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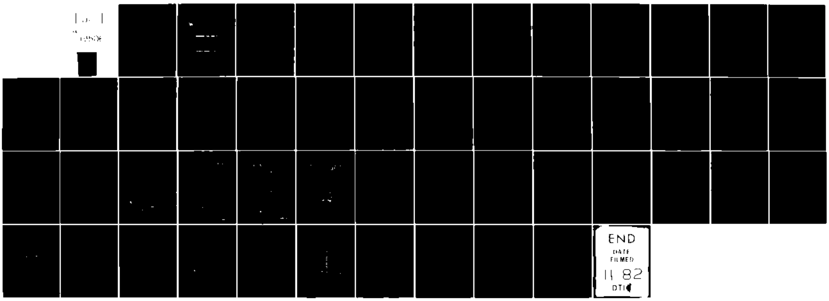

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MARINE RAILWAYS

DESIGN MANUAL 29.2

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
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ABSTRACT

Design criteria and construction information for use by qualified engineers are presented for marine railways, Category Code 213-20. The contents include: comparison with drydocks; site selection; dimensions; design loads, groundways, cradles; hauling systems, controls; and support facilities.

FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses, to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters (Code 04). As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with the SECNAVINST 5600.16.

W. M. ZOBEL
Rear Admiral, CEC, U.S. Navy
Commander
Naval Facilities Engineering Command

DRYDOCKING FACILITIES DESIGN MANUALS

DM Number	Superseded chapters in Basic DM-29	Title
29.1	1 through 9	Graving Drydocks
29.2	10	Marine Railways
29.3	11	Drydocking Facilities Characteristics

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MARINE RAILWAYS

Section 1. BASIC DATA

1. SCOPE. This manual covers the design of marine railways for drydocking vessels to permit inspection, overhaul, and repair of all underwater portions of the vessels. Section 3 compares marine railways and drydocks to show the distinctive features of marine railways and to emphasize both their value and their limitations. Because each type has its special function, it is not intended to imply that the various types of docking facilities are interchangeable. A description of a sidehaul marine railway built for temporary use of the Navy in World War II is given in Section 14. With that exception, all further statements regarding marine railways in this manual have reference only to the endhaul type.

2. BACKGROUND OF U.S. NAVY MARINE RAILWAYS. The first Navy marine railways, with capacities of 2,000 tons for destroyers and submarines, were built at Boston, Massachusetts, and Charleston, South Carolina, in 1918. Two more, of 2,500-ton capacity, were completed at San Diego, California, and Pearl Harbor, Hawaii, in 1920. The comparatively great length, displacement, and draft of naval vessels are the principal factors which have restricted the maximum size and capacity of Navy marine railways to that required for destroyers.

3. PRINCIPLE OF OPERATION. A marine railway, by utilizing the mechanical advantages of the inclined plane and geared hauling machinery, is able to pull the cradle and vessel out of the water with a combination of horizontal and vertical movements.

4. DATA ON MARINE RAILWAYS. Data concerning all marine railways at naval shipyards and activities are presented in NAVFAC DM-29.3.

5. CANCELLATION. This manual, Marine Railways NAVFAC DM-29.2, cancels and supersedes Chapter 10 of Drydocking Facilities, NAVFAC DM-29 of February 1974.

Section 2. TYPES

1. DESCRIPTION. Marine railways may be either the endhaul or sidehaul type. Both types consist of inclined groundways extending into the water, cradles that move on the groundway tracks, wheels attached to the cradles or roller trains not attached to cradle or track, hoisting machinery, and chains or cables for hauling cradles out of or into the water.

2. ENDHAUL. All existing naval marine railways are of the endhaul type because:

(1) Waterfront space is extremely valuable, and the principal advantage of the endhaul type is that it requires only about one-third as much frontage as the sidehaul or broadside type.

(2) Operation is safer and less complicated.

(3) If a long, narrow, high vessel such as a destroyer is hauled bow first with the pull exerted on a single drawhead on the centerline of the

cradle and ship, the operation is safer than if the vessel were hauled broadside with the pull exerted on multiple drawheads.

3. SIDEHAUL. A sidehaul marine railway may be the only type that can be used safely on a nontidal river bank for the following reasons:

(1) There is no slack water period to permit docking a vessel at right angles to the current.

(2) The width and location of the navigational channel, and the traffic up and down the river, may preclude the use of an endhaul docking facility.

(3) The sidehaul type is particularly adapted to hauling out vessels with flat bottoms and shallow draft, such as barges and other river craft.

Section 3. COMPARISON WITH DRYDOCKS

1. SPEED AND ECONOMY. A marine railway provides a fast, convenient, and economical method of docking and undocking relatively small vessels.

2. ADAPTABILITY. Comparison of adaptability to other waterfront facilities is as listed below:

a. Marine Railways.

(1) Marine railways are best adapted to sloping bottoms.

(2) The groundways usually extend several hundred feet beyond existing piers and wharfs. These extensions present hazards to navigation.

(3) They are more subject to mishap than other docking facilities.

(4) When deep water is available at the bulkhead line, the railway may be constructed farther inshore. However, with space included for the hauling machinery and other equipment, the larger marine railways will extend approximately 500 feet inshore.

(5) They are more economical to construct than a graving dock for the same classes of vessels.

b. Graving Docks.

(1) Graving docks have greater adaptability at shipyard sites than marine railways.

(2) Graving docks do not extend beyond the bulkhead line; they fit conveniently with adjacent quaywalls and piers, and waterfront construction may be continuous.

(3) A graving dock provides a uniform depth of water.

(4) Vessels are docked in a level position.

(5) Graving docks can be better adapted to other uses, such as vessel construction.

3. VESSEL OVERHAUL. Working conditions for vessel overhaul are compared as follows:

a. Marine Railways. Marine railways lift vessels above the water level; therefore, all working areas around or under the ship have more light and ventilation.

b. Graving Docks. Because of high walls, graving docks afford more protection against the elements, particularly wind; but in summer the temperatures on the floor of the drydock are much higher than at a marine railway. Also, graving docks usually are provided with better crane and railroad track facilities, and afford more convenient working space around the ship.

4. COSTS. Comparison of construction, operation, and maintenance costs is as follows:

a. Construction. Marine railways first costs are less than those for graving docks.

b. Operation. Marine railways cost less to operate than drydocks. The cost of hauling a cradle and ship up railways is much less than for pumping out drydocks. Drydocks require a 24-hour watch on pumping and other equipment, and more personnel for docking operations.

c. Maintenance. Routine maintenance costs of marine railways are usually more than similar costs for graving docks. Costs of major repairs on marine railways are likely to be more, because of the difficulty of making underwater repairs and the greater incidence of breakdowns.

5. TIME REQUIRED FOR DOCKING AND UNDOCKING. The time factors are as follows:

(1) A drydock must be pumped out twice to dock and undock a ship, once to set the blocks, and once to set the vessel down.

(2) A marine railway cradle must be hauled in and out twice to accomplish the same result, but the time required is less.

(3) Graving dock entrance closure caissons must be seated and unseated twice for one docking and undocking. There is no comparable time factor in using a marine railway.

a. Comparative Time Requirement. It has been estimated that, under certain conditions, either the docking or undocking of a vessel may be performed four to six times faster on a marine railway than in a graving dock.

6. CLIMATIC AND HYDROGRAPHIC INTERFERENCES. Climatic conditions interfere more with the operation of marine railways than with graving docks, especially in northern climates. Wind, waves, and unpredictable cross currents are present during most dockings. Ice conditions present problems in northern climates.

a. Marine Railways.

(1) Wind and Water Currents. The following factors must be considered in design:

(a) As a ship's bow approaches the cradle, lines are thrown from the cradle walkway up to the deck of the vessel, and secured to cleats on the walkway. Although the walkway is at the top of the superstructure, it is only a few feet above the water and well below the deck of a destroyer at the time of docking.

(b) Short lines, at considerable vertical angles, make handling of the ship difficult.

(c) After the tugs have been released and the ship is inside the cradle, it is still exposed to wind and waves as well as to unexpected cross currents that may develop.

(d) The resulting forces, sometimes exerted broadside on the ship, are transmitted to the cradle, which along with the wheels or rollers, track, and foundations, must be capable of resisting them.

(2) Ice. In cold areas, ice is likely to form on the track, rollers, and chains of a marine railway. A sudden onset of very low temperatures while a ship is under repair on the cradle may cause sudden ice formation which can delay or endanger the undocking.

b. Graving Docks.

(1) High Winds and Waves. High winds and waves may interfere with a graving dock operation, but the worst effect will probably be only a postponement of the drydocking.

(2) Ice. Occasionally ice piles up at graving dock entrances, but its removal is not difficult.

7. RELIABILITY. Safety precautions against accidents serious enough to cause injury to ships in drydock must be provided as a part of engineering design.

a. Marine Railways. Consider the following factors:

(1) Approximately three-fourths of the groundways, as well as the major portion of the structure and equipment of a marine railway, are always underwater and are not readily accessible for inspection or repair.

(2) Deposits of silt and miscellaneous debris on the rails, roller trains, or chain troughs, can be serious enough to cause derailment or even render the marine railway inoperable.

(3) Larger cradles are usually built in two sections, to allow for overhaul of the cradle in the dry. The offshore section is removed by pontoon and towed to a drydock, and the inshore end by hauling it up to the extreme inshore position. Between overhauls, the condition of the underwater parts is generally determined by divers.

(4) Where rollers are used, all sections of the roller train are successively removed at the offshore end, because they gradually creep downgrade. At this time the roller section may be inspected, repaired, and installed at the inshore end, but it may take several years before this section again reaches the offshore end.

(5) Downhaul sheaves and their anchorages, and the submerged portions of the track and chain troughs, which support and aline the chains, cannot be inspected or repaired except by divers experienced in this type of work.

b. Graving Drydocks. Most parts of graving docks are accessible for inspection and repair each dewatering, except for outboard faces of entrance closure, flooding, and dewatering systems.

Section 4. SITE SELECTION

1. REQUIREMENTS. Site selection for a marine railway may be a part of the broader problem of selecting new shipyard or shore activity locations, or it may be confined to a study of possible sites at or near an existing activity. For new activities, the general site requirements for marine railways are (1) sheltered harbor, (2) a channel adequate in depth and width, (3) suitable soil or rock foundation, (4) satisfactory tidal, current, silting, and climatic conditions, and (5) sufficient area and suitable sites for all proposed appurtenant facilities.

2. SPECIAL CONSIDERATIONS. Sites chosen for marine railways should satisfy certain definite and unusual requirements that often make their adoption impracticable, unwise, or uneconomical. The requirements set forth in the following paragraphs are extremely important.

a. Distance to the Channel. The distance from high waterline or bulkhead line to navigation channel must be adequate for construction of the railway offshore end; it must also provide a safe fairway for vessels approaching and leaving the marine railway.

b. Inshore Area. The land space available, including shore frontage, must allow for construction of the above water portion of the groundways and the hoist house. Necessary side and end clearances, spur tracks, roadways, cranes, and working areas also must be provided.

c. Hydrographic Conditions. To prevent excessive silting, natural bottom slopes along the railway offshore end should be lower than track grade, unless the location is completely free from alluvial deposits and littoral drift.

d. Foundations. Soil strength must be sufficiently high in the groundway area to make possible a foundation design that will preclude settlement.

e. Favorable Climatic and Tidal Conditions. Proposed locations should have natural protection from strong winds and waves, to avoid unfavorable drydocking conditions. The design must provide for all combinations of adverse conditions.

f. Mooring Facilities. Piers or dolphins should be provided on the windward side, or both sides, of marine railways if conditions allow, to facilitate warping vessels into the cradle.

Section 5. PRINCIPAL DIMENSIONS

1. CHARACTERISTICS OF VESSELS. The Naval Sea Systems Command (NAVSEA) furnishes docking data regarding naval vessels to be drydocked. Data include: drawings, weight curves, docking plans, length overall, length on keel, beam, draft fore and aft, docking displacement, location of center of buoyancy, location of center of gravity, and location of external projections. The rated capacity of a marine railway is the docking (displacement) in tons (of 2,240 pounds) of the heaviest vessel to be docked.

2. VERTICAL RISE OF CRADLE. Marine railways are generally designed for docking a ship at mean high water with the deck of the cradle entirely dry. The freeboard at low end of cradle deck should not be less than 1 foot when in inhauled position.

a. Minimum. In general, the vertical cradle rise which must be provided for in the track design is the sum of vertical dimensions; that is, height of keel block above track with cradle in extreme offshore position, plus vessel clearance over the top of keel blocks at mean high water of at least 1 foot, plus draft at stern of vessels to be docked.

3. TRACK SLOPES. Large marine railways are generally built with track slopes of either 3/4 or 7/8 inch per foot. The height of the blocks at the high or inshore end of the cradle should be as low as feasible to preclude the necessity of high blocks at the offshore end. Reductions in height of the offshore end keel blocks can be obtained by sloping the top of the keel blocks. A slope of 1/8 inch per foot is generally used. (See Section 8 for discussion of vertical curves in tracks.)

4. LENGTH OF TRACK. The minimum length of track is as specified below.

a. With Wheels. For cradles with wheels, the minimum required length of track is the sum of two horizontal dimensions:

(1) Distance the cradle must travel to rise the determined vertical height. This distance is equal to the vertical rise divided by the track slope.

(2) Length of blocks on cradle.

b. With Roller Trains. For cradles designed to travel on independent roller trains, determine the minimum length of tracks for wheels and add the length of two roller sections. This increase is necessary to permit occasional removal of one section at the offshore end and reinstalling it at the inshore end.

5. TOTAL LENGTH. The minimum total length of marine railway is the minimum track length plus the distance required for necessary clearances and hoist

house. The ideal length of railway includes the minimum length plus an extension of the track at inshore end of about 100 feet to permit hauling the cradle entirely out of the water for inspection and repair.

6. CRADLE DIMENSIONS. Determine the in-the-clear dimensions of the cradle by the maximum overall length, beam, and draft of vessels to be docked. Obtain the length to be provided on blocks from the NAVSEA docking plan for the longest vessel. Use this distance to determine the necessary length of cradle on rollers or wheels. Provide adequate working space all around the vessel, by extending a deck beyond the vessel's perpendiculars about 15 feet at each end and clearance of about 5 feet on each side at vessel's maximum beam. Some small cradles, which can be hauled in over stationary platforms, do not require decks.

7. HOIST HOUSE. Provide a hoist house containing hauling machinery consisting of an electric motor, a train of reduction gears, and the wildcat or wire rope drum. For large (3,000 tons) marine railway, make the hoist house about 29 feet wide by 42 feet long. A clear, paved space at least 30 feet wide should be provided at the rear of the hoist house to permit wheeled traffic between the two sides of the railway.

Section 6. DESIGN LOADS

1. REQUIREMENTS. Vessels in docking condition are in a light operating condition, but an emergency may require docking a ship in full load condition. Design all marine railways for this condition. The size of the ship does not necessarily establish the maximum load per lineal foot to be used for design purposes. Fleet tugs may have much greater load concentrations than larger ships of another class or type. Design groundways and cradle of a marine railway for the maximum unit loadings as determined from composite weight distribution curves of the various vessels that it will be required to haul.

a. Load Distribution. Consider the problem of load concentration for two ships as follows:

(1) Assume one ship has a displacement equal to the rated capacity of the marine railway, and its weight is uniformly distributed over the cradle length.

(2) Assume a second ship has a displacement less than the railway rated capacity, but its weight distribution curves show greater concentration of weight than for the first ship. Under this condition the facility may not be strong enough to support the second or smaller ship. Therefore, it will be necessary to obtain the weight distribution curves of all of the vessels to be hauled.

(3) It is also necessary to consider all types of classes of ships, planned or under design, that may have to be hauled in the future.

(4) After these data are obtained, it is necessary to consider a complete docking cycle with these ships on the cradle blocks.

(5) When a destroyer is seated on the cradle blocks, the stern end is unsupported for a considerable distance; this results in a concentration of weight on the after blocks. This concentration is indicated on the weight distribution curve, and it is necessary to make proper allowance for this redistribution of weight in the design. This allowance may be made by assuming that the weight of the entire cantilevered portion is concentrated on the last two or three blocks. This assumption generally results in a very heavy load per lineal foot, and may call for a crib and/or a grillage to be provided at this point.

b. Alternate Method of Load Distribution. Compute the trapezoidal loading on the blocks resulting from the ship's weight curve center of gravity being eccentric to the center of gravity of the effective bearing area of the keel blocks. This method is satisfactory when the cantilevered portion of the ship is not large.

2. COMPOSITE LOAD CURVE. Prepare a composite weight distribution curve of vessels under consideration. Express the ordinates of this curve in long tons per lineal foot of vessel length. Having imposed all ship weight curves on one diagram, make allowance for overhang at the bow or stern ends. This composite weight distribution curve is then faired up for use as the design load curve for the cradle and groundway. Typical composite weight distribution curves are shown in Figures 1 and 2.

3. ERRONEOUS LOAD CURVE ASSUMPTIONS. There are several possible sources of trouble to be avoided in establishing a load curve for a marine railway.

a. Previous Designs. Weight distribution curves from previously designed marine railways should be used with discretion. They will not provide proper allowance for the characteristics of new ships, and any errors in the load curves will be perpetuated.

b. Commercial Designs. Generally, there is no similarity between load concentrations encountered in a naval vessel and in a commercial vessel of similar displacement. Therefore, load curves used in the design of commercial marine railways are not used for the design of naval marine railways.

4. POPPET LOAD. Poppet loads occur under certain conditions during launching or hauling when keel blocks are built on a slope. These loads may occur under other conditions and should always be considered. For a discussion and determination of poppet loads, see Rossell and Chapman, Principles of Naval Architecture, Volume 1, Chapter VII Launching.

5. WIND LOAD. Consider load on bilge blocks and stability as follows:

a. Overturning Forces. When wind acts on the side of a docked vessel, the bilge blocks on the leeward side will be subjected to additional load because of the overturning tendency. Determine the additional wind load by applying the total wind pressure in pounds at the center of gravity of the total side presentment area of the vessel.

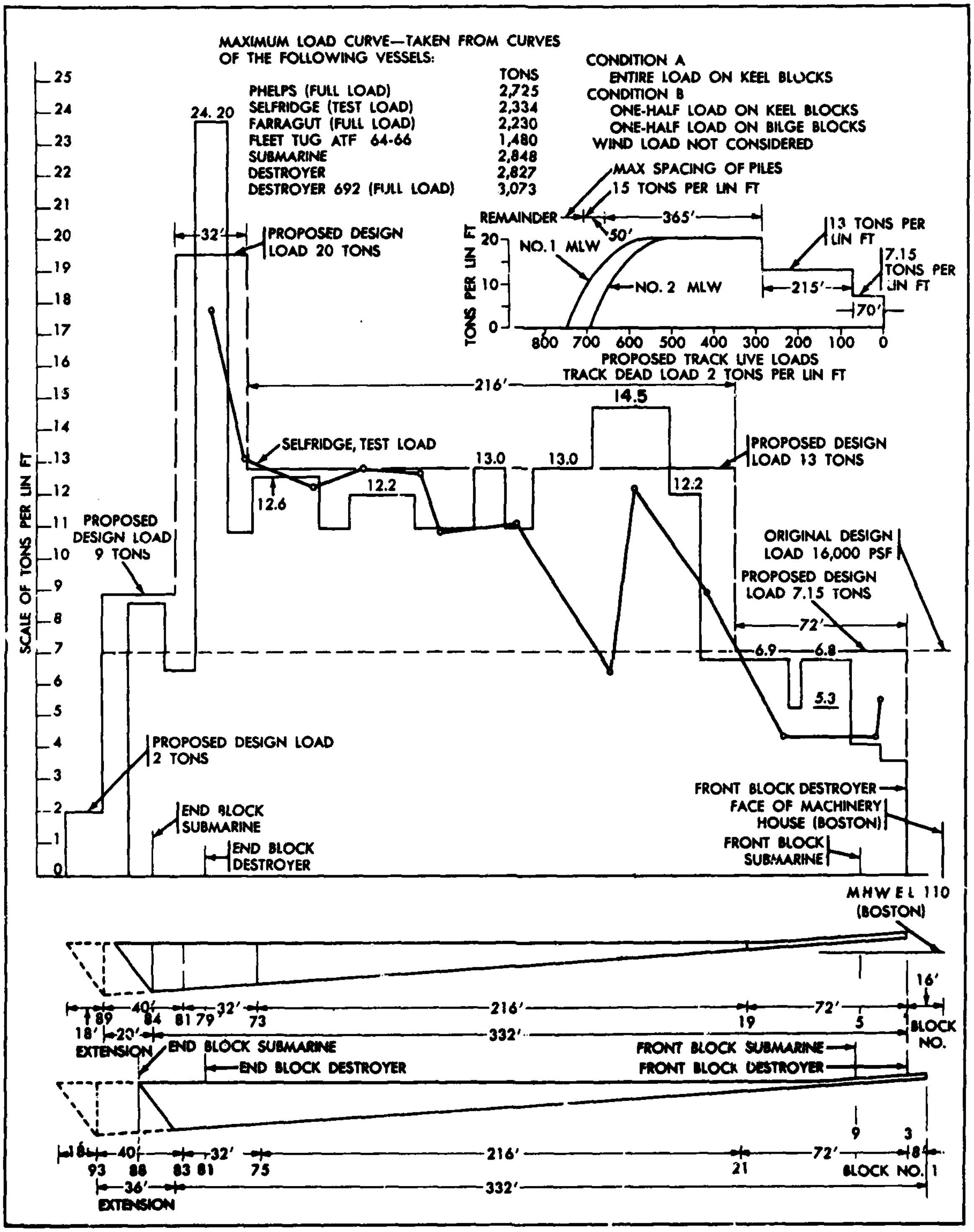


FIGURE 1
Composite Weight Curves

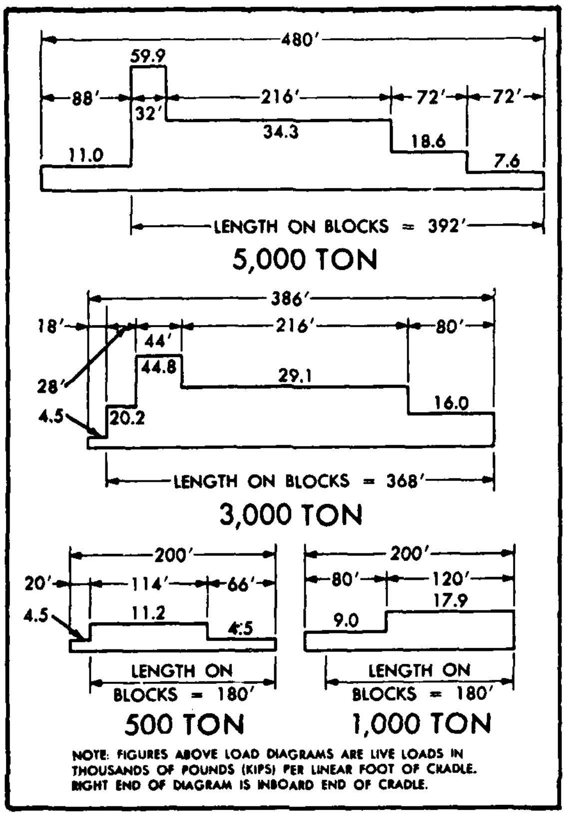


FIGURE 2
Live Loads on Marine Railway Cradles

b. Stability. In addition to the wind load on the bilge blocks, it will also be necessary to investigate both the vessel stability on the blocks and the combined stability of the vessel and cradle on the groundways. There are no anchoring devices between the cradle and the groundways.

6. SEISMIC DESIGN LOAD. Refer to Technical Manual, NAVFAC P-355 for design areas requiring seismic considerations.

Section 7. CHARACTERISTICS AND CLEARANCES

1. VESSEL CHARACTERISTICS. The characteristics of the vessels that may require docking are varied, and must be studied to determine the controlling features of the ultimate design. The controlling characteristics are as follows:

(1) Maximum displacement.

(2) Maximum overall length.

(3) Length on keel (bearing length).

(4) Maximum beam.

(5) Maximum draft forward and aft in docking condition.

(6) Shape.

(7) Weight distribution.

(8) Appendages that may extend below the keel line and require special treatment, including propellers, rudders, and sonar devices.

a. Application. From this hypothetical vessel, determine the length, beam, required draft over the blocks, and other characteristics of the cradle and ways plus the added working clearances required.

2. CRADLE CLEARANCES. It is necessary to add certain clearance dimensions to vessel dimensions to provide working space around and under the ship. For specific requirements, see Section 5.

a. Keel Block Clearances. The maximum keel block height is 4 feet. The height of the blocks forward, however, is generally established as stated in Section 5. A clearance of at least 1 foot should be provided between the keel of the vessel of the deepest draft, and the top of the keel blocks at the inshore end of the cradle at mean high water when the cradle is in extreme offshore position on the groundways.

Section 8. TRACK OR GROUNDWAYS

1. DETERMINATION OF DESIGN LOADS. A load curve for a set of groundways is shown in Figure 3.

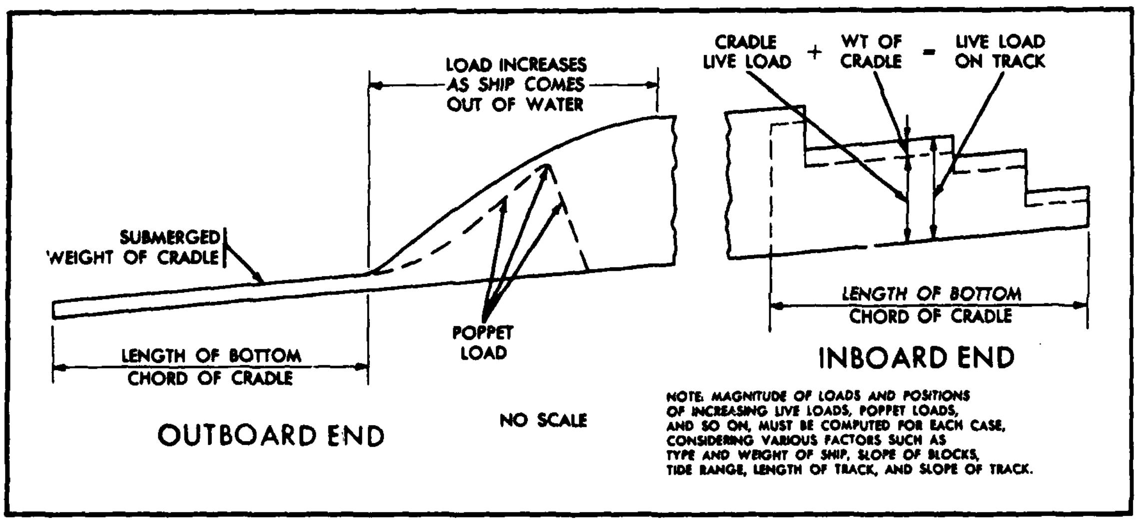


FIGURE 3
Live Load on Track

a. Inshore Position. Consider the cradle in the inshore position where the groundways are supporting the live load on the cradle, as well as the weight of the cradle and the groundways themselves. As the cradle is hauled offshore, the zone of maximum load per lineal foot on the cradle begins to move offshore also, so that the groundway is subjected to the maximum load per lineal foot until the point is reached at which the effective weight of the ship on the groundways begins to be reduced by buoyancy.

b. Offshore Position. Eventually, a point is reached at which the ship is entirely waterborne, and the only effective load on the ways is that of the cradle and the ways.

c. Poppet Load. The poppet load occurs somewhere between the two extreme positions of the cradle, as noted previously in Section 6.

2. ELEVATIONS AT OFFSHORE END. Determine elevations at the offshore end from the following:

(1) Maximum drafts, forward and aft, of the design vessel.

(2) Slope of the track.

(3) Slope of blocks on the cradle.

(4) Length of the cradle.

(5) Height of upper block above track.

(6) Depth of water (including 1 foot clearance) over blocks at offshore position of cradle.

a. Optimum Design. Although most marine railways are designed to allow for docking at mean high water, the optimum design will provide for docking the design vessel at mean low water. This should be considered when practicable, especially when the tide range is low, and when other project requirements permit.

b. Overrunning Cradle. When designing marine railways, do not assume that in docking vessels it is possible to run the cradle down until its lower end projects beyond the end of the track. This is not good practice because, when rollers are used, a section of the train may drop off the end of the track unless stops are provided. Construct cradles with a so-called fantail cantilevered projection at the outer end, thus increasing the effective length of the railway.

c. Vertical Curve. Although marine railways may be constructed with the track in the form of a vertical curve, this construction is not recommended. This arrangement permits shortening the track by increasing the slope of the offshore end, but its disadvantage is that the slope of the keel blocks varies according to the position of the cradle. There is also greater difficulty in construction.

3. TRACK SUPPORT. A practically unyielding track support is necessary to avoid excessive stresses resulting from misalinement or damage to track,

cradle, and vessel. Support groundways by piles or concrete slabs on rock or coral, or a combination of both.

a. Piles. Piles may be timber, concrete, or steel. The maximum design load for pile foundations may be determined in the NAVFAC DM-7 series, or it may be determined by foundation test piles. The groundway structural members may be concrete or timber. Provisions may be necessary for resisting lateral wind loads by the use of batter piles. Provide cross struts and horizontal and vertical diagonal bracing as required by design conditions. Simplicity in the design of underwater work is necessary.

b. Track Stringers. Do not place track stringers directly on pile heads because the difficulty of driving piles in the exact positions required, and of cutting them off underwater to exact grades, makes work slow, costly, and of uncertain quality.

(1) Cross Capped Pile Bents. With pile bents cross capped, the alinement of the piles is of less importance, and stringers may readily be brought to exact grade and full bearing by means of wedges.

(2) Two-Pile Bents. Where heavy loads are involved, two-pile bents under each rail may be necessary. In this case, every fourth or fifth cap should extend across the pile supports of both rails, and form part of the track bracing system.

4. NUMBER OF RAILS. The number of rails may be two, three, or four. Navy marine railways usually have two rails. Three- and four-rail tracks have the advantage of a continuous support under the center of the cradle and keel of the vessel. (See Figure 4 for typical crane track construction, and Figure 5 for typical marine railway track construction.)

5. CHAIN PATHS AND GUIDES. Construct chain paths and guides between rails as indicated on the drawings in Figure 5. Make these chain paths of treated or greenheart timber. Wear on the timber paths may result in the chains bearing on the holddown bolts, causing wear on the chains as well as the bolts. Experimental work with chain paths assembled with hardwood dowels in place of spikes and bolts indicates that such construction is satisfactory. Use a 1/2-inch steel wearing plate attached with countersunk head screws to prevent the chain path from wearing out too frequently. Chain paths should be continuous and constructed to permit easy renewal. Provide separate chain paths for backhaul chains.

6. CRADLE SUPPORT. There are two methods of supporting the cradle on the track: (1) by a system of rollers in contact with a continuous plate (upper track) on the bottom chord of the cradle and a second continuous plate (lower track) on the top of the groundways, or (2) by a system of wheels attached to the cradle and rolling on a rail or heavy plate forming a part of the groundways.

a. Roller System. When rollers are used, rails should be of plate steel fastened to track stringers by countersunk drift bolts. When base plates are used under the rail plate, they should be of sufficient thickness to prevent curling up of the projecting sides, caused by compression of the timber under the rail. Do not vary the rail plate thickness at different points.

b. Wheel System. When the cradle is equipped with wheels, use standard railroad or crane rails of size adequate to support the wheel loads, and use bearing plates between the rails and stringers. Use 1/4-inch spaces between the ends of adjoining rail lengths or use standard splice plates. Fasten rails securely to the track stringers, particularly at the rail ends.

7. ROLLERS. Assemble rollers in sections or nests, and hold in place by frames that are spliced together to form one continuous roller train. (See Figure 6 for assembly and details.)

a. Roller Train Length. The total length of a roller train is equal to the length of the cradle, plus one-half the distance of extreme travel of the cradle, plus a minimum of one or two extra sections to allow for creep. A serious disadvantage of rollers develops when the outer end of the roller train is running light or without cradle load. Under this condition, the presence of silt, driftwood, or other obstruction on the rail may cause the derailment of the roller train.

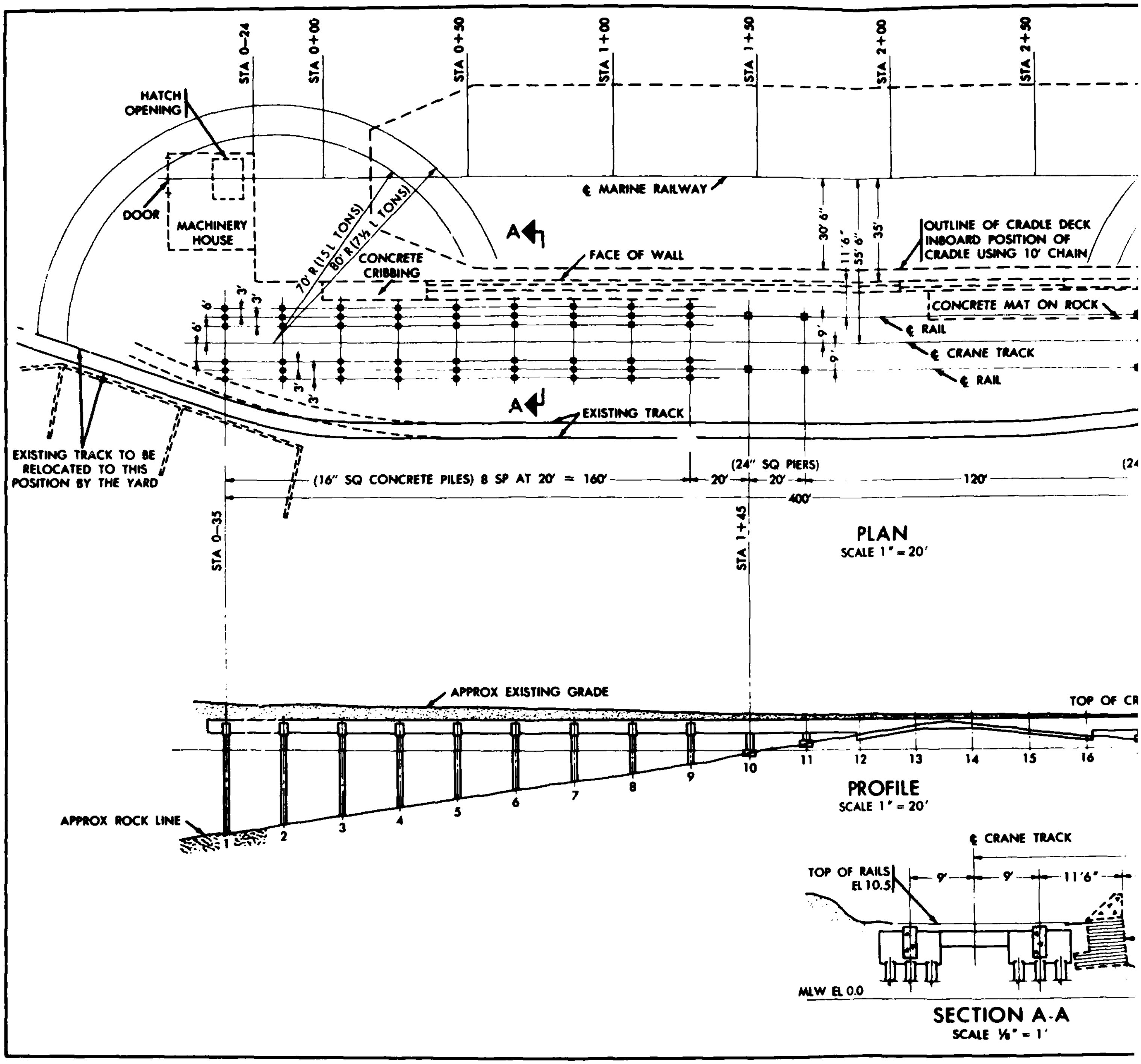
b. Spacing. The size and spacing of all the rollers is determined from the maximum design track load per lineal foot on the ways. The rollers at the offshore ends of the trains are not subjected to as much pressure as others. It is not advisable to vary the roller spacing, however, because the rollers slide slightly during operation and gradually creep down the ways; this requires periodic removal of the lowest roller sections, and their reinstallation at the inshore end of the roller train. In the course of time, every roller section will occupy a position in which it will carry extreme load; therefore, all the rollers must be of one design and spaced the same distance apart. Roller trains on the two tracks can creep at different rates.

c. Material and Design. Make rollers of cast steel by setting the steel spindle in the casting mold and pouring the molten steel in the mold, so that when the steel hardens the spindle will be rigidly fixed in the roller. Machine rollers harden after heat treatment. The physical characteristics of the roller material correspond to cast steel chain. Hold roller diameters to close tolerances not exceeding 1/32 inch.

d. Frames. Hold roller sections at the required spacing by side angle frames. Weld steel pads to the angle frames, and drill holes of the proper size through the pads and angle to form the spindle bearings. See Figure 6 for a typical welded plate splice detail of the roller frames or nests and the method of pinning it together. Use cast iron spacers with through bolts to hold the frames together. Provide a cast iron plow at the offshore end of the train, to clear the track of obstructions such as silt or driftwood.

8. WHEELS. There is less danger of a derailment or serious accident with a cradle mounted on wheels.

a. Wheel Spacing. Vary the spacing of wheels, the closest spacing being where the heaviest concentration of load occurs, and the widest spacing where the load is least. There should be a few extra wheels at minimum spacing under the inshore end of the cradle to take care of the poppet load. Vary the spacing, but all wheels and axles should be designed alike. (See Figure 7.)



STA 0−24
STA 0+00
STA 0+50
STA 1+00
STA 1+50
STA 2+00
STA 2+50
HATCH OPENING
DOOR
MACHINERY HOUSE
70' R (15 L TONS)
80' R (7½ L TONS)
CONCRETE CRIBBING
℄ MARINE RAILWAY
FACE OF WALL
OUTLINE OF CRADLE DECK INBOARD POSITION OF CRADLE USING 10' CHAIN
CONCRETE MAT ON ROCK
℄ RAIL
℄ CRANE TRACK
℄ RAIL
30' 6"
11' 6"
55' 6"
35'
9'
9'
6'
6'
3'
3'
3'
3'
A
A
EXISTING TRACK
EXISTING TRACK TO BE RELOCATED TO THIS POSITION BY THE YARD
(16" SQ CONCRETE PILES) 8 SP AT 20' = 160'
20'
(24" SQ PIERS)
20'
120'
(24
400'
STA 0−35
STA 1+45
PLAN
SCALE 1" = 20'
APPROX EXISTING GRADE
TOP OF CR
APPROX ROCK LINE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PROFILE
SCALE 1" = 20'
℄ CRANE TRACK
TOP OF RAILS EL 10.5
9'
9'
11'6"
MLW EL 0.0
SECTION A-A
SCALE ⅛" = 1'

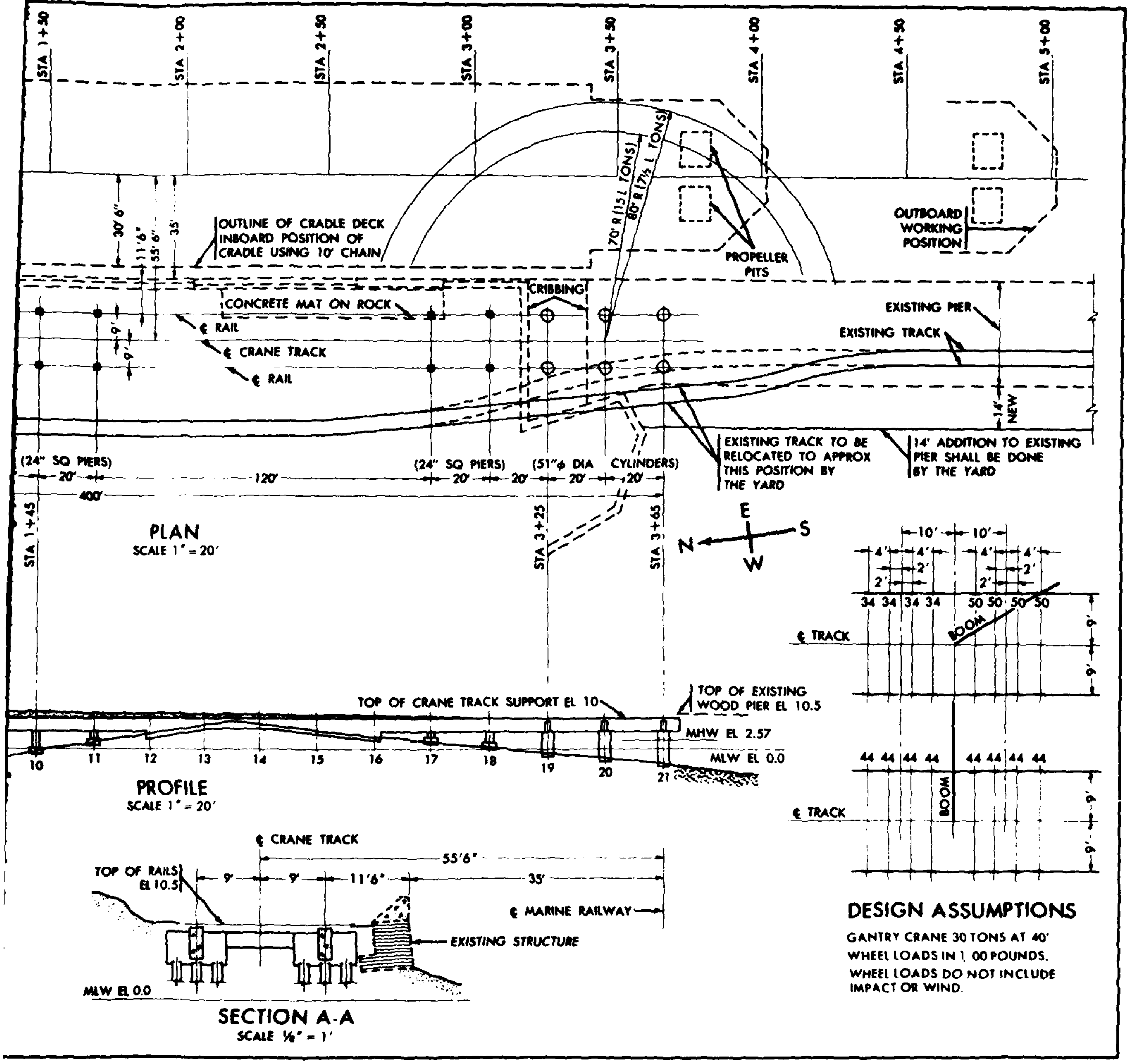
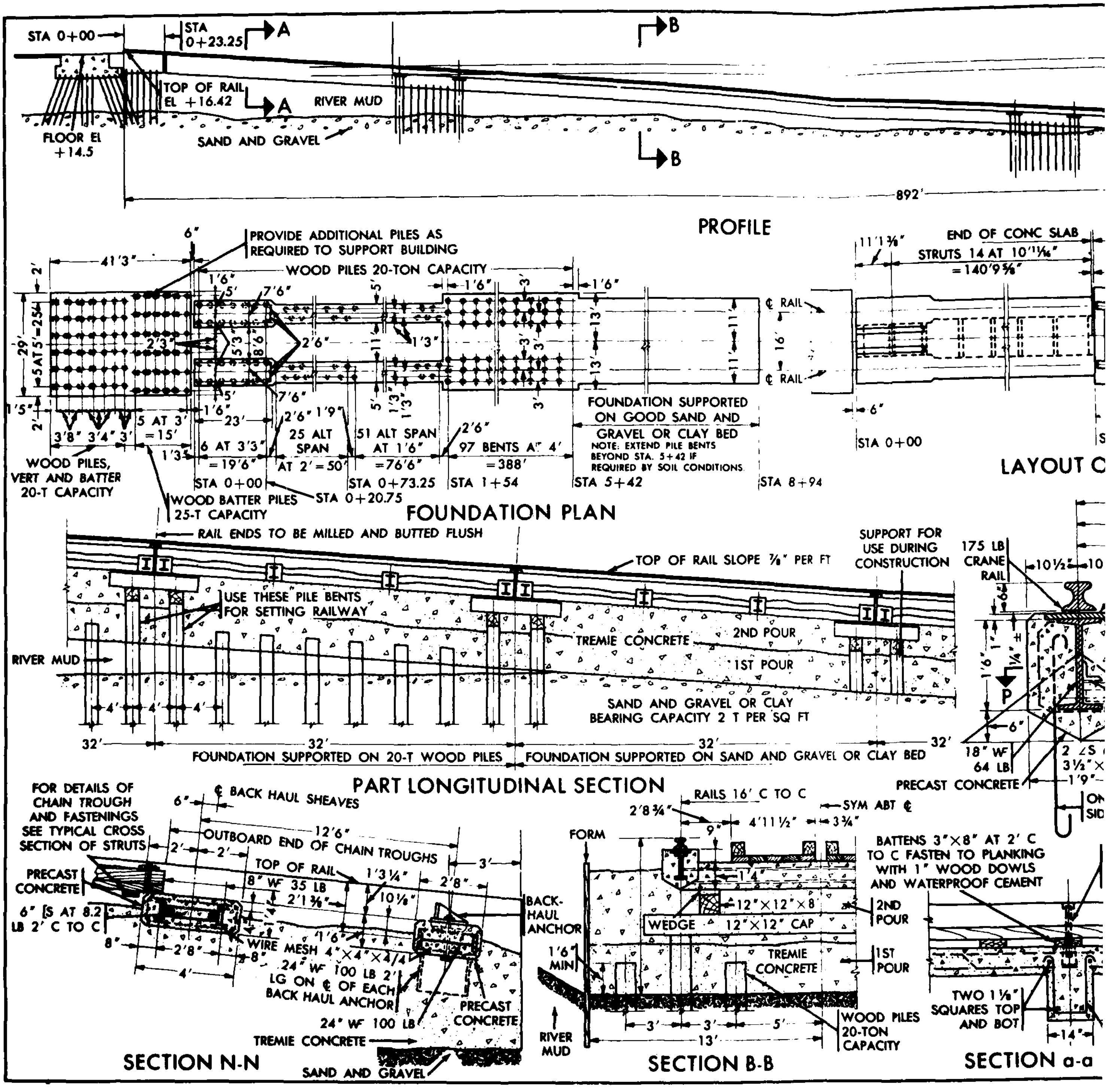


FIGURE 4
Crane Track Layout, Submarine Base,
New London, Conn.



PROFILE
STA 0+00
STA 0+23.25
TOP OF RAIL EL +16.42
RIVER MUD
FLOOR EL +14.5
SAND AND GRAVEL
892'
FOUNDATION PLAN
PROVIDE ADDITIONAL PILES AS REQUIRED TO SUPPORT BUILDING
WOOD PILES 20-TON CAPACITY
FOUNDATION SUPPORTED ON GOOD SAND AND GRAVEL OR CLAY BED
NOTE: EXTEND PILE BENTS BEYOND STA. 5+42 IF REQUIRED BY SOIL CONDITIONS.
WOOD PILES, VERT AND BATTER 20-T CAPACITY
WOOD BATTER PILES 25-T CAPACITY
6 AT 3'3" =19'6"
25 ALT SPAN AT 2'=50'
51 ALT SPAN AT 1'6" =76'6"
97 BENTS AT 4' =388'
STA 0+00
STA 0+20.75
STA 0+73.25
STA 1+54
STA 5+42
STA 8+94
END OF CONC SLAB
STRUTS 14 AT 10'1 1/16" =140'9 5/8"
LAYOUT C
PART LONGITUDINAL SECTION
RAIL ENDS TO BE MILLED AND BUTTED FLUSH
TOP OF RAIL SLOPE 7/8" PER FT
SUPPORT FOR USE DURING CONSTRUCTION
USE THESE PILE BENTS FOR SETTING RAILWAY
TREMIE CONCRETE
2ND POUR
1ST POUR
SAND AND GRAVEL OR CLAY BEARING CAPACITY 2 T PER SQ FT
FOUNDATION SUPPORTED ON 20-T WOOD PILES
FOUNDATION SUPPORTED ON SAND AND GRAVEL OR CLAY BED
175 LB CRANE RAIL
18" WF 64 LB
PRECAST CONCRETE
SECTION N-N
FOR DETAILS OF CHAIN TROUGH AND FASTENINGS SEE TYPICAL CROSS SECTION OF STRUTS
BACK HAUL SHEAVES
OUTBOARD END OF CHAIN TROUGHS
TOP OF RAIL
8" WF 35 LB
6" [S AT 8.2 LB 2' C TO C
WIRE MESH 4"×4"×4/4
24" WF 100 LB 2' LG ON ℄ OF EACH BACK HAUL ANCHOR
24" WF 100 LB
BACK-HAUL ANCHOR
TREMIE CONCRETE
SAND AND GRAVEL
SECTION B-B
RAILS 16' C TO C
SYM ABT ℄
FORM
WEDGE
12"×12" CAP
12"×12"×8
TREMIE CONCRETE
WOOD PILES 20-TON CAPACITY
RIVER MUD
SECTION a-a
BATTENS 3"×8" AT 2' C TO C FASTEN TO PLANKING WITH 1" WOOD DOWLS AND WATERPROOF CEMENT
TWO 1 1/8" SQUARES TOP AND BOT

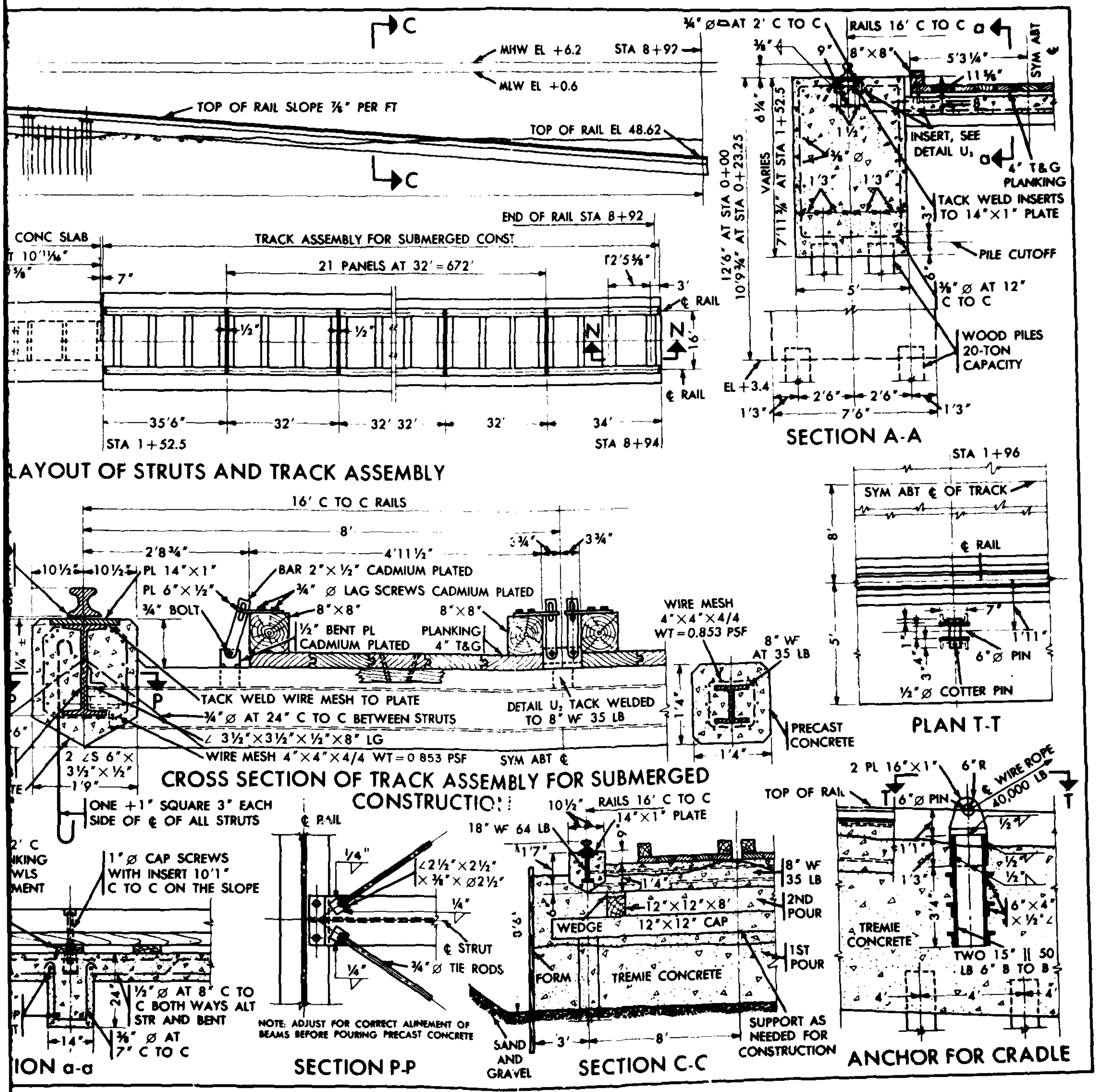


FIGURE 5
Foundation Layout, Marine Railway,
Philadelphia Naval Shipyard

2

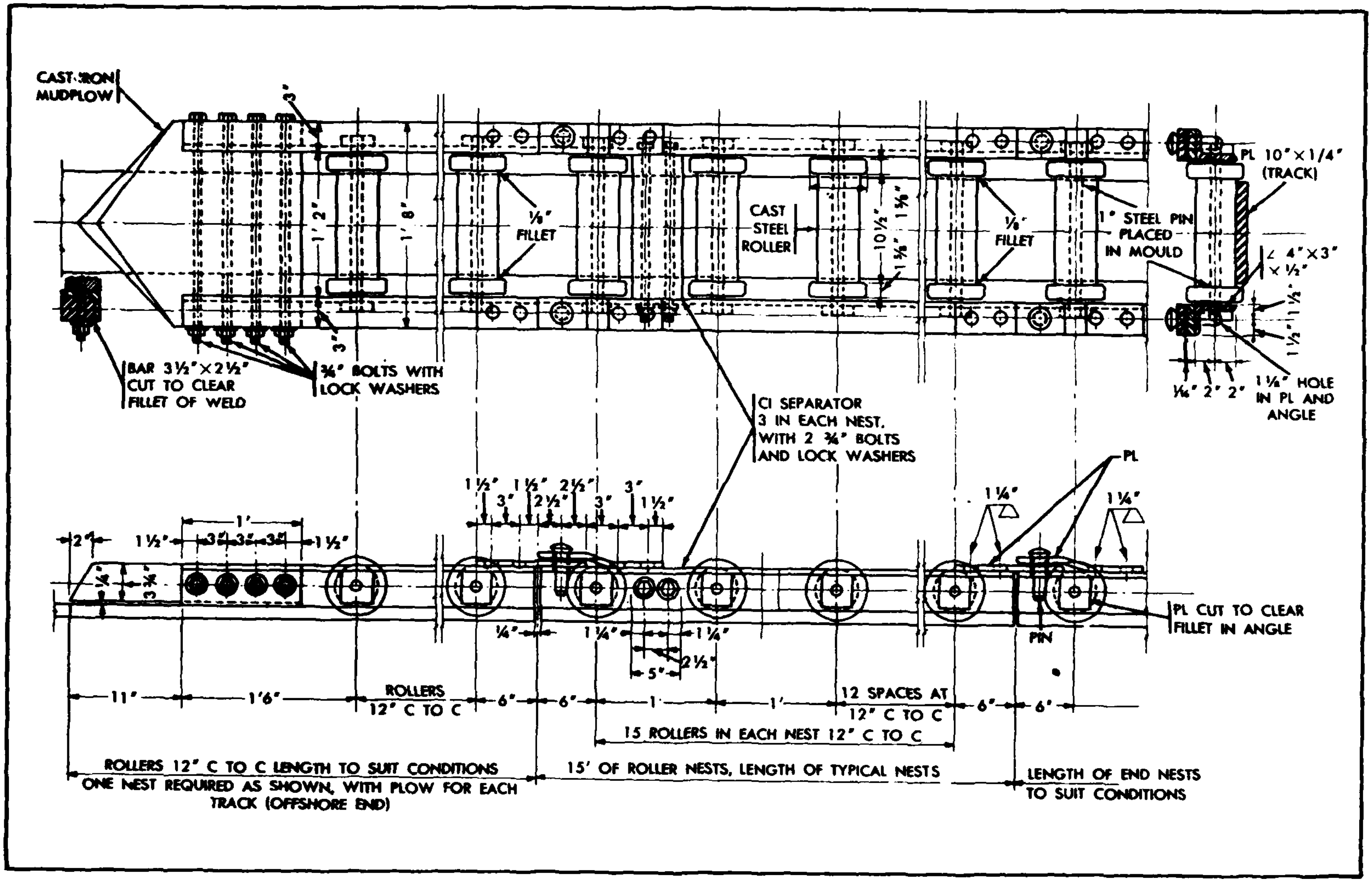


FIGURE 6
Typical Roller Nests

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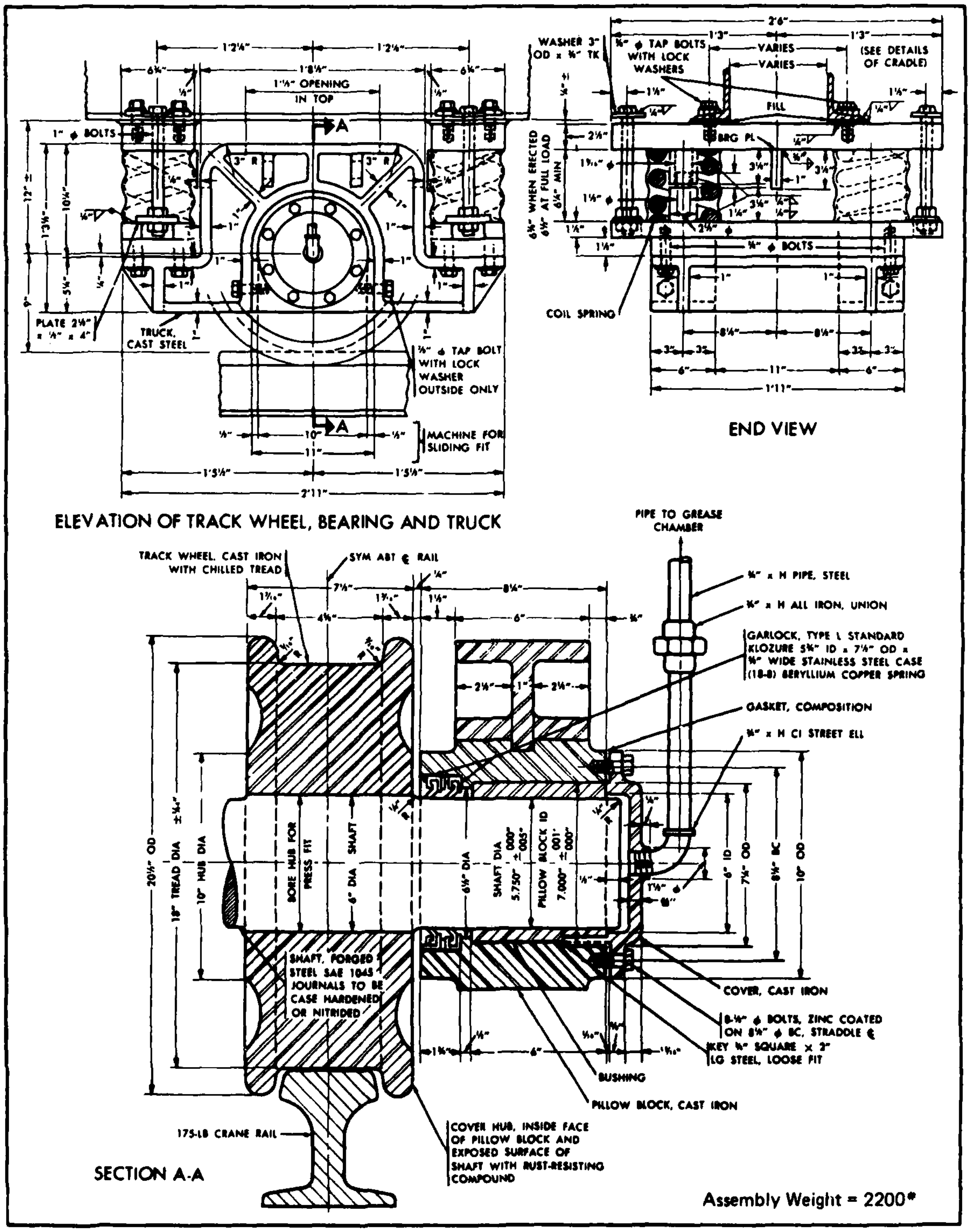


FIGURE 7
Typical Cradle Wheel

b. Wheel Bearings. For the larger marine railways, it is desirable to protect the wheel bearings by rubber or other suitable pressure seals. For small or medium sized marine railways, it is not necessary to provide protection for the wheel bearings.

c. Axles. Make axles of medium carbon steel. Make bearings of cast iron. Avoid combinations of metals that set up electrolytic action. Do not use bushings of bronze, babbit, monel, or any other copper or nickel alloy. The best combination for bearings is cast iron on steel, with adequate provision for lubrication. Pressure-sealed self-lubricating antifriction bearings, properly installed, will reduce the rolling friction.

Section 9. CRADLES

1. MATERIAL. Most cradle designs have steel frames with wood or steel decking; however, timber cradles may be used for designs of small capacity. A timber cradle requires ballast to counteract its buoyancy. Design steel cradles with few members and heavy sections to minimize the effect of corrosion.

2. SHIP AND WIND LOADS. Design the cradle for a combination of loads as listed in Section 6, and for loads occurring when the vessel is still afloat with breast lines made fast to the cradle. (See Figure 8.) Under this condition, consider concurrently the effects of wind and current forces in the design of the cradle superstructure. Also consider stability of the cradle on the tracks under this condition. Use a wind velocity of 25 miles per hour to determine the breast line pulls on the cradle. These pulls shall be increased by 100 percent to allow for impact resulting from the motion of the vessel.

3. CHAIN PULLS. Design cradles to take pulls from hauling chains attached to the crossarm. Provide transverse and longitudinal bracing to handle all loading conditions. The maximum pull on the chains shall be determined by equation 1.

$$P = W \sin \Phi + WC \qquad (1)$$

Where: P = pull of chains (lb).
W = total weight of maximum design vessel plus weight of cradle plus weight of chains (lb).
Φ = angle of inclination of ways (degrees).
C = coefficient of friction.

The coefficient of friction for rollers varies from 0.007 to 0.064 as indicated by tests at Boston and San Diego. Friction increases with: (1) the amount of silt, sand blast grit, and debris on the tracks; (2) wear and corrosion; (3) groundway deviations from grade and/or alinement; (4) lack of lubrication and maintenance. For design life cycle basis, a coefficient of 0.04 for rollers and 0.03 for wheels is satisfactory; however, larger values should be used if above variables are expected to be unusually severe at a particular site.

4. KEEL AND BILGE BLOCKS. In general, the requirements, arrangement, and fittings for blocking correspond to those required for docking vessels in graving docks.

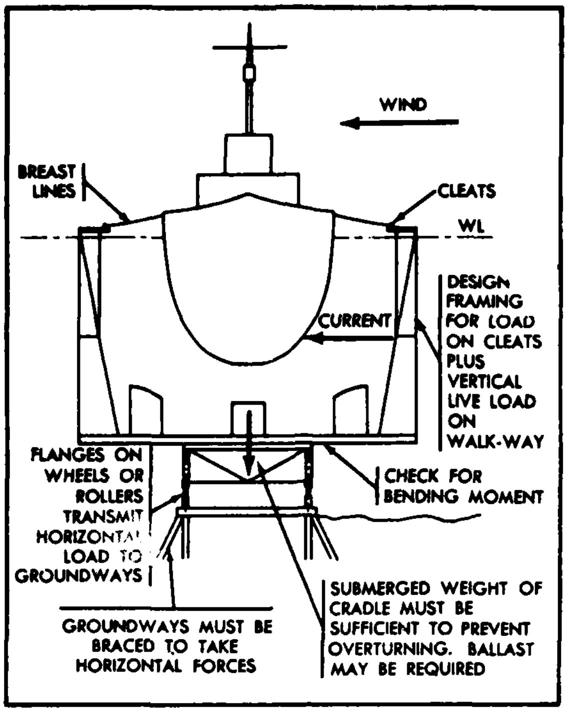


FIGURE 8
Stability Factors

a. Spacing. Space keel blocks 4 feet apart and bilge blocks 12 feet apart. When pier type keel blocks are used, they shall be spaced 6 feet apart.

b. Loads. The various cases of loading on the blocks to be used in the design of the cradle are:

(1) Vertical weight of ship entirely on the keel blocks.

(2) Vertical weight of ship entirely on keel blocks, with bilge blocks on one side taking wind load only.

(3) Keel blocks taking one-half the weight, and bilge blocks on each side taking one-quarter of the weight of the ship.

(4) Same as (3), except bilge blocks on one side take wind load in addition.

c. Special Cases. For all other special cases involving flat-bottomed scows, floating cranes, dredges, vessels with twin screws, and the like, take the spacing and vertical loading on the blocks to suit the conditions of each particular craft.

d. Special Considerations.

(1) Bilge Blocks. Give consideration to the maximum outboard position of the loaded bilge blocks, and its effect on cradle design, especially the design of the cantilever portion of the transverse frames. Move bilge blocks by hand winches located on the cradle walkway.

(2) Keel Blocks. Anchor keel blocks to prevent the possibility of being overturned by the drag and surging of a vessel incident to the hauling operation. Crib keel blocks at points of heavy load concentrations (such as the afterknuckle of keel and at the forepoppet) to provide longitudinal stability and adequate load distributions.

5. SPECIAL FRAMING OF OFFSHORE END. On some naval vessels, the propellers, sonar equipment, or rudders extend below the baseline or keel line. To accommodate these vessels, it is necessary to design the cradle to provide sufficient clearance over the deck or pits for removal and replacement of such equipment.

6. WALKWAYS. Provide elevated timber decked walkways on each side of the cradle, and on the larger railways, provide a crosswalk at the inner end. Make walkways level, about 3 feet wide, and at such an elevation that there will be adequate freeboard when the cradle is in its extreme offshore position. Fit walkways with bilge block hauling mechanism, cleats and chocks, and/or ringbolts of ample size for securing the lines. Provide handrails on the outboard side of the walkways.

7. WALKWAY UPRIGHTS. Walkway uprights of timber or steel support the walkways and form the sides of the cradle. Arrange them to assist in supporting staging, and brace them to take the line pulls incident to centering and hauling vessels. (See Figure 8.) Because these loads are transmitted to the cantilever portion of the main transverse frames, they must be considered in the design of the transverse frames.

8. CRADLE TRUSSES. Vertical members of cradle trusses are posts that carry the vertical ship and dead load from the deck framing and docking blocks to the bottom chord.

a. Top Chord. The top chord of the trusses is simply a tie to hold the floor members in alinement.

b. Bottom Chord. The bottom chord requires special consideration. It receives loads from each post and, in turn, is supported by wheels or a roller train.

(1) Stresses. A large bending moment is generally developed in the bottom chord between posts when rollers are used, and it should be analyzed as a continuous beam. The portion of the bottom chord member that is forward of the inhaul girder will be in compression, and the portion that is aft will be in tension. Combine these stresses with those resulting from bending.

(2) Bracing. To maintain the cradle parts in alinement, provide bracing in the plane of the bottom chord to take care of unequal resistance.

9. CRADLE FLOORS. A tight, nonslip type of steel floor may be used, although timber decking is common practice. Effective means for collection and disposal of sand and incidental debris should be provided, because sandblasting causes many problems in marine railway maintenance and the debris has a deleterious effect on rollers, wheels, chains, chaintroughs, and tracks.

10. LADDERS. Provide ladders as necessary to permit access from cradle floor to walkways. Locate them on the inboard side of the walkway port and starboard.

11. BOOTJACK. Provide a bootjack at the inner end of the cradle for use in lining up the bow of a ship preparatory to hauling. (See Figure 9.) Provide a bootjack eyebolt on each side of the railway centerline on each cradle transverse frame for the inshore half of the cradle.

12. DRAFT GAGES. Provide at least two draft gages, one on each of the cradle walkway structures, showing the depth of water over the end keel blocks.

13. FENDERS. Provide fenders along each inboard side of the walkway structure.

14. ANCHORS. Install anchors (pad eye for wire rope) for cradles at the inshore end of the groundways. These anchors are to be used to hold cradle in inboard position for maintenance and repair of the hauling mechanism.

15. DOCKING WINCHES. A motor operated winch may be installed on the centerline of the walkway at the shore end of a marine railway cradle to haul in the vessels. A special framework is required for mounting the winch at walkway levels. This limits the location of the bow of a ship, but where long cradles are required, this limitation may not be critical. As an alternative arrangement, to avoid loss of docking length, provide two winches, one on each side of the cradle superstructure.

Section 10. HAULING SYSTEMS

1. CHAIN REQUIREMENTS. Haul cradles with continuous chains running over sprockets or wildcats on the hoists. Provide two or four inhaul and two or four outhaul chains (number of chains depends on capacity of marine railway) connected and reeved to form one endless chain. The pull on the chains is equalized by using an arrangement as shown in Figures 10 and 11.

2. HAULING GIRDER. Fasten the ends of both the inhaul and outhaul chains to the cradle by a hauling girder. Into this girder incorporate the sheaves and other gear used to equalize the pull in the chains. Locate the hauling girder on the cradle so that it will be clear of the water when the cradle is in the inshore position.

3. INHAUL CHAINS. Use stud link chain of cast steel or dielock forged steel. Lay out the chain reeving system in the form of a closed system. (See Figures 10 and 11.) The size of the inhaul chains is determined by the load as described below.

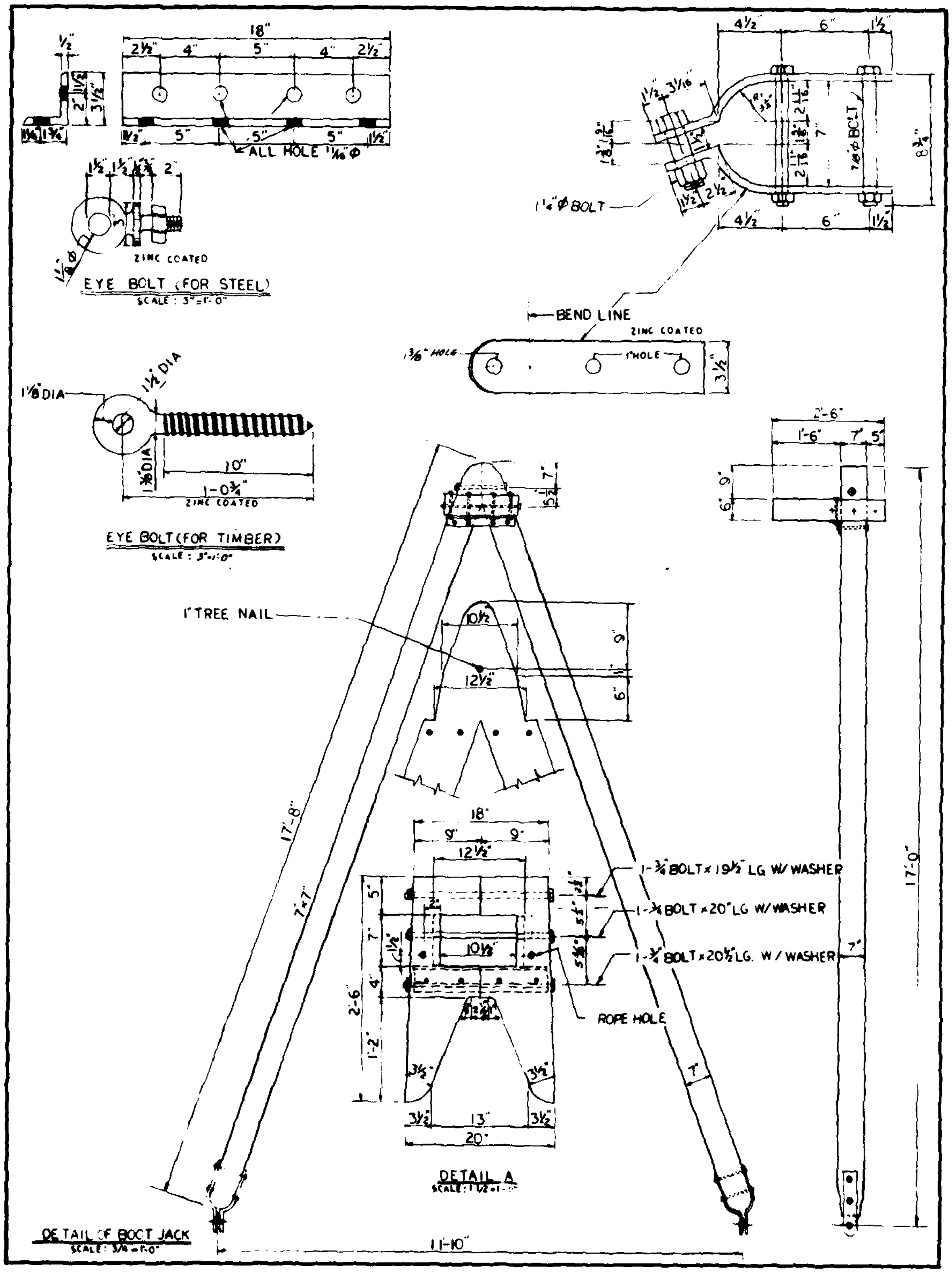


FIGURE 9
Detail of Boot Jack

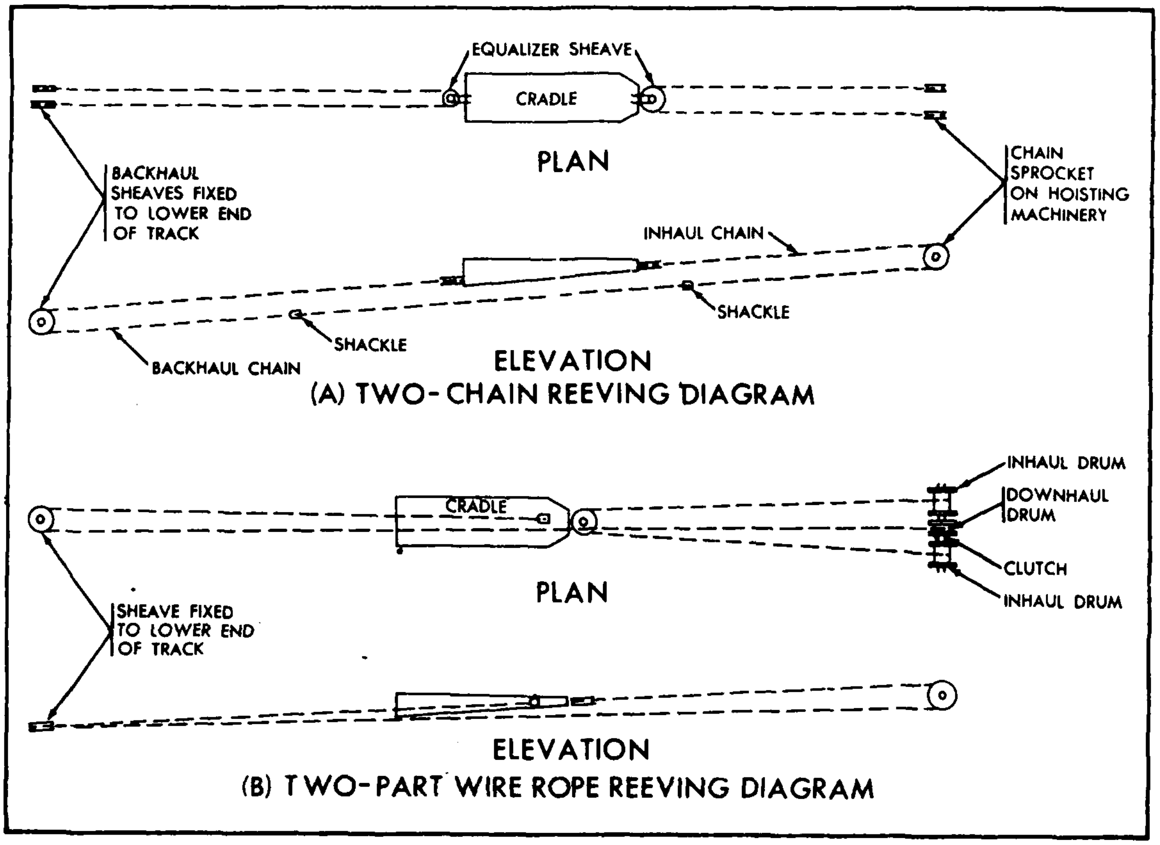


FIGURE 10
Marine Railway Hauling Systems

a. Working Strength. Take the working strength of the chain at 35 percent of its breaking strength.

b. Number and Size of Chains. Determine the number of chains from computed pull calculations. (See Section 9.) When chains are larger than 2-1/4 or 2-1/2 inches, they become unwieldy. Therefore, if the pull is such that two 3-inch chains are required, use four 2-1/4-inch chains.

4. **OUTHAUL CHAINS.** Design outhaul chains (the portion that hauls the cradle out and down the track) for the load required to overcome starting inertia. For outhaul chains, use a minimum size of 1 inch. On larger marine railways, 1-1/4-inch chain may be used.

5. **OUTHAUL SHEAVES.** Locate outhaul sheaves at the extreme offshore end of the groundways, and anchor them to the groundways. Make them readily demountable, and design sheave and anchorage to develop full breaking strength of backhaul chains.

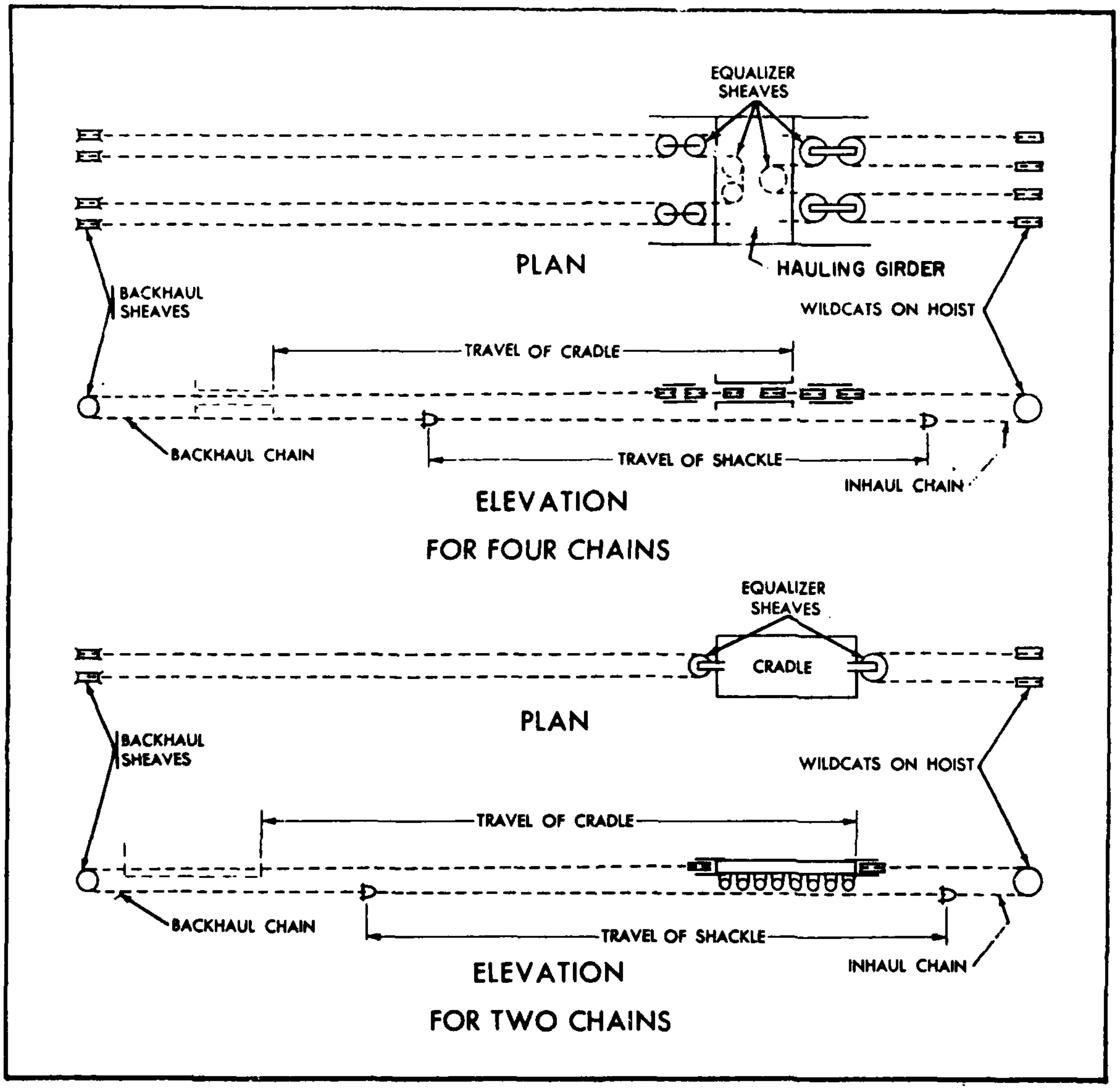


FIGURE 11
Chain Reeving Diagrams

6. HOIST. Inhaul chains pass over wildcats or sprockets mounted on the hoist shaft turned by a gear train directly connected to a hoist motor. The design of hoists for marine railways is a specialty, and it is customary to assign this task to an experienced manufacturer. The hoist requirements, however, are specified by the project specifications; therefore, the manufacturer should be furnished with pertinent information, including the following.

(1) Speed. A suitable inhaul chain speed for large marine railways is 10 feet per minute. A slightly higher speed may be used on small marine railways. Arrange gears to provide two hauling speeds, the high speed gear being used for outhauling the cradle with a vessel on the blocks or for operating it under no load. Also see Operating Time in paragraph 6(3) below.

(2) Brakes. Provide hoists with an electric automatic motor brake, an emergency handbrake, and a lever operated pawl engaging in a ratchet, all designed to hold the loaded cradle in any position on the ways. Provide limit switches to prevent overrun.

(3) Operating Time. The capacity of the hauling machinery or hoist should be such that it will haul up the loaded cradle in from 10 to 15 minutes for railways up to 500-ton capacity, and in about 30 minutes for larger railways.

a. Lubrication. Particular attention should be given the design of the lubrication system for all the bearings and gears.

b. Efficiency. Assuming that the total efficiency of a pair of gears, including journal losses, is 0.935, the overall efficiency of a marine railway hoist with four pairs of gears would be about 75 percent. Because machinery of this type should be designed with ample power, assume, in this case, an overall efficiency of 65 percent, corresponding to an efficiency of 0.90 for each pair of gears. The efficiency of machines outfitted with antifriction bearings is somewhat higher.

c. Special Precautions. Install the hoist with great care and accuracy. The hoist frame must rest upon a rigid foundation, and must be carefully set and held in place by anchor bolts of ample size. Exercise great care in the design of the frame of the hoist, to provide for all phases of operation which could cause misalinement. When misalinement occurs, gears, bearings, and shafts are subject to great overstress and the hoist may deteriorate rapidly.

7. HOIST FOUNDATION. Design the hoist foundation to take the horizontal and vertical components and impact of the maximum chain pull and the overturning moment. (See Figure 12.)

a. Rock Support. Where hoist foundations are supported on rock, transfer the horizontal load by keying the concrete foundation into the rock.

b. Pile Support. Where foundations are supported by piles, transfer the horizontal load to the subsoil by means of batter piles.

c. Stresses. With respect to the internal stresses in the foundation block, a very careful analysis of the moments and shears is necessary to assure an adequate amount of reinforcing steel and properly designed anchor bolts.

d. Cracking. To prevent foundation cracking as a result of shrinkage, provide minimum reinforcing steel equivalent to 0.3 percent of the area of the horizontal and vertical cross sections.

8. MOTOR. The motor shall be of the woundrotor induction type for operation on 3-phase voltage, and of dripproof construction. Base the horsepower power rating on intermittent operation at full load with a resultant temperature rise of not more than 40 degrees centigrade and having a breakdown torque of approximately 250 percent of full load torque. Select the motor to be of moisture resistant design, and provide space heaters of sufficient capacity to hold the temperature at approximately 5 degrees centigrade above the ambient, as a protection against dampness.

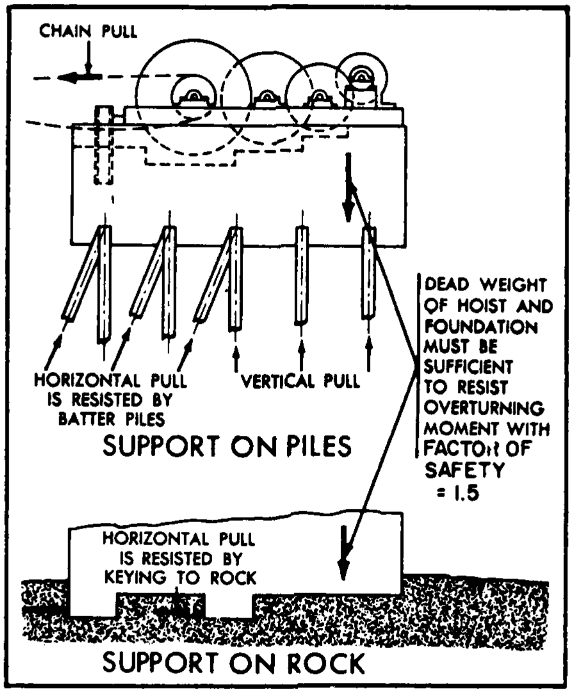


FIGURE 12
Hoist Foundation

Section 11. CONTROL EQUIPMENT

1. REQUIREMENTS. Obtain electric power from shore distribution systems. Build control equipment as metal enclosed units insofar as practicable.

2. LINE PROTECTIVE EQUIPMENT. Provide line protective equipment with proper interrupting capacity and having overload and low voltage protection. In addition, include: (1) integrating watt-hour meter, (2) recording wattmeter, (3) indicating lights, and (4) ammeter installed at master control switch location.

3. PRIMARY CONTROL EQUIPMENT. Provide primary control equipment for forward and reverse operation and plugging. In addition, include all other devices necessary for control of the primary circuit of the motor.

4. SECONDARY CONTROL EQUIPMENT. Provide secondary control equipment for automatic control of the acceleration by definite time limit devices arranged for master switch operation. Provide an adjustable notch back device so that, at a selected overload value of current, the control will automatically insert one resistance step in the secondary circuit and later automatically remove the resistance when the current returns to a normal value.

5. SECONDARY RESISTORS. Select secondary resistors for the duty encountered in operation. Construct resistors of corrosion resistant material.

6. MASTER CONTROL SWITCH. Provide a master control switch with sufficient points in each direction to insure smooth operation of the railway, with at least one point of regenerative lowering during which the motor will operate slightly above synchronous speed, and the remaining points equipped with countertorque control for retarding the load. The OFF position of the switch shall disconnect the motor and apply the brake.

7. EMERGENCY CONTROL. Provide a manually operated emergency control switch at a location convenient to the operator. This switch shall disconnect the control circuit and apply the brake.

8. OVERSPEED AND LIMIT SWITCHES. Provide overspeed and limit switches. In addition, provide a pawl, used for mechanically holding the load in case of brake failure, with a limit switch to prevent operation of the hoist motor in the direction which would damage the equipment when the pawl has not been disengaged.

9. BRAKES. Provide smooth functioning direct current magnetic type brakes, operated by a rectifier.

Section 12. MACHINERY HOUSE

1. REQUIREMENT. Design the machinery house as a one-story building of ample floor area to contain the hauling machinery, switchboard, and other equipment. The construction details are as follows:

(1) Provide an access door, and at least one large door to permit easy removal of machinery. The house shall have necessary windows for light and ventilation and to permit the operator a full view of the cradle and ways.

(2) For a 2,500-ton marine railway, the machinery house should be approximately 27 feet wide and 25 feet long with 9 feet headroom. (See Section 5 for size of hoist house for a 3,000-ton marine railway.)

(3) Provide case iron guide thimbles for the bottom of chains in the sidewalls, and provide a steel wearing plate for the top of the chains.

(4) Machinery pits shall be properly sized and drained, and furnished with necessary handrails and guards.

(5) The building may be of light noncombustible construction unless other considerations justify more substantial building.

(6) Facilities for removing machinery are necessary, and may consist of a hand operated crane in the building or a removable skylight or hatch over the hoist to permit the use of an outside crane.

Section 13. FACILITIES

1. TRACKS. Install a standard gage track along one side of the marine railway so that materials and equipment may be delivered to or from a traveling crane. Where the yard is equipped with adequate trucking facilities, this track may not be necessary. (See Figure 4.)

2. DOLPHINS AND APPROACH PIERS. Because of severe local wind, tide, or current conditions, it may be necessary to temporarily moor or guide vessels into the cradle. This function can be provided by means of piers, but the most usual method is to install dolphins or platforms beyond the offshore end of the groundways.

3. SANITATION. Toilets and washrooms for the ship's crew and for workmen must be convenient to the marine railway, and shall be provided unless adequate facilities are present in existing buildings.

4. SERVICES. Provide services through extensions from shore systems. Extend the mains approximately the full length of the cradle in its inboard position. They may be placed in a trench or tunnel which may be located on one side of the marine railway, the position being determined to some extent by the location of source of supply. The design shall provide adequate protection against freezing. Install service pits approximately every 50 feet for the full length of the mains. The services should include the following:

a. Fresh Water. Mains shall have a manifold at each service pit, provided with one 2-1/2-inch valved outlet with cap and chain. The residual pressure at any outlet shall be 40 to 80 pounds per square inch.

b. Salt Water Flushing and Fire Protection. Mains shall have a manifold at each service pit, provided with one 4-1/2-inch valved pumper connection, one 2-1/2-inch valved outlet, all with caps and chains. The residual pressure at the outlets shall be not less than 40 pounds per square inch.

c. Steam. Mains shall be 4 inches in size, and have one 2-1/2-inch valved outlet, with cap and chain, at each service pit. The residual steam pressure at the outlets should be approximately 150 pounds per square inch gage.

d. Compressed Air. Mains shall be 4 inches in size, and have a manifold at each service pit equipped with one 2-1/2-inch valved outlet with cap and chain. The air pressure at the outlets should be approximately 100 pounds per square inch.

e. Electrical Power. Weatherproof convenience receptacle stations shall be installed alongside the marine railway for single and three phase 60 Hertz power as required.

5. LIGHTING. For night lighting of the cradle, 250 candlepower lights (with reflectors), spaced about 60 feet apart on each side, are required. Attach these to the walkway supports. Connect the lighting circuit to the street lighting system of the yard. Also provide necessary lighting for the railway and floodlighting for night dockings in addition to that on the cradle.

Section 14. SIDEHAUL MARINE RAILWAY

1. MULTIPLE CRADLES. The design of a sidehaul marine railway is similar to that of an endhaul marine railway, but there are special conditions to be considered. It is customary to provide two or more cradles to make it possible to dock or undock more than one small vessel independently. When multiple cradles are used, equalization of pulls on inhaul chains becomes of special importance.

2. 3,000-TON FACILITY. For this installation, there are 12 cradles, 12 sets of groundways, and 12 hoists. (See Figures 13, 14, and 15.) The control system for the hoists is arranged so that any number of cradles can be operated together or separately as necessary to dock ships of various lengths.

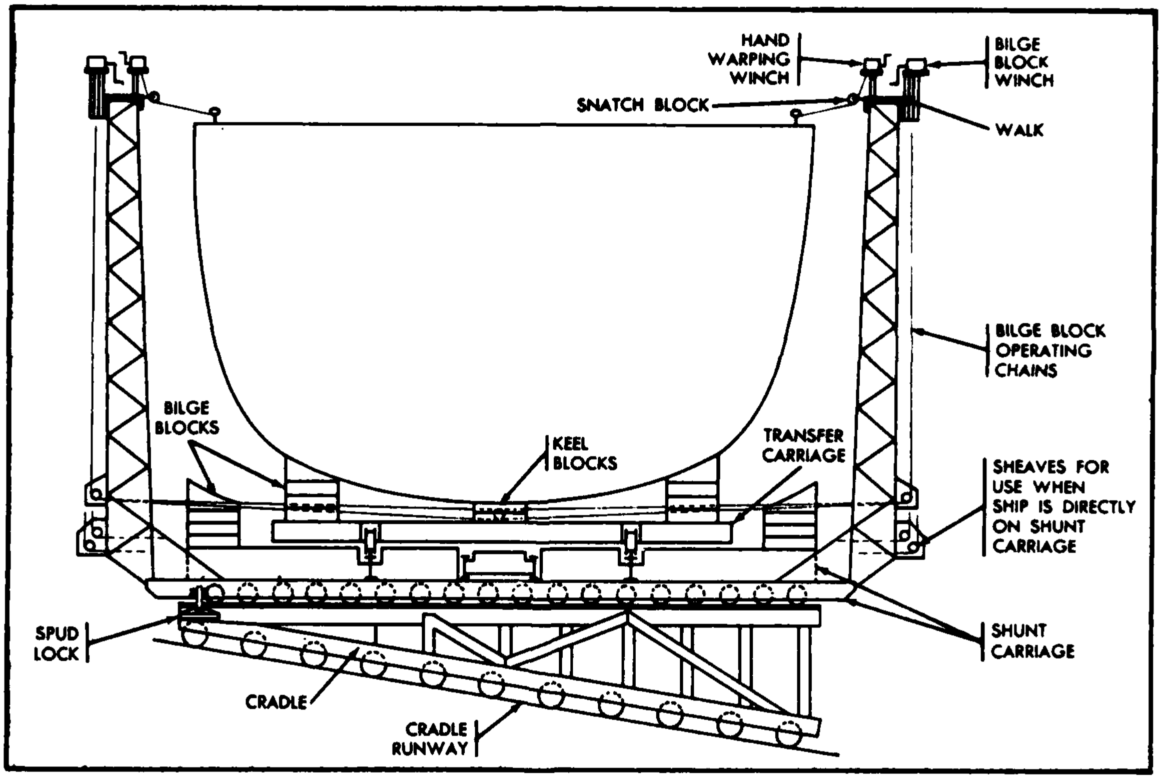
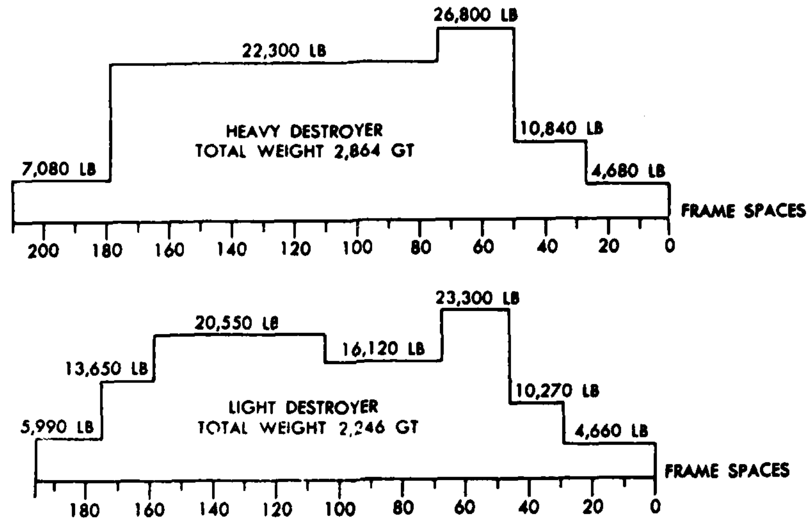
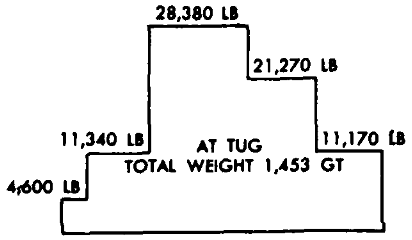


FIGURE 13
Section Through Sidehaul Marine Railway

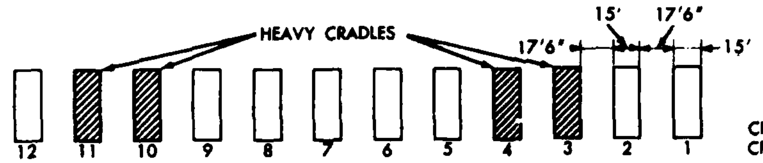
a. Design Load. Figure 14 shows the design load divided into 12 parts longitudinally, and each cradle designed to take a part of the load. For practical design, one load intensity is used for eight cradles and a heavier one for four cradles. The cradles designed to take the heavier loads are marked Heavy Cradles on Figure 14. Similarly, the various sets of groundways are designed for the two different loadings.





ALL CRADLE LOADS OBTAINED BY SIMPLE BEAM DISTRIBUTION

AVERAGE LOADS AND PULLS
3,000 (6.6) + 430 (SHUNT) + 349 (CRADLES) = 3,779 GT
AVERAGE LOAD = 3,779 ÷ 12 = 315 GT
AVERAGE PULL 132.5 KIPS (CRADLE) = 66 KIPS (EACH CHAIN)



12	11	10	9	8	7	6	5	4	3	2	1	CRADLE NUMBERS CRADLE LOADS AND CHAIN PULLS
0	24	401	334	324	324	324	330	376	241	117	69	HEAVY DESTROYER GT
0	19	331	305	298	278	234	269	293	134	67	18	LIGHT DESTROYER GT
131	303	405	326	207	81							AT TUG GT
334	405	405	334	334	334	334	334	405	405	334	334	DESIGN CRADLE LOADS GT
334	405	405	334	334	334	334	334	405	405	117	69	CRADLE LOADS GT
36	36	36	36	36	36	36	36	36	36	36	36	WT SHUNT CARRIAGE GT
27	34	34	27	27	27	27	27	34	34	27	27	WT OF CRADLE GT
397	475	475	397	347	397	397	347	475	475	397	397	TOTALS
166	199	199	166	166	166	166	166	199	199	166	166	DESIGN CRADLE PULL (KIPS)
100	100	100	100	100	100	100	100	100	100	100	100	DESIGN CHAIN PULL (KIPS)

FIGURE 14
Cradle Loads and Chain Pulls

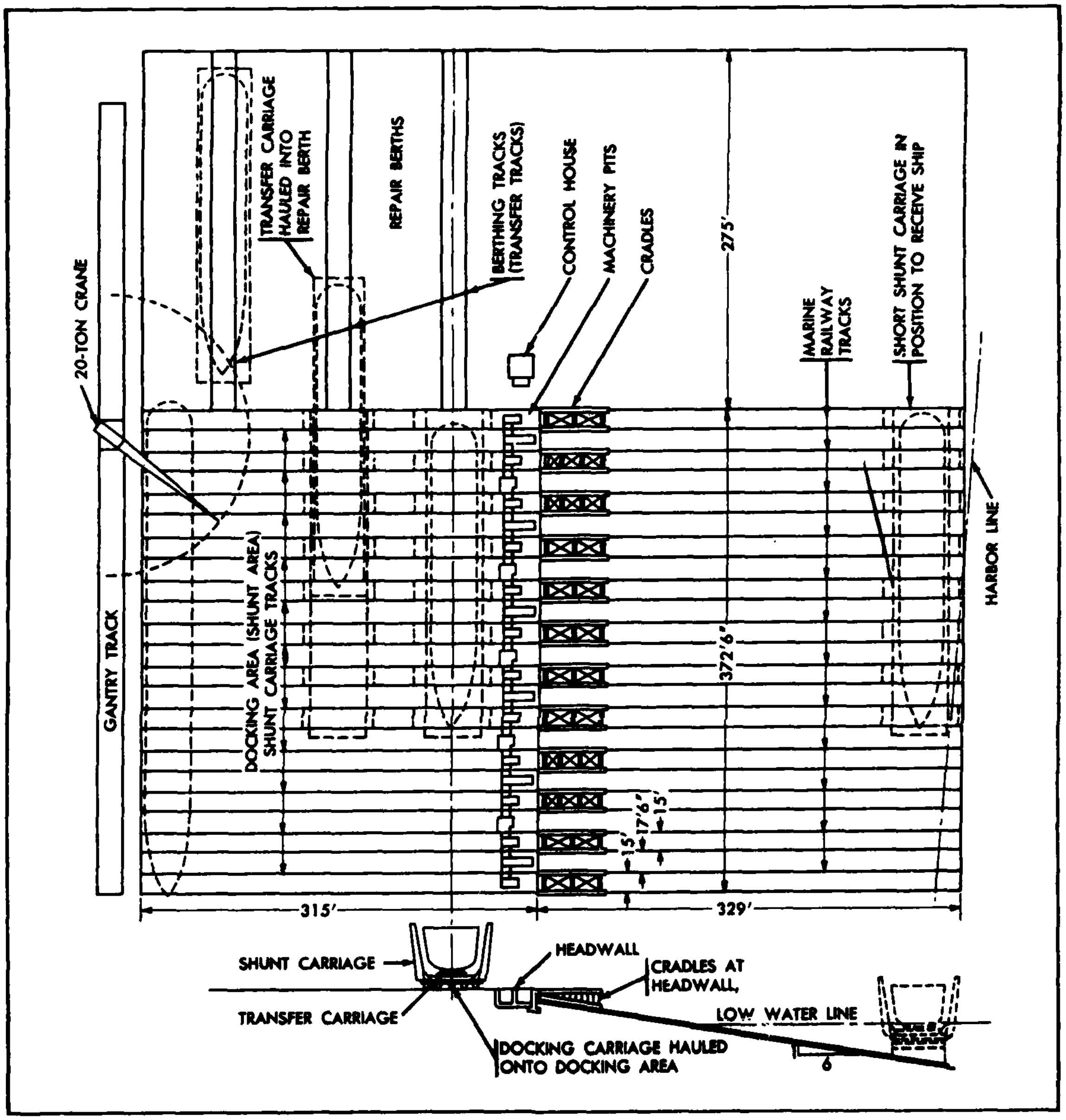


FIGURE 15
Sidehaul Marine Railways

b. Synchronization. The use of 12 cradles and 12 hoists requires an electrical system designed to synchronize the movement of the cradles. It was found that when a vessel was docked on this marine railway, the loads on the various cradles vary considerably. This variation produces a dissimilarity in chain load and chain stretch, tending to cause the more heavily loaded cradles to lag behind as they came up the track. A special design of the electrical system permits the lagging cradles to be pulled up even with the others when necessary. The design of this particular marine railway also provides for shunt and transfer carriages to permit vessels to be hauled off the cradle for repair in the yard. In this manner, as many as four vessels could be repaired at one time.

Section 15. DRAWINGS AND SPECIFICATIONS

1. REFERENCES. NAVFAC specifications and drawings contain data on marine railways designed and constructed under the cognizance of NAVFAC HQ. Future designs may be modified because of improvements in design and materials for hoist motors, electrical controls, machinery design, chains, and other features. Characteristics of existing naval marine railways are presented in NAVFAC DM-29.3.

GLOSSARY

Bilge. The curve of a ship's hull joining the side and the bottom.

Bootjack. An A-frame for lining up the bow of a ship to assist hauling into longitudinal and transverse position over a marine railway cradle when in outboard position.

Captive Crane. A traveling crane limited to use at one facility because of the absence of track connections to other facilities.

Cribbing. A framework, usually of timber, designed to distribute concentrated ship loads and to provide longitudinal stability to the keel blocks.

Gypsy Head. A small auxiliary drum at the side or top of a winch.

Keel. The principal bottom structural element of a ship extending along the centerline for the full length of the ship.

Poppet. Special construction at the ends of a ship's launching cradle. The poppets resist careening when the ship moves down the ways, and the fore-poppet takes the concentrated loading induced when the ship rotates about this poppet when the stern is lifted by buoyancy.

Skeg. Vertical projection extending below the hull of a vessel to reduce yawing.

Sonar Dome. A bulge or appendage on the keel of a ship, usually forward, for housing sonar equipment.

Wildcat. A pocketed and slotted wheel on a winch over which a chain passes.

Winch (or Windlass). An engine fitted with a rotating drum for hauling ropes. Some are fitted with multiple drums, a gypsy head for hauling ropes, or a wildcat for hauling chains.

APPENDIX A

METRIC CONVERSION FACTORS

0.5 inch = 13 mm

1 inch = 25.5 mm

1 inch =2.54 cm

1 inch square = 6.452 cm square

1 foot = 305 mm

1 foot square = 0.3 m square

3.2 feet = 1 m

100 feet = 30,480 mm

1 pound = 453.59 gm

2.2 pounds = 1 kg

100 pounds = 45.36 kg

1 ton = 907.18 kg

50 mph = 80 km/hr

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DM-29.3	Drydocking Facilities Characteristics
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