ready to be placed in bridge superstructure. Each end of the balk has a male and female joint.

Balk in the opened and closed positions.

FIG. 101. E-3 BALK CONNECTOR

BALK:

This balk connector has been designed to be used with a standard 8-inch WF 17# Beam.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

Loose parts consist of 4 pins, 1 bolt and nut, 2 splice channels, and two hinge channels.

All parts provided will permit the assembly of a hinged or moment joint.

Ends of balk are interchangeable.

CONNECTOR OPERATION:

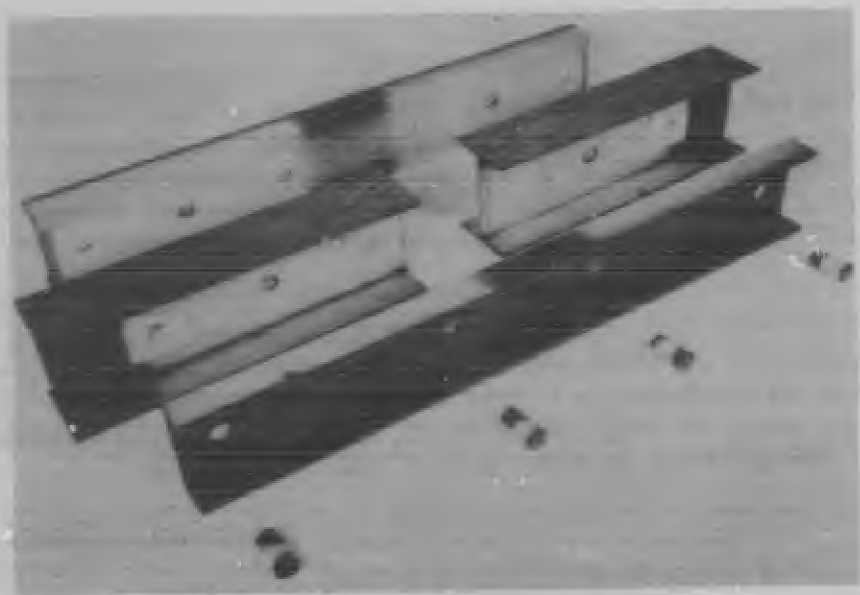
The moment joint is formed by placing two channel fish plates back to back and pinning them to the web of the balk proper. Two pins are required on each balk end. To secure these splicing channels in place, a bolt can be inserted through the web a nut screwed on to pull the channels together.

The hinge joint can be assembled by attaching two hinge channels back to back against the web of one balk end. These are secured with two pins. Another hole located on the forward end of hinge channels is placed in line with end hole in opposite balk and hinge pin is inserted.

Channel fish-plates connected to balk by four pins to form a fully continuous balk.

Hinge channels connected to balk to form a hinged joint.

FIG. 102. E-4 8-INCH WF BALK CONNECTOR



Splicing channels removed from balk to show details of fabrication. Note that flanges of channels do not contact flanges of balk, thereby allowing pins to receive entire moment.

Special hinge channels are attached to one balk by two pins and to the other by one pin. This type of hinge will only allow the balk to hinge in one direction.

FIG. 103. E-4 8-INCH WF BALK CONNECTOR

BALK:

This balk connector has been designed to be used with an 18-inch depth aluminum balk designed by Howard, Needles, Tammen, and Bergendoff. The balk is a built-up lattice type truss using special extrusions for the upper and lower chords.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in all directions.

Ends of balk are not interchangeable.

It cannot be assembled to be used as a hinged joint.

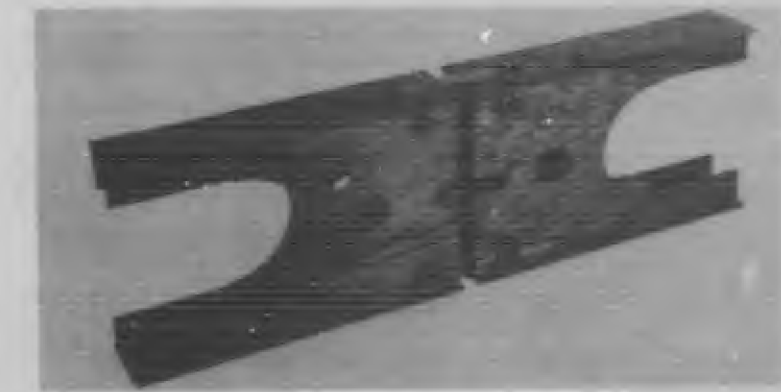
Articulation can be provided for in pin holes.

Loose parts consist of two pins.

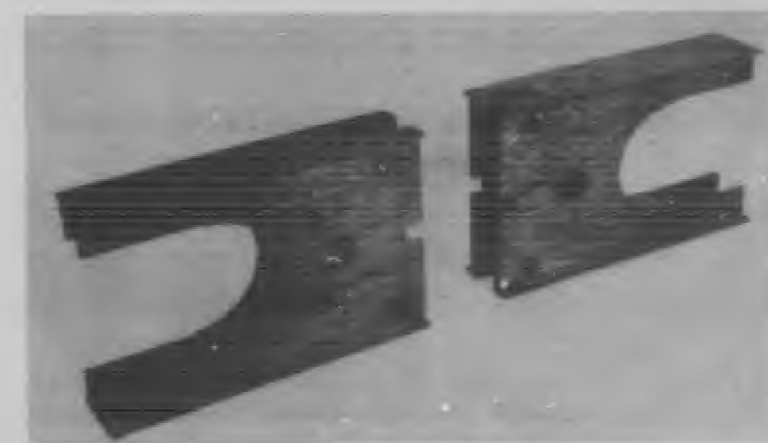
CONNECTOR OPERATION:

The joint is formed of two swinging links which are attached to one end of the balk. These links are swung to a horizontal position and moved to engage a female joint on another balk. Two pins secure these links when pin holes are alined.

The shear in the joint is carried by a shear lug which is mounted on a baffle plate which slides in guide blocks. To engage the shear lug with the slot provided for it in the other balk, the baffle plate is moved forward in its slide.



Connector assembled as a moment joint.



Swinging links turned back into balk and shear lug withdrawn.

FIG. 104. E-5 18-INCH ALUMINUM BALK CONNECTOR

BALK:

This balk connector has been designed to be used with an 18-inch depth aluminum balk designed by Howard, Needles, Tammen and Bergendoff. The balk is a built-up lattice type truss using special extrusions for the upper and lower chords.

CONNECTOR FEATURES:

The balk may be separated in any direction.
It can be assembled to be used as a hinged joint.
Ends of balk are interchangeable.
Loose parts consist of three pins.
Articulation can be provided for in pin holes.

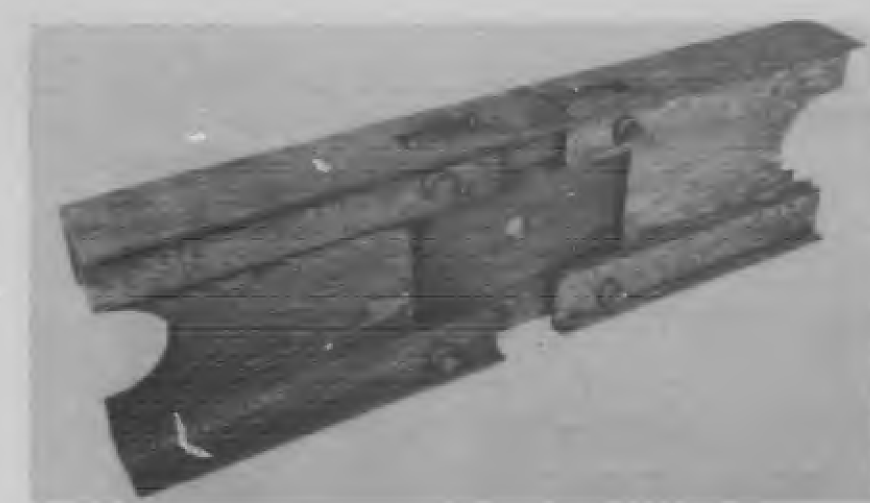
CONNECTOR OPERATION:

To assemble the joint, the balk ends are brought opposite one another. The three pins holding the swinging panel are removed and the panel is turned to engage the female end of the adjoining balk.

The balk ends are shifted to aline the holes, and pins are inserted locking the balk together.

To change the balk to a hinged joint, one of the lower pins can be removed.

In the construction of hinge span rafts, an alternate method of hinging may be employed. This method would utilize a separate hinge panel, which would be attached to a balk end and would pivot about a shaft passing through the swinging panels of adjoining balk.

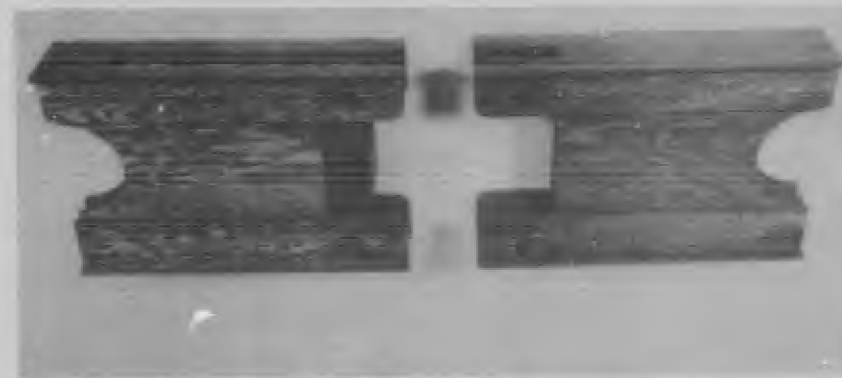


Connector assembled as a moment joint.

By removing two pins, balk may be separated. Note that male and female connectors are chamfered to aid in assembling the balk.

FIG. 105. E-6 18-INCH ALUMINUM BALK CONNECTOR

When three pins are removed, the moment panel may be turned back into the balk.



The moment panel has been turned back into the balk and the three pins inserted to secure the panel in place.

Special hinge panel attached to balk to form a hinged joint.

Hinge panel can be removed from balk by withdrawing two pins. Note that a special shaft is required with this joint.

FIG. 106. E-6 18-INCH ALUMINUM BALK CONNECTOR

BALK:

This balk connector has been designed to be used with an 8-inch WF at 17# Steel Beam (25-ton steel ponton balk).

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It has been designed to develop the full strength of the balk.

It cannot be used as a hinged joint.

Ends of balk are not interchangeable.

Loose parts consist of two pins.

Articulation cannot accurately be provided for.

CONNECTOR OPERATION:

To assemble connector, balk ends are brought end-to-end and sliding channels located between the flanges of the balk are moved forward to telescope into the opposite balk.

The balk and sliding channels are shifted until locking holes are alined. Locking pins are then inserted. Note that pins merely serve to lock the balk together and are not intended to receive any stress.

When uncoupling the balk, the connector sliding beams may be left extended or they may be moved back until their tips do not extend beyond the end of the balk.

Balk connector assembled and locking pin inserted to lock the joint together.

Single locking pin removed and connector separated.

FIG. 107. E-7 8-INCH WF BALK CONNECTOR

BALK:

This balk connector has been designed to be used with a standard 8-inch WF 17# Beam.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It cannot be used as a hinged joint.
Ends of balk are interchangeable.
Loose parts consist of one pin.
Articulation can be provided for in pin holes.

CONNECTOR OPERATION:

To assemble connector, balk ends are brought opposite one another and connecting links are turned to a horizontal position. These links are automatically held in this position by spring catches which prevent link operating handles from turning.

The two balk are shifted longitudinally to aline holes in links with holes in balk ends and locking pin is inserted.

Note that the shear in the joint is developed by a center pin fitting into cutouts in the web of the balk.

Balk connector assembled.

Locking pin removed and balk separated. Links exposed in this view may be turned back into balk by operating handles.

FIG. 108. E-8 8-INCH WF BALK CONNECTOR, TYPE II

BALK:

This balk connector has been designed to be used with an 18-inch depth aluminum balk designed by Howard, Needles, Tammen and Bergendoff. The balk is a built-up lattice type truss using special extrusions for the upper and lower chords.

CONNECTOR FEATURES:

There are no loose parts used with this connector, for it is entirely self-contained.

The joint will permit the balk to be separated vertically only.

It cannot be used as a hinged joint.

Articulation can be provided for in pin holes.

Ends of balk are not interchangeable.

CONNECTOR OPERATION:

To assemble connector, balk ends are brought together with the male joint end held high. The balk are pushed together so that the pin on top of the male balk drops behind lugs of female end and hook on lower male end passes over and around rotating pin at bottom of female end. This rotating pin is cam-shaped so that as it is turned it pulls up tight against lower hook on male end. The rotating pin is turned by means of a hand operated lever, which in turn operates a gear mechanism coupled directly to the pin.

The purpose of the gear mechanism is to allow the pin to rotate through a greater degree than the operating handle.

Balk connector completely assembled as a moment joint. Cam operating handle is held forward by a spring clip on the side of the balk.

View showing gear mechanism which turns the locking cam.

FIG. 109. E-9 18-INCH ALUMINUM BALK CONNECTOR

BALK:

This balk connector has been designed to be used with standard 25-ton steel ponton balk. (8" W. F. 17# Beams)

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It can only be used as a hinged joint.

Joint parts can readily be fitted to ends of unmodified standard balk.

Each joint is comprised of nine loose parts.

CONNECTOR OPERATION:

Hinge plates are attached to balk ends by slipping them behind vertical hanger bars on balk ends. Female plates are placed on one balk and male plates on the other balk.

Toggle bolts are then inserted and tightened thus locking hinge plates securely to balk.

The balk ends are shifted until holes are alined and then hinge pin is placed.

Hinge joint assembled.

Hinge pin removed and balk separated.

FIG. 110. E-10 8-INCH WF BALK CONNECTOR

Hinge brackets are hooked behind vertical hanger bars.

Toggle bolts removed to allow brackets to be unhooked from balk.

FIG. 111. E-10 8-INCH WF BALK CONNECTOR

BALK:

This balk connector has been designed to be used with a deck type aluminum balk designed by Sparkman and Stephens.

CONNECTOR FEATURES:

Continuity is obtained by attaching balk to both gunwales of pontons.

No provision has been made for a hinged joint.

Ends of balk are interchangeable.

Gunwales of pontons are used to effect a couple between balk.

The joint will permit the balk only to be separated vertically.

No loose parts are utilized in this joint other than the gunwales of the pontons.

CONNECTOR OPERATION:

Balk are equipped with mounting lugs which are spaced so that they will engage a special gunwale adaptor. The balk are placed so that they overlap side by side and are each pinned to the gunwales, thus providing a couple.

Balk connected to gunwale of ponton.

Balk removed from gunwale thus showing the pin used to lock thebalk in place.

FIG. 112. E-11 DECK-TYPE ALUMINUM BALK CONNECTOR

BALK:

This balk connector has been designed to be used with a built-up warren type truss balk.

CONNECTOR FEATURES:

The balk can be separated longitudinally only.
Loose parts consist of two pins.
It cannot be used as a hinged joint.
Articulation can be provided for in pin holes.
Ends of balk are interchangeable.

CONNECTOR OPERATION:

The balk ends are brought opposite one another and the holes are alined. The locking pins are inserted and the joint is fully coupled.

Complete balk showing details of construction. Note that balk ends are fully reversible.

FIG. 113. E-12 WARREN TYPE TRUSS BALK CONNECTOR

BALK:

This balk connector has been designed to be used with the standard 10-ton wood ponton balk.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It cannot be used as a hinged joint.

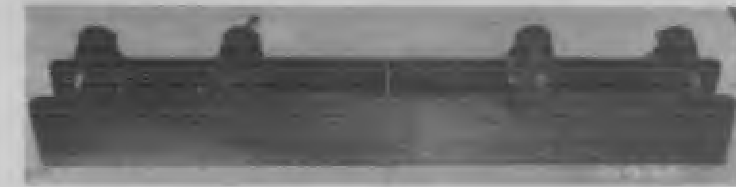
Loose parts consist of connector body, four pins and four pad plates.

Articulation cannot be accurately provided for.

Ends of balk are interchangeable.

CONNECTOR OPERATION:

To assemble connector, balk are brought together end to end and connector body is placed over balk. Pad plates and pins are then placed, thus locking balk together to form a continuous beam.



Balk connector assembled for transporting.

Two ponton balk inserted in connector to form a co tinuous beam.

FIG. 114. E-13 WOOD PONTON BALK CONNECTOR

BALK:

This balk connector has been designed to be used with an 18-inch depth aluminum balk designed by Howard, Needles, Tammen & Bergendoff. The balk is a built-up lattice type truss using special extrusions for the upper and lower chords.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It can be assembled to be used as a hinged joint.

Ends of balk are interchangeable.

Loose parts consist of two pins.

Articulation can be provided for in pin holes.

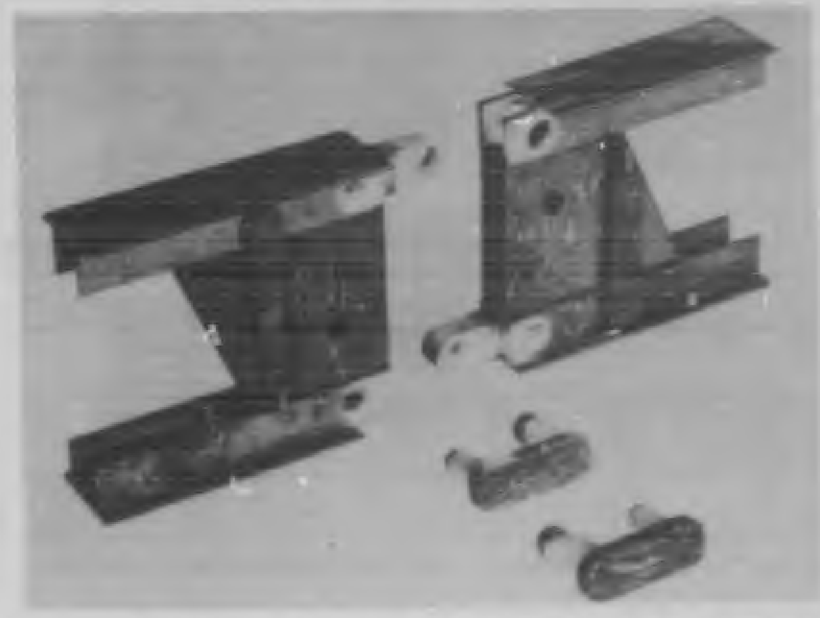
CONNECTOR OPERATION:

To assemble connector, balk ends are brought opposite one another and the two locking pins are removed from their carrying holes. Their removal will allow the swinging links to be turned to a horizontal position.

The balk are shifted until holes are alined and pins are inserted to lock the unit together. Note that one lug on the locking pin is used to develop shear in the joint, while the other receives tension or compression under an imposing moment. The shear lug hole is elongated to prevent stress from being developed in the tie plate used to connect the shear lug and the locking pin.

To change the balk connection from a moment joint to a hinged joint, the lower locking pin is removed, and the free link is turned back into the balk.

Balk connector assembled.



Locking and shear pins removed, allowing balk to be separated. Exposed links can be turned back into balk ends by operating link handles.

FIG. 115. E-14 18-INCH ALUMINUM BALK CONNECTOR

Links turned back into balk ends and locking pins inserted in carrying holes.

Lower locking pin removed to form a hinged joint. This loose pin may be inserted in carrying holes.

FIG. 116. M-14 18-INCH ALUMINUM BALK CONNECTOR

BALK:

This balk connector has been designed to be used with a standard 8-inch WF 17# Beam.

CONNECTOR FEATURES:

The balk can be separated vertically and horizontally.

The connector is comprised of no loose parts.

It cannot be used as a hinged joint.

Shear and moment in the joint is carried by two pins.

Articulation has been provided for in pin holes

CONNECTOR OPERATION:

The balk are joined by grasping handles and pulling pins out and then sliding balk together. When holes are alined, the pins are pushed or driven in, thus securing the two balk together.

The balk connector was originally designed with a spring which held pins in place; however, this feature did not prove practical.

FIG. 117. E-15 8-INCH WF BALK CONNECTOR, TYPE IV

Balk fully connected.

Pins withdrawn and balk pulled apart.

BALK:

This balk connector has been designed to be used with a standard 8-inch WF 17# Beam.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It can be assembled to form a fully continuous beam.

Ends of balk are interchangeable.
No provision has been made for shear.
It cannot be used as a hinged joint.
Articulation cannot accurately be provided for.

CONNECTOR OPERATION:

To assemble connector, balk ends are brought together and links are placed over lugs attached to ends of balk. These links may be of any length and may be used to join several balk together at the same time.

A drift type wedge is then inserted through a hole in top link and driven down, forcing links to engage and seize the balk lugs.

Balk connector completely assembled to receive moment.

Balk connector being assembled. Note that links may be moved laterally to disengage lugs on balk.

FIG. 118. E-16 8-INCH WF BALK CONNECTOR

BALK:

This balk connector has been designed to be used with an 18-inch depth aluminum balk designed by Howard, Needles, Tammen, and Bergendoff. The balk is a built-up lattice type truss using special extrusions for the upper and lower chords.

CONNECTOR FEATURES:

The joint will permit the balk to be separated in any direction.

It can be assembled to be used as a hinged joint.

Ends of balk are not interchangeable.

Loose parts consist of two pins and a center balk panel.

Articulation can be provided for in pin holes.

CONNECTOR OPERATION:

To assemble connector for moment, center balk panel may be secured to one end of balk by two pins. This joint section is then connected to another balk by raising it so that lugs and lug catches will engage properly. After the section is in position, a lever located in the joint section is thrown thus rotating a cam which locks the balk together.

To assemble the connector to form a hinged joint, the lower pin is removed from the center balk panel, thereby allowing the balk to hinge on the remaining pin.

Balk connector completely assembled.

Balk disconnected by rotating cam operating lever.

FIG. 119. E-17 18-INCH ALUMINUM BALK CONNECTOR, TYPE II

Balk disconnected by removing two locking pins.

Center balk section removed by withdrawing two locking pins and rotating locking cam.

FIG. 120. E-17 18-INCH ALUMINUM BALK CONNECTOR, TYPE II

BALK:

This balk connector has been designed to be used with a standard 8-inch WF 17# Beam.

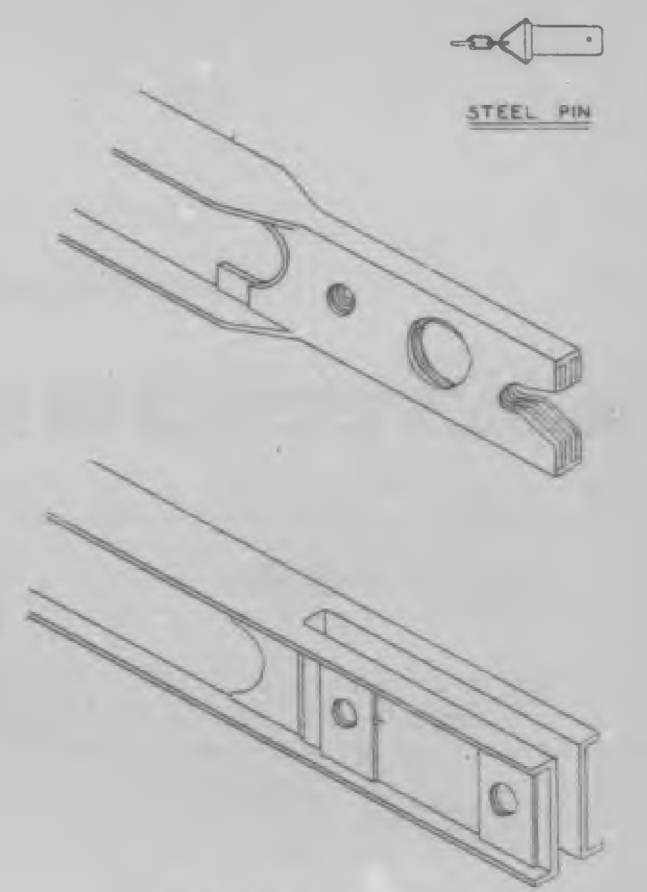
CONNECTOR FEATURES:

The balk can be separated vertically and horizontally.
The connector is comprised of two loose pins.
It cannot be used as a hinged joint.
Articulation has been provided in pin holes.
Balk ends are not interchangeable.

CONNECTOR OPERATION:

To assemble the connector, the male end is slipped into the female end and the two pins can be inserted to lock the sections together. The rear locking pin may be left in place during the assembly as the end male connection is yoked so that it may slip over the rear pin.

To disengage the balk horizontally only one pin need be removed. To disengage the balk vertically, two pins must be removed.



SINGLE BALK

TREADWAY TYPE CONNECTION

FIG. 121. E-18 8-INCH WF BALK CONNECTOR

BALK:

This connector has been designed to be used with the standard M1938 Footbridge; however, it could readily be adapted to any type of balk.

CONNECTOR FEATURES:

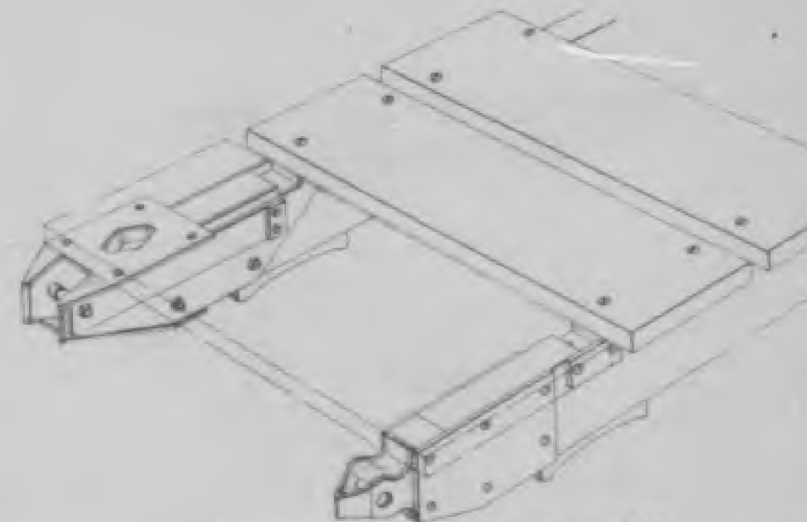
The connector can be separated vertically or horizontally.

It is entirely self-contained with no loose parts.

It can only be used as a hinged joint.

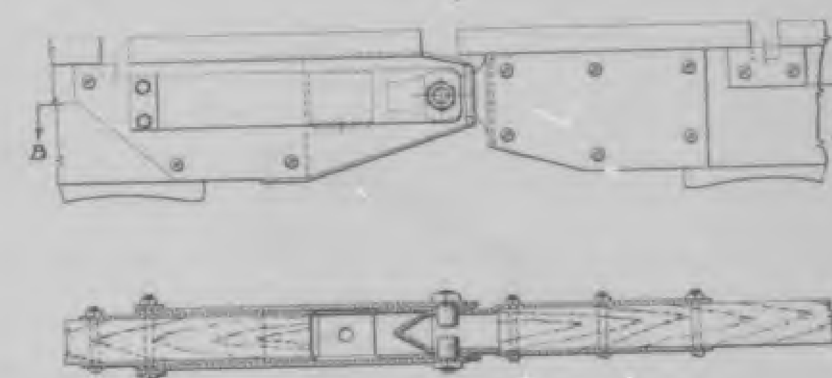
CONNECTOR OPERATION:

To connect joint, the wedge-shaped male fastening is forced between the lugs of the female fastening until the lugs snap into the holes in the sides of male fastening. The joint may be uncoupled by using a special fitting to pry open the female lugs to allow the male connection to be pulled free.



DUCKBOARD CONNECTORS - MODEL 1938

A1717-8



DUCKBOARD CONNECTOR, LATCHED - MODEL 1938

A1717-9

FIG. 122. E-19 M1938 FOOTBRIDGE CONNECTOR

BALK:

This balk connector has been designed to be used with a 12-inch aluminum WF beam.

CONNECTOR FEATURES:

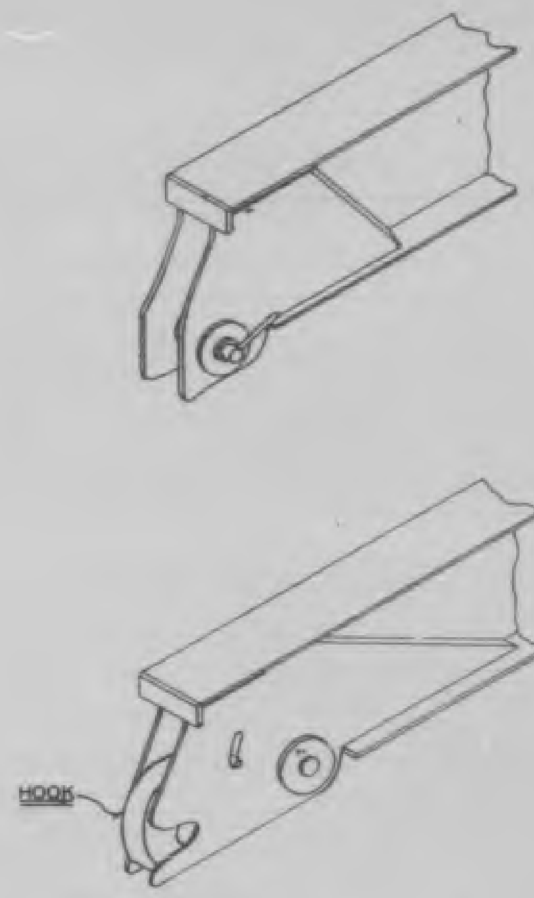
There are no loose parts used with this connector, for it is entirely self-contained.
The joint can only be separated horizontally
It cannot be used as a hinged joint.
Articulation can be provided for.
Ends of balk are not interchangeable.

CONNECTOR OPERATION:

To assemble the connector, the balk are brought end to end and with the hook raised are forced together. The drops and locks behind the pin on female end.

To disconnect balk, the hook is raised and the balk pulled apart.

Note that the connected balk will not take a negative moment as the top of the balk butts together.



SINGLE BALK
HOOK TYPE CONNECTION

FIG. 123. E-20 12-INCH ALUMINUM BALK CONNECTOR

BALK:

This method of connecting balk is used to secure 10-ton and 25-ton standard wood and steel ponton balk to standard ponton gunwales.

CONNECTOR FEATURES:

The balk can only be removed vertically.
It cannot be used as a hinged joint.
It is comprised of no loose parts.
Ends of balk are not interchangeable.
Articulation cannot be provided for.

CONNECTOR OPERATION:

Balk are placed so that they over lap across gunwales of one ponton. Balk fasteners located and mounted in pontons are hooked through metal straps fastened to balk. These fasteners lock the balk to he the gunwales.

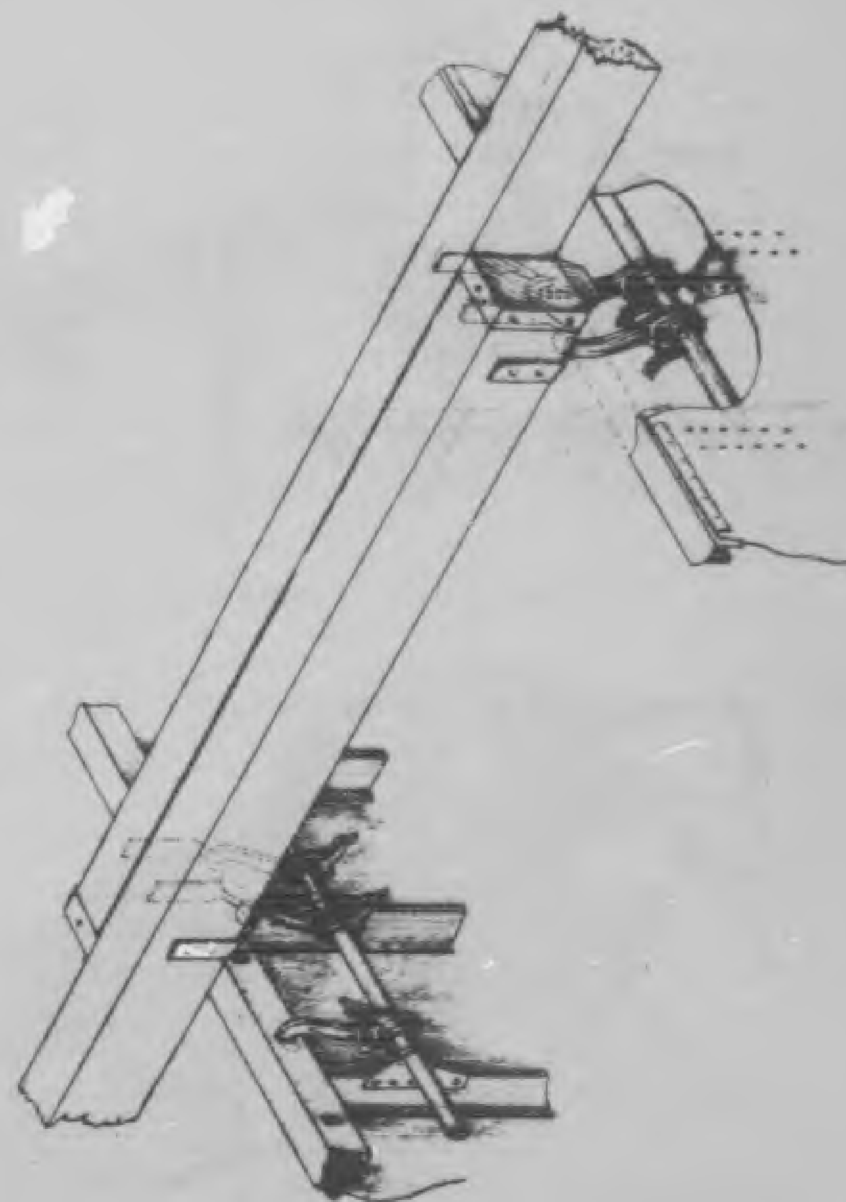


FIG. 124. E-21 10-TON AND 25-TON PONTON BALK CONNECTORS

BALK:

The primary function of this connector is to join one raft to another. To do this, it joins all balk in the span simultaneously to form a fully continuous superstructure.

CONNECTOR FEATURES:

The connector will permit the balk or raft to be separated in any direction.

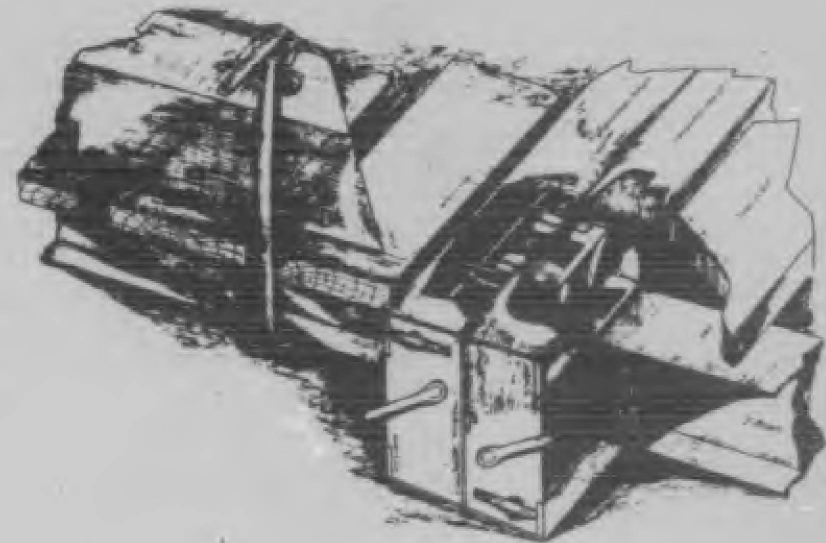
It cannot be used as a hinged joint.
It is comprised of no loose parts.
Ends of balk are not interchangeable.
Articulation can be provided for.

CONNECTOR OPERATION:

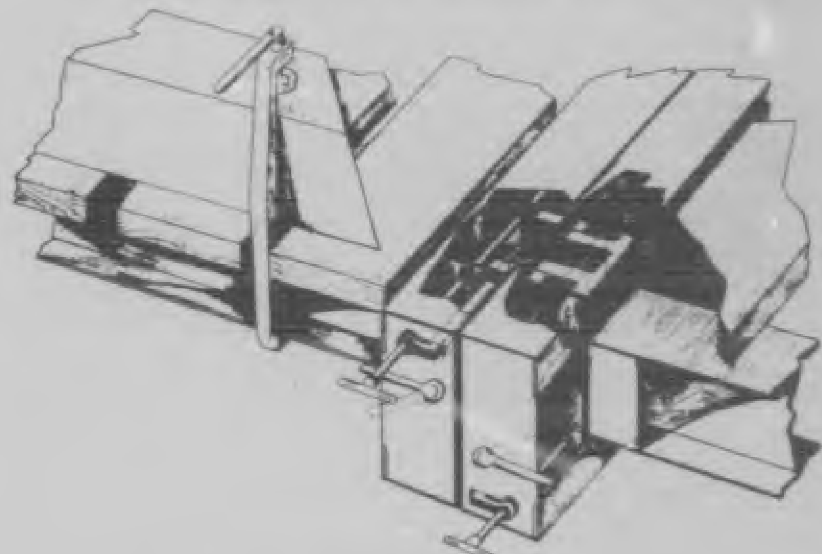
To install a connector, the balk are placed on the ponton and spaced so that their ends will enter the pocket of the connector. The pocket pins are removed and the connector is then pushed home on the balk ends; the holes in the balk and those of the connector pockets coinciding, the pins then will be inserted, connecting the balk to the connector.

To connect one raft to another, first, project the conical orienting pins in the connector of both the fixed or anchored section and the bay to be attached and butt both sections together. The conical pins will orient the openings for the latches. By means of a handled shaft, latches are projected into the openings of the adjoining connector. A sliding bar locks these latches closed.

To disconnect a bay, the foregoing procedure is reversed.

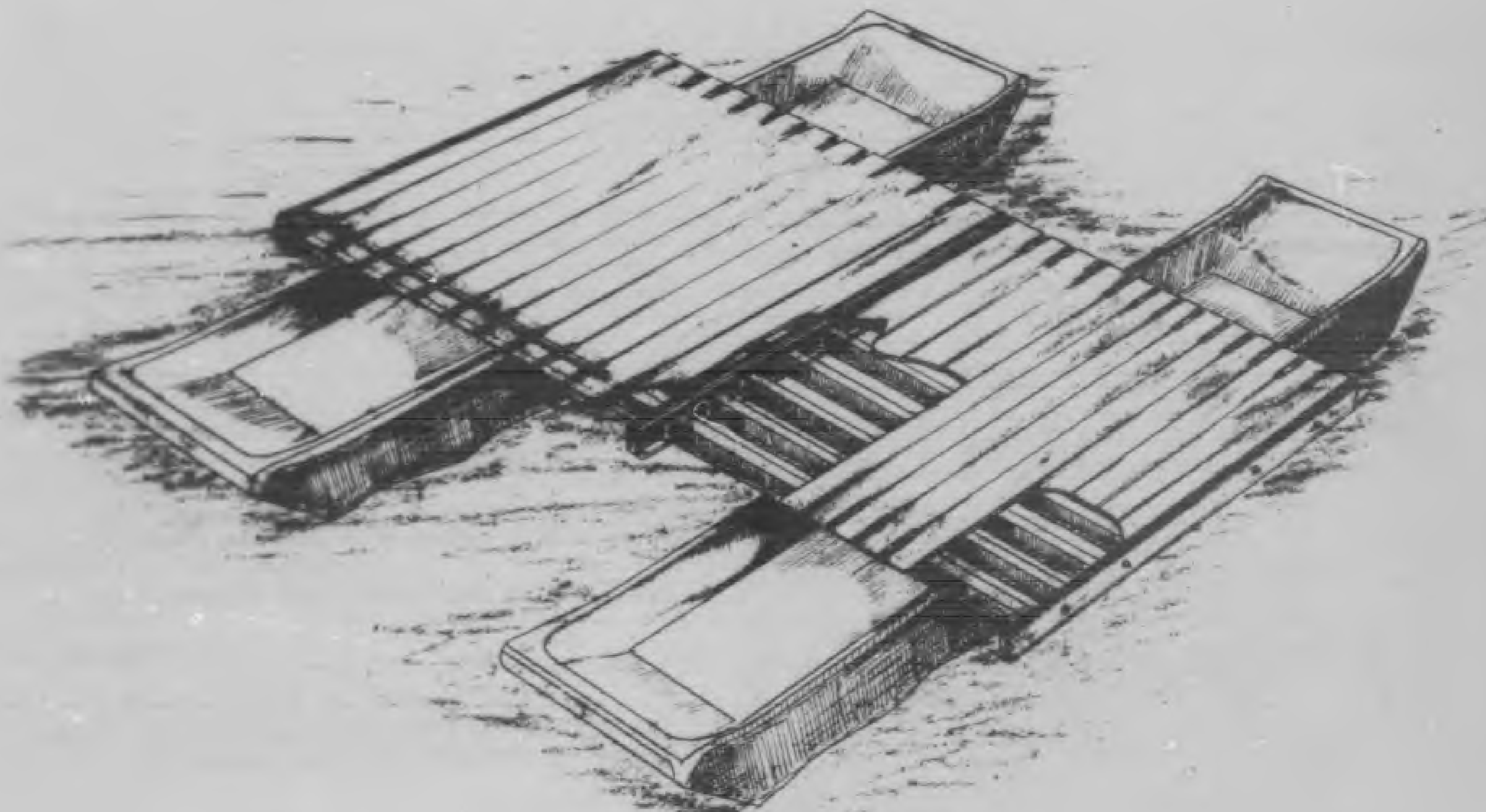


Raft Connector in Latched Position.



Raft Connector in Unlatched Position.

FIG. 125. E-22 RAFT CONNECTOR, TYPE I



Two-Bay Raft Assembled

FIG. 126. E-22 RAFT CONNECTOR, TYPE I

BALK:

This connector has been designed to permit all balk to be disconnected simultaneously, thereby allowing a bridge section to be removed easily.

CONNECTOR FEATURES:

The connector will permit the balk or raft to be separated in any direction.

It cannot be used as a hinged joint.

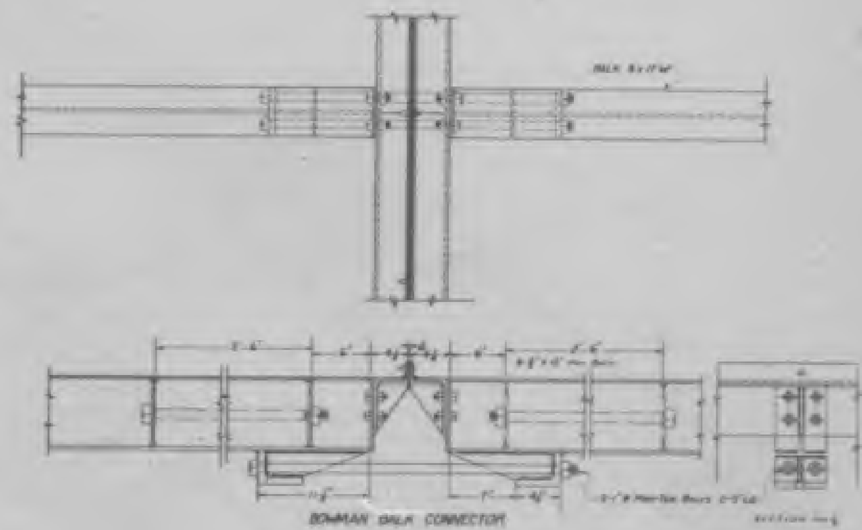
It is comprised of 20 one-inch bolts, eighty 5/8-inch bolts and 20 brackets.

Ends of balk are interchangeable.

Articulation can be provided for.

CONNECTOR OPERATION:

To install connector, balk are placed in a line evenly spaced and brackets are bolted to each balk by 5/8 bolts. When brackets are placed, raft sections can be placed end to end and secured by one-inch bolts which pass through to bolting brackets welded to each balk.



Ten-ton and 25-ton ponton balk connector completely assembled.

FIG. 127. E-23 RAFT CONNECTOR

APPENDIX F

SHORE CONNECTIONS

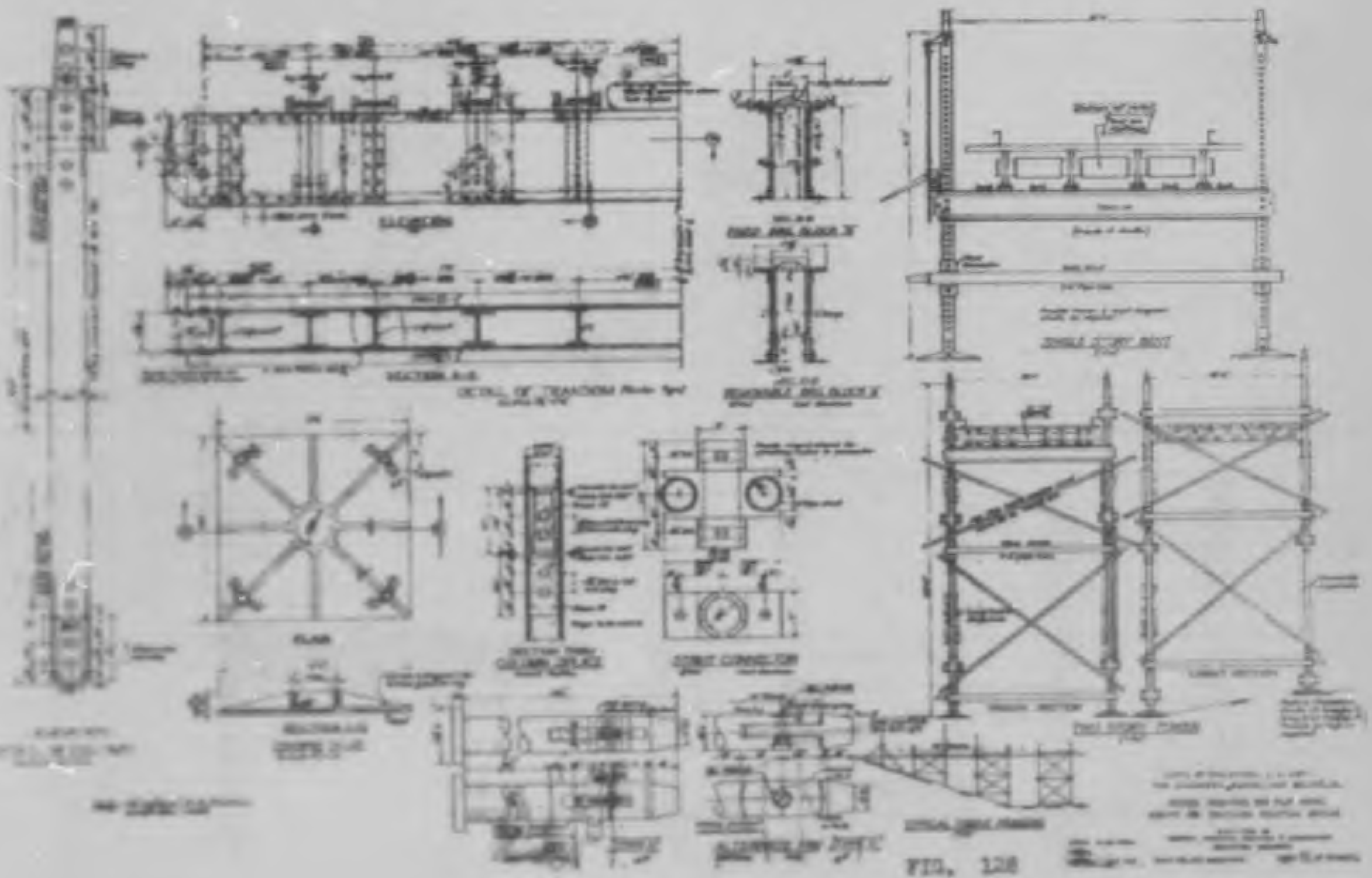


FIG. 128

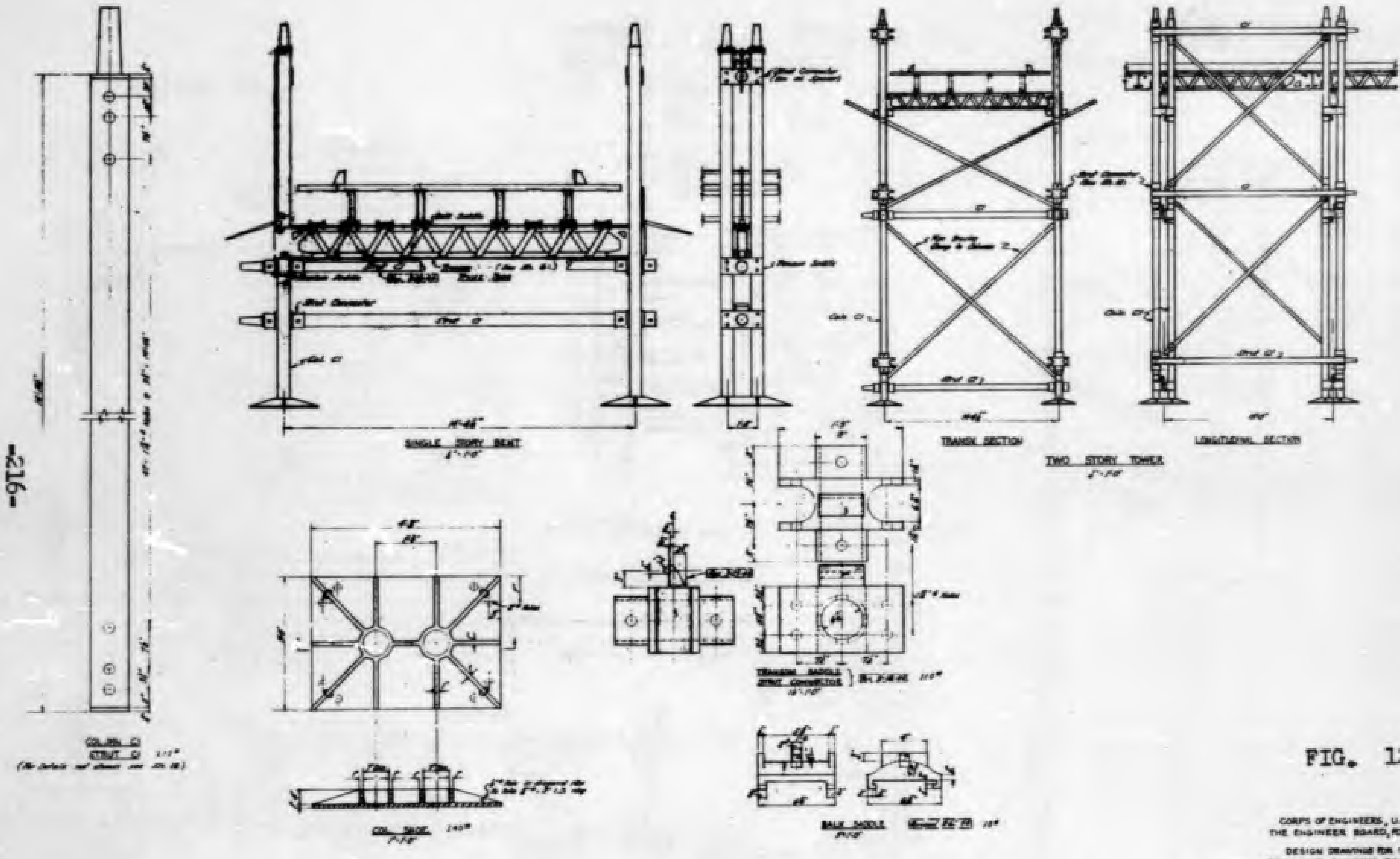


FIG. 129

CORPS OF ENGINEERS, U.S. ARMY.
THE ENGINEER BOARD, FORT BELVOIR, VA.
DESIGN DRAWINGS FOR PILOT MODEL
ARMY OR DIVISION PONTON BRIDGE

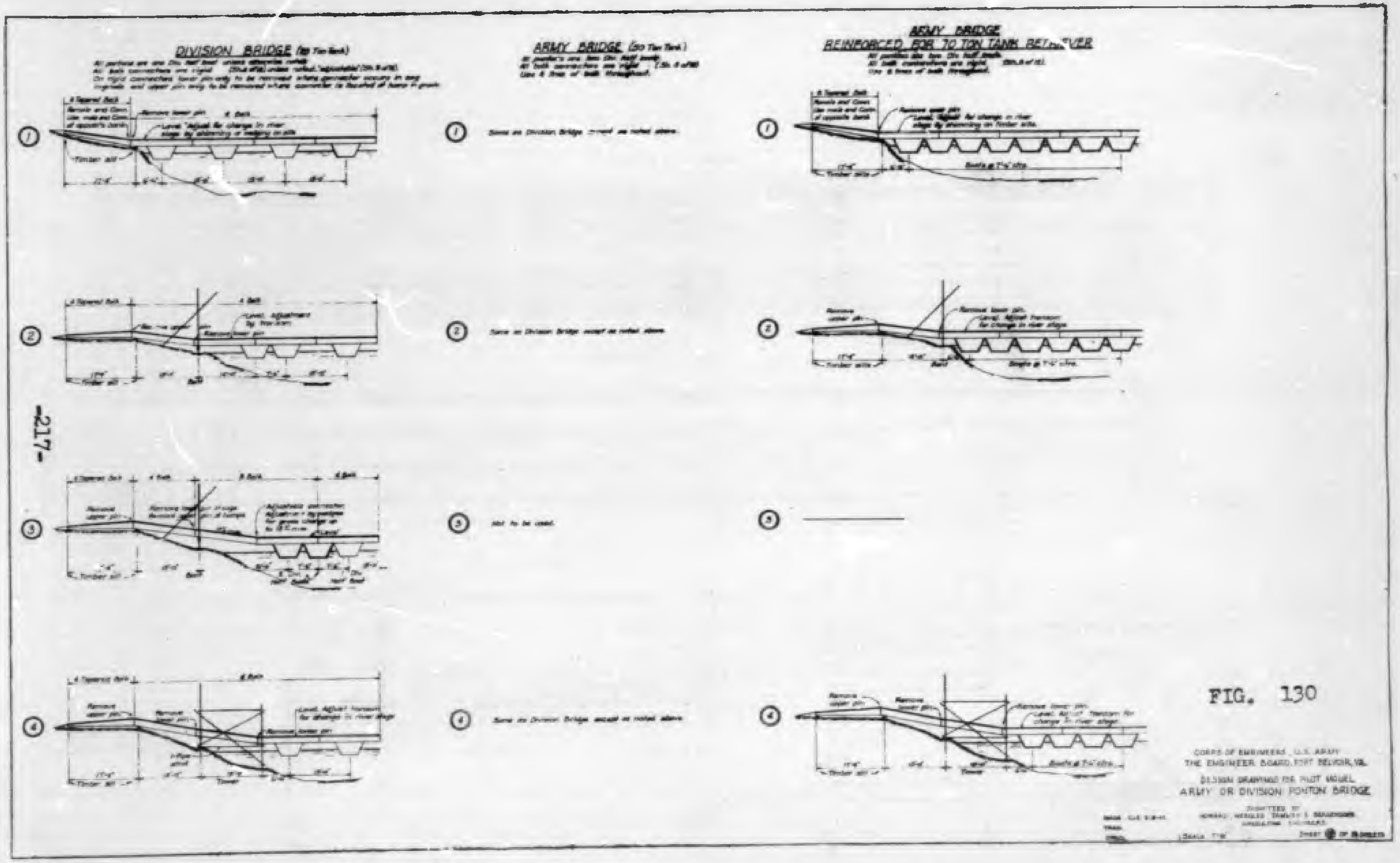

DIVISION BRIDGE
ARMY BRIDGE
ARMY BRIDGE
Same as Division Bridge except as noted above.
Not to be used.
CORPS OF ENGINEERS, U.S. ARMY
THE ENGINEER BOARD, FORT BELVOIR, VA.
DESIGN DRAWINGS FOR PILOT MODEL
ARMY OR DIVISION PONTON BRIDGE

FIG. 130

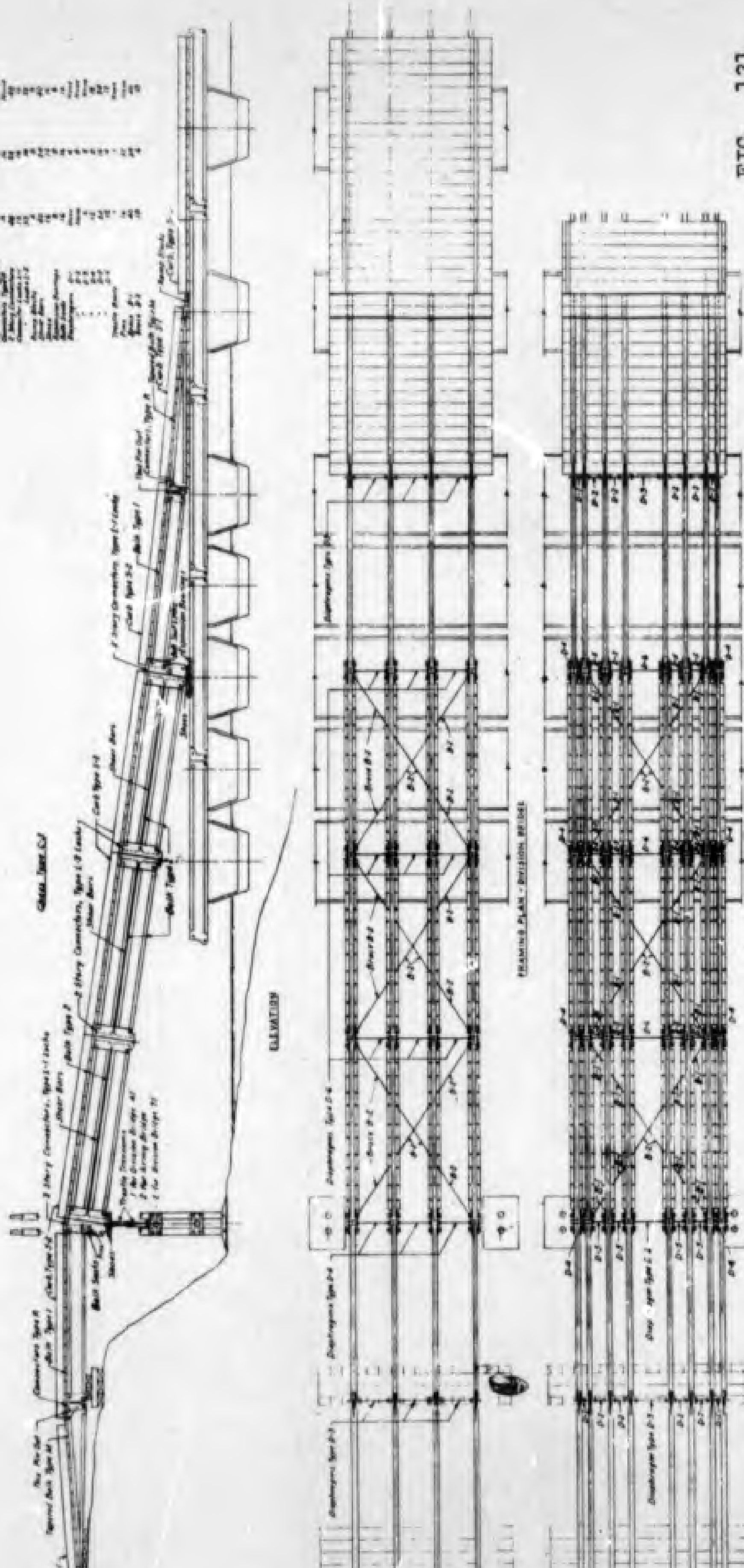


FIG. 131

CORPS OF ENGINEERS, U.S. ARMY
THE ENGINEER BOARD, FORT BELVOIR, VA
DESIGN DRAWING FOR PILOT MODEL
ARMY OR DIVISION PONTON BRIDGE

Landing Bay Span

Proposed by

Howard, Needles, Tammen and Bergendoff

This landing bay is a pin-connected pony truss adjustable for lengths of 16, 32, 48, 64, and 80 feet. A water level fluctuation of five feet is provided for under all loads including the 70-ton tank retriever. The whole span has 279 parts, there being only 13 different types, of which 6 types are used in the trusses. Floor beams, stringers, laterals, and bearings are uniform. Special parts include distributing beams required at the floating end, tapered balk, and curb of special length. All loads can be manhandled and the trusses can be erected on shore. The raft for support consists of five half-pontons for division loads and five full pontons for army loads.

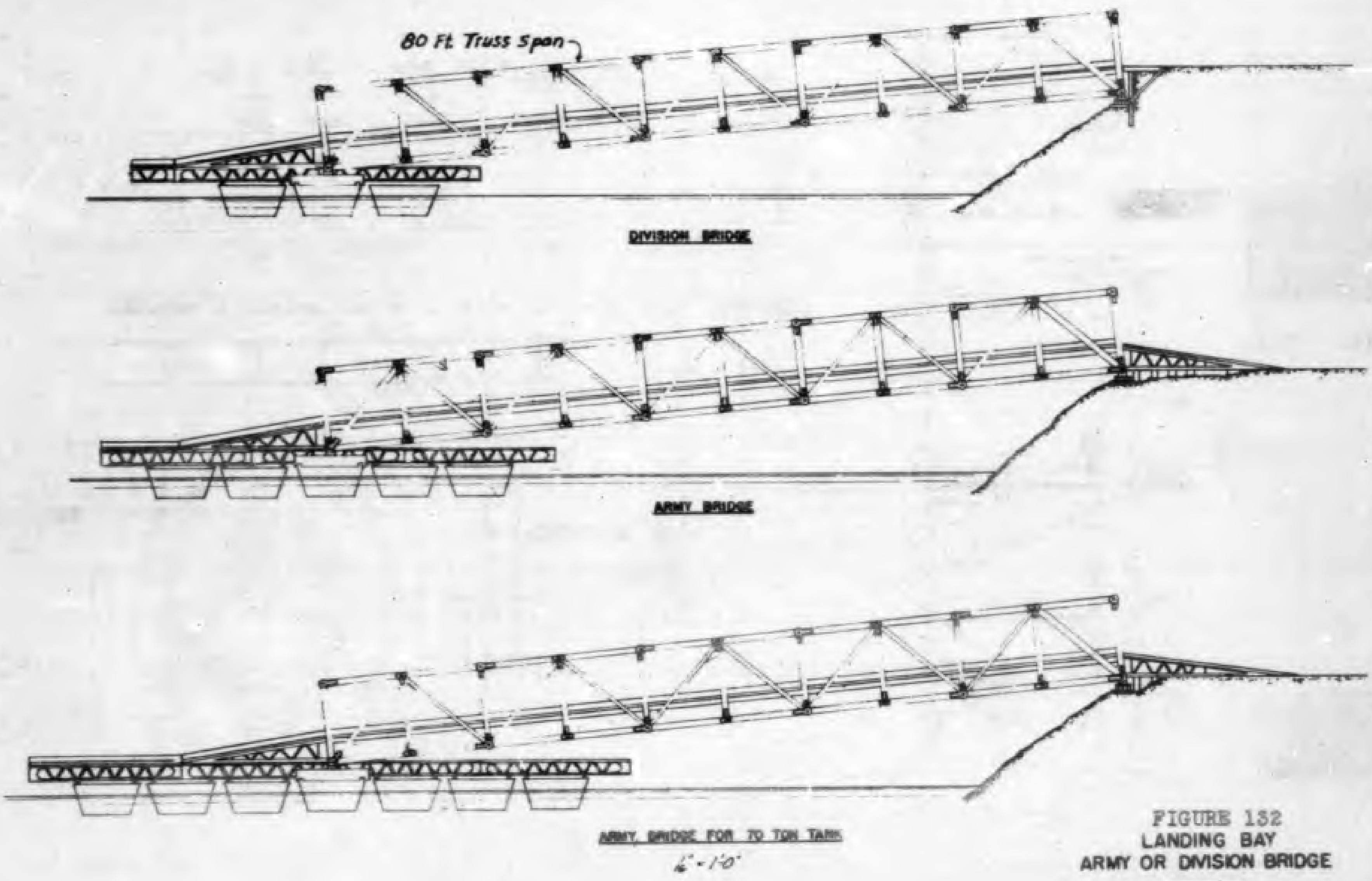


FIGURE 132
LANDING BAY
ARMY OR DIVISION BRIDGE

HOWARD, NEEDLES, TAMMEN & BERGENDOFF
CONSULTING ENGINEERS

DATE: 1-20-44 EXHIBIT NO.37

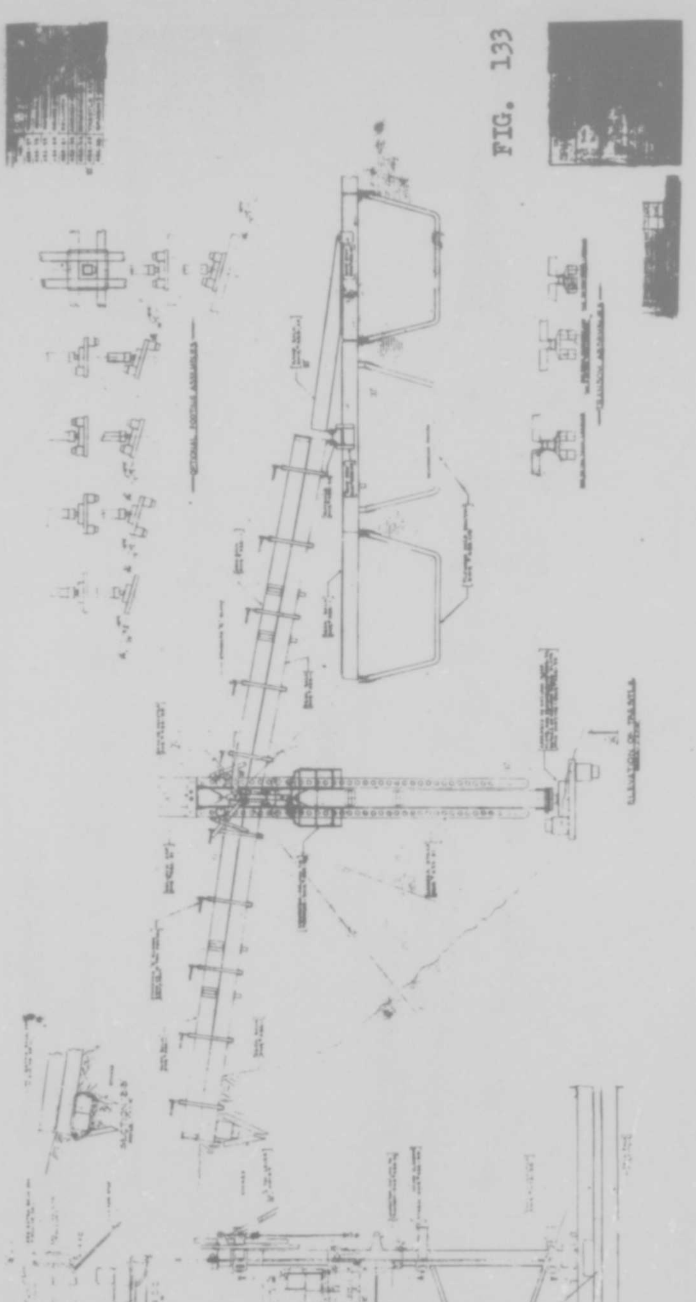


FIG. 133

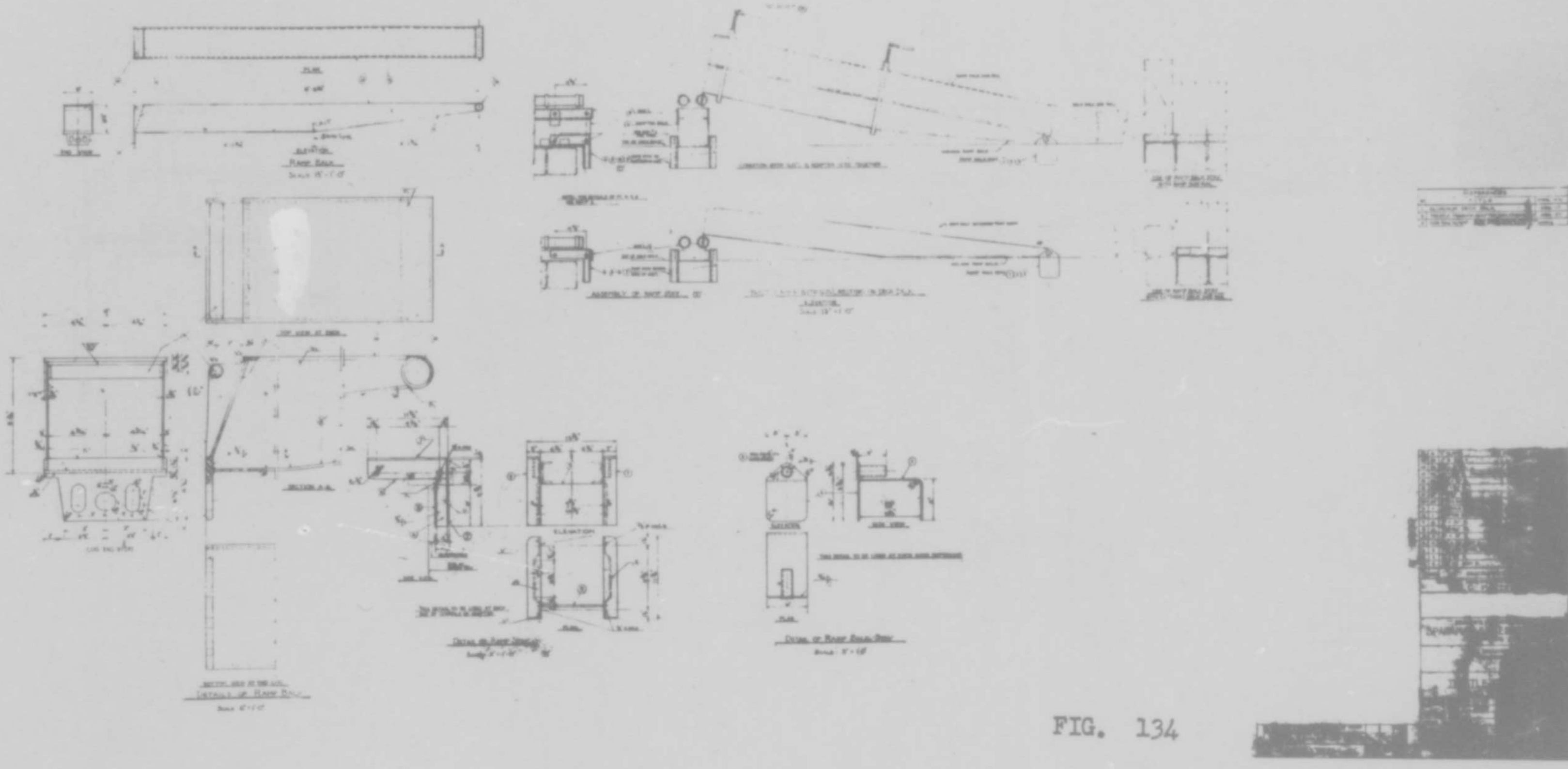
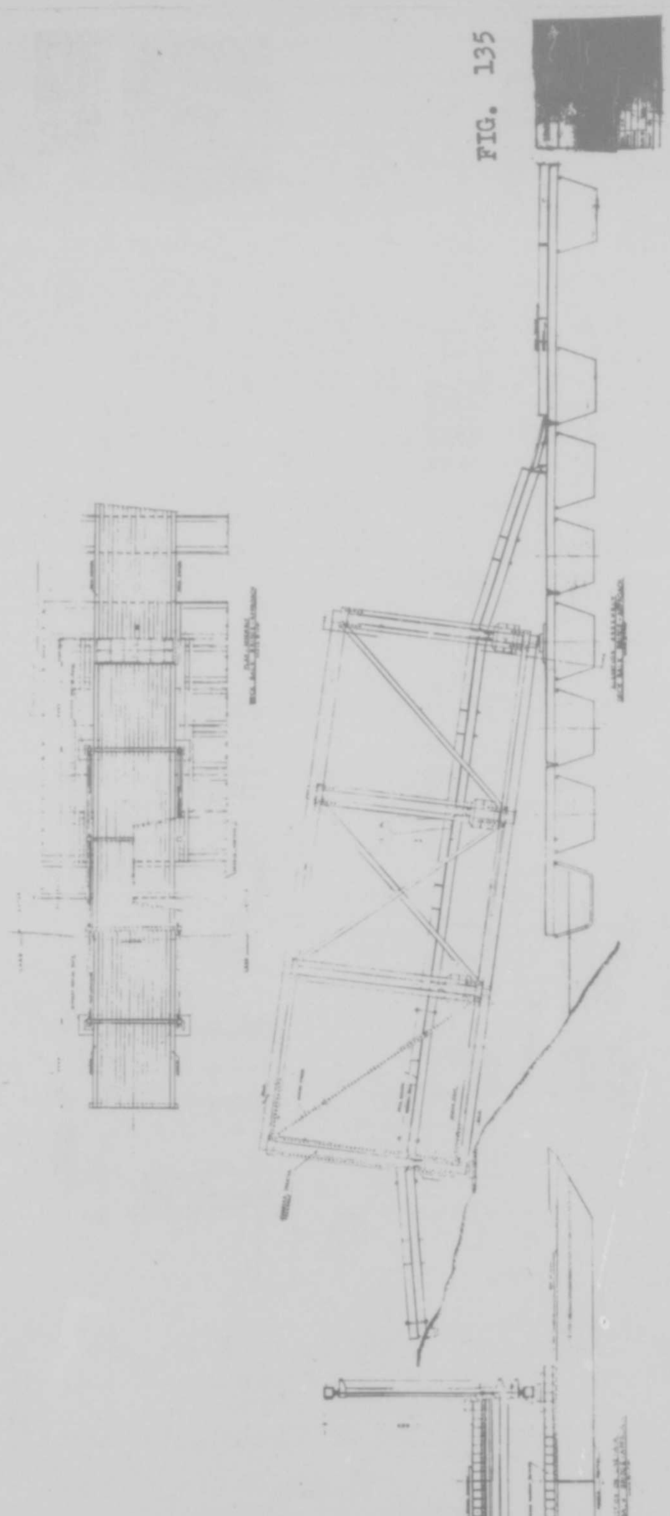


FIG. 134

FIG. 135



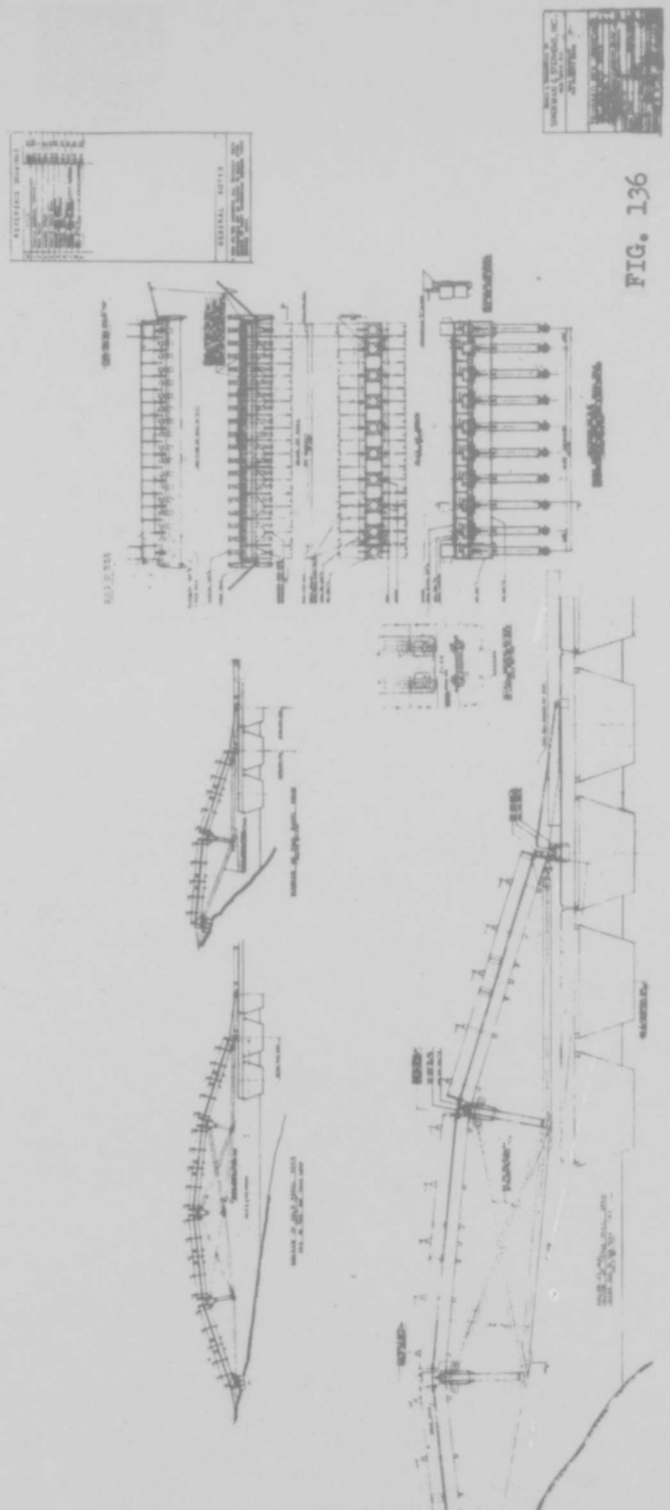


FIG. 136

ELM/los
18 April 1944

MEMORANDUM to: Captain Swain

Subject: Long Landing Bay.

1. The long landing bay consists of an assembly of parts; the maximum weight of any one part not exceeding 275 pounds. The parts are so designed that span units of 15 feet are the standard divisional increments, namely, 15, 30 and 45 feet as may be required. Each truss beam will carry a load concentrated at the middle of 10 tons. This load induces a maximum unit stress of 24,000 pounds. With the use of transverse beams to distribute the load equally to each beam, it can be seen that the amount of load of any span will be governed roughly by the number of beams used in the span, diminishing with the span lengths over 15 feet. A 30-foot span consisting of 20 beams will carry a concentrated load at the middle of the span of 40 to 50 tons, providing the load is distributed to all the beams.

2. The assembly consists of two principal elements and a group of auxiliary parts to act as fastening devices for the two principal elements. The principal elements consist of:

a. The truss beam is 15 feet long, 20 inches deep and 4 inches wide. The members of the beams are made of high strength aluminum extruded sections, held together by steel rivets and bolts. The beam is fitted at each end with two pin eyes to connect it to other beams. The total weight of this member is about 275 pounds.

b. The floor grating consists of a panel made up from either steel or high strength aluminum, the floor grating is in rectangular panels, the approximate depth of the grating is the same as the 25-ton ponton bridge chess. The steel grating weighs about the same as the wood chess per square foot and the aluminum design about one-half the weight of the wood chess per square foot.

3. The auxiliary parts consist of the following:

a. Triangular or horn beam end for the truss beam.

b. A ramp beam for making a support for the decked ramp from the bridge deck to the landing bay deck.

c. Spacing frames for the truss beams.

d. Steel guard rail also to be used as a transverse beam.

e. Skids to be used on the bridge deck as a support and spacer for the beams of the landing bay.

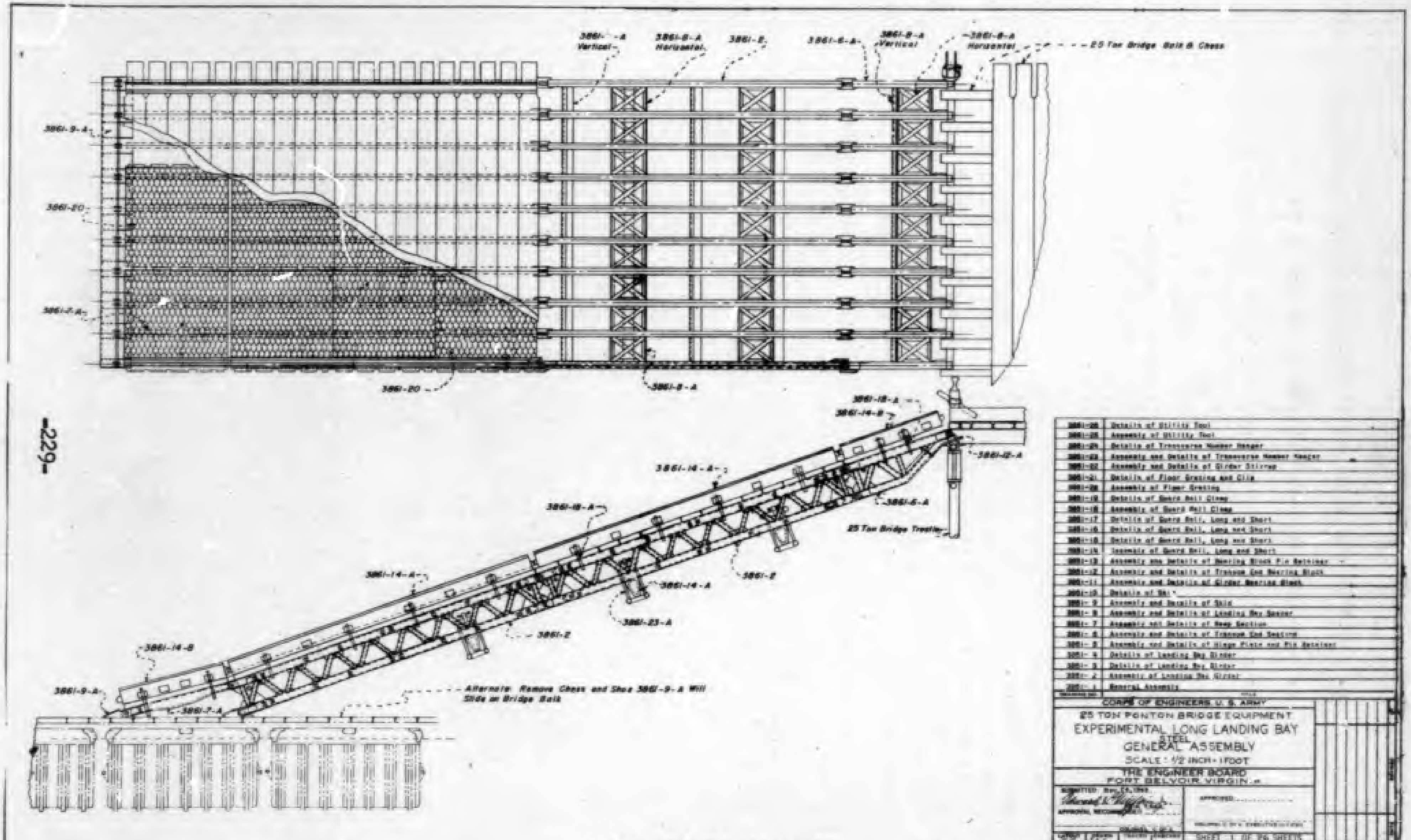
f. Clamps for securing the beams to their supporting objects.

g. Hangers for securing parts to the beams.

4. In addition to the design use of the equipment as a landing bay for the 25-ton ponton bridge, it can be used as a decking for both the trestle spans and floating spans of ponton bridges. When properly assembled, clear spans of 30 feet with a carrying capacity of a static concentrated load of 40 tons may be had. The factor of safety would be about 24/40 of the yield point if high strength aluminum is used. On standard trestle bents this load can be increased up to the carrying capacity of the trestle. For floating spans the beam elements can be used as in the continuous beam type decking or set up in either raft or bay type decking to suit tactical requirements. Other features for the landing bay equipment is that with the use of standard trestles and bracing, docks and piers for landing operations may be built, also it may have a substantial tactical value in that it will build into a submerged trestle bridge, thereby reducing its vulnerability by air attack. Attachments for these uses are part of the long landing unit.

5. The unit lengths have been selected that will allow the items to be transported in standard bodies of military cargo vehicles, also considerations in the design were given to the elimination of projections so that voids in shipping space would be held to a minimum and damage by handling practically eliminated.

/s/
Edward L. Mifflin, Jr.,
Principal Engineer,
Design and Drafting Section.



GENERAL ASSEMBLY OF LANDING BAY

3861-1

FIG. 137

APPENDIX G

DETAILS OF PROCUREMENT

DETAILS OF PROCUREMENT

1. Based on the designs accepted for trial, the following items have been placed under procurement:

a. Pontons

(1) Aluminum, S. & S. design No. 4.
(2) Plywood, S. & S. design No. 26.
(3) Plywood, Engineer Board design No. 4.

b. Superstructure

(1) Deck balk, S. & S. design No. 350.
(2) Approach span and trestle, S. & S. design.
(3) Balk, H.N.T.& B. design No. 168.
(4) Chess, H.N.T.& B. design No. 330.
(5) Adjustable connectors, guard rails, etc., H.N.T.& B. design.
(6) Balk, I-beam design No. 64.

These will provide sufficient equipment to make partial engineering tests on the proposed floating portions of the bridge according to three designs of superstructure. The Sparkman and Stephens approach span also can be tested.

2. Procurement planned within a short period and waiting on the bill of material from the fabricator consists of:

a. Fixed connectors, H.N.T.& B. design.
b. Trestles, H.N.T.& B. design.
c. 60-foot Division approach span, H.N.T.& B. design.
d. Miscellaneous small items.

In addition, it is anticipated that additional quantities of equipment will be required at such time as the engineering tests have progressed to a decisive stage. In order for service tests to be performed, it will be necessary to obtain sufficient equipment to provide one complete unit of such design as may be accepted. Design changes during engineering tests, a number of which have already occurred, will also require additional procurement.

3. a. The general status of the items ordered is given in the Procurement Status section of this appendix.

b. The expenditures involved up to 15 April 1944 are shown in the Cost Summary section of this appendix. This provides an indication of the relative cost of the different designs, though quantity production can be expected to change the relationship somewhat.

4. a. The procurement of experimental orders of aluminum extrusions, sheets, and shapes provides one of the largest single delays in this bridge development program. In general, it is now possible to obtain delivery of aluminum extrusions, where construction of a die is concerned, in about six to seven weeks after preparing the requisition. Fabrication then requires an additional 30 to 75 days. Therefore, it may be expected that it will require a minimum of 10 weeks, and probably 12, to obtain a quantity of experimental items after a design has been determined.

b. Present regulations governing scheduling of aluminum extrusions hold the producer no closer than 45 to 105 days delivery after placing the order. However, close cooperation with the manufacturer is creating advance shipments up to a minimum of five to six weeks after placing the order.

c. It has been proposed to set up a stockpile of aluminum for use in future experimental purchasing. However, C.M.P. regulations do not permit the manufacturer to accept orders for materials unless accompanied by final specifications. Since different extrusions and shapes require different sized billets and blooms, it is not possible to physically set up a stockpile of material to be rolled or extruded at a later date. Therefore, it is not possible to expedite procurement of experimental aluminum orders until the specifications for each item are known. Actual deliveries on production directives are determined to a large extent by the load of orders already in the mill at the time of the request, the interference with scheduled orders by issuance of the production directive, and the urgency of the project involved. Therefore, there is no way to indicate in advance of the request for production directive just what delivery can be accomplished.

d. There is no official special priority placed on this project which automatically requires top preference in scheduling deliveries; each order is considered separately. However, it is not believed that any delay has occurred to date because of this fact, since the mills have made shipments at the earliest possible date consistent with their schedules.

PROCUREMENT STATUS
DIVISION - ARMY BRIDGE
BR 473 AND 474

15 April 1944

Requisition No.	Item	Status
13/698	Balk, Chess, Gunwale Adapters, etc., HNT&B design.	Contract W 44-009-eng-132 with Allison Steel Manufacturing Co. Delivery expected 15 June.
13/700	Gunwale Adapters, upper and lower, light and heavy, HNT&B design.	Contract W 44-009-eng-130 with Aluminum Company of America. Items 1 and 2 shipped 15 April; Item 3 shipped 8 April; Item 4 to be shipped 29 April.
13/680	Aluminum extrusions for chess and balk, HNT&B design.	Contract W 44-009-eng-122 with Aluminum Company of America. Delivery expected 22 April.
13/695	Steel plates, checkered and plain, for HNT&B chess.	P.O. 31613 - shipped 7 March. Received.
13/694	Miscellaneous aluminum bars, plates, angles, etc.	Contract W 44-009-eng-134 with Aluminum Company of America. P.O. 31333 with Whitehead Metal Products Company. All items shipped for receipt approximately 29 April, except 20% of 3/4 O.D. tubing to be shipped 1 May express.
13/712	Aluminum plates for HNT&B design.	P.O. 31336 shipped from Los Angeles 20 March. Received.
13/718	Addition to Reqn. 13/680 - extrusions.	Supplement to Contract W 44-009-eng-122, same delivery.
13/582	200 aluminum balk, S&S design.	Contract W 44-009-eng-103. 92 balk received 15 April.
13/667	150 additional balk, S&S design.	Supplement to Contract W 44-009-eng-103.
13/342	400 extrusions for 200 S&S balk.	Received 18 February.

PROCUREMENT STATUS
DIVISION - ARMY BRIDGE
BR 473 AND 474 -cont.

15 April 1944

Requisition No.	Item	Status
13/664	300 extrusions for 150 additional S&S balk.	Received 18 February.
13/589	One-inch round bar aluminum.	Received 14 January.
13/588	100 square feet of 3/8-inch plate, aluminum.	Received 30 January.
13/669	Plywood strips for S&S balk.	Received 25 February.
13/592	Aluminum plate, checkered and plain, for S&S balk.	Received 29 February.
13/665	Aluminum plate for S&S balk.	Received 29 February.
13/703	Balk, aluminum, I-beam type.	Contract W 44-009-eng-133 with Allison Steel Manufacturing Co. Delivery expected 10 May.
13/693	Aluminum plate for I-beam balk.	P.O. 31333 with Whitehead Metal Products Company. Shipped 15 April.
13/681	Aluminum extrusions for I-beam balk.	Contract W 44-009-eng-122 with Aluminum Company of America. Delivery expected 22 April.
13/710	Aluminum extruded angles for I-beam balk.	P.O. 31616 with Aluminum Company of America. Received.
13/684	Aluminum pontons, S&S design.	Contract W 44-009-eng-125 with Lord and Burnham. Fabrication delayed pending receipt of Government-supplied materials. Delivery prior to 30 May.
13/666	Aluminum plates and extrusions for S&S pontons.	P.O. 31321 with Aluminum Company of America. All items shipped. Except receipt at Lord and Burnham 25 April.

PROCUREMENT STATUS
DIVISION - ARMY BRIDGE
BR 473 AND 474 - cont.

CHJ/dt_z
15 April 1944

Requisition No.	Item	Status
13/580, 626, 673, 692	Plywood pontons, S&S design.	Contract W 44-009-eng-100 with Henry B. Nevins. 15 pontons shipped and received. Balance expected 30 April.
13/601, 670, 729, 736.	Plywood angles for pontons being fabricated at Engineer Board.	All materials received.

COST SUMMARY
EXPERIMENTAL PROCUREMENT
DIVISION - ARMY BRIDGE

26 April 1944

Major Item	Design	Item	No. Ordered	Cost/Piece	Total Cost
Super-structure	HNT&B	Balk	168 (Materials) 168 (Fabrication)	$ 418.00	$70,324.00
		Chess	330	79.00	26,070.00
		Curb	40	83.00	3,320.00
		Balk Connectors (Adjustable)	32	120.00	3,840.00
		Anchor	512	19.50	9,984.00
		General Adapter	64	180.39	11,545.00
				TOTAL	$125,083.00
	S & S	Chess-Balk	350	$ 98.40	$ 34,446.00
		Trestle			6,595.00
		Transom Connector and Struts			5,508.00
		Ramp Balk	45	46.25	2,081.00
	I-Beam	Balk	70 (Materials) 64 (Fabrication)	167.81	10,744.00
Floating Piers	S & S	Plywood Pontons	26	$2,961.50	77,000.00
		Aluminum Pontons	4	3,421.50	13,686.00
	Clement	Plywood Pontons	2	3,080.00	6,160.00
		TOTAL - EXPERIMENTAL PROCUREMENT			$281,303.00
Design	HNT&B	Superstructure			22,351.00
	S & S	Superstructure and Floating Piers			73,400.00
				GRAND TOTAL	$377,054.00

APPENDIX H

RESEARCH

INTRODUCTION

The first section of this appendix consists of Major Cowley's report on the preliminary study and computations made to determine which types of floating bridges would offer the best approach to a design which would meet all military requirements for Group 25, Group 50, and Group 80 bridges. Six different combinations of pontons and superstructure were compared on a basis of simplicity of design and fabrication, ruggedness of parts and assemblies, speed and ease of construction, weights of individual parts and the total shipping weight, ease of transportation, flexibility of construction possible and ease of conversion for heavier loads, whether or not rafts used before construction could be incorporated into the bridge, and the traffic capacity of the bridge. Special studies of the most effective depth of sections used as balk and the effectiveness and limitations of articulated and adjustable articulated joints are also presented.

A mathematical treatment of the action of ponton bridges under load, with and without articulation in the balk joints, is discussed in the second section by Professor Bowman. In the first section, without articulation, the following assumptions are made: (1) the balk act as continuous beams; (2) the support of a ponton may be considered as a point support; (3) the righting moment due to rotation of a ponton may be neglected; and (4) the ponton is assumed to have a box shape so that displacement is directly proportional to the ponton reaction. Equations are then derived for various loadings on bridges having any number of supporting pontons. Articulated joints are treated with the same assumptions except of course that the balk do not act as continuous beams until the limit of articulation is reached.

The third section, Lt. Colonel Howard's report on the use of floating bridges in streams having swift currents, begins with a discussion of the failure of established methods of training to prepare bridging crews for operations in stream velocities over three or four feet per second. Proper methods of construction of the approaches, approach spans and their footings, anchorages which will not collect debris and fail, and notes on the effectiveness of debris collecting booms, bow adapters and methods of locking chess in place are discussed. Also included are recommendations for safe and efficient operations of raft equipment.

The methods used in testing the effect of magnitude of load, position of load and stream velocity on the safety of floating bridges are explained in the report of Lieutenant Black. Curves which show the relationship between freeboard and velocity and between safe load and velocity are included.

SELECTION OF TYPE OF FLOATING BRIDGES

By
W. E. Cowley
Major, Corps of Engineers

1. General. The primary objective in the design of Floating Bridges is that the completed bridge satisfy the military requirements. Second objective is that the bridge be the most efficient and practical type of its kind.

2. Military Requirements.

a. See Appendix B, Directive for the Engineer Test of Division, Army, and Heavy Bridge Equipage.

3. Types of Floating Bridges Studied. There are two general types: those which act as simple beams between floating supports and those which act as continuous beams to spread the load over several supports. Six arrangements of these general types were studied:

a. A deck on stringers acting as simple beams over long spans between floats made up of several pontons (Figure 1).

b. A deck on simple beam stringers between single ponton floats with heavy continuous beams attached to the side of the bridge to get load distribution over several pontons (Figure 2).

c. A deck on stringers acting as continuous beams (Figure 3).

d. A deck on stringers which have articulated joints in which articulating tolerances are fixed (Figure 4).

e. A deck on stringers which have adjustable articulated joints (Figure 5).

f. A deck incorporated into the tops of stringers which have articulated joints (Figure 6).

4. Types of Deck. There are three usual types of deck:

a. Full decked or chess type (Types a to e above).

b. Treadway type.

c. Deck incorporated into top of stringers, eliminating the transverse pieces of chess (Type f above).

5. Features Requiring Consideration in the Design Analysis. There are a number of features that must be considered in the bridge to be designed. These features listed in order of importance are:

a. Requirements. These must satisfy military requirements as outlined in appendix.

b. Simplicity. The design must be simple with reference to the assembly of parts such that troops, other than especially trained bridge troops, can, under competent direction, efficiently construct the bridge under adverse conditions. The number of different parts must be held to a minimum, and similarity of different purpose parts be avoided to prevent errors in construction. There must be a minimum of close-fitting parts which would make construction difficult.

c. Ruggedness. The individual parts must be rugged to withstand abuse in transport and handling without loss of serviceability.

d. Rapidity of Construction. The bridge must be capable of rapid construction, especially in the Division capacity. Its parts must be readily assembled for use in ferries and rafts. Military requirements of the specified limiting times for construction are given in the appendix.

e. Flexibility of Construction.

(1) The bridge equipment must be such that the capacities outlined in the military requirements can be obtained in the bridges and rafts with a minimum of special purpose parts.

(2) The bridge must be capable of reinforcement for higher loads with a minimum of traffic interruption.

(3) It is desirable that rafts used in the early stages of the taking of a bridgehead can be assembled into the bridge with a minimum of effort.

(4) The stringers will be such that a landing bay of 30 feet can be obtained without reinforcement and should be capable of reinforcement up to 40 or 50 feet.

(5) Provision will be made to obtain an adjustment for change in water level to a maximum of 15 percent slope on the landing bays.

(6) It is desirable that any portion of the floating bridge can be readily removed to obtain a drawbridge for river traffic, debris, or security.

(7) The stringers and decking must be usable on trestles, bents or piles to construct fixed bridges, or for reinforcement of existing fixed bridges.

(8) Short ramp stringers will be provided to extend the roadway from the abutment sill to the ground. The decking on these ramps will not be special.

f. Traffic Capacity. The bridge will be capable of passing traffic under tactical conditions without being a "bottle neck."

g. Gross Weight and Shipping Volume. The weight and volume will be the minimum possible to satisfy the military requirements.

h. Method of Construction. The bridge must be capable of manual construction as specified in the military requirements.

i. Transportation. The use of standard transportation facilities is desirable.

6. Design Analysis of Different Types.

a. It is necessary to go through the preliminary design of specific types of bridges to properly evaluate the merits of each with reference to the military requirements and the features outlined in paragraph 5. A bridge, to satisfy the military requirements of the Division, Army and Heavy Bridge, will be designed (preliminary design) in each of the listed specific types.

b. It would be advantageous to analyze these different types of bridges with variable values instead of specific values limited to the military requirements; however, the limitations on float weights in military requirements would defeat the purpose of the analysis. The bridges designed are limited to a certain extent by these requirements.

c. The following assumptions are made in the following examples:

(1) Maximum loads will be a 25-ton tank, 50-ton tank, and for the Heavy Bridge, the maximum obtainable with the equipment used in the Division and Army Bridge.

(2) A float having a net displacement of approximately 16 tons (full float) can be constructed having a weight of not more than 1200 pounds per half-float.

(3) For these examples, the heavy ponton chess will be used for decking. This will give a relative weight value.

(4) Aluminum will be used where practical. The design maximum bending stress is to be 28,000 pounds per square inch.

(5) To tie the design together, it is necessary to assume a minimum distance between capacity loads. The minimum distance between the capacity loads is assumed as

approximately 80 feet. This value is dependent upon traffic regulations, but controlled by engineers on the bridge.

(6) It is desirable that the free water percentage never be less than 40%.

7. Example 1, Stringer Bridge on Floating Piers.

a. Preliminary estimates indicate that the most efficient length of span, considering the maximum float size as approximately 16 - 17 tons, net displacement (full float), is approximately 50 feet.

b. Basing the calculations on a 50-foot span (Figure 1), and using aluminum for all members except the decking and curbs, the structural members as indicated in Figure 1 are as follows:

(1) Float Size, 33,600 pounds net displacement. Approximate dimensions are fifty feet by six feet by three feet. Two floats are required per pier on Division Bridge, three per pier on Army Bridge, and five per pier on Heavy Bridge.

(2) Stringer A is a 16-inch by 7-inch aluminum wide flange beam. Weight per foot is 12.1 pounds. Section modulus of the section is 56.3 inches cubed. Seven stringers are required in the Division Bridge, ten stringers are required in the Army Bridge, and sixteen stringers on the Heavy Bridge. The individual stringer weight, including two connections on each stringer, is 690 pounds.

(3) Float stringer B is a 12-inch by 5-inch aluminum wide flange beam. The weight is 10.3 pounds per foot. Section modulus is 36 inches cubed. The stringers are about 17 feet long and spliced for a total length of 34 feet for the Army and Heavy Bridges. Two stringers are sufficient for the Division Bridge, five for the Army Bridge and eight for the Heavy Bridge. The float stringer weight on the Division Bridge is 350 pounds per pier, the Army Bridge stringer weight is 1750 pounds per pier, and the Heavy Bridge stringer weight is 2800 pounds per pier.

(4) Stringer sill C is a fabricated aluminum member. The top and bottom plates are 12 inches by 3/8 inch and the side members are 6 inches by 2.75 pound aluminum channels. Slots are cut in the top and bottom plates to position the stringers, which have a dowel pin that engages with the slots.

(5) Transverse balks D are clamped under the stringers to increase the stringer efficiency. Eighty percent stringer

efficiency was assumed in the calculation when the transverse balk was used. The transverse balk are 12-inch by 5-inch by 10.3-pound aluminum I-beams clamped in position approximately at the rigid splice in the stringers. The weight for two balks is 275 pounds.

(6) The curb E is assumed to be positive and to have a weight of 30 pounds per running foot of bridge. The curb is set at 128 inches on the Division Bridge and 150 inches on the Army and Heavy Bridges.

c. Summary.

(1) The weight of the above bridges are: Division Bridge 385 pounds per foot of floating bridge, Army Bridge 500 pounds per foot, and Heavy Bridge 700 pounds per foot.

(2) The capacity of the Division Bridge is approximately 30 tons, the Army Bridge 50 tons, and the Heavy Bridge 75 tons. The minimum distance between capacity loads is 50 feet.

(3) The approach spans can be any length up to 50 feet and would compensate for changes in water level.

(4) The building of rafts to ferry loads would necessitate the construction of rafts with the floats directly under the stringers. The rafts then could not readily be used in a bridge.

(5) The free water percentage is approximately 75 percent on Division Bridge, 65 percent on the Army Bridge, and 40 percent on the Heavy Bridge.

(6) The bridge is not flexible in construction as it would be difficult to reinforce without adding extra and longer float stringers, and extra deck stringers, which would mean reconstructing the bridge.

(7) The construction would be slow due to the close fitting and numerous parts necessary in rigidly connecting the stringer parts.

8. Example 2, Combination of Stringer Bridge with a Continuous Beam (Articulated) over Floating Piers.

a. Preliminary calculations indicate that distance between floats should be approximately 16 feet on Division and Army Bridge and on 8-foot centers on Heavy Bridge. Balk length is 16 feet.

b. Basing the calculations on the above values and using aluminum for all structural members except curbs and chess, the structural members as indicated in Figure 2 are as follows:

(1) Float Size. The net displacement per full float is 32,000 pounds. The approximate size is 50 feet by 6 feet by 3 feet. The float weight is assumed to weigh 2400 pounds.

(2) Stringer B is an 8-inch by 4-inch aluminum I-beam, weight per foot is 7.3 pounds. Six stringers are required. The weight per stringer is 100 pounds.

(3) The Float transom C is an aluminum box section weighing approximately 14.2 pounds per foot. The transom weight is approximately 240 pounds. The transom has connecting devices (Figure 2A) that secure the articulated beams and form the tension side of the beam joint. Slotted holes are in the lower flange of the transom to position the stringer, which has dowel pins that match the holes. The transom functions as a sill on rafts and bridges.

(4) The articulated beams A are aluminum box sections weighing approximately 14.25 pounds per foot. The beam weight is approximately 300 pounds. The clearances in the joints give an articulation one way of 2½ inches. Two beams are used on Division Bridge, four on Army Bridge, and six on the Heavy Bridge.

(5) The guard rail (not shown) is a curved steel section which clamps on the deck and is secured by clamps to the stringers. These members would weigh approximately 30 pounds per running foot of bridge.

c. Summary.

(1) The weight of the Division Bridge would be approximately 325 pounds per foot of floating bridge, of the Army Bridge 450 pounds per foot, and of the Heavy Bridge 625 pounds per foot.

(2) The load capacity of the Division Bridge would be a 25-ton tank, of the Army Bridge a 50-ton tank, and of the Heavy Bridge approximately 80 tons. The minimum distance between capacity loads is 80 feet.

(3) The approach spans are limited to about 24 feet length without additional reinforcement.

(4) Rafts could be readily incorporated into a bridge. Raft and bridge approach ramps are shown in Figure 2A.

(5) The bridge can be readily reinforced in the Division capacity up to a capacity of approximately 80 tons with little traffic interruption.

(6) The free water percentage is approximately 62 percent on the Division and Army Bridge and 25 percent on the Heavy Bridge.

(7) No provision is made in the design for change in water level due to the short approach span. This feature could be added by the addition of an adjustable beam section at the end float.

9. Example 3, Continuous Beam over Floating Piers.

a. Preliminary calculations indicate that the distance between floats should be approximately sixteen feet on the Division and Army Bridge and eight feet on the Heavy Bridge. Balk length are 16 feet. The load would be distributed over five floats when the load is directly over a float and on four floats when load is between floats for Division and Army Bridge, and distributed over nine floats and eight floats for the Heavy Bridge.

b. Basing the calculations on the above values and using aluminum for all structural members except deck and curbs, and structural members as indicated in Figure 3 are as follows:

(1) Float Size. The maximum net float displacement (full float) is 32,000 pounds. The approximate size of float is 50 feet by 6 feet by 3 feet. The float weight is assumed as 2400 pounds.

(2) Balk A is a 16-inch by 5-inch light aluminum section weighing approximately eight pounds per foot. The section modulus is 44 inches cubed. Four balk are required for the Division Bridge, six balk are required for the Army Bridge, and eight balk are required for the Heavy Bridge. The weight per balk with connection is approximately 150 pounds. The balk rests on the float gunwales with hold-down and positioning clamps. The gunwales will serve as transverse balk in equalizing the balk stresses.

(3) The curbs are estimated to weigh approximately 30 pounds per running foot of bridge.

(4) Bolts, clamps, etc., are estimated as 100 pounds per 16-foot span.

c. Summary.

(1) The weight of the Division Bridge would be 280 pounds per foot of floating bridge, of the Army Bridge 370 pounds per foot, and of the Heavy Bridge 540 pounds per foot.

(2) The load capacity of the Division Bridge would be a 25-ton tank, of the Army Bridge a 50-ton tank, and of the Heavy Bridge slightly over 80 tons according to the load distribution. The minimum distance between capacity loads is 80 feet.

(3) The approach spans would be 24 feet maximum without additional balk reinforcement. To get longer approach spans, it would be necessary to reinforce the approach span out over the second float with additional balk.

(4) The construction is very flexible and could be constructed for almost any capacity up to approximately 80 tons by the use of the proper number of balk and correct float spacing. Rafts can be readily incorporated into a bridge by properly positioning the floats. To reinforce the bridge it is necessary to practically reconstruct.

(5) The free water percentage is approximately 62 percent on the Division and Army Bridges, and 25 percent on the Heavy Bridge.

(6) The construction would be slow in one respect; that is, the connecting of the balk due to the necessary close clearances to make a rigid beam. Any play in these connections would decrease the bridge capacity.

(7) This design does not compensate for changes in water level; however, a short adjustable angle balk could be inserted between the first float and the abutment sill to give this compensation.

10. <u>Example 4, Fixed Articulated Continuous Beams over Floating Piers</u>.

<u>a</u>. Preliminary calculations indicate that the most efficient distance between floats should be approximately 16 feet on Division and Army Bridges, and 8 feet on Heavy Bridge. The balk lengths are 16 feet. The load would be distributed over 5 floats on Division and Army Bridges and 9 floats on Heavy Bridge, when the load is directly over a float.

<u>b</u>. Basing the calculations on the above values and using aluminum for all structural members except deck and curbs, the structural members as indicated in Figure 4 are as follows:

(1) Float Size. The maximum net float displacement (full float) is 32,000 pounds. The approximate size of the

full float is 50 feet by 6 feet by 3 feet. The float weight is assumed as 2,400 pounds.

(2) Balk A is a 21-inch by 5-inch light aluminum section weighing approximately 9 pounds per foot. The section modulus must be 43.5 inches cubed minimum, and moment of inertia must be 455 inches fourth minimum. Four balk are required in the Division Bridge, six balk are required in the Army Bridge and 8 balk are required in the Heavy Bridge. The weight per balk allowing for articulated connection weight is approximately 200 pounds. The balks rest on the float gunwales which have hold down and positioning clamps. The gunwales will serve as transverse balk and assist in equalizing the balk stresses.

(3) The connection in the Balk A must give an articulation of 2.5 inches (one way) in the 16-foot balk length. An increase in articulation makes necessary a corresponding increase in the moment of inertia of the balk.

(4) The curbs are estimated to weigh approximately 30 pounds per running foot of bridge.

(5) Piers, clamps, etc., are estimated as 50 pounds per 16-foot span.

c. Summary.

(1) The weight of the Division Bridge would be 315 pounds per foot of floating bridge, of the Army Bridge 390 pounds per foot, and of the Heavy Bridge 565 pounds per foot.

(2) The load capacity of the Division Bridge would be the 25-ton tank, of the Army Bridge the 50-ton tank, and of the Heavy Bridge approximately 80 tons. The minimum distance between capacity loads is 80 feet.

(3) The approach spans would be 24 feet maximum without additional balk reinforcement. To get longer approach spans, it would be necessary to reinforce the approach spans out over the second float with additional balk.

(4) The construction is very flexible and could be constructed for almost any capacity desired up to approximately 80 tons by use of the proper number of balk and correct float spacing. Rafts can be readily incorporated into a bridge by properly positioning the floats. However, to reinforce the Division and Army Bridge it is necessary to practically reconstruct.

(5) The free water percentage is approximately 62 percent on the Division and Army Bridges, and 25 percent on the Heavy Bridge.

(6) The rapidity of construction depends primarily on the actual detail design of the balk connections. This connection must be rugged, simple, large clearances on moving parts, in fact, a (sloppy) joint and capable of being connected when not exactly in line. The joint should be such that any two balks can be connected to hold the rafts together if the remaining balks are not matching properly. The details of the joint will not be described here but is a detail of utmost importance. The connector should be an integral part of the balk.

(7) Compensation for change in water level could possibly be obtained in the balk connection design, but if complicated, should be obtained by the insertion of an adjustable section between the ends of standard balk. The use of hinge spans or trestles is not desirable.

11. Example 5, Adjustable Articulated Continuous Beams over Floating Piers.

a. The design of the adjustable articulated continuous beam bridge is so closely connected with the articulated design that an example is deemed unnecessary. The articulation and moment of inertia of the balk would have to be correlated such that the maximum of flotation could be utilized when articulation is a maximum, that is, when articulation is maximum, the maximum load capacity could be obtained, but to decrease the distance between vehicles of lighter than capacity loads, the articulation could be decreased and utilize the strength of the balk to the maximum. Also, if the articulation were decreased and more balk added, the capacity load could be increased.

b. The weight of a bridge of this design would be essentially the same as Example 4 with the exception of the balk connectors.

12. Example 6, Articulated Decked Type Balk.

a. The same general float spacing and displacement was used on this design as the articulated design in Example 4 (Figure 6).

b. Balk A is an aluminum box section, welded on the neutral axis similar to the S. S. design except a deep section. The balk is 14 inches by 9 inches, 3/16-inch weld metal and 5/16-inch flange metal. The traction surface is provided by punching the top and bottom extensions to give a roughened surface. This section has a weight of 12.25 pounds per foot, and section modulus of 48.2 inches cubed. The balk are spaced in the bridge on $10\frac{1}{2}$-inch centers. This allows $1\frac{1}{2}$ inches for cleaning and decreases the total balk necessary to make the full deck. Fourteen balk are used in the Division Bridge; seventeen are used in the Army and Heavy Bridges. In each case, additional balk are clamped on the sides for curbs. Balk weight with connections would be approximately 240 pounds.

c. A suggested balk joint is indicated in Figure 6. This joint gives an articulation of approximately $3\frac{1}{2}$ inches one way in the 16-foot length.

d. The weight of the Division Bridge would be 335 pounds per foot of floating bridge, of the Army Bridge 455 pounds per foot, and of the Heavy Bridge 600 pounds per foot.

e. The load capacity of the Division Bridge would be a 25-ton tank, of the Army Bridge a 50-ton tank, and of the Heavy Bridge approximately 80 tons dependent upon the load distribution.

f. It is necessary to securely connect every balk to the float gunwales or to transverse balk to transmit the deck load to the floats other than those adjacent to the balk carrying the load. The balk joint suggested in Figure 6 combines the transverse balk and the raft connector.

g. The approach spans are limited to 24-foot length without additional reinforcement.

h. Rafts used in the initial operation could readily be incorporated into a bridge.

i. The free water percentage is approximately 62 percent for the Division and Army Bridge, and 25 percent for the Heavy Bridge.

j. No provision is made for changes in water level. This could be provided by constructing a long approach span similar to S. S. design.

13. Tabular Comparison of Examples. The design examples can be more readily compared in tabular form. (See Figure 7.)

14. Balk Depth.

a. The effect of balk depth on the total balk weight and balk bending stress is tabulated below. The balk weights given are flange weights only of a fabricated section and must not be considered as an accurate balk weight. The basis of this comparison is the articulated continuous beam bridge on floating piers (Army Bridge load classification (50-ton tank), Example 4).

b. Minimum moment of inertia for the balk, with 2.5 inches articulation, to get the desired capacity, using the 16-ton floats on 16-foot centers, is 2720 inches fourth. The moment of inertia is held constant in the analysis. (See table below.)

ALUMINUM BALK
M = 7,150,000 Inch Pounds

Balk Depth	Moment of Inertia	Section Modulus	Bending Stress	Balk Flanges Weight per Foot
24 in.	2720 in.^{4}	227 in.^{3}	31,500 p.s.i.	24.4 lb
22 ".	"	248 in.^{3}	28,800 "	27.0 "
21.4".	"	255 in.^{3}	28,000 "	28.5 "
20 ".	"	272 "	25,200 "	33.0 "
18 ".	"	302 "	23,600 "	40.8 "
16 "	"	340 "	21,000 "	52.0 "
14 "	"	390 "	18,300 "	68.2 "
12 "	"	443 "	16,100 "	94.5 "
10 "	"	545 "	13,100 "	110.0 "

c. The above table portrays the fact that there is a minimum efficient balk depth and the importance of selecting same. In this design the correct depth is 21.4 inches. If a 16-inch balk is used, the relative balk weight increases almost 85 percent.

d. In the above analysis, the 50-ton tank load is distributed over five floats when the load is directly over a float, which is the critical displacement condition. The center float has a net displacement of 32,000 pounds and gross displacement of 38,250 pounds. The first float out from the center float has a net displacement of 24,560 pounds, and gross displacement of 30,800 pounds. The second float out from the center float has a net displacement of 9,440 pounds and gross displacement of 15,700 pounds. Total net displacement is 50 tons and total gross displacement is 131,200 pounds. The maximum float displacement per full float is approximately 54,000 pounds.

e. The float in this example had an average displacement of 1460 pounds per inch for the full float. The center float was submerged, not counting dead load, 22 inches; the first float out from the center float, 16-3/4 inches; and the second float out, 6½ inches.

15. Articulation.

a. Articulation as applied to floating bridges is herein defined as flexibility built into a continuous beam by clearance in uniformly spaced joints in the beam. The effect of the articulation when a load is placed on the superstructure is to immediately transmit load to the adjacent floats before loading floats not adjacent to the beams directly under the load, thus decreasing the bending moment on the beams in comparison to the moment on beams of the same stiffness under the same conditions with no articulation. Paragraph b compares the stiffness necessary when articulation is varied under the same load conditions.

b. The bridge on which the articulation is varied in Figure 8 is the Army 50-ton bridge in Example 4. The load is carried on five floats when directly over a float. The float displacement per inch was assumed to average 1460 pounds per inch.

Articulation (One Way)	Minimum I For Balks	I/C for Balk s = 28,000 p.s.i.	Depth of Balk
0 in.	2100 in 4	250 in. 3	16.8 in.
1 "	2290 "	254 "	18.1 "
2 "	2510 "	255 "	19.6 "
2.5"	2720 "	255 "	21.4 "
3 "	3000 "	252 "	23.8 "
4 "	3750 "	251 "	30.0 "
6 "	6300 "	248 "	50.6 "

c. This example stresses the importance of controlled articulation. The amount of articulation determines the clearance in the joint connections and the rapidity in which the connection can be made under adverse conditions. For example, if the joint is a two-pin connection, the pins 12 inches between centers, the balk 16 feet long, and the articulation desired 1 inch, then the total pin clearances would be 1/16 inch, or actual pin clearance in the holes of 1/32 inch. This would be entirely too close for economical manufacturing and too close for rapid assembly. Under the above conditions, an articulation of $2\frac{1}{2}$ inches would give an actual pin clearance of 5/64 inch, a more reasonable value. However, if the pin center distance were increased to 18 inches, then actual pin clearance would be almost 1/8 inch, a "sloppy fit", but a field connection and not a precision connection.

16. Adjustable Articulation.

a. The need for adjustable articulation is questionable. The principal arguments for adjustable articulation are that under conditions where the maximum load crossing over a bridge is under the capacity load of the bridge, then by decreasing the articulation, the distance between vehicles can be decreased and thus increase the traffic capacity of the bridge. Also, if in the future, it is desired to increase the maximum capacity load, the articulation could be decreased, and more balk added, and thus distribute the load over more floats and increase the maximum load capacity.

b. The increase in traffic capacity does not appear to justify the added complication of adjustable articulation. The decrease in load automatically decreases the minimum distance between the vehicles almost in proportion to the weight, dependent somewhat on the load base or distribution.

c. The need for adjustable articulation to increase the load capacity of the bridge for future use is more indefinite. If the adjustable articulation does not materially affect the simplicity of design or construction, it would be desirable; however, if in the original design, sufficient articulation is incorporated such that later it could be decreased by simple changes, such as replacement of small parts. This would be more desirable than an intricate and complicated original design.

17. Discussion of Design Examples.

a. Weight. The estimated weights per foot of floating bridge tabulated in Figure 7 shows that of the design examples the variations in weights are not sufficient to be the controlling factor.

b. Free Water. The free water percentages shown in Figure 7 are the same for the examples with the exception of Example 1, which has higher free water values. In general, the designs were tied together such that the other examples were designed to be the same. This is due to the military requirements limiting float weights and specifying manual construction, in effect limiting part weights to obtain rapid construction. Example 6 has possibilities of very simply increasing the free water percentage by increasing the balk length and decreasing articulation, for in this design, the balk are over strength and the controlling factor on the balk length was an effort to keep the balk weight toapproximately 250 pounds maximum. This would also automatically decrease the weight per foot of floating bridge.

c. Balk and Balk Connections. The details of balk connections are not complete in these designs; however, in the consideration of these examples the necessary balk connections should be considered. In Examples 1 and 2, a rigid balk splice is indicated. A joint of this type is not considered as a rapid field connection as it entails a number of close fitting and accurately machined parts. In the design the balk weights were limited to four men working loads with the exception of the trusses in Example 2. In this design, the number of heavier parts were limited.

d. Deck Systems. To get a comparative weight value, it was necessary to consider the decking the same on all examples except Example 6, which incorporates the balk and deck in one unit. The heavy ponton decking is not considered as a satisfactory decking, but is a usable deck and should be considered until a better deck has been developed.

e. Ramp Connector vs. Balk Connector. The rapidity desired in the construction of rafts and bridges under adverse conditions eliminates any complicated and numerous connections necessary to connect floating portions of the bridge. It would be desirable to have only two connections to make when a raft is connected into a bridge. This would indicate that raft connections are more desirable than balk connectors. However, consideration must be given to balk connectors when they approach the simplicity and rapidity of a raft connector. A balk connector that would allow the initial connection of the two outside balk and later the connection of the internal balk would be acceptable. Examples 2, 4 and 5 could very readily satisfy these requirements. Examples 1, 3, and 6 do not readily satisfy these requirements.

f. Reinforcement. The desirable feature of reinforcement of Division Bridge to take Army and Heavy Bridges should be accomplished with a minimum of traffic interruption. Examples 2 and 6 could be reinforced with hardly a break in traffic. To reinforce the other designs would entail the reconstruction of the bridge.

18. Recommendations. It is recommended that:

a. Examples 1, 3, and 5 not be considered as incorporating the desirable characteristics.

b. Example 4 be considered as secondary design having possibilities of providing the desirable characteristics.

c. Examples 2 and 6 be given primary consideration in the design of the proposed bridges.

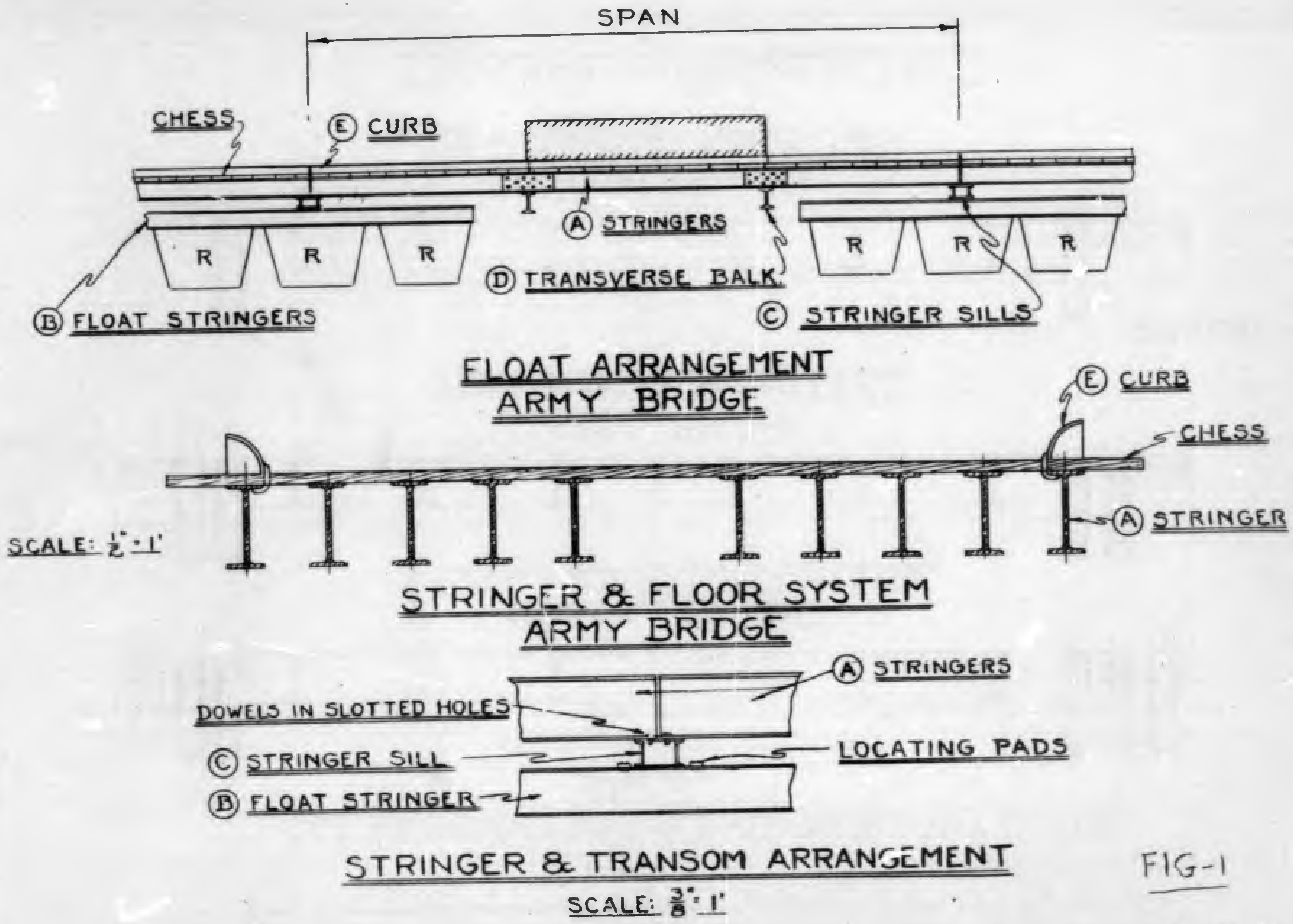
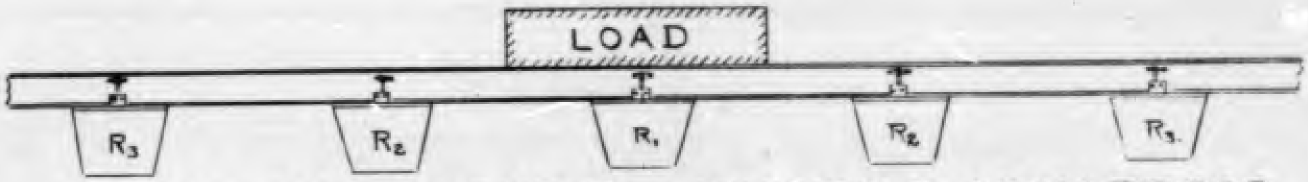


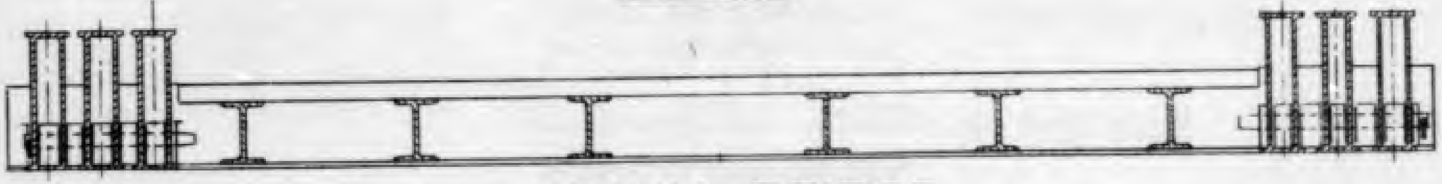
FIG-1

Y108-D-145



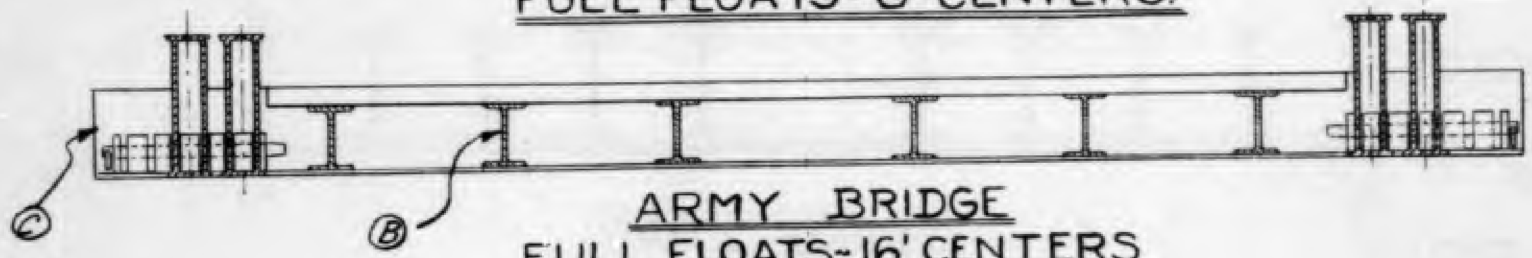
FLOAT ARRANGEMENT FOR DIVISION & ARMY BRIDGE

FIG. 2.



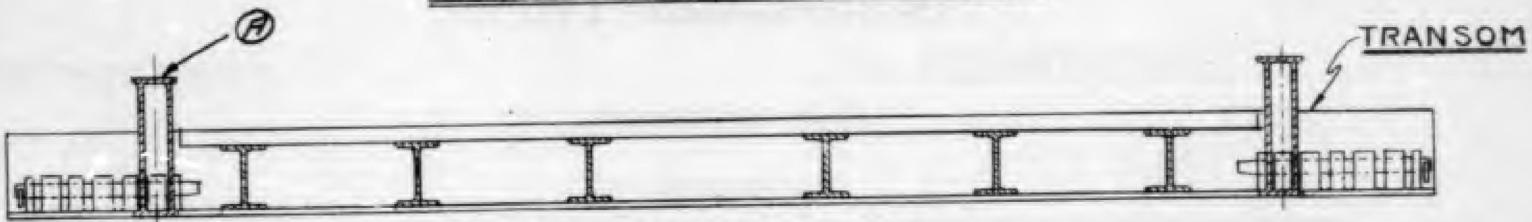
HEAVY BRIDGE

FULL FLOATS~8' CENTERS.



ARMY BRIDGE

FULL FLOATS~16' CENTERS

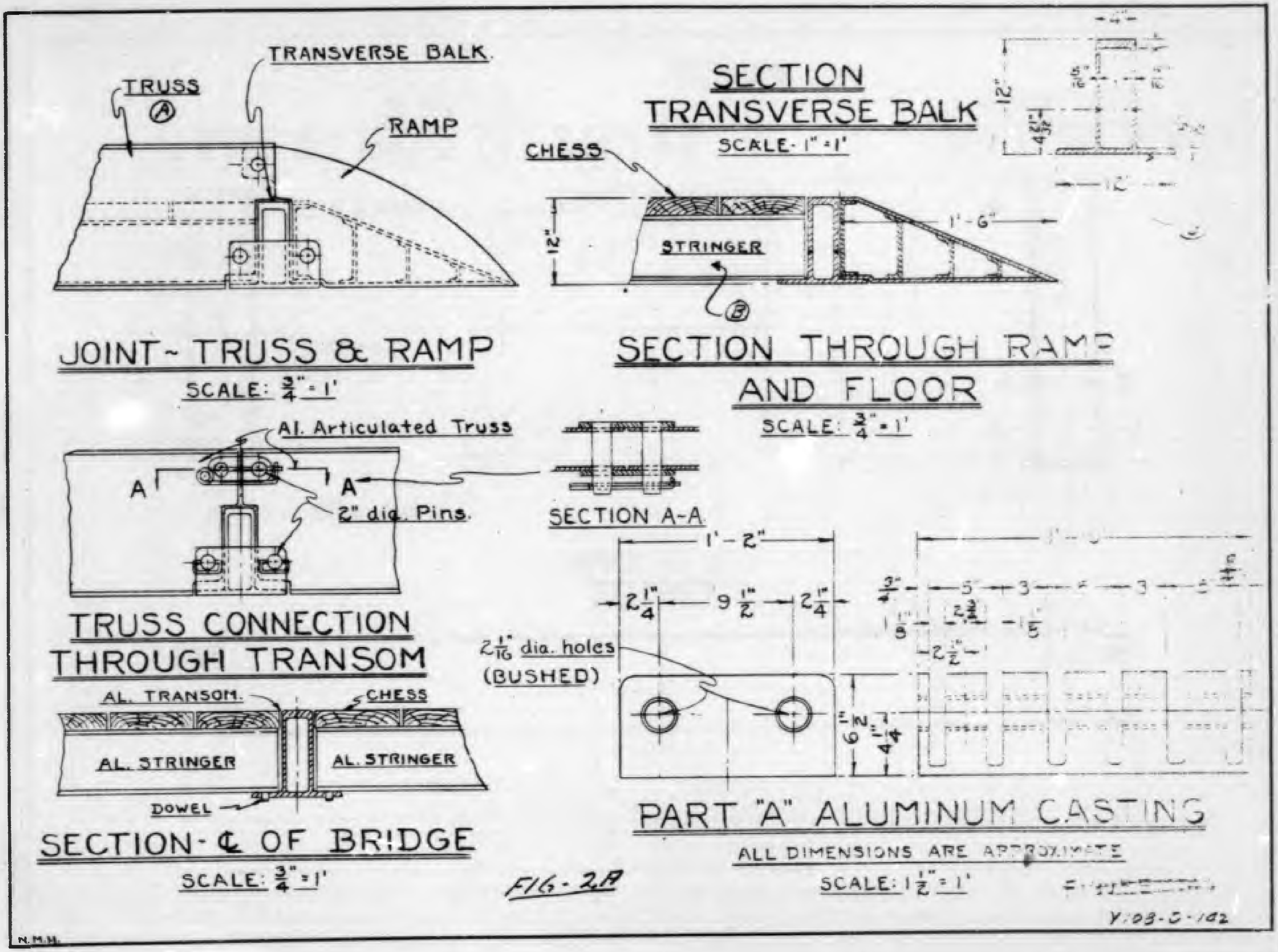


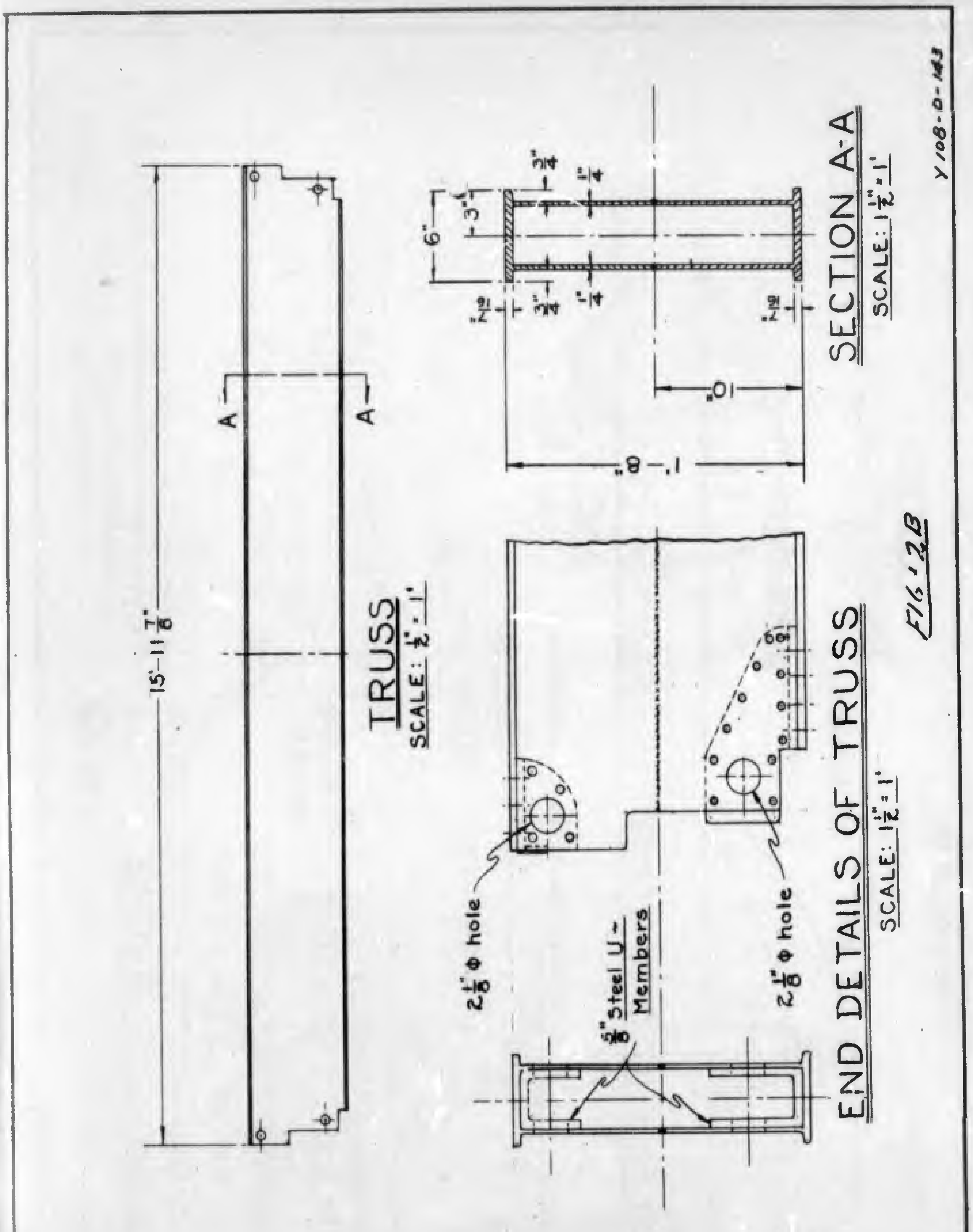
DIVISION BRIDGE

HALF FLOATS~16' CENTERS.

DECK AND TRUSSES~SECTIONS

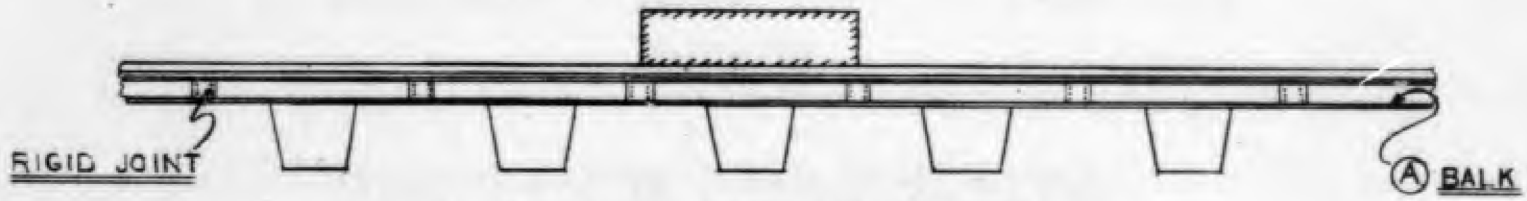
108-D-144


TRANSVERSE BALK.
TRUSS
A
RAMP
JOINT ~ TRUSS & RAMP
SCALE: 3/4" = 1'
SECTION
TRANSVERSE BALK
SCALE - 1" = 1'
CHESS
STRINGER
B
12"
1'-6"
SECTION THROUGH RAMP
AND FLOOR
SCALE: 3/4" = 1'
Al. Articulated Truss
A
A
2" dia. Pins.
TRUSS CONNECTION
THROUGH TRANSOM
SECTION A-A
1'-2"
2 1/4"
9 1/2"
2 1/4"
2 1/16" dia. holes
(BUSHED)
AL. TRANSOM.
CHESS
AL. STRINGER
AL. STRINGER
DOWEL
SECTION - ℄ OF BRIDGE
SCALE: 3/4" = 1'
PART "A" ALUMINUM CASTING
ALL DIMENSIONS ARE APPROXIMATE
SCALE: 1 1/2" = 1'
Y:03-C-102
N.M.H.
FIG. 2A

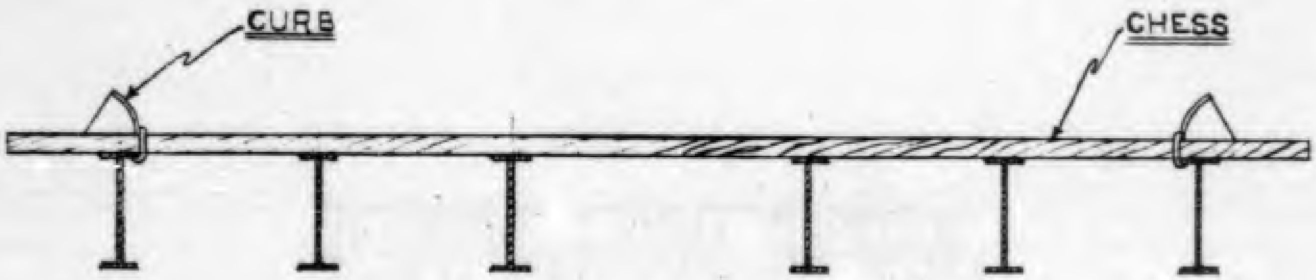


15'-11 7/8"
A
A
TRUSS
SCALE: 1/2" = 1'
SECTION A-A
SCALE: 1 1/2" = 1'
6"
3"
3/4"
1/4"
1/2"
10"
1'-8"
2 1/8" Φ hole
5/8" Steel U~ Members
2 1/8" Φ hole
END DETAILS OF TRUSS
SCALE: 1 1/2" = 1'
FIG. 12B
Y108-D-143

FIG. 3



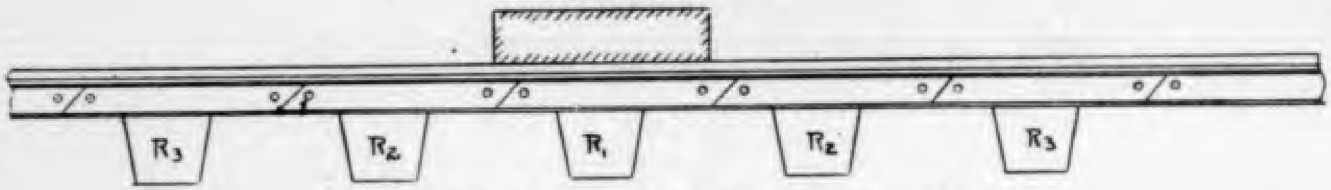
FLOAT ARRANGEMENT
DIVISION & ARMY BRIDGE



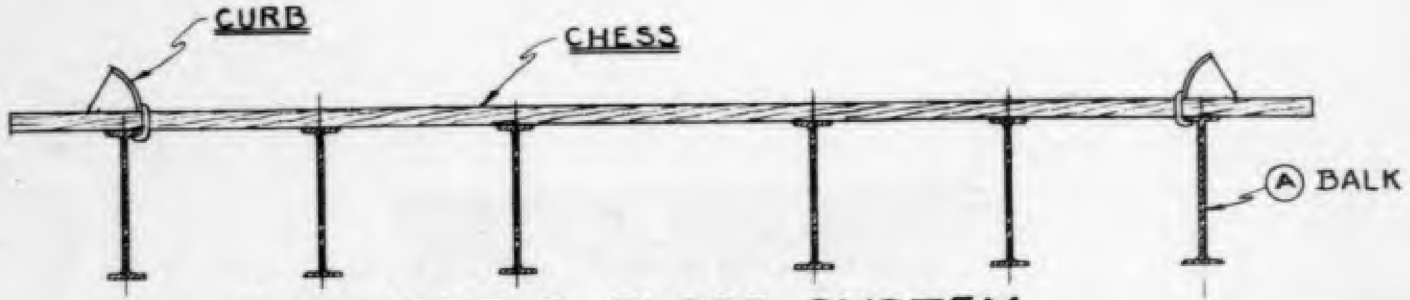
STRINGER & FLOOR SYSTEM
ARMY BRIDGE

Y-108-D-147

FIG. 4



FIXED ARTICULATED JOINT
DIVISION & ARMY BRIDGE



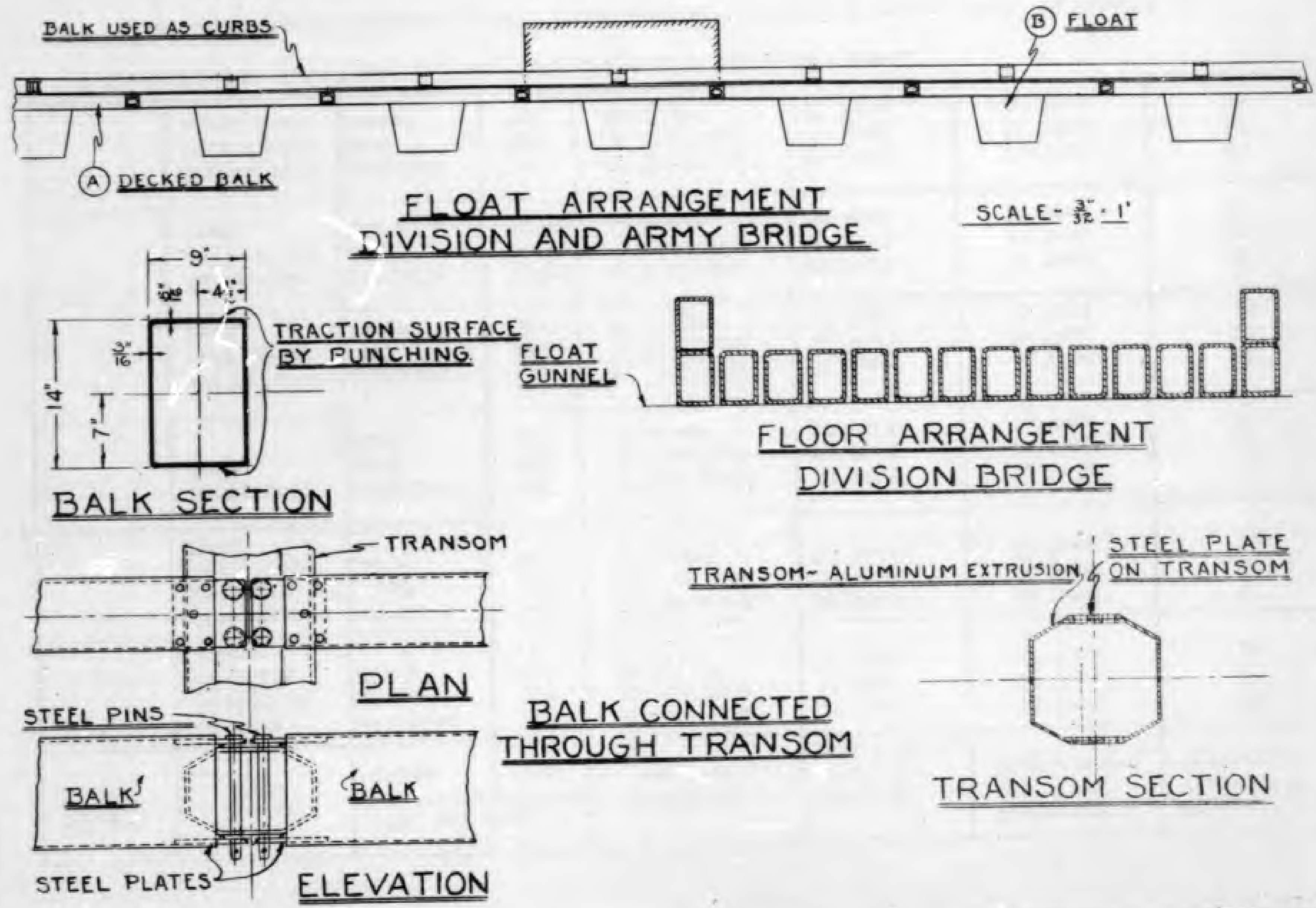
STRINGER & FLOOR SYSTEM

FIG. 5

SAME AS "FIG. 4" EXCEPT THAT THE ARTICULATED JOINTS ARE ADJUSTABLE

Y108-D-148

FIG. 6


BALK USED AS CURBS
(B) FLOAT
(A) DECKED BALK
FLOAT ARRANGEMENT
DIVISION AND ARMY BRIDGE
SCALE - 3/32" = 1'
9"
4 1/2"
14"
7"
3/16"
TRACTION SURFACE
BY PUNCHING
FLOAT
GUNNEL
FLOOR ARRANGEMENT
DIVISION BRIDGE
BALK SECTION
TRANSOM
PLAN
STEEL PINS
BALK
BALK
STEEL PLATES
ELEVATION
BALK CONNECTED
THROUGH TRANSOM
TRANSOM- ALUMINUM EXTRUSION
STEEL PLATE
ON TRANSOM
TRANSOM SECTION

TABULAR COMPARISON
OF EXAMPLES

Example Number	Bridge Type	Wt. per Foot		Calculated Capacity	Minimum Capacity Load Distance	Approximate Net Float Displacement	Approximate Clear Water Percentage
		Class	Wt.				
1	Stringer Bridge on Floating Piers	Division Army Heavy	385 500 700	30 Ton Tank 50 Ton Tank 75 Tons*	50 Feet 50 Feet 50 Feet	17 Tons 17 Tons 17 Tons	75 65 40
2	Combination Stringer and Continuous Beam	Division Army Heavy	325 450 625	25 Ton Tank 50 Ton Tank 80 Tons*	80 Feet 80 Feet 80 Feet	16 Tons 16 Tons 16 Tons	62 62 25
3	Continuous Beam	Division Army Heavy	280 370 540	25 Ton Tank 50 Ton Tank 80 Tons*	80 Feet 80 Feet 80 Feet	16 Tons 16 Tons 16 Tons	62 62 25
4	Articulated Continuous Beam	Division Army Heavy	315 390 565	25 Ton Tank 50 Ton Tank 80 Tons*	80 Feet 80 Feet 80 Feet	16 Tons 16 Tons 16 Tons	62 62 25
5	Adjustable Articulated Beam	Division Army Heavy	315** 390** 565**	25 Ton Tank 50 Ton Tank 80 Tons*	80 Feet 80 Feet 80 Feet	16 Tons 16 Tons 16 Tons	62 62 25
6	Decked Type Balk Continuous Beam	Division Army Heavy	335 455 600	25 Ton Tank 50 Ton Tank 80 Tons*	80 Feet 80 Feet 80 Feet	16 Tons 16 Tons 16 Tons	62 62 25

* Controlled by Load Distribution. Calculated as a Heavy Tank Load.

** These values would increase if Balk Connection was materially heavier than in Example 4.

FIGURE 7

OFFICE OF SCIENTIFIC RESEARCH
AND DEVELOPMENT

NATIONAL DEFENSE RESEARCH COMMITTEE
Division 12

REACTIONS OF PONTON BRIDGES With and Without Articulation

H. L. Bowman,
Drexel Inst. Tech.,
Phila., Pa.

H.L. BOWMAN, Drexel Inst. Tech., Phila., Pa.; Consultant, Division 12, NATIONAL DEFENSE RESEARCH COMMITTEE

REACTIONS OF CONTINUOUS (i.e., without articulation) PONTON BRIDGES

A continuous ponton bridge of any length (Fig. 1) may be considered as a simple beam supported at 0 (i.e, zero) and n. It may be investigated for one or more loads acting downward and a series of (generally) upward forces, that is, the reactions of the pontons, under all of which it must meet deflection conditions to give a consistent solution. That is, under load (Fig. 2) the end pontons will go down and the (assumed) simple beam will deflect below the line joining the ends. At each interior ponton a force will be applied which will lower that ponton, raise the end pontons, and cause the beam to deflect above the line joining the ends. Clearly, the distance that a ponton goes down must equal the difference between the amounts the corresponding point on the beam goes down due to the loads and up due to the ponton reactions.

For convenience it is assumed that the ponton reaction is a force at the center of the ponton and that all horizontal sections through the ponton have the same area. The displacement, C, per foot depth of ponton equals the product of this area (sq. ft.) and 62.4 (lb./cu.ft), and is expressed in pounds per foot.

Let a load P act at point b (distance kL from 0) on a beam of length nL supported by pontons at 0 and n (Fig. 3). Corresponding to point a (distance fL from 0) it is desired to find a_1a_2, the distance that a point on AB the straight line joining the beam ends, is below A_1B_1 the original (unloaded) position of the line. The portion of the load that goes to the ponton at 0 is

$\left(\frac{nL - kL}{nL}\right)P$ and, therefore $A_1A = \frac{(n-k)P}{nC}$

Similarly, $B_1B = \frac{kP}{nC}$

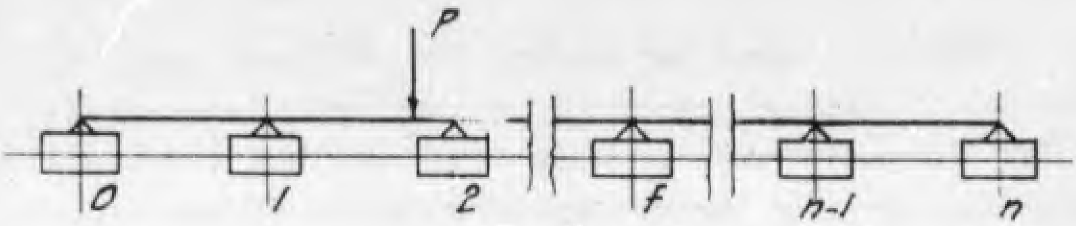


Fig. 1.

Fig. 2.

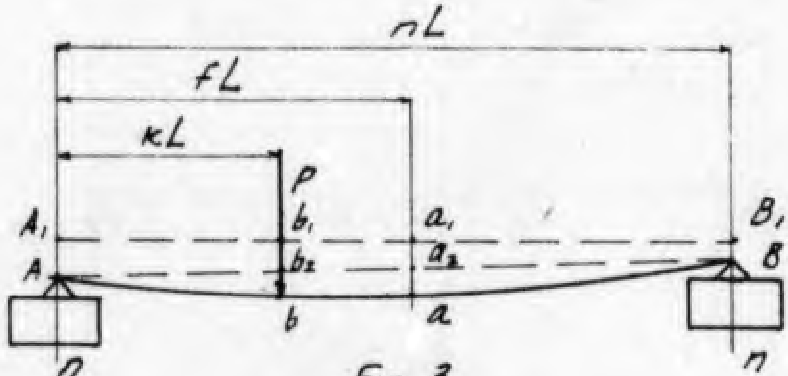


Fig. 3.

$$\text{Then } a_1 a_2 = \frac{(n-k)P}{nC} - \frac{f}{n}\left[\frac{(n-k)P}{nC} - \frac{kP}{nC}\right]$$

$$= \frac{P}{nC}\left[(n-k) - \frac{f}{n}(n-2k)\right]$$

$$= \frac{P}{nC}\left(n-k-f+\frac{2fk}{n}\right)$$

In like manner, an interior ponton reaction, R, at a distance xL from O will at a raise AB an amount

$$\frac{R}{nC}\left(n-x-f+\frac{2fx}{n}\right)$$

Next it is desired to find the distance $\underline{a_2 a}$ (Fig. 3) which $\underline{P}$ and $\underline{R}$ cause $\underline{a}$ to deflect from line $\underline{AB}$. (The computation will be made by the "conjugate beam method but the same result would be obtained by any other method for computing deflections.) Load $\underline{P}$ causes the reactions and moment curve of Fig 4 (a) and (b). The conjugate beam and its load are shown in Fig 4 (c). Due to this load the right reaction is

$$R_R = \frac{1}{2}\, nL\, \frac{PL}{EI}\, \frac{k(n-k)}{n}\, \frac{(n+k)L}{3nL}$$

$$= \frac{PL^2}{6EI}\, \frac{k(n^2-k^2)}{n}$$

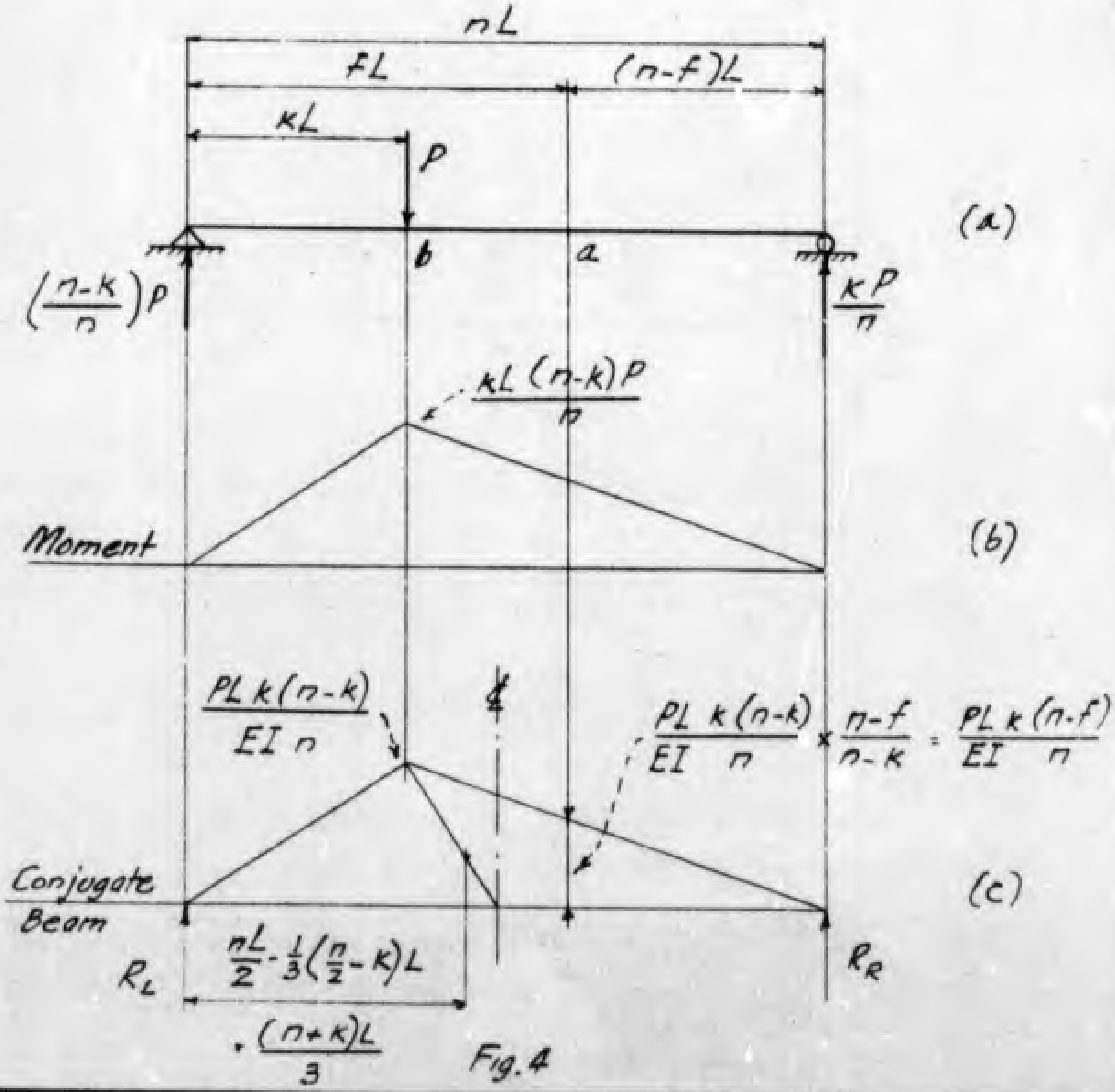


Fig. 4

Then

$$a_2a = \left[\frac{PL^2}{6EI}\,\frac{k(n^2-k^2)}{n}\right](n-f)L - \frac{1}{2}\left[(n-f)L\left(\frac{PL}{EI}\,\frac{k(n-f)}{n}\right)\left(\frac{(n-f)L}{3}\right)\right]$$

$$= \frac{PL^3}{6EI}\left[\frac{k(n^2-k^2)(n-f)}{n} - \frac{k(n-f)^3}{n}\right]$$

$$= \frac{PL^3}{6EI}\left[\frac{k(n-f)\left[(n^2-k^2)-(n-f)^2\right]}{n}\right]$$

$$= \frac{PL^3}{6EI}\left[\frac{k(n-f)(2nf-k^2-f^2)}{n}\right]$$

In like manner it may be shown that if P is applied to the right of a

$$a_2a = \frac{PL^3}{6EI}\left[\frac{f(n-k)(2nk-f^2-k^2)}{n}\right]$$

and if P is applied at a

$$a_2a = \frac{PL^3}{6EI}\left[\frac{2f^2(n-f)^2}{n}\right]$$

Similar upward deflections occur when the reaction R is applied to the left of a, to the right of a, and at a.

Finally, due to a reaction, R, a ponton will go down a distance

$$\frac{R}{C}$$

Assume that there is a ponton at a distance fL from O and that this ponton has a reaction R_f (a subscript (for example, x) after a ponton reaction indicates that the ponton is at a distance xL from O). Using the values which were derived above, it is possible to write the following equation.

$$\sum \frac{P}{nC}\left[n-k-f+\frac{2fk}{n}\right]$$

A term like this for every load.

$$+\sum \frac{PL^3}{6EI}\left[\frac{k(n-f)(2nf-k^2-f^2)}{n}\right]$$

A term like this for every load applied to the left of f.

$$+\frac{PL^3}{6EI}\left[\frac{2f^2(n-f)^2}{n}\right]$$

A term like this if a load is applied at f.

$$+\sum \frac{PL^3}{6EI}\left[\frac{f(n-k)(2nk-f^2-k^2)}{n}\right]$$

A term like this for every load applied to the right of f.

$$-\sum \frac{R_x}{nC}\left[n-x-f+\frac{2fx}{n}\right]$$

A term like this for every interior ponton including f.

$$-\sum \frac{R_s L^3}{6EI}\left[\frac{s(n-f)(2nf-s^2-f^2)}{n}\right]$$

A term like this for every interior ponton to the left of f.

$$-\frac{R_f L^3}{6EI}\left[\frac{2f^2(n-f)^2}{n}\right]$$

One term like this.

$$-\sum \frac{R_r L^3}{6EI}\left[\frac{f(n-r)(2nr-f^2-r^2)}{n}\right]$$

A term like this for every interior ponton to the right of f.

$$=\frac{R_f}{C}$$

One term like this.

For convenience in computing, multiply all of the foregoing terms by nC and let

$$\frac{CL^3}{6EI}=H$$

In any case the solution will be made for a known load (or loads) in a fixed position. Hence, the terms containing P will be known numbers and the unknowns in the equation will be the interior ponton reactions. Placing all unknowns to the left of the equals sign we may write

(1) $\sum R_x \left[n - x - f + \frac{2fx}{n} \right]$. A term like this for every interior ponton, including f.

(2) $+ \sum R_s H \left[s(n-f)(2nf - s^2 - f^2) \right]$ A term like this for every interior ponton to the left of f.

(3) $+ R_f H \left[2f^2 (n-f)^2 \right]$ One term like this.

(4) $+ nR_f$ One term like this.

(5) $+ \sum R_r H \left[f(n-r)(2nr - f^2 - r^2) \right]$ A term like this for every interior ponton to the right of f.

(6) $= \sum P \left[n - k - f + \frac{2fk}{n} \right]$ A term like this for every load.

(7) $+ \sum PH \left[k(n-f)(2nf - k^2 - f^2) \right]$ A term like this for every load applied to the left of f.

(8) $+ PH \left[2f^2 (n-f)^2 \right]$ A term like this if a load is applied at f.

(9) $+ \sum PH \left[f(n-k)(2nk - f^2 - k^2) \right]$ A term like this for every load applied to the right of f.

Just as the foregoing equation has been written for the ponton reaction of _f_, a similar equation will be written for every interior ponton. In this way there will be obtained a group of equations in which there are as many unknowns as there are interior pontons. Since there will be this same number of equations, a solution of these simultaneous equations will give the numerical values of the interior ponton reactions. Following this the values of the ponton reactions at 0 and _n_ may be found by statics and the shear and moment curves may be drawn for the structure.

A number of examples will be solved to show the application of the method.

Example 1. Find the reactions and draw the shear and moment curves for the structure and load of Fig. 5.

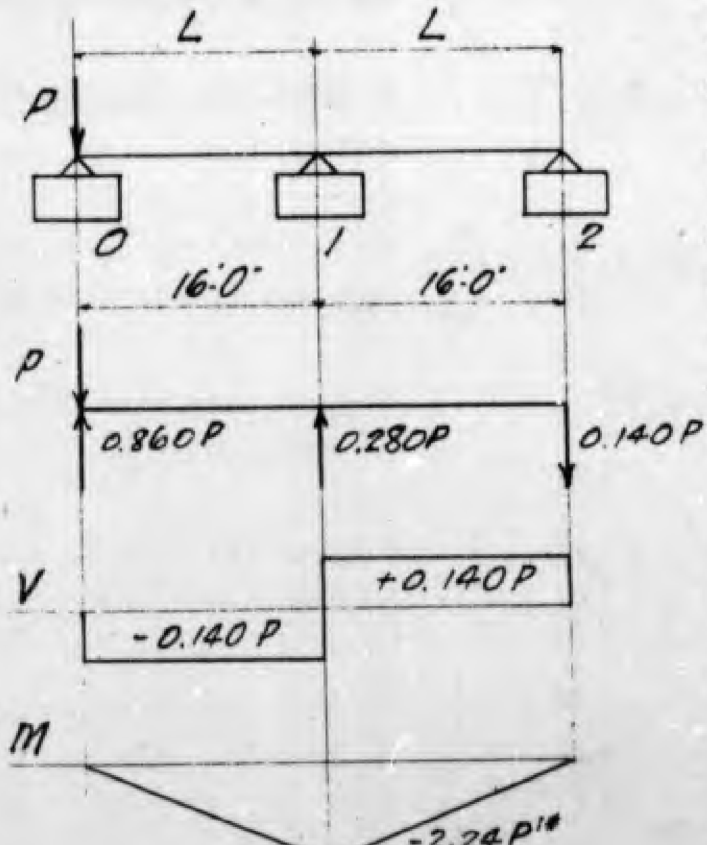


Fig. 5

Solution: Here $n=2$ and $k=0$. Utilizing the formula of Sheet #6 an equation will be written for R_1, the only interior ponton reaction, that is, for $\underline{f}=1$.

For convenience the terms of the formula of sheet #6 have been numbered. There will, in this instance, be values corresponding to terms 1, 3, 4 and 6. Normally term 7 would also appear since it involves a load to the left of <u>f</u>. Here, however, it equals zero since zero is the value of <u>k</u>

$$R_1\left(2-1-1+\frac{2\times1\times1}{2}\right)+R_1H\left(2\times1^2\times1^2\right)+2R_1=P\left(2-0-1+\frac{2\times1\times0}{2}\right)$$

$$R_1+2HR_1+2R_1=P$$

$$3R_1+2HR_1=P$$

This is as far as the solution can be carried until a value is assigned to <u>H</u>. The following will be assumed:

$L = 16$ ft.
$E = 1{,}500{,}000$ lb. per sq. in.
$I = 41\left(\frac{1}{12}\times5\frac{3}{16}\times\left(7\frac{3}{4}\right)^3\right) = 2211$ in.^{4}
$C = 160$ sq. ft. $\times$ 62.4 lb. per cu. ft. $= 10{,}000^{\#}$ per ft.

Then $H = \frac{CL^3}{6EI} = \frac{10{,}000\times16^3}{6\times1{,}500{,}000\times12^2\times\frac{2211}{12^4}}$

$= 0.296$

Note that it has been necessary to express <u>E</u> and <u>I</u> in foot units since <u>C</u> and <u>L</u> are in foot units; also that <u>H</u> is a dimensionless number, that is, all units cancel.

$$\left(\frac{\frac{lb.}{ft.}\times ft^3}{\frac{lb}{ft^2}\times ft^4}\right)$$

$$3R_1+2(0.296)R_1=P$$

$$R_1=\frac{P}{3.592}=0.280P\uparrow$$

By $\Sigma M=0$ about 0, $R_2 = 0.140\,P\downarrow$ (ie., <u>down</u>)
By $\Sigma V=0$ $\quad R_0 = 0.860\,P\uparrow$

Example 2. Solve the structure of the previous example when the load is placed at the middle of the first span, Fig. 6.

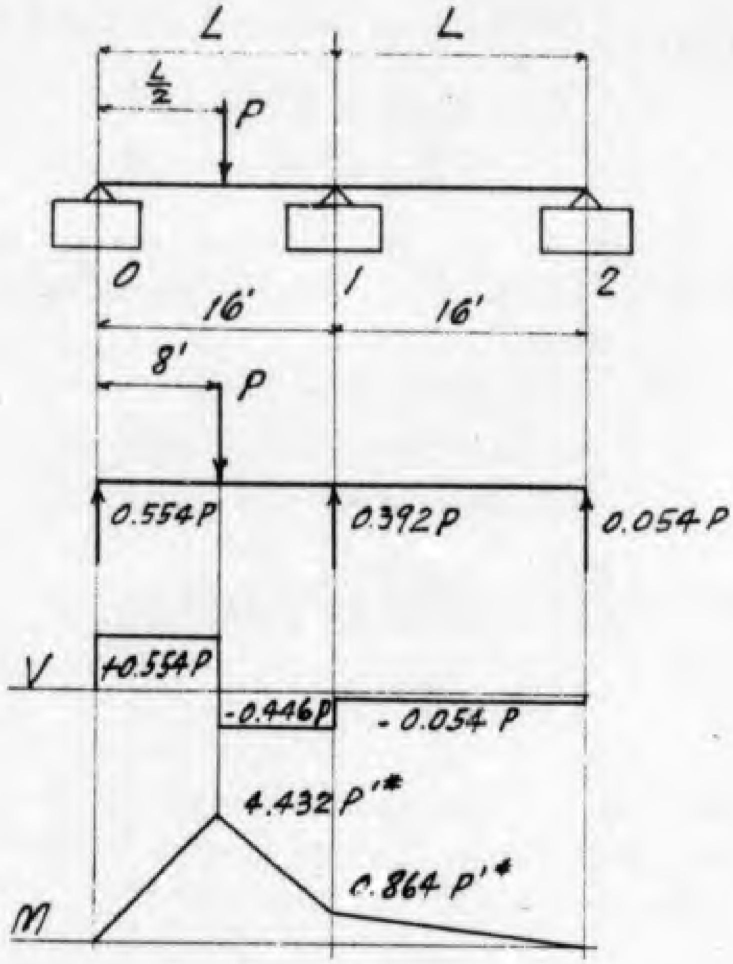


Fig. 6

Solution: For every two span structure the left side of the equation is constant. Now $K = \frac{1}{2}$. Therefore

$$3.592\, R_1 = P\left(2 - \tfrac{1}{2} - 1 + \frac{2 \times 1 \times \frac{1}{2}}{2}\right) + PH\left(\tfrac{1}{2}(2-1)(2 \times 2 \times 1 - \tfrac{1}{4} - 1\right)$$

$$3.592\, R_1 = P + \tfrac{11}{8} HP$$

$$= P + \tfrac{11}{8}(0.296) P$$

$$= 1.407\, P$$

$$\therefore R_1 = 0.392\, P$$

$$R_2 = 0.054\, P$$

$$R_o = 0.554\, P$$

Example 3. Solve the structure of the previous example if the load is applied over the center ponton, Fig. 7.

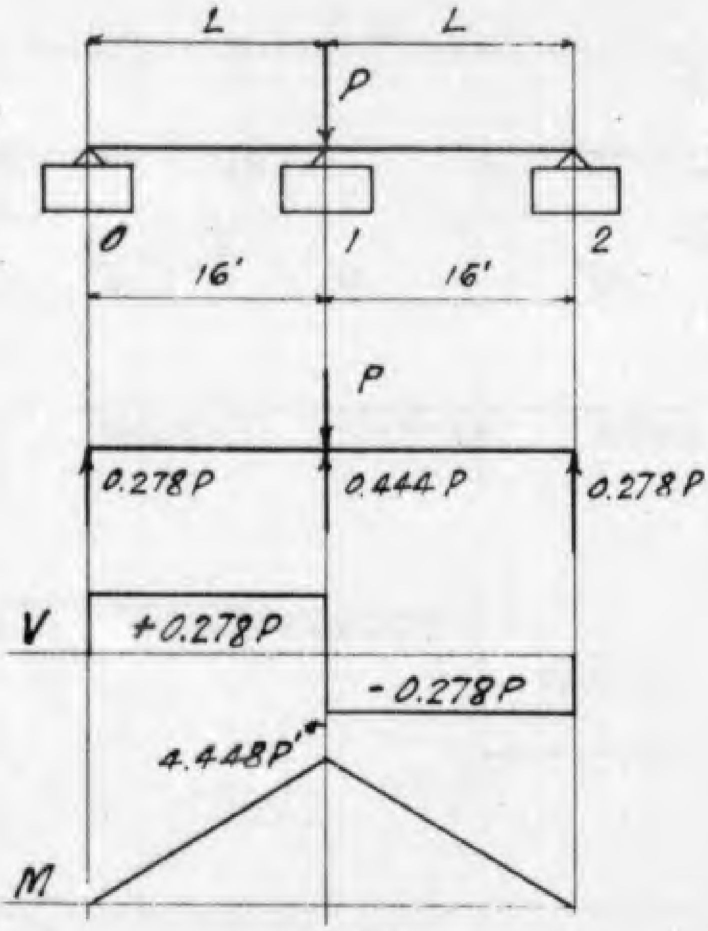


Fig. 7

Solution: Here $k = 1$. Therefore

$$3.592\,R_1 = P\left(2-1-1+\frac{2\times1\times1}{2}\right) + PH\left(2\times1^2\,(2-1)^2\right)$$

$$3.592\,R_1 = P + 2\,HP$$

$$= 1.592\,P$$

$$\therefore R_1 = 0.444\,P$$

$$R_0 = R_2 = 0.278\,P$$

<u>Example-4</u>. Find the reactions and draw the shear and moment curves for the structure and load of Fig. 8. Assume that <u>H</u> has the same value as in the previous examples.

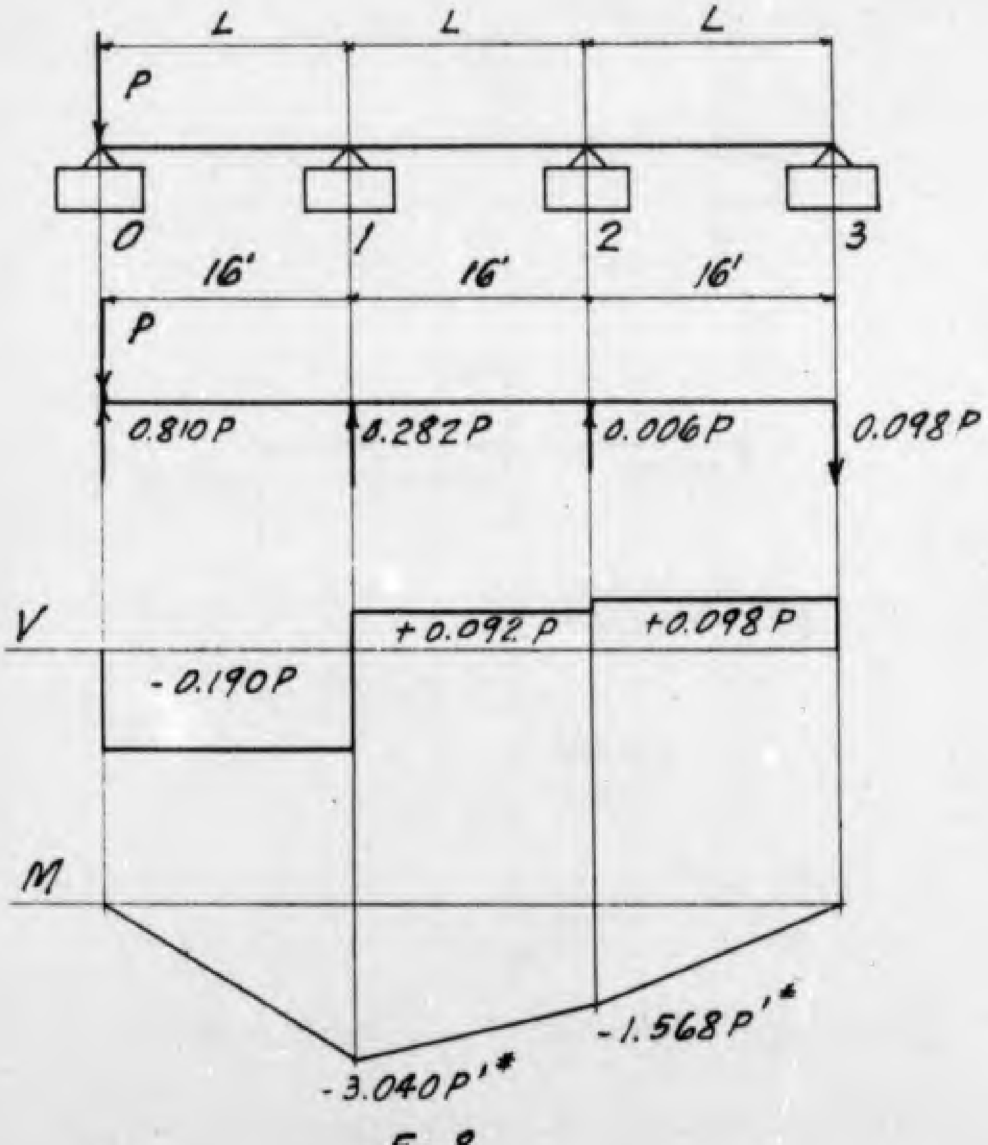


Fig. 8.

<u>Solution</u>: Here two equations must be written, i.e, for $\underline{f} = 1$ and $\underline{f} = 2$

For $\underline{f} = 1$ we obtain

$$R_1\left(3\cdot1\cdot1+\frac{2\times1\times1}{3}\right)+R_2\left(3\cdot2\cdot1+\frac{2\times1\times2}{3}\right)+R_1H\left(2\times1^2(3-1)^2\right)+3R_1$$
$$+R_2H\left(1(3-2)(2\times3\times2-1^2-2^2)\right)=P\left(3\cdot0\cdot1+\frac{2\times1\times0}{3}\right)$$

$$\tfrac{5}{3}R_1 + \tfrac{4}{3}R_2 + 8HR_1 + 3R_1 + 7HR_2 = 2P$$

$$\tfrac{14}{3}R_1 + 8HR_1 + \tfrac{4}{3}R_2 + 7HR_2 = 2P \qquad (1)$$

For $f = 2$,

$$R_1\left(3\text{-}1\text{-}2 + \tfrac{2\times2\times1}{3}\right) + R_2\left(3\text{-}2\text{-}2 + \tfrac{2\times2\times2}{3}\right) + R_1H\left(1\,(3\text{-}2)(2\times3\times2 - 1^2 - 2^2)\right)$$
$$+ R_2H\left(2\times2^2(3\text{-}2)^2\right) + 3R_2 = P\left(3\text{-}0\text{-}2 + \tfrac{2\times2\times0}{3}\right)$$

$$\tfrac{4}{3}R_1 + \tfrac{5}{3}R_2 + 7HR_1 + 8HR_2 + 3R_2 = P \qquad (2)$$

Therefore, since $H = 0.296$

$$7.035\,R_1 + 3.405\,R_2 = 2P \qquad (1')$$
$$3.405\,R_1 + 7.035\,R_2 = P \qquad (2')$$
$$7.035\,R_1 + 14.500\,R_2 = 2.064\,P \qquad (2'')$$
$$11.095\,R_2 = 0.064\,P \qquad (2''\text{-}1')$$
$$R_2 = 0.006\,P$$

$$7.035R_1 + 3.405(0.006)P = 2P$$
$$R_1 = 0.282\,P$$

The values of $\underline{R_0}$ and $\underline{R_3}$, may be found by use of the equations $\Sigma \underline{M} = 0$ and $\Sigma \underline{V} = 0$.

Example 5. Find the reactions and draw the shear and moment curves for the five-span structure of page 14 due to the two loads shown.

Solution: The complete solution is shown on the sheet with the figure. Note that in the section labeled "Formation of Equations" there are four areas which are bounded by heavy solid lines. The computation within these areas relates to every regular five-span structure and need never be made again. Furthermore, in this same section there are four areas and in the section "Solution of Equations" another area all bounded by heavy dashed lines. This much of the sheet relates to this particular structure and is independent of the load. That is, to investigate a structure for an additional position of the loads would necessitate the repetition of perhaps one-third of the work represented by this sheet.

Technical literature records many possible methods for the solution of equations. Obviously any other method which is a favorite of the individual computer might have been substituted in the section "Solution of Equutions.

<u>Summary</u>. The equation of page 6 serves for the case where all support is furnished by pontons. Two other cases that are of frequent occurence are (1) that where one end of the structure is on an unyielding support and (2) that where both ends are on such supports. The equations of all three cases are given on page 15.

<u>Assumptions</u>. Note that the derivations of this paper are based on the following assumptions:

1. The balk act as continuous beams.
2. The support at a ponton may be considered as a point support.
3. The righting moment due to the rotation of a ponton may be neglected.
4. Ponton displacement and ponton reaction are directly proportional to each other.

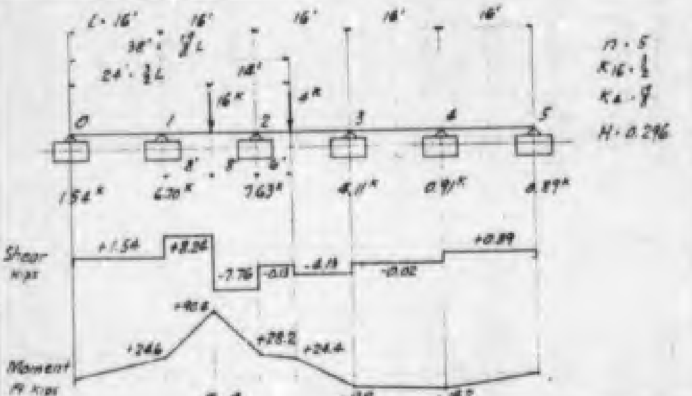


Fig. 9.

Eq.	R_1	R_2	R_3	R_4	Absolute +10
d'			R_3 R_3	+0.041	0.452 0.411
a'		R_2 R_2	+0.282	+0.081	1.086 0.763
1'	R_1 R_1	+0.688	+0.324	+0.083	1.725 0.670

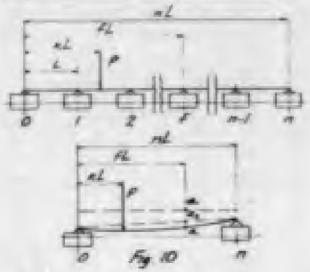
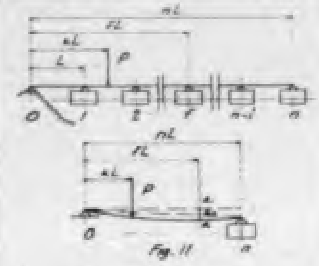
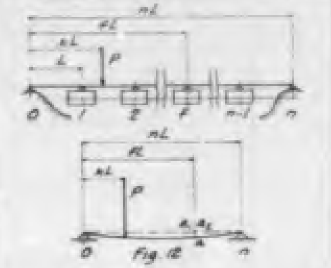
SOLUTION OF EQUATIONS

	Eq.	R_1	R_2	R_3	R_4	Absolute +10	Check
	1	17.87	16.12	14.04	8.41	30.83	87.27
	2	16.12	28.91	22.53	14.04	43.40	125.01
	3	14.04	22.53	28.91	16.12	39.95	121.55
	4	8.41	14.04	16.12	17.87	24.61	81.05
	1'	1	0.902	0.787	0.472	1.725	4.886
	2'	1	1.794	1.398	0.872	2.693	7.757
	3'	1	1.605	2.060	1.148	2.846	8.659
	4'	1	1.670	1.917	2.126	2.926	9.639
2'-1'	a		0.892	0.611	0.400	0.968	2.871
3'-1'	b		0.703	1.273	0.676	1.121	3.773
4'-1'	c		0.768	1.130	1.654	1.201	4.753
	a'		1	0.685	0.448	1.086	3.219
	b'		1	1.811	0.962	1.595	5.368
	c'		1	1.472	2.153	1.564	6.189
b'-a'	d			1.126	0.514	0.509	2.149
c'-a'	e			0.787	1.705	0.478	2.970
	d'			1	0.456	0.452	1.908
	e'			1	2.167	0.607	3.774
e'-d'	f				1.711	0.155	1.866
	f'				1	0.091	1.091

FORMATION OF EQUATIONS

	R_1	R_2	R_3	R_4	Absolute
Equation 1.	$R_1(5\cdot1\cdot1+\frac{2\cdot1\cdot1}{5})$ [=3.4 R_1] $+R_1H(2\cdot1\cdot16)$ [=32 HR_1] $+5R_1$ [=5 R_1]	$+R_2(5\cdot2\cdot1+\frac{2\cdot1\cdot2}{5})$ [=2.8 R_2] $+R_2H(1\cdot3(2\cdot5\cdot2\cdot1\cdot4)$ [=45 HR_2]	$+R_3(5\cdot3\cdot1+\frac{2\cdot1\cdot3}{5})$ [=2.2 R_3] $+R_3H(1\cdot2(2\cdot5\cdot3\cdot1\cdot9)$ [=40 HR_3]	$+R_4(5\cdot4\cdot1+\frac{2\cdot1\cdot4}{5})$ [=1.6 R_4] $+R_4H(1\cdot1(2\cdot5\cdot4\cdot1\cdot16)$ [=23 HR_4]	$16(5\cdot\frac{3}{2}\cdot1+\frac{2\cdot1\cdot\frac{3}{2}}{5})$ [=49.6] $+16H(1\cdot\frac{1}{2}(2\cdot5\cdot\frac{3}{2}\cdot1\cdot\frac{9}{4})$ [=658 H] $+4(5\cdot\frac{19}{8}\cdot1+\frac{2\cdot1\cdot\frac{19}{8}}{5})$ [=10.3] $+4H(1\cdot\frac{5}{8}(2\cdot5\cdot\frac{19}{8}\cdot1\cdot\frac{361}{64})$ [=180 H]
	8.4 R_1 + 32 HR_1	+2.8 R_2 + 45 HR_2	+2.2 R_3 + 40 HR_3	+1.6 R_4 + 23 HR_4 =	59.9 + 838 H
	17.87 R_1	+16.12 R_2	+14.04 R_3	+8.41 R_4 =	308.3
Equation 2.	$R_1(5\cdot1\cdot2+\frac{2\cdot2\cdot1}{5})$ [=2.8 R_1] $+R_1H(1\cdot3(2\cdot5\cdot2\cdot1\cdot4)$ [=45 HR_1]	$+R_2(5\cdot2\cdot2+\frac{2\cdot2\cdot2}{5})$ [=2.6 R_2] $+R_2H(2\cdot4\cdot9)$ [=72 HR_2] $+5R_2$ [=5 R_2]	$+R_3(5\cdot3\cdot2+\frac{2\cdot2\cdot3}{5})$ [=2.4 R_3] $+R_3H(2\cdot2(2\cdot5\cdot3\cdot4\cdot9)$ [=68 HR_3]	$+R_4(5\cdot4\cdot2+\frac{2\cdot2\cdot4}{5})$ [=2.2 R_4] $+R_4H(2\cdot1(2\cdot5\cdot4\cdot4\cdot16)$ [=40 HR_4]	$16(5\cdot\frac{3}{2}\cdot2+\frac{2\cdot2\cdot\frac{3}{2}}{5})$ [=43.2] $+16H(\frac{3}{2}\cdot3(2\cdot5\cdot2\cdot\frac{9}{4}\cdot4)$ [=990 H] $+4(5\cdot\frac{19}{8}\cdot2+\frac{2\cdot2\cdot\frac{19}{8}}{5})$ [=10.1] $+4H(2\cdot\frac{3}{8}(2\cdot5\cdot\frac{19}{8}\cdot4\cdot\frac{361}{64})$ [=296 H]
	2.8 R_1 + 45 HR_1	+7.6 R_2 + 72 HR_2	+2.4 R_3 + 68 HR_3	+2.2 R_4 + 40 HR_4 =	53.3 + 1286 H
	+16.12 R_1	+28.91 R_2	+22.53 R_3	+14.04 R_4 =	434.0
Equation 3.	$R_1(5\cdot1\cdot3+\frac{2\cdot3\cdot1}{5})$ [=2.2 R_1] $+R_1H(1\cdot2(2\cdot5\cdot3\cdot1\cdot9)$ [=40 HR_1]	$+R_2(5\cdot2\cdot3+\frac{2\cdot3\cdot2}{5})$ [=2.4 R_2] $+R_2H(2\cdot2(2\cdot5\cdot3\cdot4\cdot9)$ [=68 HR_2]	$+R_3(5\cdot3\cdot3+\frac{2\cdot3\cdot3}{5})$ [=2.6 R_3] $+R_3H(2\cdot9\cdot4)$ [=72 HR_3] $+5R_3$ [=5 R_3]	$+R_4(5\cdot4\cdot3+\frac{2\cdot3\cdot4}{5})$ [=2.8 R_4] $+R_4H(3\cdot1(2\cdot5\cdot4\cdot9\cdot16)$ [=45 HR_4]	$16(5\cdot\frac{3}{2}\cdot3+\frac{2\cdot3\cdot\frac{3}{2}}{5})$ [=36.8] $+16H(\frac{3}{2}\cdot2(2\cdot5\cdot3\cdot\frac{9}{4}\cdot9)$ [=900 H] $+4(5\cdot\frac{19}{8}\cdot3+\frac{2\cdot3\cdot\frac{19}{8}}{5})$ [=9.9] $+4H(\frac{19}{8}\cdot2(2\cdot5\cdot3\cdot9\cdot\frac{361}{64})$ [=292 H]
	+2.2 R_1 + 40 HR_1	+2.4 R_2 + 68 HR_2	+7.6 R_3 + 72 HR_3	+2.8 R_4 + 45 HR_4 =	46.7 + 1192 H
	+14.04 R_1	+22.53 R_2	+28.91 R_3	+16.12 R_4 =	399.5
Equation 4.	$R_1(5\cdot1\cdot4+\frac{2\cdot4\cdot1}{5})$ [=1.6 R_1] $+R_1H(1\cdot1(2\cdot5\cdot4\cdot1\cdot16)$ [=23 HR_1]	$+R_2(5\cdot2\cdot4+\frac{2\cdot4\cdot2}{5})$ [=2.2 R_2] $+R_2H(2\cdot1(2\cdot5\cdot4\cdot4\cdot16)$ [=40 HR_2]	$+R_3(5\cdot3\cdot4+\frac{2\cdot4\cdot3}{5})$ [=2.8 R_3] $+R_3H(3\cdot1(2\cdot5\cdot4\cdot9\cdot16)$ [=45 HR_3]	$+R_4(5\cdot4\cdot4+\frac{2\cdot4\cdot4}{5})$ [=3.4 R_4] $+R_4H(2\cdot16\cdot1)$ [=32 HR_4] $+5R_4$ [=5 R_4]	$16(5\cdot\frac{3}{2}\cdot4+\frac{2\cdot4\cdot\frac{3}{2}}{5})$ [=30.4] $+16H(\frac{3}{2}\cdot1(2\cdot5\cdot4\cdot\frac{9}{4}\cdot16)$ [=522 H] $+4(5\cdot\frac{19}{8}\cdot4+\frac{2\cdot4\cdot\frac{19}{8}}{5})$ [=9.7] $+4H(\frac{19}{8}\cdot1(2\cdot5\cdot4\cdot16\cdot\frac{361}{64})$ [=174 H]
	1.6 R_1 + 23 HR_1	+2.2 R_2 + 40 HR_2	+2.8 R_3 + 45 HR_3	+8.4 R_4 + 32 HR_4 =	40.1 + 696 H
	+8.41 R_1	+14.04 R_2	+16.12 R_3	+17.87 R_4 =	246.1

REACTIONS OF PONTON BRIDGES (without articulation)

	CASE-I - Both ends on Pontons	CASE-II - One end on a Fixed Support	CASE-III - Both Ends on Fixed Supports
	 Fig. 10	 Fig. 11	 Fig. 12
Consider a bridge of any length as a simple beam supported at O and n. Due to a load P applied at a distance kL from O, a straight line joining the beam ends will, at a distance fL from O, be below the reference line (i.e. the original position of the beam) an amount $a_f a_s$. (C is the load to cause a ponton to settle a unit distance.) In like manner, an interior ponton reaction R_s, at a distance sL from O will cause an upward motion $a_f a_s$.	(a) $a_f a_s = \frac{P}{Cn}\left(n-k-f+\frac{2fk}{n}\right)$ (b) $a_f a_s = \frac{R_s}{Cn}\left(n-s-f+\frac{2fs}{n}\right)$	$a_f a_s = \frac{Pfk}{Cn^2}$ $a_f a_s = \frac{R_s f s}{Cn^2}$	$a_f a_s = 0$ $a_f a_s = 0$
Due to a load P, distance kL from O there will be a deflection $a_s a$ below the straight line joining the beam ends and at a distance fL from O. — If $k < f$ / If $k = f$ / If $k > f$	(c) $a_s a = \frac{PL^3}{6EI}\left(\frac{k(n-f)(2nf-k^2-f^2)}{n}\right)$ (d) $a_s a = \frac{PL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$ (e) $a_s a = \frac{PL^3}{6EI}\left(\frac{(n-k)f(2nk-k^2-f^2)}{n}\right)$	$a_s a = \frac{PL^3}{6EI}\left(\frac{k(n-f)(2nf-k^2-f^2)}{n}\right)$ $a_s a = \frac{PL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$ $a_s a = \frac{PL^3}{6EI}\left(\frac{(n-k)f(2nk-k^2-f^2)}{n}\right)$	$a_s a = \frac{PL^3}{6EI}\left(\frac{k(n-f)(2nf-k^2-f^2)}{n}\right)$ $a_s a = \frac{PL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$ $a_s a = \frac{PL^3}{6EI}\left(\frac{(n-k)f(2nk-k^2-f^2)}{n}\right)$
Similarly, a ponton reaction R, will cause a deflection $a_s a$ at a distance fL from O. — If R_s is the reaction and sL its distance from O where $s < f$. If R_f is the reaction and fL its distance from O. If R_r is the reaction and rL its distance from O where $r > f$.	(f) $a_s a = \frac{R_sL^3}{6EI}\left(\frac{s(n-f)(2nf-s^2-f^2)}{n}\right)$ (g) $a_s a = \frac{R_fL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$ (h) $a_s a = \frac{R_rL^3}{6EI}\left(\frac{f(n-r)(2nr-r^2-f^2)}{n}\right)$	$a_s a = \frac{R_sL^3}{6EI}\left(\frac{s(n-f)(2nf-s^2-f^2)}{n}\right)$ $a_s a = \frac{R_fL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$ $a_s a = \frac{R_rL^3}{6EI}\left(\frac{f(n-r)(2nr-r^2-f^2)}{n}\right)$	$a_s a = \frac{R_sL^3}{6EI}\left(\frac{s(n-f)(2nf-s^2-f^2)}{n}\right)$ $a_s a = \frac{R_fL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$ $a_s a = \frac{R_rL^3}{6EI}\left(\frac{f(n-r)(2nr-r^2-f^2)}{n}\right)$
Also, under a reaction R_f, the ponton at a distance fL from O will go down a distance d.	(i) $d = \frac{R_f}{C}$	$d = \frac{R_f}{C}$	$d = \frac{R_f}{C}$
Now Σ(b) $+ \Sigma$(f) + (g) + Σ(h) + (i) $= \Sigma$(a) $+ \Sigma$(c) + (d) $+ \Sigma$(e) or ... That is, as f varies from 1 to n-1 there will be:			
A term like this for every reaction, including f	$\sum \frac{R_s}{Cn}\left(n-s-f+\frac{2fs}{n}\right)$	$\sum \frac{R_s fs}{Cn^2}$	—
A term like this for every interior reaction to the left of f, distance sL from O	$+\sum \frac{R_sL^3}{6EI}\left(\frac{s(n-f)(2nf-s^2-f^2)}{n}\right)$	$+\sum \frac{R_sL^3}{6EI}\left(\frac{s(n-f)(2nf-s^2-f^2)}{n}\right)$	$\sum \frac{R_sL^3}{6EI}\left(\frac{s(n-f)(2nf-s^2-f^2)}{n}\right)$
One term like this	$+\frac{R_fL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$	$+\frac{R_fL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$	$+\frac{R_fL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$
One term like this	$+\frac{R_f}{C}$	$+\frac{R_f}{C}$	$+\frac{R_f}{C}$
A term like this for every interior reaction to the right of f, distance rL from O	$+\sum \frac{R_rL^3}{6EI}\left(\frac{f(n-r)(2nr-r^2-f^2)}{n}\right)$	$+\sum \frac{R_rL^3}{6EI}\left(\frac{f(n-r)(2nr-r^2-f^2)}{n}\right)$	$+\sum \frac{R_rL^3}{6EI}\left(\frac{f(n-r)(2nr-r^2-f^2)}{n}\right)$
A term like this for each load	$=\sum \frac{P}{Cn}\left(n-k-f+\frac{2fk}{n}\right)$	$=\sum \frac{Pfk}{Cn^2}$	= —
A term like this for each load for which $k < f$	$+\sum \frac{PL^3}{6EI}\left(\frac{k(n-f)(2nf-k^2-f^2)}{n}\right)$	$+\sum \frac{PL^3}{6EI}\left(\frac{k(n-f)(2nf-k^2-f^2)}{n}\right)$	$\sum \frac{PL^3}{6EI}\left(\frac{k(n-f)(2nf-k^2-f^2)}{n}\right)$
A term like this for a load $k = f$	$+\frac{PL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$	$+\frac{PL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$	$+\frac{PL^3}{6EI}\left(\frac{2f^2(n-f)^2}{n}\right)$
A term like this for each load for which $k > f$	$+\sum \frac{PL^3}{6EI}\left(\frac{(n-k)f(2nk-k^2-f^2)}{n}\right)$	$+\sum \frac{PL^3}{6EI}\left(\frac{(n-k)f(2nk-k^2-f^2)}{n}\right)$	$+\sum \frac{PL^3}{6EI}\left(\frac{(n-k)f(2nk-k^2-f^2)}{n}\right)$
Multiply all terms by Cn and let $H = \frac{CL^3}{6EI}$. Finally, there will be:			
A term like this for every reaction, including f	$\sum R_s\left(n-s-f+\frac{2fs}{n}\right)$	$\sum \frac{R_s fs}{n}$	—
A term like this for every reaction to the left of f, distance sL from O	$+\sum R_sH\left(s(n-f)(2nf-s^2-f^2)\right)$	$+\sum R_sH\left(s(n-f)(2nf-s^2-f^2)\right)$	$\sum R_sH\left(s(n-f)(2nf-s^2-f^2)\right)$
One term like this	$+R_fH\left(2f^2(n-f)^2\right)$	$+R_fH\left(2f^2(n-f)^2\right)$	$+R_fH\left(2f^2(n-f)^2\right)$
One term like this	$+R_fn$	$+R_fn$	$+R_fn$
A term like this for every interior reaction to the right of f, distance rL from O	$+\sum R_rH\left(f(n-r)(2nr-r^2-f^2)\right)$	$+\sum R_rH\left(f(n-r)(2nr-r^2-f^2)\right)$	$+\sum R_rH\left(f(n-r)(2nr-r^2-f^2)\right)$
A term like this for each load	$=\sum P\left(n-k-f+\frac{2fk}{n}\right)$	$=\sum \frac{Pfk}{n}$	= —
A term like this for each load for which $k < f$	$+\sum PH\left(k(n-f)(2nf-k^2-f^2)\right)$	$+\sum PH\left(k(n-f)(2nf-k^2-f^2)\right)$	$\sum PH\left(k(n-f)(2nf-k^2-f^2)\right)$
A term like this if for a load $k = f$	$+PH\left(2f^2(n-f)^2\right)$	$+PH\left(2f^2(n-f)^2\right)$	$+PH\left(2f^2(n-f)^2\right)$
A term like this for each load for which $k > f$	$+\sum PH\left((n-k)f(2nk-k^2-f^2)\right)$	$+\sum PH\left((n-k)f(2nk-k^2-f^2)\right)$	$+\sum PH\left((n-k)f(2nk-k^2-f^2)\right)$

H. L. Bowman
April, 1944

Method of Solution. - Letting f vary from 1 to n-1, write one equation of the form shown above for every interior reaction. The unknowns in these equations will be the values of the interior reactions and there will be as many equations as there are unknowns. Solve this set of simultaneous equations for the values of the interior reactions. Then use the equations $\Sigma M = 0$ and $\Sigma V = 0$ to determine the end reactions. With all reactions known, shears and moments may be found throughout the structure.

Fig. 123

H.L. BOWMAN, Drexel Inst. Tech., Phila., Pa.; Consultant, Division 12, NATIONAL DEFENSE RESEARCH COMMITTEE

REACTIONS OF ARTICULATED PONTON BRIDGES.

For certain combinations of ponton properties and bridge stiffnesses it has been found necessary to permit an amount of articulation in the joints between the rafts which make up the structure. That is, the joints are so arranged that some degree of motion must take place before they can transmit moment. Frequently the arrangement is such that the joints transmit no moment or, when closed positive moment but are unable under any condition to transmit neg ative moment.

As an example, consider the three-raft structure of Fig. 13. Fig. 13(a) shows the structure without load. If a small load, P, is placed over the center raft, that raft will be displaced downward (Fig. 13 b) but the adjoining rafts will simply rotate without supporting any (considerable) load. This rotation will continue until the joints between rafts lock.

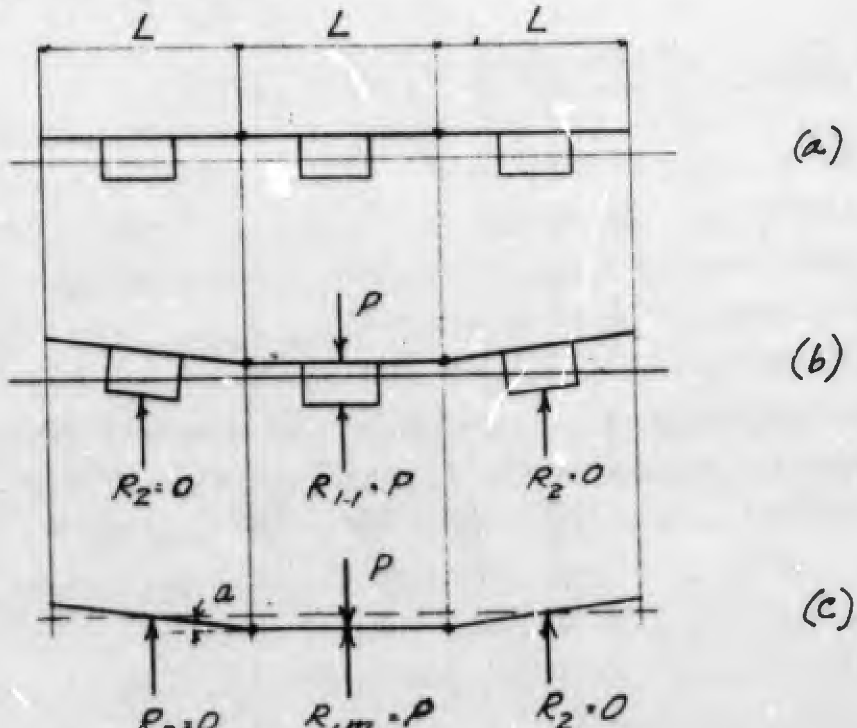


Fig. 13

Until this locking takes place the outer reactions have equaled zero. Any further load will be shared in some ratio among the three reactions.

For convenience, the sketch of Fig. 13(c) will be considered equivalent to Fig. 13(b), except that in Fig. 13(c) it is assumed that the load has been increased until the joints lock ($\underline{R}_2$ still equals zero). This will give the maximum reaction, $\underline{R_{1m}}$, which one raft alone can support. As shown, the elastic curve of the structure will have, at the joints, an abrupt angle, $\underline{a}$. The magnitude of this angle (i.e., the amount of articulation) will depend on the construction.

As before, let $\underline{L}$ equal the raft length in feet, and $\underline{C}$ the displacement of a ponton (or raft) in pounds per foot. In Fig. 13(c) it will be seen that the center ponton has been submerged an amount $\frac{CaL}{2}$, for which the symbol $\underline{K}$ will be used. Hence

$$P_{1m} = R_{1m} = \frac{CaL}{2} = K$$

Seven Rafts Acting, Maximum.

A number of additional structures will now be investigated for a single centerload. The greatest odd number of rafts acting will be taken as 7 (i.e., a 9 raft structure with the outer reactions equal to zero). From the center, the reactions for this case will be designated $R_{1\text{-}7m}$, $R_{2\text{-}7m}$, etc. (Fig. 14). By the geometry of the figure it may be shown that due to an angle of articulation, $\underline{a}$, in each joint the amounts successive points of reaction are above the point of reaction at the center are (as written on line $\underline{XX}$) $\frac{aL}{2}$, $\frac{4aL}{2}$, $\frac{9aL}{2}$ and $\frac{16aL}{2}$.

Added to the offsets due to articulation there will be deflections due to load. For example, the two loads $R_{2\text{-}7m}$ alone will cause a symmetrical moment curve (one-half shown on line($\underline{b}$)), and, as may be shown by any method for computing beam deflections, will produce, above R_1, upward deflections at the points of application of R_2, R_3, R_4, and R_5 = (0)

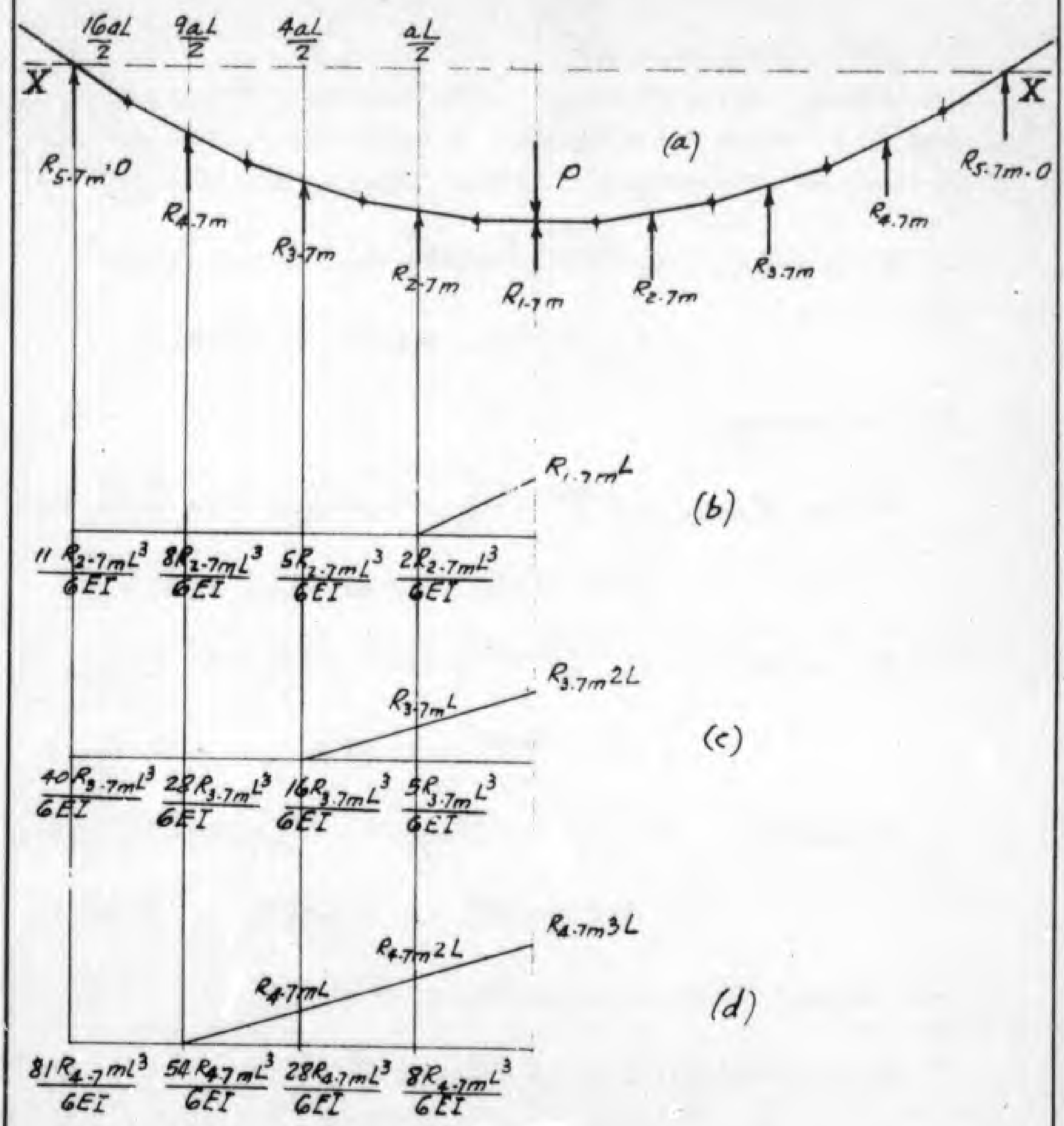


Fig. 14

of $\frac{2R_{2\cdot7m}L}{6EI}$, $\frac{5R_{2\cdot7m}L}{6EI}$, $\frac{8R_{2\cdot7m}L}{6EI}$ and $\frac{11R_{2\cdot7m}L}{6EI}$.

In like manner, the moment curves and deflections produced by $R_{3\cdot7m}$ and $R_{4\cdot7m}$ are shown on lines (c) and (d). It will be understood, of course, that the offsets due to articulation and the three sets of deflections are acting simultaneously.

Clearly, the difference in the reactions $R_{1\cdot7m}$ and $R_{2\cdot7m}$ will be $\underline{C}$ times the difference in the amounts which the two pontons are submerged. That is, (placing, as before, $\frac{CL^3}{6EI} = H$)

$$R_{1\cdot7m} - R_{2\cdot7m} = C\left(\frac{aL}{2} + \frac{2R_{2\cdot7m}L^3}{6EI} + \frac{5R_{3\cdot7m}L^3}{6EI} + \frac{8R_{4\cdot7m}L^3}{6EI}\right)$$

$$= K + 2HR_{2\cdot7m} + 5HR_{3\cdot7m} + 8HR_{4\cdot7m}$$

In like manner,

$$R_{1\cdot7m} - R_{3\cdot7m} = C\left(\frac{4aL}{2} + \frac{5R_{2\cdot7m}L^3}{6EI} + \frac{16R_{3\cdot7m}L^3}{6EI} + \frac{28R_{4\cdot7m}L^3}{6EI}\right)$$

$$= 4K + 5HR_{2\cdot7m} + 16HR_{3\cdot7m} + 28R_{4\cdot7m}$$

$$R_{1\cdot7\cdot7} - R_{4\cdot7m} = C\left(\frac{9aL}{2} + \frac{8R_{2\cdot7m}L^3}{6EI} + \frac{28R_{3\cdot7m}L^3}{6EI} + \frac{54R_{4\cdot7m}L^3}{6EI}\right)$$

$$= 9K + 8HR_{2\cdot7m} + 28HR_{3\cdot7m} + 54HR_{4\cdot7m}$$

$$R_{1\cdot7m} - 0 = C\left(\frac{16aL}{2} + \frac{11R_{2\cdot7m}L^3}{6EI} + \frac{40R_{3\cdot7m}L^3}{6EI} + \frac{81R_{4\cdot7m}L^3}{6EI}\right)$$

$$= 16K + 11HR_{2\cdot7m} + 40HR_{3\cdot7m} + 81HR_{4\cdot7m}$$

Transposed, these four equations become

$$R_{1\cdot7m} - (1+2H)R_{2\cdot7m} - 5HR_{3\cdot7m} - 8HR_{4\cdot7m} = K$$

$$R_{1\cdot7m} - 5HR_{2\cdot7m} - (1+16H)R_{3\cdot7m} - 28HR_{4\cdot7m} = 4K$$

$$R_{1\cdot7m} - 8HR_{2\cdot7m} - 28HR_{3\cdot7m} - (1+54H)R_{4\cdot7m} = 9K$$

$$R_{1\cdot7m} - 11HR_{2\cdot7m} - 40HR_{3\cdot7m} - 81HR_{4\cdot7m} = 16K$$

Since $\underline{H}$ and $\underline{K}$ are constants whose values are fixed for any given bridge which is being investigated, it will be seen that there have been obtained four simultaneous equations with four unknowns (i.e., the values of the reactions). A solution by the method of determinants yielded the following values

$$R_{1\text{-}7m} = \frac{K(16 + 252H + 256H^2 + 41H^3)}{1 - 60H + 42H^2 - 3H^3}$$

$$R_{2\text{-}7m} = \frac{K(15 + 166H + 73H^2)}{1 - 60H + 42H^2 - 3H^3}$$

$$R_{3\text{-}7m} = \frac{K(12 + 29H - 30H^2)}{1 - 60H + 42H^2 - 3H^3}$$

$$R_{4\text{-}7m} = \frac{K(7 - 42H + 6H^2)}{1 - 60H + 42H^2 - 3H^3}$$

The maximum load, P_{7m}, which seven rafts may carry without becoming the 9-raft case may be obtained from the equation

$$P_{7m} = R_{1\text{-}7m} + 2R_{2\text{-}7m} + 2R_{3\text{-}7m} + 2R_{4\text{-}7m}$$

Substituting the values which have been obtained for the reactions

$$P_{7m} = \frac{K(84 + 558H + 354H^2 + 41H^3)}{1 - 60H + 42H^2 - 3H^3}$$

Seven Rafts Acting, Not Max. (That is, seven rafts are supporting load but the load is not great enough to close the next joints.) The first three equations for this case will be the same as the first three for the seven-raft-max. case. The fourth equation is

$$R_{1\cdot 7} + 2R_{2\cdot 7} + 2R_{3\cdot 7} + 2R_{4\cdot 7} = P$$

That is, the four equations which will permit the reactions to be found are

$$R_{1\cdot 7} - (1+2H)R_{2\cdot 7} - 5HR_{3\cdot 7} - 8HR_{4\cdot 7} = K$$

$$R_{1\cdot 7} - 5HR_{2\cdot 7} - (1+16H)R_{3\cdot 7} - 28HR_{4\cdot 7} = 4K$$

$$R_{1\cdot 7} - 8HR_{2\cdot 7} - 28HR_{3\cdot 7} - (1+54H)R_{4\cdot 7} = 9K$$

$$R_{1\cdot 7} + 2R_{2\cdot 7} + 2R_{3\cdot 7} + 2R_{4\cdot 7} = P$$

Solved, these yield the values

$$R_{1\cdot 7} = \frac{P(1+72H+131H^2+26H^3) + K(\text{[illegible]}\ 26H+2H^2)}{7+196H+193H^2+26H^3}$$

$$R_{2\cdot 7} = \frac{P(1+57H+46H^2) + K(21+16H-4H^2)}{7+196H+193H^2+26H^3}$$

$$R_{3\cdot 7} = \frac{P(1+23H-18H^2) + K(65H+14H^2)}{7+196H+193H^2+26H^3}$$

$$R_{4\cdot 7} = \frac{P(1-18H+3H^2) - K(35+68H+11H^2)}{7+196H+193H^2+26H^3}$$

Five Rafts Acting, Maximum. Again use may be made of Fig. 14 with the modification that $R_{4\cdot5} = 0$ and, hence, line (d) is meaningless.
Proceeding as before

$$R_{1\text{-}5m} - R_{2\cdot5m} = C\left(\frac{aL}{2} + \frac{2R_{2\cdot5}\,mL^3}{6EI} + \frac{5R_{3\cdot5}\,mL^3}{6EI}\right)$$

$$= K + 2HR_{2\text{-}5m} + 5HR_{3\text{-}5m}$$

$$R_{1\text{-}5m} - R_{3\cdot5m} = C\left(\frac{4aL}{2} + \frac{5R_{2\cdot5}\,mL^3}{6EI} + \frac{16R_{3\cdot5}\,mL^3}{6EI}\right)$$

$$= 4K + 5HR_{2\text{-}5m} + 16HR_{3\text{-}5m}$$

$$R_{1\text{-}5m} - 0 = C\left(\frac{aL}{2} + \frac{8R_{2\text{-}5}\,mL^3}{6EI} + \frac{28R_{3\text{-}5}\,mL^3}{6EI}\right)$$

$$= 9K + 8HR_{2\text{-}5m} + 28HR_{3\text{-}5m}$$

Transposing,

$$R_{1\text{-}5m} - (1+2H)\,R_{2\cdot5m} - 5HR_{3\text{-}5m} = K$$

$$R_{1\text{-}5m} - 5HR_{2\text{-}5m} - (1+16H)\,R_{3\text{-}5m} = 4K$$

$$R_{1\text{-}5m} - 8HR_{2\cdot5m} - 28HR_{3\cdot5m} = 9K$$

Solving,

$$R_{1\text{-}5m} = \frac{K(9+42H+11H^2)}{1-18H+3H^2}$$

$$R_{2\text{-}5m} = \frac{K(8+19H)}{1-18H+3H^2}$$

$$R_{3\text{-}5m} = \frac{K(5-6H)}{1-18H+3H^2}$$

But $P_{5m} = R_{1\text{-}5m} + 2R_{2\cdot5m} + 2R_{3\text{-}5m}$

i.e., $$P_{5m} = \frac{K(35+68H+11H^2)}{1-18H+3H^2}$$

This last value may be readily checked. Consider the seven-raft case with load reduced until $R_{4\cdot 7} = 0$, that is, until the five-raft-max. case resutls. That is, setting $R_{4\cdot 7}$ on page 21 equal to zero, the above value is obtained.

Five Rafts Acting, Not Max. The first two equations are the same as for the five-raft-max. case. The third equation is as given below. That is,

$$R_{1\cdot 5} - (1+2H)R_{2\cdot 5} - 5HR_{3\cdot 5} = K$$

$$R_{1\cdot 5} - 5HR_{2\cdot 5} - (1+16H)R_{3\cdot 5} = 4K$$

$$R_{1\cdot 5} + 2R_{2\cdot 5} + 2R_{3\cdot 5} = P$$

When solved, these yield

$$R_{1\cdot 5} = \frac{P(1+18H+7H^2) + K(10-2H)}{5+34H+7H^2}$$

$$R_{2\cdot 5} = \frac{P(1+11H) + K(5+4H)}{5+34H+7H^2}$$

$$R_{3\cdot 5} = \frac{P(1-3H) - K(10+3H)}{5+34H+7H^2}$$

<u>Three Rafts Acting, Maximum.</u> In the manner previously used, the following two equations are written

$$R_{1\text{-}3m} - R_{2\text{-}3m} = C\left(\frac{aL}{2} + \frac{2R_{2\text{-}3m}L^3}{6EI}\right) = K + 2HR_{2\text{-}3m}$$

$$R_{1\text{-}3m} - 0 \quad = C\left(\frac{4aL}{2} + \frac{5R_{2\text{-}3m}L^3}{6EI}\right) = 4K + 5HR_{2\text{-}3m}$$

Transposing,

$$R_{1\text{-}3m} - (1+2H)\,R_{2\text{-}3m} = K$$

$$R_{1\text{-}3m} \qquad - 5HR_{2\text{-}3m} = 4K$$

Solving,

$$R_{1\text{-}3m} = \frac{K(4+3H)}{1-3H}$$

$$R_{2\text{-}3m} = \frac{3K}{1-3H}$$

But $\quad P_{3m} = R_{1\text{-}3m} + 2R_{2\text{-}3m}$

That is, $\quad P_{3m} = \dfrac{K(10+3H)}{1-3H}$

This value may be readily checked by setting $R_{3.5} = 0$

<u>Three Rafts Acting, Not Max.</u> For this case the first equation is the same as the first equation in the three-span-max. case. The second equation is as given below

$$R_{1\text{-}3} - (1+2H)\,R_{2\text{-}3} = K$$

$$R_{1\text{-}3} \qquad + 2R_{2\text{-}3} = P$$

Solved, these give

$$R_{1\cdot 3} = \frac{P(1+2H)+2K}{3+2H}$$

$$R_{2\cdot 3} = \frac{P-K}{3+2H}$$

This last value when set equal to zero checks the value given on page 17 for R_{1m}

<u>Eight</u> <u>Rafts</u> <u>Acting</u>, <u>Max</u>. Fig. 15 shows this case, the various values having the same signifigance* as in Fig. 14. The following equations may be written

$$R_{1\cdot 8m} - R_{2\cdot 8m} = C\left(\frac{4}{2}\,\frac{aL}{2} + \frac{3}{4}\,\frac{R_{1\cdot 8m}L^3}{6EI} + \frac{23}{4}\,\frac{R_{2\cdot 8m}L^3}{6EI} + \frac{47}{4}\,\frac{R_{3\cdot 8m}L^3}{6EI} + \frac{71}{4}\,\frac{R_{4\cdot 8m}L^3}{6EI}\right)$$

$$= 2K + \frac{3}{4}HR_{1\cdot 8m} + \frac{23}{4}HR_{2\cdot 8m} + \frac{47}{4}HR_{3\cdot 8m} + \frac{71}{4}HR_{4\cdot 8m}$$

$$R_{1\cdot 8m} - R_{3\cdot 8m} = C\left(\frac{12}{2}\,\frac{aL}{2} + \frac{6}{4}\,\frac{R_{1\cdot 8m}L^3}{6EI} + \frac{50}{4}\,\frac{R_{2\cdot 8m}L^3}{6EI} + \frac{118}{4}\,\frac{R_{3\cdot 8m}L^3}{6EI} + \frac{190}{4}\,\frac{R_{4\cdot 8m}L^3}{6EI}\right)$$

$$= 6K + \frac{6}{4}HR_{1\cdot 8m} + \frac{50}{4}HR_{2\cdot 8m} + \frac{118}{4}HR_{3\cdot 8m} + \frac{190}{4}HR_{4\cdot 8m}$$

$$R_{1\cdot 8m} - R_{4\cdot 8m} = C\left(\frac{24}{2}\,\frac{aL}{2} + \frac{9}{4}\,\frac{R_{1\cdot 8m}L^3}{6EI} + \frac{77}{4}\,\frac{R_{2\cdot 8m}L^3}{6EI} + \frac{193}{4}\,\frac{R_{3\cdot 8m}L^3}{6EI} + \frac{333}{4}\,\frac{R_{4\cdot 8m}L^3}{6EI}\right)$$

$$= 12K + \frac{9}{4}HR_{1\cdot 8m} + \frac{77}{4}HR_{2\cdot 8m} + \frac{193}{4}HR_{3\cdot 8m} + \frac{333}{4}HR_{4\cdot 8m}$$

$$R_{1\cdot 8m} - 0 = C\left(\frac{40}{2}\,\frac{aL}{2} + \frac{12}{4}\,\frac{R_{1\cdot 8m}L^3}{6EI} + \frac{104}{4}\,\frac{R_{2\cdot 8m}L^3}{6EI} + \frac{268}{4}\,\frac{R_{3\cdot 8m}L^3}{6EI} + \frac{480}{4}\,\frac{R_{4\cdot 8m}L^3}{6EI}\right)$$

$$= 20K + \frac{12}{4}HR_{1\cdot 8m} + \frac{104}{4}HR_{2\cdot 8m} + \frac{268}{4}HR_{3\cdot 8m} + \frac{480}{4}HR_{4\cdot 8m}$$

* The displacements due to articulation and deflection are above the point of application of the load.

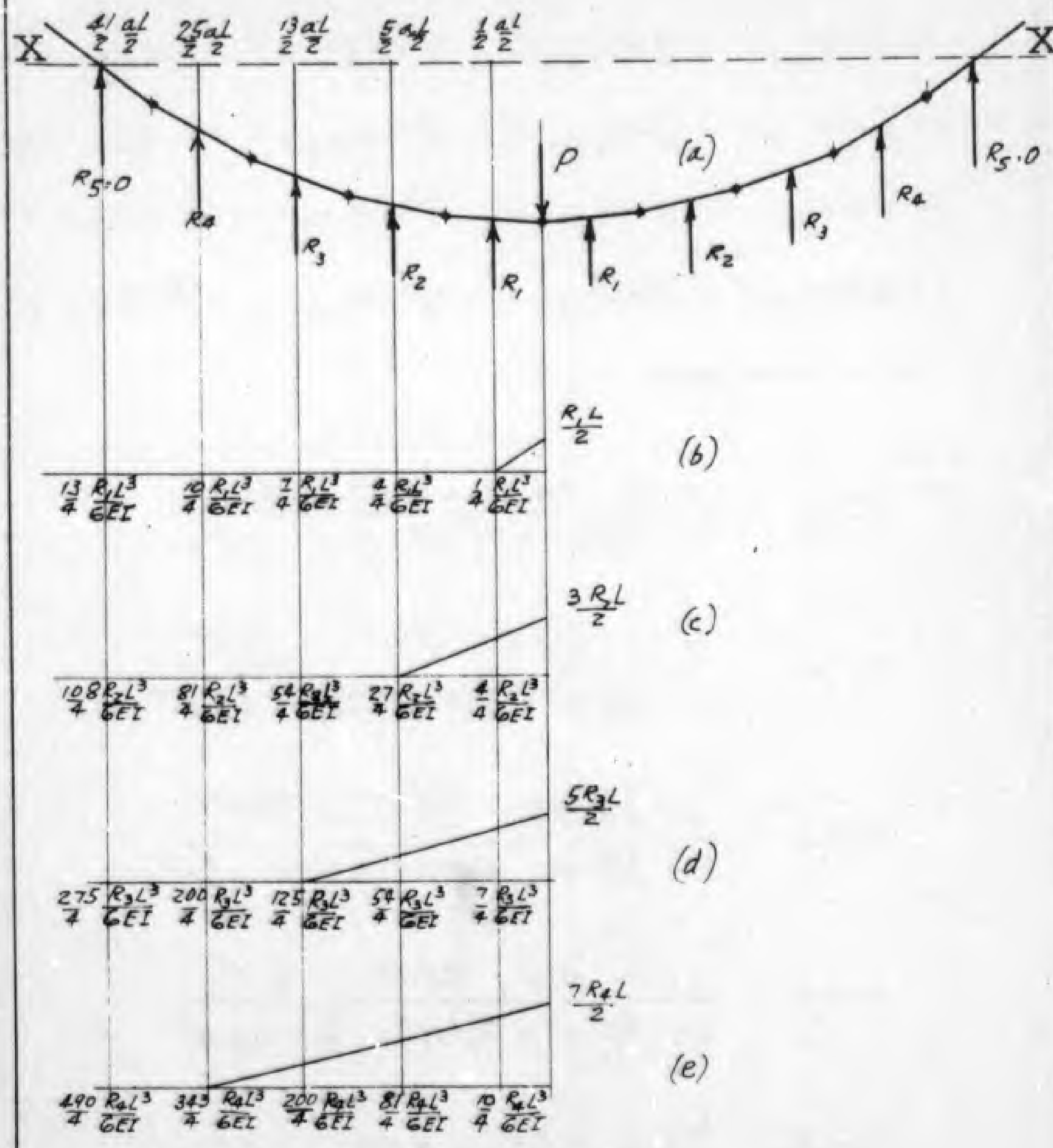


Fig. 15

Transposing,

$$\left(1-\tfrac{3}{4}H\right)R_{1\cdot 8m}+\left(-1-\tfrac{23}{4}H\right)R_{2\cdot 8m}+\left(-\tfrac{47}{4}\right)R_{3\cdot 8m}+\left(-\tfrac{71}{4}\right)R_{4\cdot 8m}=2K$$

$$\left(1-\tfrac{6}{4}H\right)R_{1\cdot 8m}+\left(-\tfrac{50}{4}H\right)R_{2\cdot 8m}+\left(-1-\tfrac{118}{4}H\right)R_{3\cdot 8m}+\left(-\tfrac{190}{4}\right)R_{4\cdot 8m}=6K$$

$$\left(1-\tfrac{9}{4}H\right)R_{1\cdot 8m}+\left(-\tfrac{77}{4}H\right)R_{2\cdot 8m}+\left(-\tfrac{193}{4}H\right)R_{3\cdot 8m}+\left(-1-\tfrac{333}{4}H\right)R_{4\cdot 8m}=12K$$

$$\left(1-\tfrac{12}{4}H\right)R_{1\cdot 8m}+\left(-\tfrac{104}{4}H\right)R_{2\cdot 8m}+\left(-\tfrac{268}{4}H\right)R_{3\cdot 8m}+\left(-\tfrac{480}{4}H\right)R_{4\cdot 8m}=20K$$

Solved, these yield

$$R_{1\cdot 8m}=\frac{K\left(20+476H+670H^2+\frac{269}{2}H^3\right)}{1-\frac{390}{4}H+\frac{483}{4}H^2-\frac{81}{4}H^3+\frac{3}{4}H^4}$$

$$R_{2\cdot 8m}=\frac{K\left(18+246H+\frac{194}{4}H^2-\frac{57}{2}H^3\right)}{1-\frac{390}{4}H+\frac{483}{4}H^2-\frac{81}{4}H^3+\frac{3}{4}H^4}$$

$$R_{3\cdot 8m}=\frac{K\left(14+13H-\frac{378}{4}H^2+\frac{15}{2}H^3\right)}{1-\frac{390}{4}H+\frac{483}{4}H^2-\frac{81}{4}H^3+\frac{3}{4}H^4}$$

$$R_{4\cdot 8m}=\frac{K\left(8-87H+30H^2-\frac{3}{2}H^3\right)}{1-\frac{390}{4}H+\frac{483}{4}H^2-\frac{81}{4}H^3+\frac{3}{4}H^4}$$

But $P_{8m}=2R_{1\cdot 8m}+2R_{2\cdot 8m}+2R_{3\cdot 8m}'+2R_{4\cdot 8m}$

Substituting the values found above

$$P_{8m}=\frac{K\left(120+1296H+1308H^2+224H^3\right)}{1-\frac{390}{4}H+\frac{483}{4}H^2-\frac{81}{4}H^3+\frac{3}{4}H^4}$$

Eight Rafts, Not Max. The first three equations are the same as those of the preceeding case. These together with the necessary fourth equation are

$$(1-\tfrac{3}{4}H)R_{1-8} + (-1-\tfrac{23}{4}H)R_{2-8} + (-\tfrac{47}{4}H)R_{3-8} + (-\tfrac{71}{4}H)R_{4-8} = 2K$$

$$(1-\tfrac{6}{4}H)R_{1-8} + (-\tfrac{50}{4}H)R_{2-8} + (-1-\tfrac{118}{4}H)R_{3-8} + (-\tfrac{190}{4}H)R_{4-8} = 6K$$

$$(1-\tfrac{9}{4}H)R_{1-8} + (-\tfrac{77}{4}H)R_{2-8} + (-\tfrac{193}{4}H)R_{3-8} + (-1-\tfrac{133}{4}H)R_{4-8} = 12K$$

$$2R_{1-8} + 2R_{2-8} + 2R_{3-8} + 2R_{4-8} = P$$

Solving

$$R_{1-8} = \frac{P(1+\frac{474}{4}H+\frac{1295}{4}H^2+\frac{141}{4}H^3)+K(40-48H+4H^2)}{8+388H+660H^2+142H^3}$$

$$R_{2-8} = \frac{P(1+\frac{330}{4}H+\frac{199}{4}H^2-18H^3)+K(24+96H-20H^2)}{8+388H+660H^2+142H^3}$$

$$R_{3-8} = \frac{P(1+\frac{110}{4}H-\frac{231}{4}H^2+\frac{18}{4}H^3)-K(8-160H-76H^2)}{8+388H+660H^2+142H^3}$$

$$R_{4-8} = \frac{P(1-\frac{138}{4}H+\frac{57}{4}H^2-\frac{3}{4}H^3)-K(56+208H+60H^2)}{8+388H+660H^2+142H^3}$$

Six Rafts Acting, Maximum. Here

$$R_{1\text{-}6m} - R_{2\text{-}6m} = C\left(\frac{4}{2}\frac{aL}{2} + \frac{3}{4}\frac{R_{1\cdot 6m}L^3}{6EI} + \frac{23}{4}\frac{R_{2\cdot 6m}L^3}{6EI} + \frac{47}{4}\frac{R_{3\cdot 6m}L^3}{6EI}\right)$$

$$= 2K + \tfrac{3}{4}HR_{1\text{-}6m} + \tfrac{23}{4}HR_{2\cdot 6m} + \tfrac{47}{4}HR_{3\cdot 6m}$$

$$R_{1\text{-}6m} - R_{3\cdot 6m} = C\left(\frac{12}{2}\frac{aL}{2} + \frac{6}{4}\frac{R_{1\cdot 6m}L^3}{6EI} + \frac{50}{4}\frac{R_{2\cdot 6m}L^3}{6EI} + \frac{118}{4}\frac{R_{3\cdot 6m}L^3}{6EI}\right)$$

$$= 6K + \tfrac{6}{4}HR_{1\text{-}6m} + \tfrac{50}{4}HR_{2\text{-}6m} + \tfrac{118}{4}HR_{3\cdot 6m}$$

$$R_{1\text{-}6m} - 0 = C\left(\frac{24}{2}\frac{aL}{2} + \frac{9}{4}\frac{R_{1\cdot 6m}L^3}{6EI} + \frac{77}{4}\frac{R_{2\cdot 6m}L^3}{6EI} + \frac{193}{4}\frac{R_{3\cdot 6m}L^3}{6EI}\right)$$

$$= 12K + \tfrac{9}{4}HR_{1\text{-}6m} + \tfrac{77}{4}HR_{2\text{-}6m} + \tfrac{193}{4}HR_{3\text{-}6m}$$

That is

$$\left(1-\tfrac{3}{4}H\right)R_{1\text{-}6m} + \left(-1-\tfrac{23}{4}H\right)R_{2\text{-}6m} + \left(-\tfrac{47}{4}H\right)R_{3\text{-}6m} = 2K$$

$$\left(1-\tfrac{6}{4}H\right)R_{1\text{-}6m} + \left(-\tfrac{50}{4}H\right)R_{2\text{-}6m} + \left(-1-\tfrac{118}{4}H\right)R_{3\text{-}6m} = 6K$$

$$\left(1-\tfrac{9}{4}H\right)R_{1\text{-}6m} + \left(-\tfrac{77}{4}H\right)R_{2\text{-}6m} - \left(-\tfrac{193}{4}H\right)R_{3\text{-}6m} = 12K$$

Solving,

$$R_{1\text{-}6m} = \frac{K\left(12 + 95H + 36H^2\right)}{1 - \frac{138}{4}H + \frac{57}{4}H^2 - \frac{3}{4}H^3}$$

$$R_{2\text{-}6m} = \frac{K\left(10 + 27H - \frac{15}{2}H^2\right)}{1 - \frac{138}{4}H + \frac{57}{4}H^2 - \frac{3}{4}H^3}$$

$$R_{3\text{-}6m} = \frac{K\left(6 - 18H + \frac{3}{2}H^2\right)}{1 - \frac{138}{4}H + \frac{57}{4}H^2 - \frac{3}{4}H^3}$$

But $P_{6m} = 2R_{1\text{-}6m} + 2R_{2\text{-}6m} + 2R_{3\text{-}6m}$

$$\therefore P_{6m} = \frac{K\left(56 + 208H + 60H^2\right)}{1 - \frac{138}{4}H + \frac{57}{4}H^2 - \frac{3}{4}H^3}$$

It will be noticed that this same value is obtained when $R_{4\text{-}8}$ is set equal to zero.

Six Rafts Acting, Not Max. Two of the equations for this case are the same as two for the six-raft-max. case. These, together with the third equation are:

$$\left(1-\tfrac{3}{4}H\right)R_{1\text{-}6}+\left(-1-\tfrac{23}{4}H\right)R_{2\text{-}6}+\left(-\tfrac{47}{4}H\right)R_{3\text{-}6}=2K$$

$$\left(1-\tfrac{6}{4}H\right)R_{1\text{-}6}+\left(\tfrac{50}{4}H\right)R_{2\text{-}6}+\left(-1-\tfrac{118}{4}H\right)R_{3\text{-}6}=6K$$

$$2R_{1\text{-}6}+2R_{2\text{-}6}+2R_{3\text{-}6}=P$$

When solved, these equations give the values

$$R_{1\text{-}6}=\frac{P\left(1+\frac{141}{4}H+\frac{91}{4}H^2\right)+K\left(16-4H\right)}{6+88H+38H^2}$$

$$R_{2\text{-}6}=\frac{P\left(1+17H-\frac{9}{2}H^2\right)+K\left(4+20H\right)}{6+88H+38H^2}$$

$$R_{3\text{-}6}=\frac{P\left(1-\frac{33}{4}H+\frac{3}{4}H^2\right)-K\left(20+16H\right)}{6+88H+38H^2}$$

Four Rafts Acting, Maximum. Here

$$R_{1\text{-}4m}-R_{2\text{-}4m}=C\left(\frac{4}{2}\,\frac{aL}{2}+\frac{3}{4}\,\frac{R_{1\text{-}4m}L^3}{6EI}+\frac{23}{4}\,\frac{R_{2\text{-}4m}L^3}{6EI}\right)$$

$$=2K+\tfrac{3}{4}HR_{1\text{-}4m}+\tfrac{23}{4}HR_{2\text{-}4m}$$

$$R_{1-4m} = 0 = C\left(\frac{12}{2}\,\frac{aL}{2} + \frac{6}{4}\,\frac{R_{1-4m}L^3}{6EI} + \frac{50}{4}\,\frac{R_{2-4m}L^3}{6EI}\right)$$

$$= 6K + \frac{6}{4}HR_{1-4m} + \frac{50}{4}HR_{2-4m}$$

Transposing,

$$\left(1-\frac{3}{4}H\right)R_{1-4m} + \left(-1-\frac{23}{4}H\right)R_{2-4m} = 2K$$

$$\left(1-\frac{6}{4}H\right)R_{1-4m} + \left(\quad -\frac{50}{4}H\right)R_{2-4m} = 6K$$

Solving,

$$R_{1-4m} = \frac{K\left(6+\frac{38}{4}H\right)}{1-\frac{33}{4}H+\frac{3}{4}H^2}$$

$$R_{2-4m} = \frac{K\left(4-\frac{6}{4}H\right)}{1-\frac{33}{4}H+\frac{3}{4}H^2}$$

From the equation

$$P_{4m} = 2R_{1-4m} + 2R_{2-4m}$$

there is obtained

$$P_{4m} = \frac{K(20+16H)}{1-\frac{33}{4}H+\frac{3}{4}H^2}$$

the same value which comes from setting R_{3-6} equal to zero.

<u>Four Rafts</u> <u>Acting</u>, <u>Not</u> <u>Max</u>. The necessary equations for this case are

$$\left(1-\frac{3}{4}H\right)R_{1-4} + \left(-1-\frac{23}{4}H\right)R_{2-4} = 2K$$

$$2R_{1-4} + 2R_{2-4} = P$$

These give the values:

$$R_{1-4} = \frac{P\left(1 + \frac{23}{4}H\right) + 4K}{4 + 10H}$$

$$R_{2-4} = \frac{P\left(1 - \frac{3}{4}H\right) - 4K}{4 + 10H}$$

<u>Two Rafts Acting, Maximum.</u> For this case the equation is:

$$R_{1-2m} - 0 = C\left(\frac{4}{2}\,\frac{aL}{2} + \frac{3}{4}\,\frac{R_{1-2m}L^3}{6EI}\right)$$

$$= 2K + \frac{3}{4}HR_{1-2m}$$

This gives the value

$$R_{1-2m} = \frac{2K}{1 - \frac{3}{4}H}$$

from which is obtained

$$P_{2m} = \frac{4K}{1 - \frac{3}{4}H}$$

<u>Two Rafts Acting, Not Max.</u> Clearly in this case,

$$R_{1-2} = \frac{P}{2}$$

<u>Use of Equations</u>. When the make up of the structure is decided upon, values can be computed for <u>K</u> and <u>H</u>. Then there will be computed the values of P_{1m}, P_{2m}, P_{3m}, etc. Suppose the investigation is being made for an odd number of rafts and the load being considered lies between P_{5m} and P_{7m}. This will mean that the case is "Seven Rafts Acting,

Not Max." The equations for this case will give the values of the reactions and the shear and moment curves follow directly.

Loads Different From a Single Concentrated Load. Each of the foregoing derivations has been made for a single concentrated load placed at the middle of the structure. Provided an actual tank, truck, or other load is not spread over too great a length, fair accuracy will be obtained by assuming that the reactions will be the same as for a single concentrated load of the same magnitude. However, the actual distribution of loads will be used in drawing shear and moment curves. It is felt that the error due to this assumption will be no greater than those errors which arise from (1) variations in articulation due to shop inaccuracies and (2) disregarding the fact that the pontons do not have the shape of a box (i.e., submergence and reaction are not directly proportional).

Reactions of Articulated Ponton Bridges

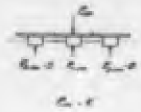
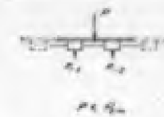
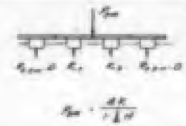
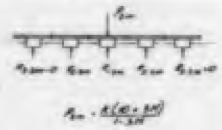
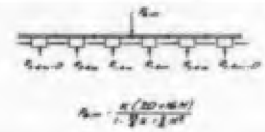
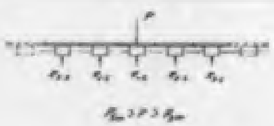
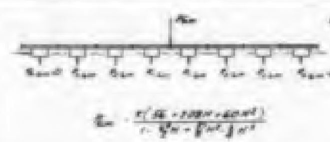
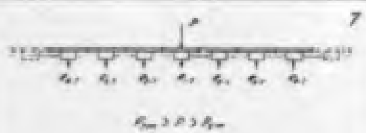
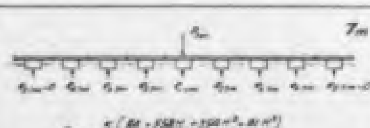
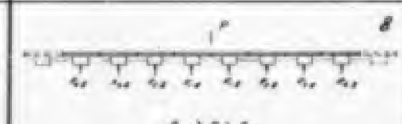
Notation

$$H = \frac{C L^3}{2 E I}$$ and $$K = \frac{C \phi L}{2}$$

where E = Modulus of Elasticity of Balk,
I = Moment of Inertia of Balk,
φ = Angle of Articulation (radians) Between Rafts,
L = Length of One Raft,
C = Raft Displacement per Unit of Depth.

Method of Use

For a selected structure (that is, with H and K known) determine, by means of these formulas, the values of $P_{1m}, P_{2m} \ldots P_{8m}$. Consider the actual load as a center concentrated load. Place either at a joint (even number of rafts) or at the center of a raft (odd number of rafts). If odd, determine where the load comes with relation to $P_{1m}, P_{3m}, P_{5m}, P_{7m}$. If (say) between P_{5m} and P_{7m}, the reactions are given as R_{17}, R_{27}, R_{37}. Compute the reactions, replace the assumed concentrated load by the actual load, and draw the shear and moment curves for the structure.

Case	Diagram	Reactions
1		$R_1 = P$
1m		$R_{1m} = K$
2		$R_2 = \frac{P}{2}$
2m		$R_{2m} = \frac{2K}{1-\frac{1}{2}H}$
3		$R_{13} = \frac{P(1+2H)+2K}{3+2H}$; $R_{23} = \frac{P-K}{3+2H}$ [partly illegible]
3m		$R_{2m} = \frac{K(4+3H)}{1-3H}$; $R_{2\cdot 3m} = \frac{3K}{1-3H}$ [partly illegible]
4		[illegible]
4m		[illegible]
5		[illegible]
5m		[illegible]
6		[illegible]
6m		[illegible]
7		[illegible]
7m		[illegible]
8		[illegible]
8m		[illegible]

Identity of Methods. The method of pages 16-34 may be applied to continuous (i.e., without articulation) structures if K is set equal to zero. Hence, for continuous structures, the metods summarized on sheets 15 and 34 should give identical results. For illustration, the five-ponton structure of Fig. 16 will be investigated. The notation corresponds to page 15, and by the method

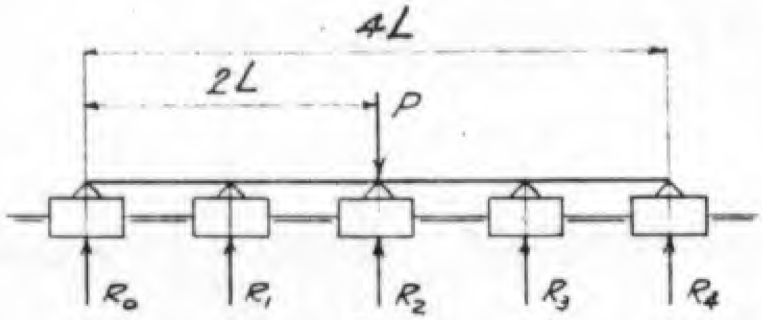


Fig. 16

of that page, two equations may be written (for $f = 1$, and $f = 2$) since, by symmetry there are only, two unknown *interior* ponton reactions.

For $f = 1$

$$R_1\left(4-1-1+\frac{2\times1\times1}{4}\right)+R_2\left(4\cdot2-1+\frac{2\times1\times2}{4}\right)$$

$$+R_3\left(4\cdot3-1+\frac{2\times1\times3}{4}\right)+R_1H(2\times1\times9)+4R_1$$

$$+R_2H(1\times2(2\times4\times2-4-1))+R_3H(1\times1(2\times4\times3-9-1))$$

$$=P\left(4-2-1+\frac{2\times1\times2}{4}\right)+PH(2\times1(2\times4\times2-4-1))$$

Remembering that $R_3 = R_1$, this may be rewritten

$$8R_1+32HR_1+2R_2+22HR_2 = 2P+22HP$$

Similarly, for $\underline{f} = 2$,

$$R_1\left(4\cdot1\cdot2 + \frac{2\times2\times1}{4}\right) + R_2\left(4\cdot2\cdot2 + \frac{2\times2\times2}{4}\right)$$

$$+ R_3\left(4\cdot3\cdot2 + \frac{2\times2\times3}{4}\right) + R_1H\left(1\times2\left(2\times4\times2-1-4\right)\right)$$

$$+ R_2H\left(2\times4\times4\right) + 4R_2 + R_3H\left(2\times1\left(2\times4\times3-9-4\right)\right)$$

$$= P\left(4\cdot2\cdot2 + \frac{2\times2\times2}{4}\right) + PH\left(2\times4\times4\right)$$

Or,

$$4R_1 + 44HR_1 + 6R_2 + 32HR_2 = 2P + 32HP$$

Therefore. (dividing all terms by 2)

$$R_1 = \frac{P\begin{vmatrix} 1+11H & 1+11H \\ 1+16H & 3+16H \end{vmatrix}}{\begin{vmatrix} 4+16H & 1+11H \\ 2+22H & 3+16H \end{vmatrix}} = \frac{P(3+49H+176H^2-1-27H-176H^2)}{12+112H+256H^2-2-44H-242H^2}$$

$$= \frac{P(2+22H)}{10+68H+14H^2} = \frac{P(1+11H)}{5+34H+7H^2}$$

$$R_2 = \frac{P\begin{vmatrix} 4+16H & 1+11H \\ 2+22H & 1+16H \end{vmatrix}}{10+68H+14H^2} = \frac{P(4+80H+256H^2-2-44H-242H^2)}{10+68H+14H^2}$$

$$= \frac{P(2+36H+14H^2)}{10+68H+14H^2} = \frac{P(1+18H+7H^2)}{5+34H+7H^2}$$

The value of $\underline{R}_0 (= \underline{R}_5)$ may be obtained from the equation $\Sigma V = 0$.

That is,

$$2R_0 + 2R_1 + R_2 - P = 0$$

$$R_0 = \frac{1}{2}\left(P - 2R_1 - R_2\right)$$

$$R_0 = \frac{1}{2}\left(P - \frac{2P(1+11H) + P(1+18H+7H^2)}{5+34H+7H^2}\right)$$

$$= \frac{P}{2}\left(\frac{5+34H+7H^2-2-22H-1-18H-7H^2}{5+34H+7H^2}\right)$$

$$= \frac{P}{2}\left(\frac{2-6H}{5+34H+7H^2}\right) = \frac{P(1-3H)}{5+34H+7H^2}$$

The following comparison is found between the notation of pages 15 and 34

Page 34		Page 15
R_{1-5}	=	R_2
R_{2-5}	=	R_1
R_{3-5}	=	R_0

Hence, it is apparent that the values computed above are the same as those given on page 34 for the case where $\underline{K} = 0$. Clearly, the results of page 34 will give increased speed over those of page 15 for cases of symmetrical loading in continuous bridges provided that the actual load does not have too great a distribution.

NOTES ON STREAM CROSSING IN SWIFT WATER

by

George W. Howard
Lt. Colonel, Corps of Engineers

SYLLABUS

Included in this appendix are notes on proper construction of approaches, construction of bridges, anchorages, handling of debris, and rafting procedure in high velocity flow. Described herein are experiences of the Engineer Board personnel operating in the Colorado River at Imperial Dam, California. The discussion is concerned primarily with technique and points out, in general, that there is no substitute for experience in bridging operations in swift water.

GENERAL

1. The effect of velocity upon the characteristics of all floating bridges, both American and foreign, is marked. Some bridges which in still water will carry a tank weighing as much as 35 tons will carry a tank weighing only 20 to 25 tons under similar conditions of freeboard in a velocity of 7 feet per second. The actual reduction in capacity of the bridge with an increase in velocity is determined by the shape of the floating supports for the particular structure in question; for instance, one bridge which will carry an 18-ton tank when fully reinforced in no velocity will fail completely without a load upon it in a velocity of 7 feet per second. Substitution of a different type of support in this bridge will enable it to maintain its 18-ton capacity in no velocity and still carry the 18-ton load at 7 feet per second. Generally speaking, then, the suitability of floating bridges in velocity can be determined by the hydraulic characteristics of these floating supports. In addition to these floating supports, however, there are many other items which enter into the technique of bridging in high velocities and all of these go together to make up a suitable bridge to carry the rated loads.

2. Bridges constructed in streams having high velocities present difficulties of erection which are not present in the construction of bridges in still water or low velocities. If proper consideration is given to velocity, however, it is frequently possible to turn effects which would be considered ordinarily as difficulties into construction aids.

3. Maintenance of bridges in high currents presents more problems than that of bridges which are constructed in still water.

With a high current against the bridge and great traffic intensity there are such factors as chess moving sidewise on the bridge, trestle footings giving away, anchors shifting or guy lines loosening, which must be provided for in construction and watched at all times by this maintenance crew.

APPROACHES

4. The approach and departure from a bridge are of extreme importance, for these govern the manner in which the traffic will come on the bridge and dictate much concerning the maintenance of approach spans. If traffic comes upon an approach span at an angle, it is axiomatic that there will be trouble with the maintenance of this span. In every instance observed in which traffic has approached a bridge at even the slightest angle, it has been necessary to rearrange the approach to the bridge. There should be a long, smooth roadway to the bridge of at least 100 feet, and if it is possible of construction, the roadway should be 200 feet long. This type of approach enables all vehicles, particularly capacity loads, to guide upon the bridge and come straight on the span. If an approach at least this long is not possible, the result is that the vehicles must reduce speed so that they turn and come upon the span properly, thus retarding the traffic column and providing additional trouble to maintenance crews. If there is a long, straight approach to the bridge, it is possible for capacity loads to enter the bridge practically on the center line, and there is no reason why these loads, in crossing the structure, cannot remain centered on the bridge even in blackouts. A smooth approach is the best possible means for preventing traffic bottlenecks at bridges.

5. In the bridge, the approach should be considered not only as that portion which is made a part of a road down to the water's edge, but should include also that part of the bridge which is not floating. This fixed portion, too, should be smooth and should not have the hump which is found often in it from trestle construction. There should be an even grade from the abutment sill to the floating portion of the bridge. This grade prevents approaching traffic from having to make a momentary pause in climbing upon a fixed section and then descending from that section to the floating portion of the bridge. If this fixed portion is on an even plane from the abutment sill to the hinge sill, there is no cause for any pause on the part of the traffic; and furthermore, there is less impact on the fixed portion of the bridge between the abutment sill and the hinge sill. For an ideal approach, then, here should be a straight, smooth roadway in one plane from a distance of 100 to 200 feet back of the abutment sill to the hinge sill. Such an entrance permits traffic to make an even, straight approach at maximum allowable speed from the time of arrival in the roadway, until the road reaches the floating portion of the bridge.

CONSTRUCTION OF BRIDGES

6. Construction of bridges in swift water is generally little different from construction of bridges in water of low velocities or no velocity. There are, however, certain basic rules developed at Imperial Dam that must necessarily be followed in order to obtain fast construction with minimum manpower. These rules are:

a. Never use a holdfast where time permits construction of a deadman.

b. Never operate a power boat above a bridge except in emergency.

c. Never turn a boat loose from shore in velocity with the engine dead.

d. In attaching wire rope clips always use four clips and place U-bolts on dead end of rope.

e. Always use shore guys.

f. Never launch a ponton above a bridge being constructed in swift water.

g. Never keep boats, floats or pontons above a bridge as they may get loose and go down into (and under) the bridge.

h. Never put an initial load on a bridge that will strain its capacity; start with something about half of the maximum load.

These rules are in general no more than the application of common sense. It is necessary, however, that the effect of velocity upon the construction of the bridge be considered by all concerned with construction. If the effect of velocity is not considered, it is possible that the bridge will fail before it is closed.

7. Trestle footings should always be placed at the water's edge, if possible. It is desirable that the trestle be kept out of water since it enables the footing to be readily inspected. Trestles always should have the bearing area of the shoe increased by using landing mats or boards when the material is sand or silt. Figure 1 shows the type of failure that occurs from improper trestle footings.

ANCHORAGES

8. The greatest single aid that can be given the bridge to enable it to withstand the effect of high velocity by its construction

crew lies in the proper anchorage of the structure. It is possible from anchorages alone to make or break a bridge. An instance of a bridge failure from improper anchorages is shown in the photograph of Figure 1. A bridge that carried 35 tons in a velocity of 8 feet per second has been observed to fail under a load of 8 tons in a velocity of 8 feet per second when the anchorage was improperly placed. This bridge, even when improperly anchored, would have been entirely satisfactory for the rated load of 35 tons in velocities up to 3 or 4 feet per second, but when a velocity of 8 feet per second was experienced, the bridge failed under a load of 8 tons. Simply by changing the type of anchorage the bridge was enabled to carry 35 tons at 8 feet per second.

9. If the stream is completely free of debris, and there will be no flash floods, there is no reason why the standard kedge anchor cannot be used in a satisfactory manner in construction. It is important, however, that it be known that there will be no debris in the stream, for the lines leading from the end of the pontons down to the anchors are dangerous for catching debris. Anchors starting from the bow of the ponton or the float are entirely satisfactory as long as that bow has sheer; if not, it is necessary that the anchors be fastened to the deck, since there is a downward component on the upstream end of the ponton by the pull from the anchor lines. If the anchors are secured properly, the bridge should be able to withstand severe currents.

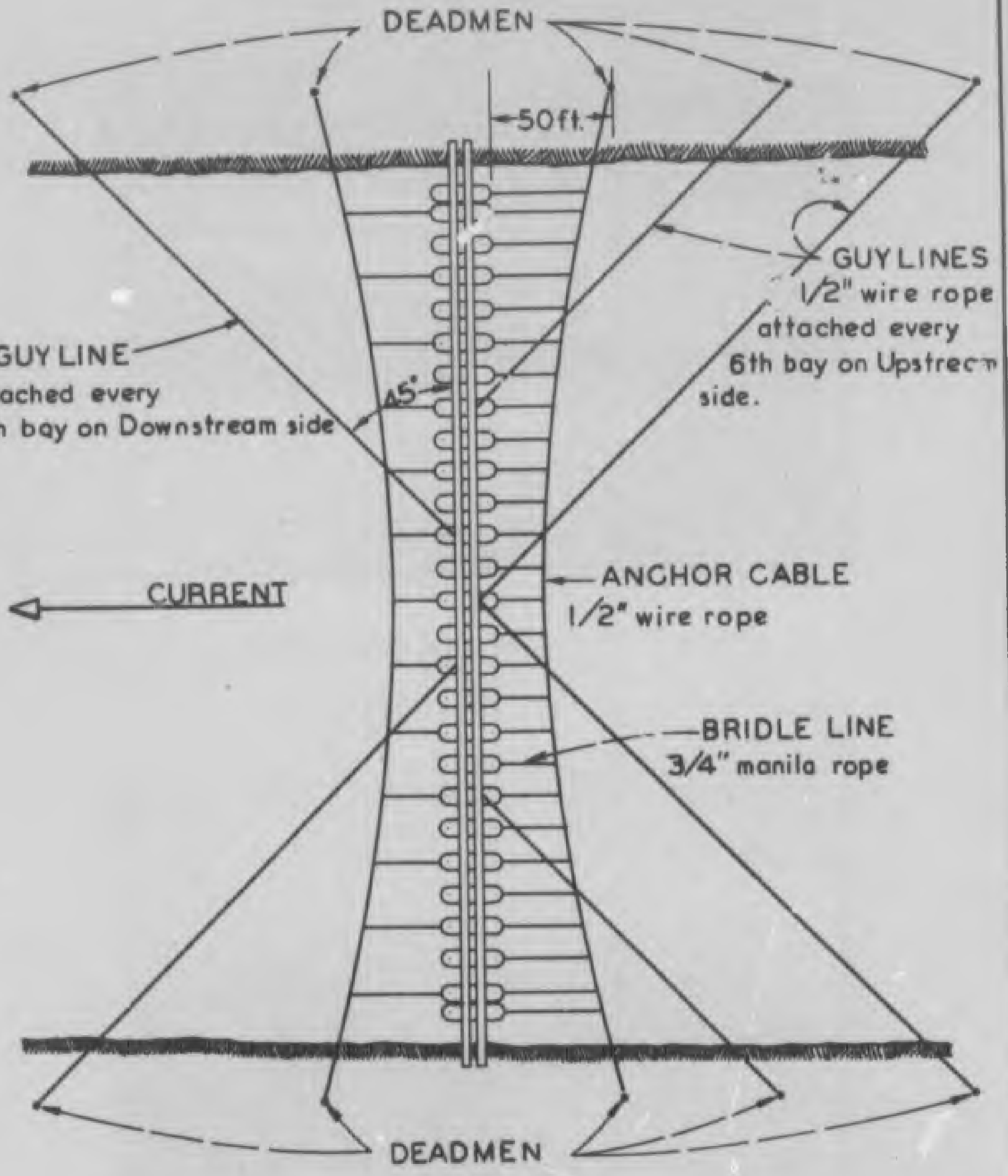
10. The use of bridles from an anchor cable is probably the most generally suitable manner to anchor the bridge. Here it is possible to place across the stream a wire rope cable at a distance of 50 to 80 feet above the bridge and run bridle lines from this cable to the floats or pontons. The bridle lines should be equipped with a boat snap to permit easy fastening to the anchor cable. The lines then can be tied from the bow of the ponton or floats to the anchor cable. The anchor cable should be high enough off the water so that it does not start the formation of an obstruction to debris coming downstream, by building up small pieces of debris into a mat. Anchor cables should be always fastened to deadmen on either shore. At times it will be necessary to raise the cable by means of shears on either side of the bank.

11. Anchorages for bridges in velocities over 3 feet per second should at no time be considered complete unless there are guy lines from the bridge to the shore. These lines should be placed at an angle of approximately 45 degrees with the bridge at distances of approximately 100 feet along the structure. When high velocities are to be experienced, it is not necessary that there be as many downstream as upstream shore guys for the bridge. When reversal of flow is expected, the same number of shore guys should be upstream and downstream. These shore guys aid the anchorage of the bridge more than any other factor. They serve to hold the bridge securely,

Improper trestle footing caused failure.

Lack of shore guys caused failure.

IMPROPER CONSTRUCTION CAUSES FAILURES.



METHOD OF ANCHORING
STEEL TREADWAY BRIDGE.

Bridge across Volturno without benefit
of bridle lines or shore guys.

Shore guys on another Volturno bridge are
conspicuous by their absence.

IMPROPERLY ANCHORED OPERATIONAL BRIDGES.

whereas the anchors or bridle lines serve chiefly for the construction of the bridge. It is essential, therefore, that the guy lines be firmly fastened. Figure 2 shows the proper method for a bridge anchorage. If there is no debris in the stream, however, kedge anchors can be substituted for bridle lines.

12. Two operational bridges across the Volturno River in Italy are shown in Figure 3. Neither of these bridges is anchored properly, and reports indicate that both bridges were washed out in flash floods. If properly anchored, it is believed that these bridges could have been saved, at least in floods up to velocities of 10 to 12 feet per second. Above this velocity it is probable that failure would have resulted from the shape of the ends of the floats, since this shape makes the floats extremely unstable in high stream velocities.

DEBRIS

13. A major factor in proper maintenance of a bridge in high velocity flow or in sudden rises of the stream is the control of debris. This control can be accomplished either through protective booms placed upstream from the bridge or by construction of the bridge in such a way that the debris will pass through it.

14. Construction of booms upstream from a bridge is practical, but dangerous. There should be at least two, and preferably three, booms placed at about two hundred yard intervals starting about three hundred yards above the bridge. These booms should be at an angle with the stream so that the debris will be swept into shore where a patrol can dispose of it. The use of the three booms is as a safety factor. It is quite possible that there will be such a pile above one of the booms that it will break and all come downstream.

15. The British constructed a boom above the Capua bridge in Italy. The boom consisted of Italian naval floats (cylinders about 2' 6" in diameter and 3' 6" long), which supported wire rope cables above and below the floats. Coils of dannert were fastened between the cables. The boom was at an angle to the stream and proved most effective. It collected such a large amount of debris that there was fear of failure, since the debris could not be removed fast enough, even though explosives were used. The boom held, however, but all concerned with the operation felt that there was too much possibility of failure of the boom to use one all the time. If there had been several booms, the danger of failure of one boom would have been reduced.

16. The construction of the bridge in such a way that debris will pass through it, can be accomplished best by the use of an anchorage system of bridle lines to an anchor cable. This procedure

leaves nothing in the water on which debris can catch. It is satisfactory to use anchor cables up to distances of about 600 feet. Over this distance, it is necessary to improvise something either to hold up the anchor cable or to hold anchors. This support can be secured in several ways. One way is the use of one ponton anchored by a one-half inch wire rope to approximately 5 or 6 anchors. This individual ponton is placed about 100 feet above the bridge and anchor lines from five pontons in the bridge are tied to the ponton. By this method, there is only one line going down into the stream and five boats are held. Figure 4 shows this method in use. It is imperative that men be stationed inside the boat upstream from the bridge in order to keep the one line free of debris in a heavily laden stream. Another method is to place a pile driver on a raft during construction, move upstream from the proposed center lines of the bridge and drive one or two piling to secure an anchor cable. It is then possible to place bridle lines from the bow of the pontons or the floats to the anchor cable.

17. That certain types of anchorages for bridges will allow debris to pass cannot be over-emphasized. Anything hanging down into the water will catch debris. Anything caught will tend to increase greatly the chances of catching other debris which comes downstream. When the bridge is properly anchored, it is possible for large amounts of debris to pass directly under metal pontons. Such action is shown in Figure 4. In a bridge with pneumatic floats, undoubtedly there will be considerable damage from large debris jams, but if there is nothing to hold the debris against the bridge, it is remarkable how much will pass under without serious damage to the floats.

BOW ADAPTERS

18. The shape of 10 and 25-ton metal pontons has been proven inadequate for high velocity operation. Model tests have indicated that the most economical means for increasing the freeboard at the bow of this ponton is by means of a splash board of the type shown in Figure 5. By the use of bow adapters it is possible to pass a given load in stream velocities as much as 2 to 3 feet per second faster than without the adapter.

"CREEPING" CHESS

19. Bridges left in place over long time intervals sometimes will have chess move sidewise to such an extent that the floor of the bridge becomes damaged. This phenomenon seems caused by incessant traffic over prolonged periods under changing current conditions. To prevent this occurrence, chess can be placed on edge between the roadway chess and outer reinforcing balk. This chess fills the gap between the roadway and the balk. It is kept in place by the reinforcing balk as shown in Figure 5.

Pontons anchored upstream with one rope on five anchors must have men in them to clear lines. This ponton had none.

Debris passing under properly anchored bridge as 45-ton tank passes over bridge. Note bridle lines and shore guys.

HANDLING DEBRIS BY PROPER BRIDGE ANCHORAGE.

Adapter to increase height of bow to prevent swamping.

Placing chess on edge between outside balk and floor prevents deck chess from moving sideways.

EXPEDIENTS FOR HIGH VELOCITY AND TRAFFIC INTENSITY.

Never place a raft site above a bridge.

Always chock vehicles on rafts.

IMPROPER RAFTING PROCEDURE.

RAFTING

20. An efficiently operating raft crew should be as highly trained as any bridging unit in the army. There is more teamwork connected with fast ferrying operations than with any other phase of bridging. In view of the fact that the raft crew is a small team, it is necessary that every man be alert constantly. Here, as well as in bridging, there are certain basic rules which must be followed in order to obtain maximum efficiency:

a. Never place a raft site above a bridge site (see Fig. 6).

b. Always chock vehicles on rafts (see Fig. 6).

c. Always provide holdfasts on both banks.

d. Always have landings prepared about twice as wide as is absolutely necessary.

e. Keep a man ready to cut a trail ferry loose.

21. Selection of a raft site should include easy approaches and good holdfasts. If it is not possible to utilize tree holdfasts, it is essential that four holdfasts on each shore be placed for handling lines. It is possible to start rafting without them but much time will be saved by placing holdfasts immediately so that it is not necessary for additional men to be on shore to hold a line as the raft comes to the landing. Figure 7 shows a four-float Steel Treadway raft and the location of holdfasts for shore lines. This type of raft construction assumes that a bulldozer will have cut down a landing, if necessary. Such a landing prepared by a bulldozer should be at least twice the width of the roadway in order that it not be essential for the raft to be docked in exactly the same spot each time. The landing permits more latitude to the men on the raft for jumping on and off in placing the shore lines. It also permits traffic to move as soon as the end of the raft has come over the shore.

22. Loading and unloading sites should be directly opposite each other, except in cases where the power used for propelling the raft is not sufficient for holding the loaded raft against the current. To overcome this deficiency, it is necessary to have the loading site upstream from the unloading site a sufficient distance to allow for the distance lost in crossing the stream. The light raft can be moved upstream to the loading site very easily. Certain locations prevent the use of smooth landing space for a raft with an overhanging deck, and at such places it is necessary sometimes to use landing stages. The general use of landing stages is

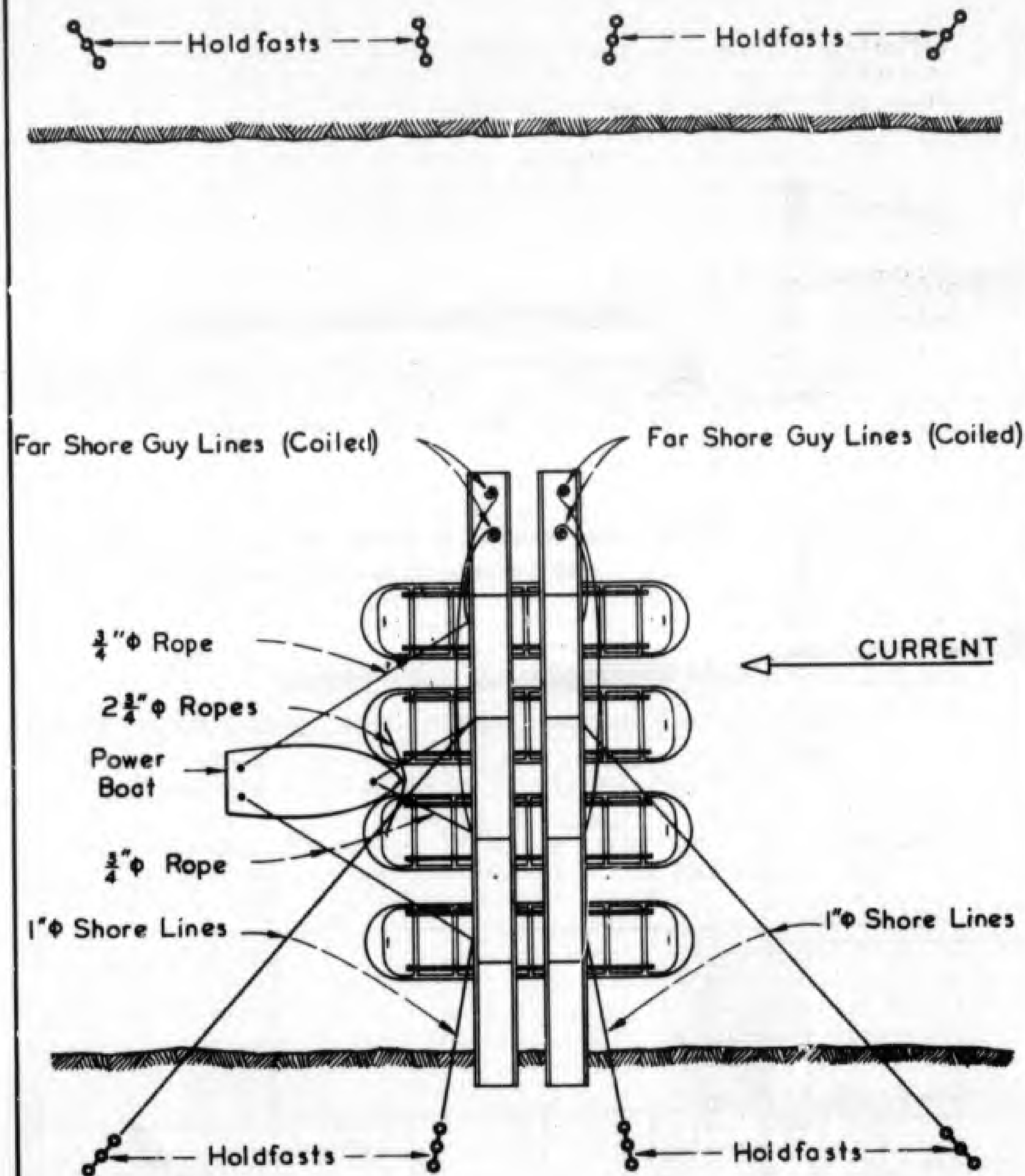
definitely discouraged, however, except at such places where it is impossible to get along without them. The best type of landing stage ever tested is shown in Figure 8.

23. In operating rafts, one particular feature is important to safety and should be recognized by all crew members, for it gives confidence in their raft. When the raft starts out into the stream, should anything happen to the motor of the power boat or outboard motor, it is possible to go downstream and tie up until repairs can be made. This characteristic provides a definite advantage over a bridge, for if the wave wash is too high it will come into the boats, whereas the raft simply gives way. Also, if the raft in going out into the stream begins to take water when pushed to the limit of available power, one can always reduce the power and drift downstream slightly, coming up on the far side in a location where the current has decreased.

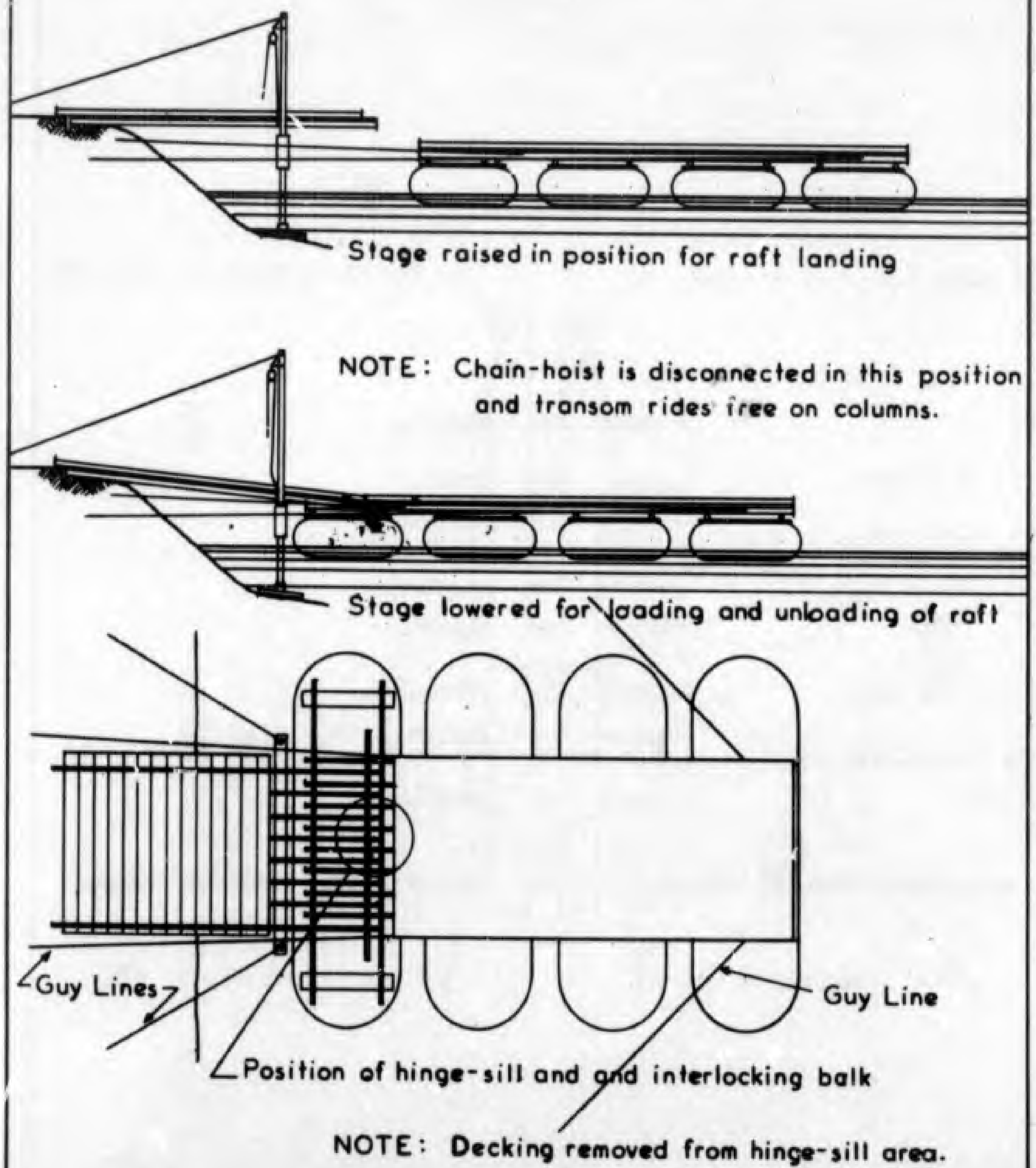
24. Each man in a raft crew must know his duties. The men handling the shore lines must be constantly on the alert in order to secure these lines to holdfasts for the discharging of the load. Figure 9 shows the handling of shore lines in rafting operations. The loading and unloading of a raft normally take more time than any other operation connected with rafting. Proper training can cut this lost time to a minimum and increase greatly the number of vehicles that are crossed.

25. Trail ferries are dangerous for untrained troops. The possibility of loosing the entire ferry cannot be over-emphasized. The danger comes from having the ferry made fast to a line and not being permitted to drift with the current if the operator gets in trouble. It is a very satisfactory means, however, for passing loads across streams without the use of power and with the absence of noise. No particular difficulty is encountered by untrained troops in velocities of 3 to 5 ft./sec., but in stronger currents, it is desirable to have one man standing by with a knife or machette to cut the raft loose in case of trouble. It is also important to place the loads against the downstream siderail. By so doing, the maximum permissible velocity for operation of the ferry with a given load may be increased as much as 2 ft./sec. due to the increased freeboard at the upstream end of the pontons or floats. A trail ferry in operation with a properly positioned load is shown in Figure 9.

26. The fastest rafting operations ever observed on maneuvers were accomplished by the 12th Engineer Battalion over the Colorado River near Palo Verde, California during two river crossing problems. In the first problem, operation of a raft near a bridge site was observed from 5:00 A.M., when the first load was ferried, until 1:30 P.M., when operations ceased. During this entire period, the raft

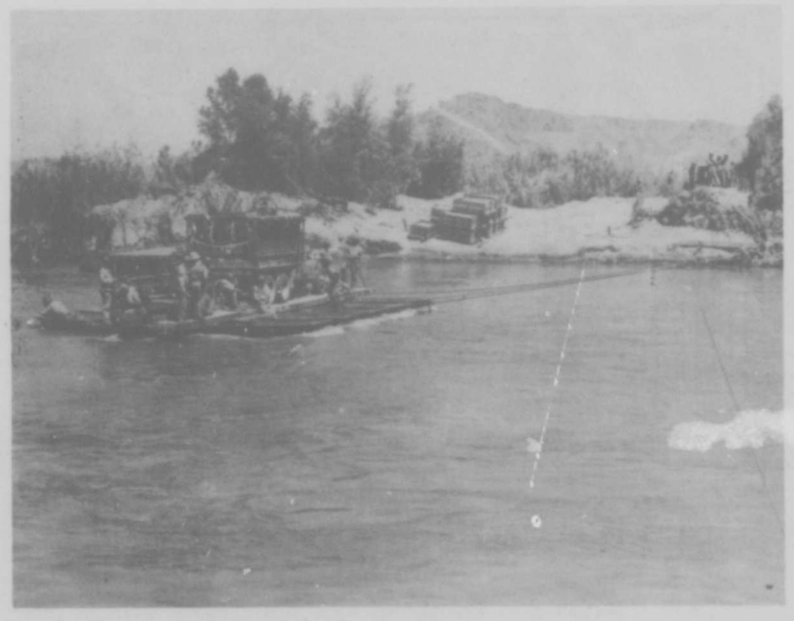


RIGGING AND SHORE GUY LINES FOR RAFTING OPERATIONS.



LANDING STAGE

Proper use of holdfasts during ferrying operations.



Trail ferry using Infantry Support Raft equipment.

was in continuous operation. The only delays that were encountered were those normal to the operation, such as time lost by refueling, repair of approaches, changes in landing site, etc., which are experienced in every operation. The length of time (8 hours and 30 minutes) which this raft was in operation was such to make the data dependable. Forty-seven round trips were made with the raft in this time and 133 vehicles were crossed. The raft was equipped with three outboard motors, two for operation and one spare. These motors operated for the entire time without any trouble. The current was about 5 feet per second. Seventy-seven of the vehicles ferried were 1/4-ton trucks. The heaviest load was a 2½-ton truck towing a 105 mm. howitzer. Since 47 round trips were made in 8 hours and 30 minutes, the average time for one round trip was about 11 minutes. During the period of operation, four sites were used on the near shore and three sites on the far shore. The time required for the loaded raft to cross the stream at the worst site (when the raft had to move upstream about 50 yards to the unloading site) was about 2 3/4 minutes, while the return trip was made with the light raft in about 2 minutes. The total distance between the sites was about 450 feet. It can be noted that the entire time of the cycle was 11 minutes while the operating time of the raft was only about 5 minutes. Most of the time was taken up in loading and unloading. Although this crew had built the raft several times before this ferrying operation, they had not ferried an appreciable amount of vehicles in practice. The idea followed so frequently in training, of building a raft and then loading a truck on it and shoving it around in the water to unload again is basically unsound. Vehicles should be ferried against time in training.

27. One week following the operation described above the problem was repeated, and the same unit repeated the ferrying operations. At this time 50 round trips were made in 5 hours. The vehicles that were crossed were essentially the same as those crossed the week before. In one week the time cycle was reduced from 11 minutes to 6 minutes. The reduction in time was due entirely to training.

28. So much lost time had been observed in the operations described above that a test was conducted at Imperial Dam to determine how to alleviate the time lag in loading and unloading. This test was accomplished by using a four-float pneumatic raft constructed of equipment from the Pneumatic Ponton Bridge M3, powered by a utility power boat in a velocity of approximately three feet per second. Operation of the raft was by a crew which had been trained for tests in rafting and which observed the basic rules described above. The channel was approximately 350 feet wide. In this three-hour test the raft made 46 round trips and ferried 60 vehicles. Only three of these vehicles were 1/4-ton trucks. The majority of the loads were 2½-ton trucks and 6-ton bridge trucks.

In three hours, this raft made 46 trips, or one trip less than the number of trips that were made by the Infantry Support Raft in the first crossing at Palo Verde in 8 hours and 30 minutes. The chief difference-the time element-results from training.

29. A second test using a different crew and a Steel Treadway raft was made in order to see what effect training would have on the second crew. Medium Tanks were used entirely in this test as they were the capacity loads for the raft. Construction of the raft is shown in Figure 8. The test lasted for three hours. During this period, 57 round trips were made, each with a Medium Tank on the raft. This test was over the same course as the four-float pneumatic raft in a velocity of about 4 feet per second, with a distance between banks of over 300 feet. Nineteen trips were made each hour and the best time for a round trip was 2 minutes in a current of approximately 4 feet per second. Here a crew of 15 men was used to handle the raft and the power boat. The site preparation consisted only of placing four holdfasts on each bank and cutting down the approach to allow the ends of the treadways to rest on the bank. Crews were changed with inexperienced men during the operation. Here again was demonstrated the fact that teamwork and training result in rapid ferrying operations.

30. The raft crew varies with the size of the raft. For a large raft, a crew of 15 men is desirable where vehicles of the size of the Medium Tank are being crossed. For the tests described above on the Steel Treadway raft, the crew was as follows:

a. 8 men on guy lines.

b. 2 men on chocks.

c. 2 men on wedges.

d. 2 men on power boats.

e. 1 NCO.

31. Use of the team in rafting where substitutes can be supplied if the rafting period is long, is by far the best way to approach the problem. This team-work provides an interest and enthusiasm which cannot be attained in any other way.

TESTING PROCEDURE FOR EFFECT OF CURRENT ON PONTON BRIDGES

by

Winston E. Black
1st Lieut., Corps of Engineers

1. General. The capacity of a ponton bridge in current is directly dependent on the freeboard of the pontons under load. Freeboard, as herein defined, is the minimum distance between the gunwale of the ponton and the maximum height to which the water rises on the ponton with constant regularity. Factors which influence the freeboard of a ponton bridge of fixed construction are as follows:

a. Magnitude of load.

b. Position of load, longitudinally and laterally.

c. Stream velocity,

In the testing of ponton bridges, the three factors listed above are varied to include all critical combinations of loading conditions. Freeboard readings are taken in each test on the pontons in the vicinity of the load. From the data thus obtained, the effect of stream velocity upon freeboard and upon bridge capacity may be determined.

2. Loading. In tests of ponton bridges, two types of loads can be used, (a) actual vehicular loads, or (b) variable static loads designed to simulate vehicular loads. In cases where a given vehicle is known to constitute the most severe loading that the bridge must carry, tests of the bridge under that particular load may be satisfactory. For the purpose of determining the capacity of a bridge with respect to no particular vehicle, however, the use of a variable simulated load is preferable, since the data that can be obtained with such a load are more comprehensive. The load should properly be applied in four or five increments, the range of loads being selected to extend both above and below the estimated capacity of the bridge.

3. Position of Load.

a. Longitudinal. The longitudinal position of the test load is that producing minimum freeboard on a ponton which is located in the swiftest portion of the stream. This position is generally directly over the ponton.

b. Lateral. The lateral position, or eccentricity, of the load may be considered to reflect the care with which vehicles are guided across the bridge in an actual crossing. Without restriction, but under normal control, vehicles occasionally may drive against either siderail. In simulating such a condition, the full eccentricity to the siderail must be used. For crossing with caution, it is possible for drivers of vehicles to keep their vehicles within approximately six inches of the centerline of the bridge. Furthermore, since upstream eccentricities are more detrimental than downstream in current a vehicle may travel on or to the downstream side of the centerline when crossing with extreme caution or risk. Extreme downstream eccentricities, however, may prove dangerous in some instances. Therefore, in testing ponton bridges the load should be placed in the following lateral positions:

(1) On the centerline of the deck.

(2) Against upstream siderails.

(3) Against downstream siderail.

(4) Six inches upstream of the centerline (halfway to the upstream siderail was formerly used instead).

4. Stream Velocity. A stream velocity of 5 miles per hour (7.3 feet per second) has been selected arbitrarily as the maximum velocity in which a ponton bridge must be able to support its capacity loads. In velocity tests, therefore, for each loading condition, the current has been set at approximately 0, 3, 5, and 7 feet per second in separate tests. In the Gila Sluiceway of Imperial Dam, the current may be varied at will by controlling the head gates of the sluiceway. The current at the bridge is measured by means of a current meter placed six feet or more upstream from the bridge approximately 18 inches beneath the surface.

5. Test Data. The testing of a ponton bridge consists of a series of tests, in each one of which the loading and stream velocity are fixed quantities (within practical limits) and the freeboard is measured at the dependent variable. Freeboard is measured normally on the three pontons nearest the load. Six measurements are taken on each ponton, at bow and stern, and at two locations on each side of the ponton. Freeboard gages may be portable and designed to hang over the gunwale of the ponton, or they may be painted on the sides of the pontons. Readings may be made by direct observation or by the use of mirrors, depending on the location.

6. Presentation of Data. Results of tests of ponton bridges in current may be presented in either of two graphical forms:

a. Freeboard velocity curves. This manner of presentation plots directly the minimum measured freeboard against the stream velocity producing that freeboard. Thus, there is a curve for each condition of loading, i.e., for each load in each position. In general, the critical load is selected, and a family of curves is plotted for three or more eccentricities of that load. These eccentricities should include the center-line position, the extreme upstream eccentricity, the extreme downstream eccentricity, and an intermediate position on the upstream side, e.g., 6 inches eccentric upstream. The effects of current upon the freeboard at the ends and at the sides of the pontons may be seperated by plotting separate families of curves for the two locations. The freeboard at the sides is critical at low stream velocities, and the freeboard at the bow is high velocities. A typical family of freeboard-velocity curves is shown in Fig. 1.

b. Safe Load-Velocity Curves. When complete data on velocity tests are available, it is possible to present graphically the effect of current upon bridge capacity by plotting safe load against stream velocity. This requires first the assumption of a safe minimum allowable freeboard, listed as follows for the various types of pontons tested at the Yuma Test Branch:

(1) Open top pontons (10-ton, 25-ton)	6 inches
(2) Decked pontons (British)	0 inches at bow 4 inches at sides
(3) Pneumatic Floats (with raked ends)	1 inch at sides 4 inches at bow

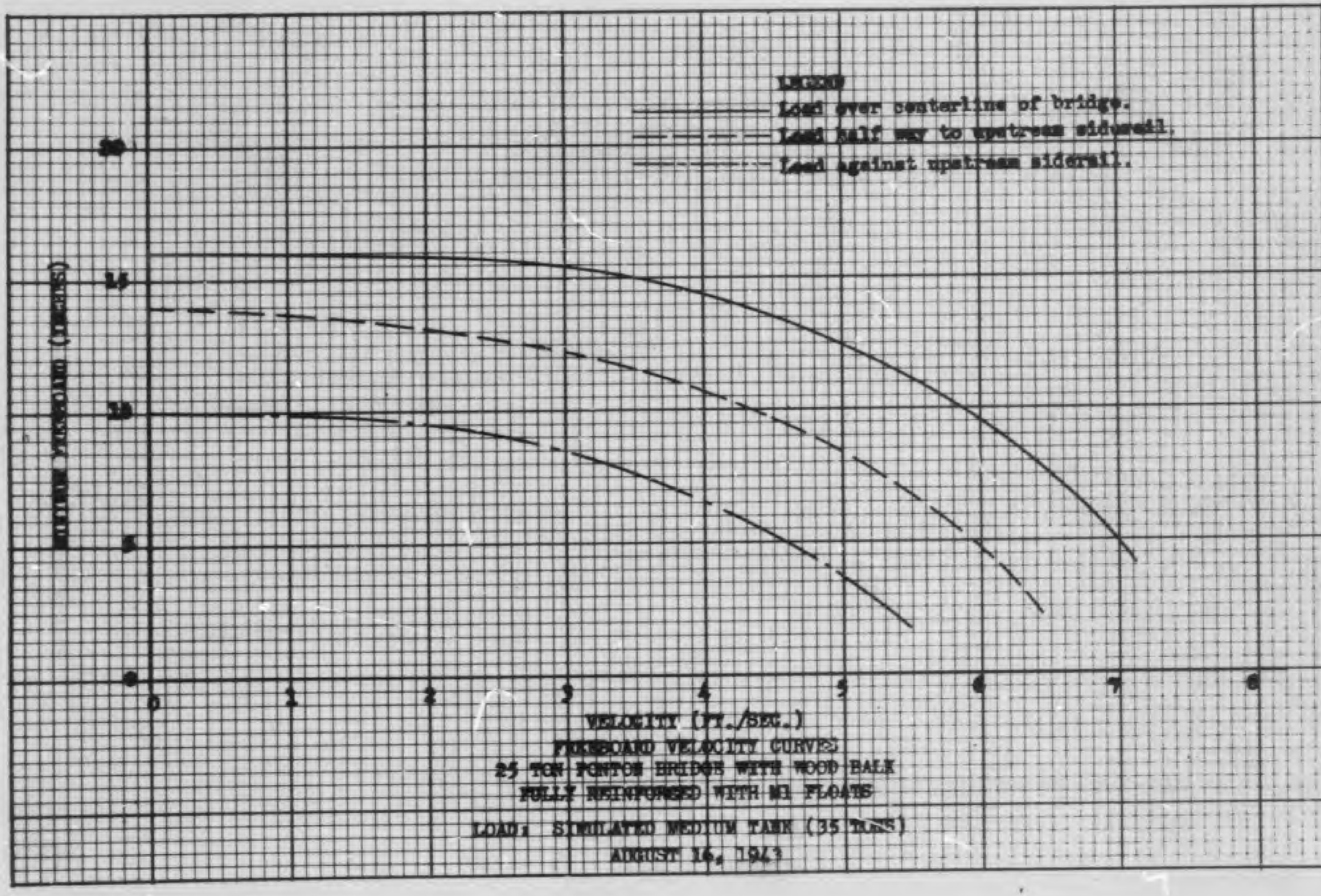
A typical family of capacity curves is shown in Fig. 2. It will be noted from this illustration that the effect of stresses on the capacity should also be included in this type of presentation. At low stream velocities, stresses in the superstructure frequently govern the capacity, while at high stream velocities, freeboard is the governing factor.

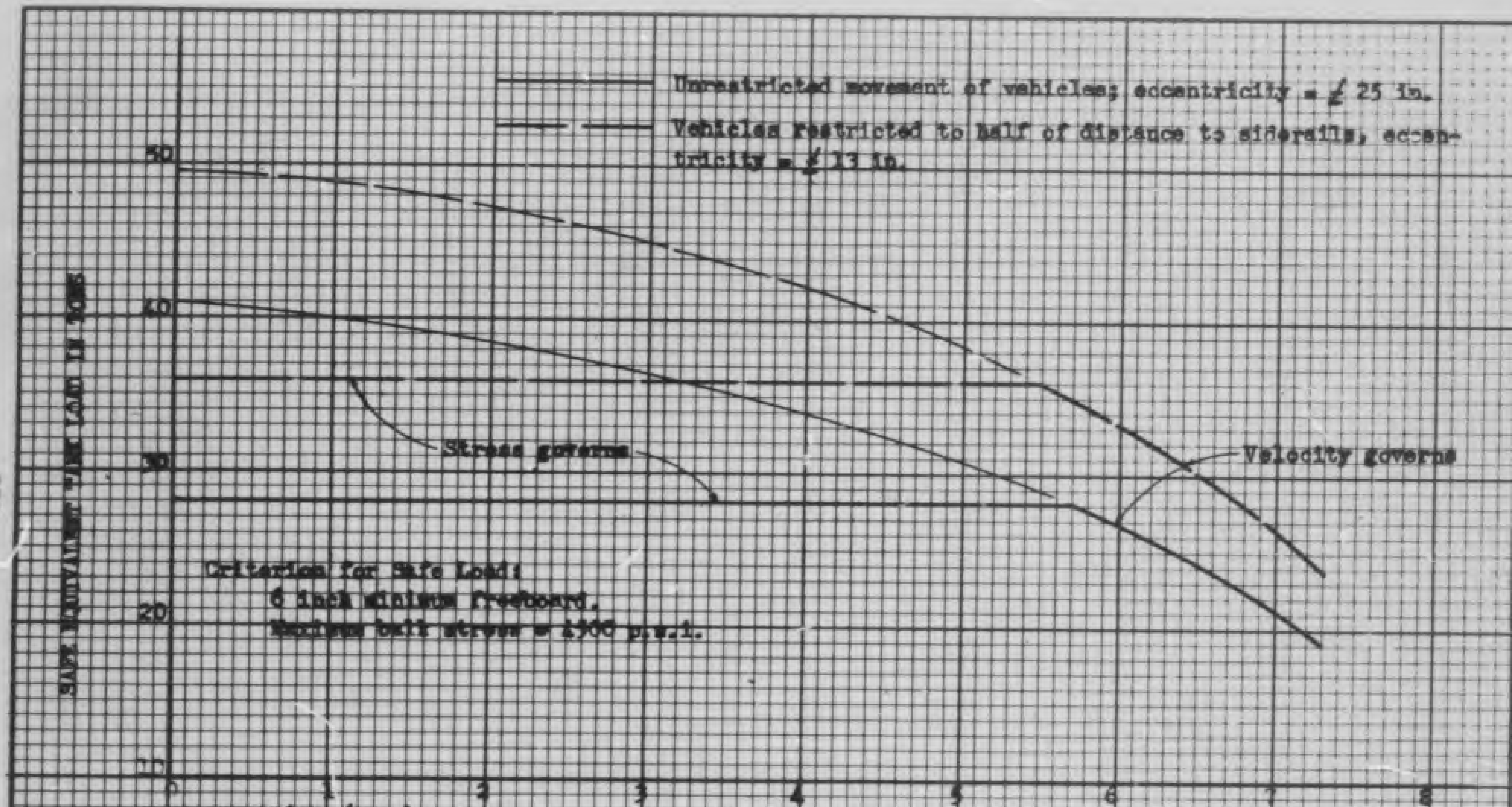
7. Special Features Affecting Capacities of Ponton Bridges in Current.

a. Deck Off-Center Downstream. The capacity of a ponton bridge may be increased by constructing the deck off center downstream from 4 to 6 inches. This result is achieved because of the increase in freeboard at the bow, which is generally the critical location in high stream velocities. The maximum upstream eccentricity of the load is in effect reduced by 4 or

6 inches. This method of construction may increase the capacity of a bridge by as much as 5 tons.

b. Ponton Bow Adapter. The critical location for freeboard occurs at the bow of pontons similar to the 10-ton and 25-ton pontons in currents above 5 feet per second. Because of this fact, a ponton bow adapter was developed to increase the height of the ponton at the bow, and has been used to considerable advantage to increase the capacity of ponton bridges in current. The adapter is desirable for use in all tests of ponton bridges, whether information pertaining to the use of the bow adapter is desired or not.


LEGEND
Load over centerline of bridge.
Load half way to upstream siderail.
Load against upstream siderail.
20
15
10
5
0
0
1
2
3
4
5
6
7
8
VELOCITY (FT./SEC.)
FREEBOARD VELOCITY CURVES
25 TON PONTON BRIDGE WITH WOOD BALK
FULLY REINFORCED WITH M1 FLOATS
LOAD: SIMULATED MEDIUM TANK (35 TONS)
AUGUST 16, 1943



EFFECT OF STREAM VELOCITY ON LOAD CAPACITY
25-TON PONTON BRIDGE WITH WOOD BALK
REINFORCED WITH 12-TON PNEUMATIC FLOATS, M1
TWO EXTRA BALK PER BAY

22 DECEMBER 1943

Y100-B24