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MILITARY HANDBOOK

MARINE RAILWAYS

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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.

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FOREWORD

This handbook has been 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 (NAVFACENGCOM), other Government agencies, and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from these criteria, in the planning, engineering, design, and construction of Naval shore facilities, cannot be made without prior approval of NAVFACENGCOM HQ Code 04.

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commander, Naval Facilities Engineering Command (Code 04), 200 Stovall Street, Alexandria, VA 22332-2300; telephone (202) 325-0450.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

CRITERIA POLICY AND PROCEDURES MANUALS

Criteria Manual	Title	PA
MIL-HDBK-1029/1	Graving Drydocks	HDQTRS
MIL-HDBK-1029/2	Marine Railways	HDQTRS
MIL-HDBK-1029/3	Drydocking Facilities Characteristics	HDQTRS

MARINE RAILWAYS

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Section 1: INTRODUCTION

1.1 Scope. This handbook covers the design of marine railways for drydocking vessels to permit inspection, overhaul, and repair of all underwater portions of the vessels. Section 2 compares marine railways and drydocks to show the distinctive features of marine railways and to emphasize both their value and the limitations of the various types of docking facilities. A description of a sidehaul marine railway built for temporary use of the Navy in World War II is given in Section 11. With that exception, all further statements regarding marine railways in this handbook have reference only to the endhaul type.

1.2 Cancellation. This handbook, MIL-HDBK-1029/2, dated 30 June 1989, cancels and supersedes NAVFAC DM-29.2 of January 1982.

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Section 2: BACKGROUND, PRINCIPLES, AND TYPES

2.1 Background of U.S. Navy Marine Railways. The first Navy marine railways, with capacities of 2,000 tons (tons of 2,240 lbs) 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. Marine railways with a capacity of 3,000 tons were built in New London, Connecticut and Philadelphia, Pennsylvania in the early 1940's. 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.

Data concerning all marine railways at Naval shipyards and activities are presented in MIL-HDBK-1029/3, Drydocking Facilities Characteristics.

2.2 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.

2.3 Types of Marine Railways. 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 train not attached to cradle or track, hoisting machinery, and chains or cables for hauling cradles out of or into the water.

2.3.1 Endhaul. All existing Naval marine railways are of the endhaul type for the following reasons:

a) Easier pulling equalization than for side-haul type.

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

c) Operation is considered to be safer and less complicated than for sidehaul designs. 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.

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

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

b) 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.

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

2.4 Comparison of Marine Railways, Drydocks, and Graving Docks. A marine railway provides a fast, convenient, and economical method of docking and undocking vessels up to about 5,000 tons. Comparison of adaptability to other waterfront facilities is reviewed below.

2.4.1 General Considerations. General construction and safety considerations for marine railways and graving drydocks are given below.

a) Marine railways are best adapted to sloping bottoms.

b) Groundways for marine railways usually extend several hundred feet beyond existing piers and wharfs. These extensions present hazards to navigation unless they are below the general dredged bottom.

c) When deep water is available at the bulkhead line, the marine 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 (152.4 m) inshore.

Graving docks provide the following advantages:

a) Greater adaptability at shipyard sites than marine railways.

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

c) Graving docks provide a uniform water depth. Most marine railways have a sloped top of keel block line.

d) Vessels are usually docked in a level position.

2.4.2 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.

2.4.3 Costs. Cost factors for marine railways, drydocks, and graving docks are compared below.

a) Construction. Marine railways first costs are less than those for graving docks for the same classes of vessels.

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. Refer to para. 2.4.6.

2.4.4 Time Required for Docking and Undocking. Time factors are as follows:

a) Drydock. 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.

b) Marine railway. A marine railway cradle must be hauled in and out twice to accomplish the same result as a drydock, but the time required is less. 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.

c) Graving dock. 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.

2.4.5 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.

The following factors must be considered in design of marine railways.

a) Wind and water currents.

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

(2) Transmission of Forces. After the tugs have been released and the ship is inside the cradle, it is still exposed to wind, waves, and to any cross currents that may develop. 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.

b) Ice. In cold areas, ice can form on the track, rollers, and chains of a marine railway. Ice formation while a ship is under repair on the cradle can delay or endanger the undocking.

High winds and waves may interfere with a graving dock operation, but the worst effect will probably be only a postponement of the drydocking. Similarly, ice may pile up at the graving dock entrances, but its removal is not difficult.

2.4.6 Reliability. Safety precautions against accidents serious enough to damage ships must be provided as a part of engineering design. Most parts of graving docks (except for outboard faces of entrance closure, flooding, and dewatering systems) are accessible for inspection and repair after each dewatering.

In marine railways, 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 not readily accessible for inspection or repair Consequently, marine railways are more subject to mishap and breakdowns than graving drydocks because of the difficulty of underwater maintenance and repairs. Refer to para. 2.4.3.

The following factors decrease reliability of marine railways.

a) Deposits of silt and miscellaneous debris on the rails, roller trains, or chain troughs, can cause derailment or render the marine railway inoperable.

b) Larger cradles are usually built in two sections, to allow for overhaul of the cradle out of the water. 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.

c) 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.

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

Section 3: SITE SELECTION

3.1 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:

a) A sheltered harbor,

b) A channel adequate in depth and width,

c) Suitable soil or rock foundation,

d) Satisfactory tidal, current, silting, and climatic conditions,

e) Sufficient area and suitable sites for all proposed appurtenant facilities.

3.2 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.

3.2.1 Distance to the Channel. The distance from highwater line 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.

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

3.2.3 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.

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

3.2.5 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.

3.2.6 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.

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Section 4: DESIGN CRITERIA FOR ENDHAUL MARINE RAILWAYS

4.1 Dimensions and Physical 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 the heaviest vessel to be docked.

4.2 Characteristics of Existing Drydock Facilities. 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 MIL-HDBK-1029/3.

4.3 Basic Dimensions. The basic dimensions of the marine railway depend on the following:

a) Cradle -- vertical rise, dimensions, and clearances,

b) Track -- slopes and minimum length,

c) Machinery/hoist house -- dimensions and clearances.

4.3.1 Cradle

4.3.1.1 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 (0.3 m) when in inhauled position.

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. Refer to para. 6.2.1 for additional information on keel block height.

4.3.1.2 Cradle Dimensions. The in-the-clear dimensions of the cradle depend on the maximum overall length, beam, and draft of vessels to be docked. Determine 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 clearances (refer to para. 6.2).

4.3.2 Track Design

4.3.2.1 Track Slopes. Large marine railways are generally built with track slopes of either 3/4 or 7/8 inch per foot (60 to 67 mm per m). 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 (10 mm per m) is generally used. (Refer to para. 7.8 for discussion of vertical curves in tracks.)

4.3.2.2 Minimum Track Length. Track length is different for roller systems and wheel systems. Minimum track length for either design is as specified below.

a) 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) 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 reinstallation at the inshore end.

4.3.3 Machinery/Hoist House. Provide a machinery/hoist house containing hauling machinery consisting of an electric motor, a train of reduction gears, and the wildcat or wire rope drum. (Refer to para. 9.1 for house dimensions). A clear, paved space at least 30 feet wide (9 m) should be provided at the rear of the hoist house to permit wheeled traffic between the two sides of the railway.

4.3.3.1 Total Track Length. The minimum total track length is the minimum track length plus the distance required for necessary clearances and hoist house.

The ideal total track length is the minimum total track length plus an extension of the track at inshore end of about 100 feet (30.5 m) to permit hauling the cradle entirely out of the water for inspection and repair.

Section 5: DESIGN LOADS

5.1 Requirements. 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. Vessels to be drydocked are ordinarily in a light operating condition, but an emergency may require docking a ship which is fully loaded. Design all marine railways for this contingency. 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. Weight curves and their construction vary between Naval Architects, Engineers, and Navy Operating Personnel. It is important for the designer to understand the nature of the vessel (steel, timber-deep, shallow-overhanging stern or barge), the action of the blocking, and the stiffness of the cradle.

5.2 Load Distribution. In designing the marine railway, it is necessary to consider all types of classes of ships, planned or under design, and the weight distribution curves of all of the vessels that may have to be hauled in the future. After these data are obtained, it is necessary to consider a complete docking cycle with these ships on the cradle blocks.

Consider the problem of load concentration for two ships. One has a displacement equal to the rated capacity of the marine railway, and its weight is uniformly distributed over the cradle length. 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 smaller ship.

Similarly, 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; proper allowance must be made 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.

5.3 Alternative Method of Calculating 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.

5.4 Composite Load Curve. Prepare a composite weight distribution curve of all 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. Figure 1 shows typical composite weight distribution curves. Figure 2 shows live loads on cradles.

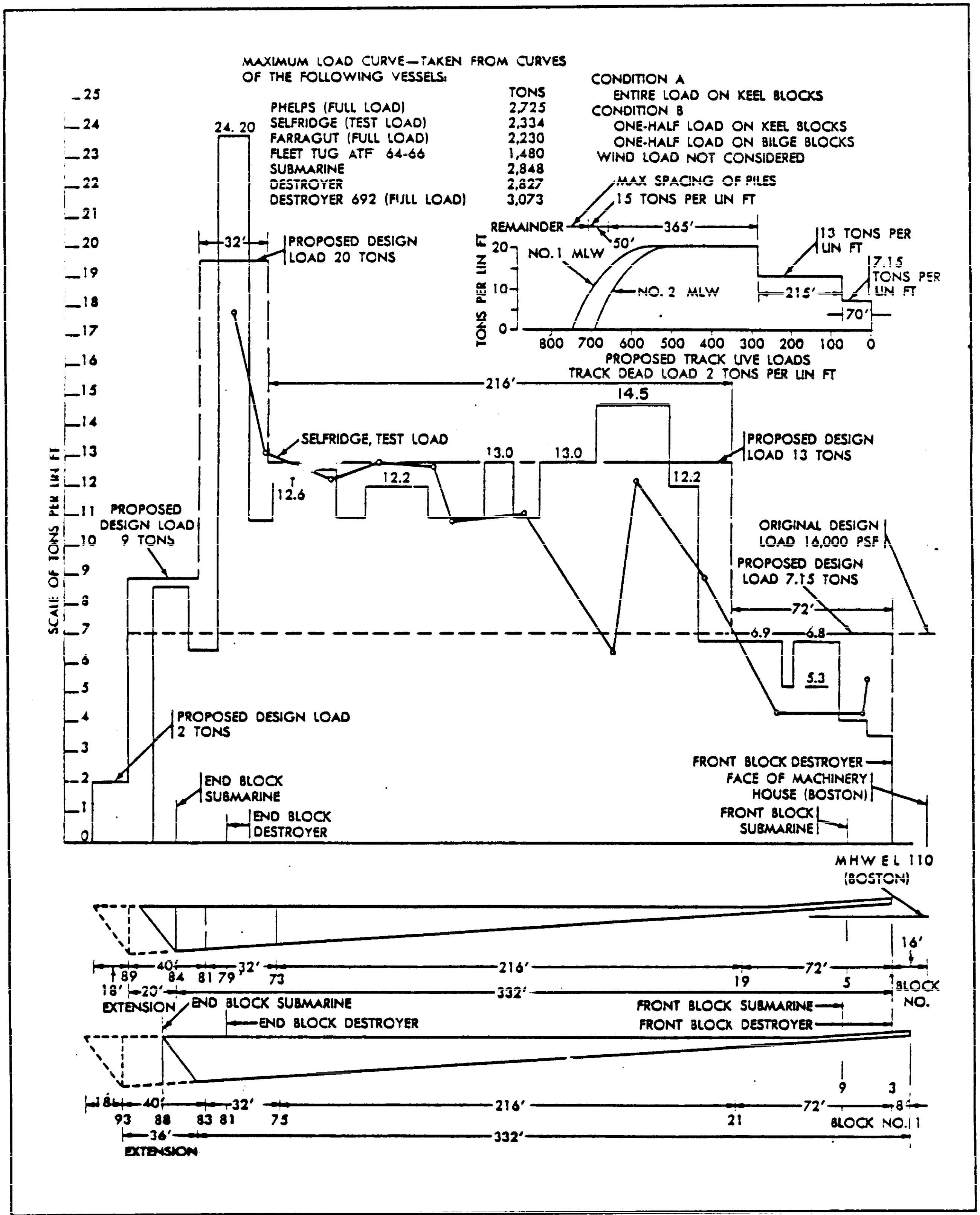
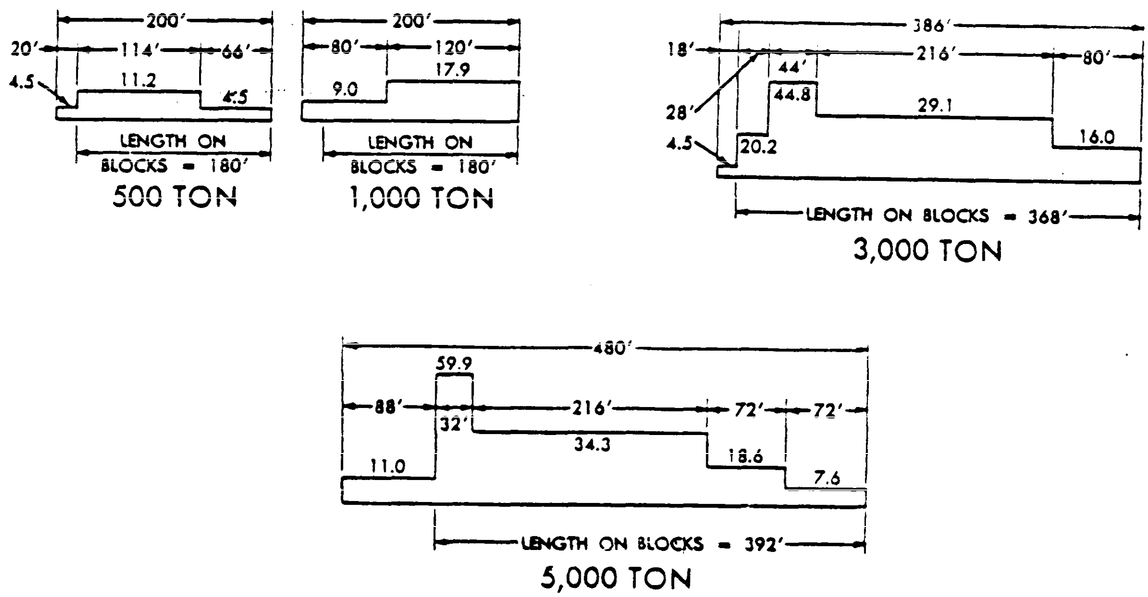


Figure 1
Composite Weight Curves



Note: Figures above load diagrams are live loads in thousands of pounds (kips) per linear foot of cradle. Right end of diagram is inboard end of cradle.

Figure 2
Live Loads on Marine Railway Cradles

5.5 Erroneous Load Curve Assumptions. There are at least two possible sources of trouble to be avoided in establishing a load curve for a Navy marine railway.

a) Previous Designs. Weight distribution curves from older marine railways should be used with discretion. Their use will not provide for the characteristics of new ships and will perpetuate any past errors.

b) Commercial Designs. Load concentrations of Navy vessels are generally different from those of commercial vessels of similar displacement. Therefore, load curves used in the design of commercial marine railways should not be used for the design of Naval marine railways.

5.6 Poppet Load. Poppet loads occur under certain conditions during launching or hauling when keel blocks are built on a slope; they can be reduced by proper sloping of the blocks. Poppet loads may occur under other conditions and should always be considered. For a discussion and determination of poppet loads, refer to Principles of Naval Architecture, Rossell and Chapman, Volume 1.

5.7 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.

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.

5.8 Seismic Design Load. Refer to NAVFAC P-355, Seismic Design for Buildings, for design areas requiring seismic considerations. Refer to MIL-STD-1625, Safety Certification Program For Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships, for design criteria for each seismic zone.

Section 6: CHARACTERISTICS AND CLEARANCES

6.1 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:

a) Maximum displacement,

b) Maximum overall length,

c) Length on keel (bearing length),

d) Maximum beam,

e) Maximum draft forward and aft in docking condition,

f) Shape,

g) Weight distribution,

h) Appendages that may extend below the keel line and require special treatment, including propellers, rudders, and sonar domes or other devices,

i) Width of keel bearing, and

j) Any damages below the waterline which would interrupt the bearing or structural continuity of the vessel.

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.

6.2 Clearances. It is necessary to add certain clearance dimensions to vessel dimensions to provide working space around and under the ship. Provide adequate working space all around the vessel, by extending a deck beyond the vessel's perpendiculars about 15 feet (4.57 m) at each end and clearance of about 5 feet (1.52 m) on each side at vessel's maximum beam. Some small cradles, which can be hauled in over stationary platforms, do not require decks.

6.2.1 Keel Block Clearances. The maximum keel block height is 4 feet (1.2 m) except in special cases. The height of the blocks forward, however, is generally established as stated in para. 4.3.1.1. A clearance of at least 1 foot (0.3 m) 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.

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Section 7: TRACK OR GROUNDWAYS

7.1 Determination of Design Loads. A load curve for a set of groundways is shown in Figure 3.

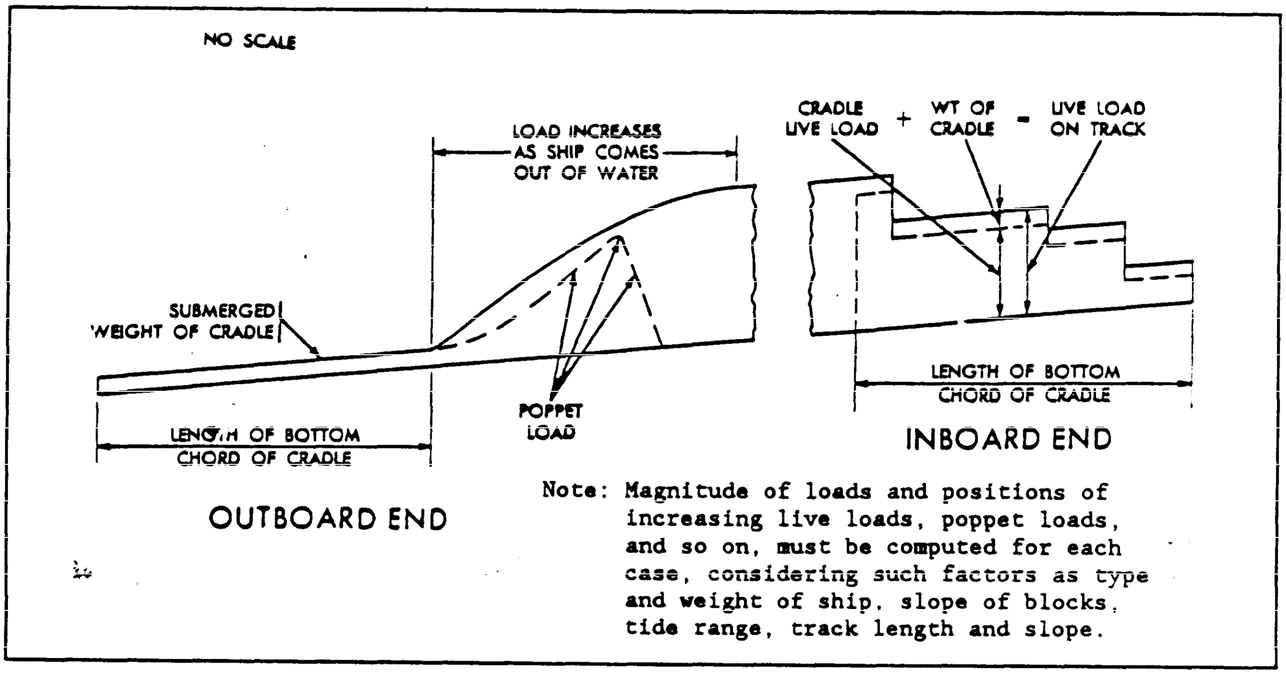

Figure 3
Live Load on Track

7.2 Inshore and Offshore Positions. In the inshore position, 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.

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. The poppet load occurs somewhere between the two extreme positions of the cradle, as noted previously in para. 5.6.

7.3 Elevations at Offshore End. Determine elevations at the offshore end from the following:

a) Maximum drafts, forward and aft, of the design vessel,

b) Slope of the track,

c) Slope of blocks on the cradle,

d) Length of the cradle,

e) Height of upper block above track,

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

7.4 Optimum Design. Although most marine railways are designed to allow docking at mean high water, optimum design will allow docking at mean low water. This should be considered when practicable, if significant tidal variations can invite overloading, the tide range is low, and when other project requirements permit.

7.5 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. However, it is common practice to allow for overrun in determining the length of the roller string. Construct cradles with a so-called nonload-bearing fantail cantilevered projection at the outer end, thus increasing the effective length of the railway.

7.6 Vertical Curves. Marine railways may be constructed with the track in the form of a vertical curve. Ninety percent of new railways are now built with curved tracks, mostly with convex curvatures and occasionally for special reasons, with concave curves. Construction on a vertical curve is no more difficult than for a straight grade but does demand more engineering skill. Vertical curves for marine railways offer the following advantages:

a) Shortening of the horizontal track distance, while increasing the slope of the offshore end.

b) The cradle can be made to rotate from an inclined deck and keel block line well suited to the vessels keel declivity afloat to a horizontal or slightly inclined deck for easy side or end transfer.

c) Better fit of natural ground topography without excessive dredging.

d) Since the track slope decreases as vessel load increases, the machine and chain loads are reduced.

e) For large railways, the curved track reduces the cradle depth aft for easier self-docking or maintenance.

7.7 Track Support. A practically unyielding track support is necessary to avoid excessive stresses resulting from misalignment or damage to track, cradle, and vessel. Support groundways by piles or concrete slabs on rock, coral, or a firm soil.

a) Piles. Piles may be timber, concrete, or steel. The maximum design load for pile foundations may be determined using the NAVFAC DM-7 series, or it may be determined directly by foundation test piles. The groundway structural members may be steel, 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.

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

d) 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.

7.8 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. However, three-track ways are not as efficient as two-track facilities since most of the ship load will be carried by the center way.

7.9 Chain Paths and Guides. Construct chain paths and guides between rails. Make these chain paths of steel or of treated or greenheart timber. Wear on 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 (12.7 mm) steel wearing plate attached with countersunk head screws to prevent the chain path from wearing out too frequently and to prevent excessive chain wear from grit impregnated timber. Chain paths may be continuous but intermittent guides are preferable. They should be constructed to permit easy renewal. Separate chain paths may be provided for backhaul chains.

7.10 Cradle Support. There are two methods of supporting the cradle on the track:

a) 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. A serious disadvantage of rollers develops when the outer end of the roller train is running light or without cradle load. Under this condition, silt, driftwood, or other obstructions on the rail can derail the roller train.

b) A system of wheels attached to the cradle and rolling on a rail or heavy plate forming a part of the groundways. There is less danger of a derailment or serious accident with a cradle mounted on wheels.

7.11 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.

7.11.1 Roller Assembly. Assemble rollers in sections or nests, and hold in place by frames spliced together to form one continuous roller train.

7.11.2 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.

7.11.3 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 an 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.

7.11.4 Material and Design. Make rollers of cast iron or steel. Hold roller diameters to close tolerances not exceeding 1/32 inch (0.76 mm).

7.11.5 Roller 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 4 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.

7.12 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 (6.35 mm) 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.

7.12.1 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. Extra wheels should also be put at the outshore end of the cradle for higher keel loading which usually occurs at the stern of a vessel. Vary the spacing, but all wheels and axles should be designed alike. Figure 5 illustrates a typical cradle wheel.

7.12.2 Wheel Bearings. For 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, such protection is not necessary.

7.12.3 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, babbitt, 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.

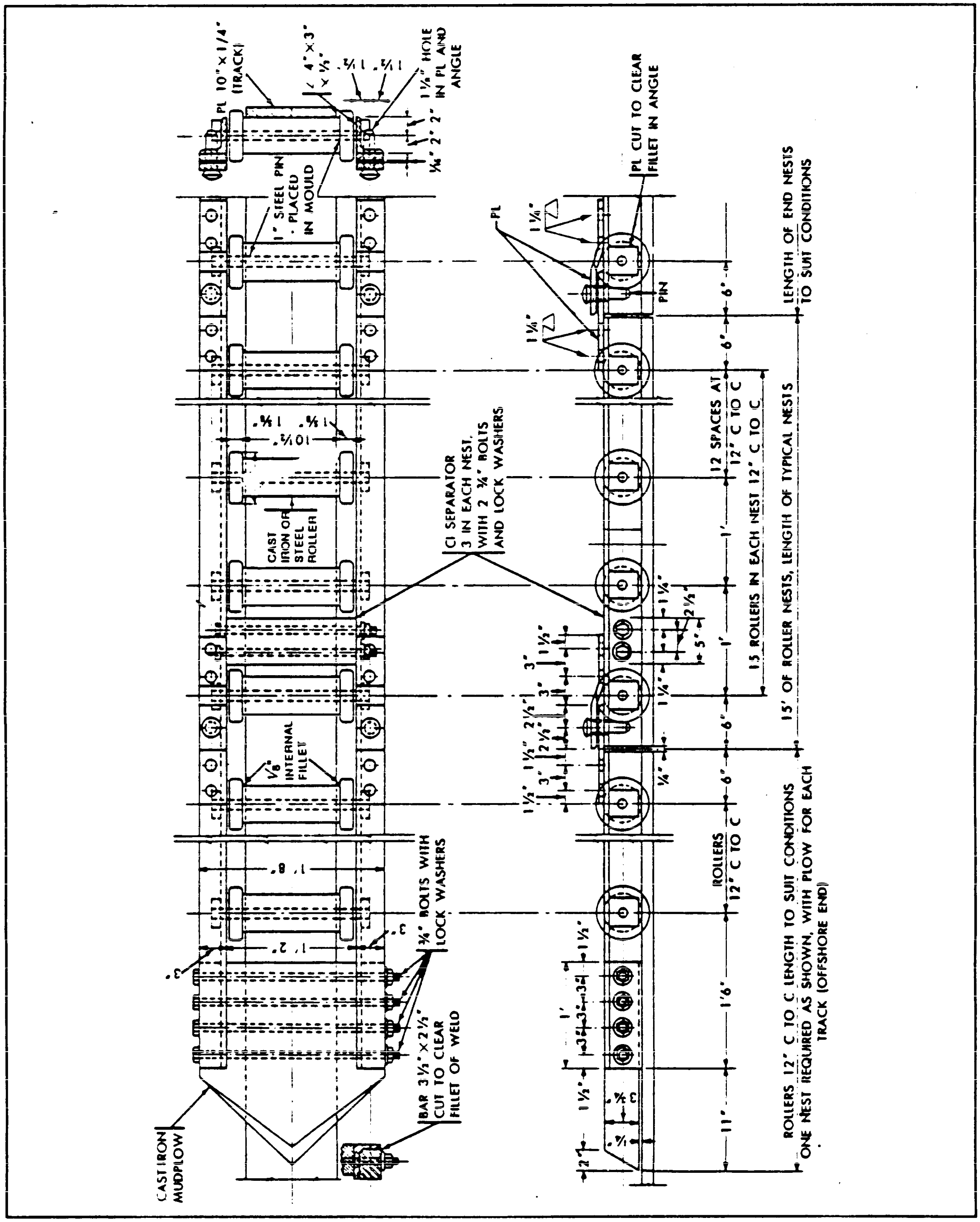

Figure 4
Typical Roller Nest

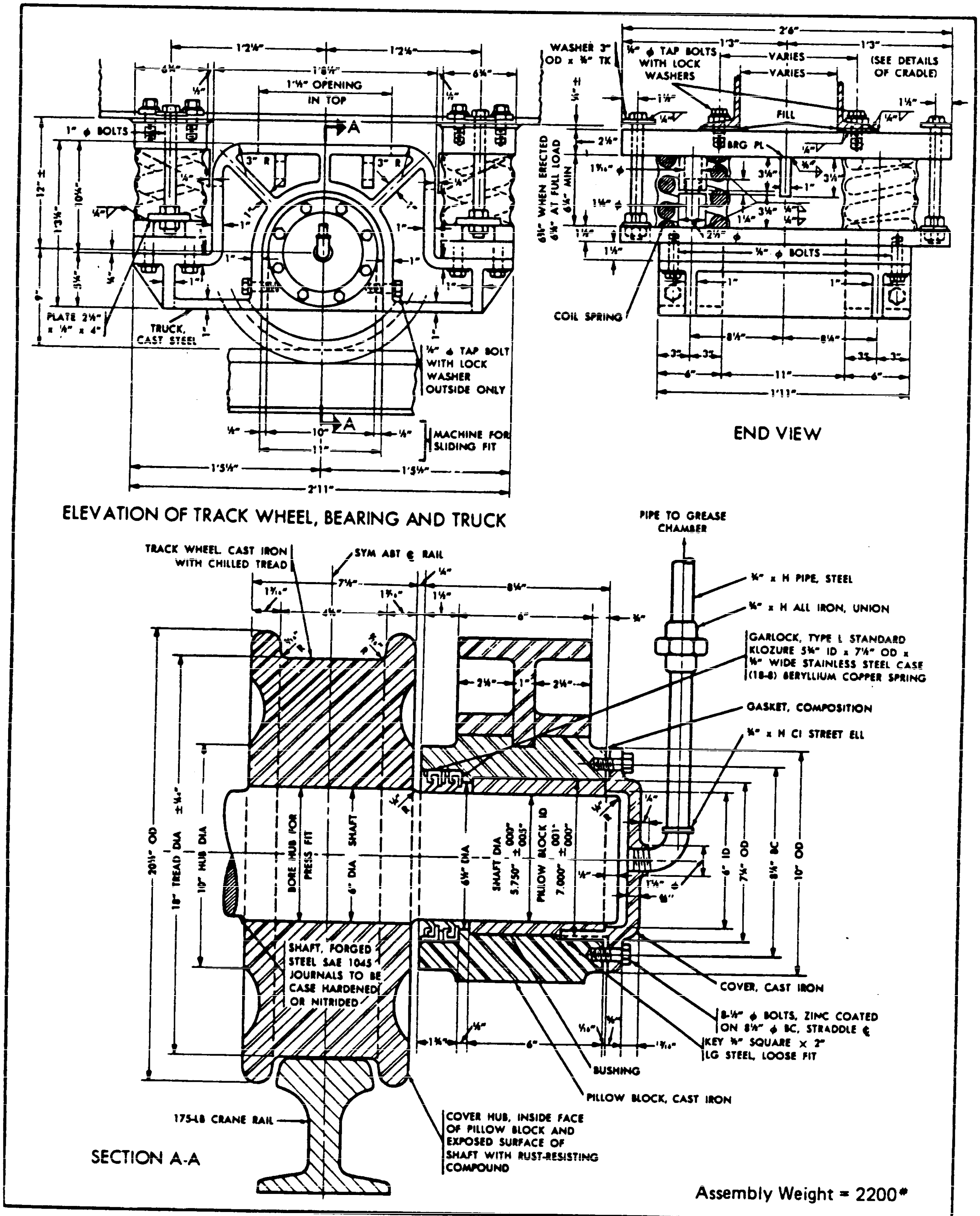

Figure 5
Typical Cradle Wheel

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Section 8: CRADLES

8.1 Cradle Materials. 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.

8.2 Ship and Wind Loads. Design the cradle for a combination of loads as listed in Section 5, and for loads occurring when the vessel is still afloat with breast lines made fast to the cradle. (See Figure 6.) 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 (40 km 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.

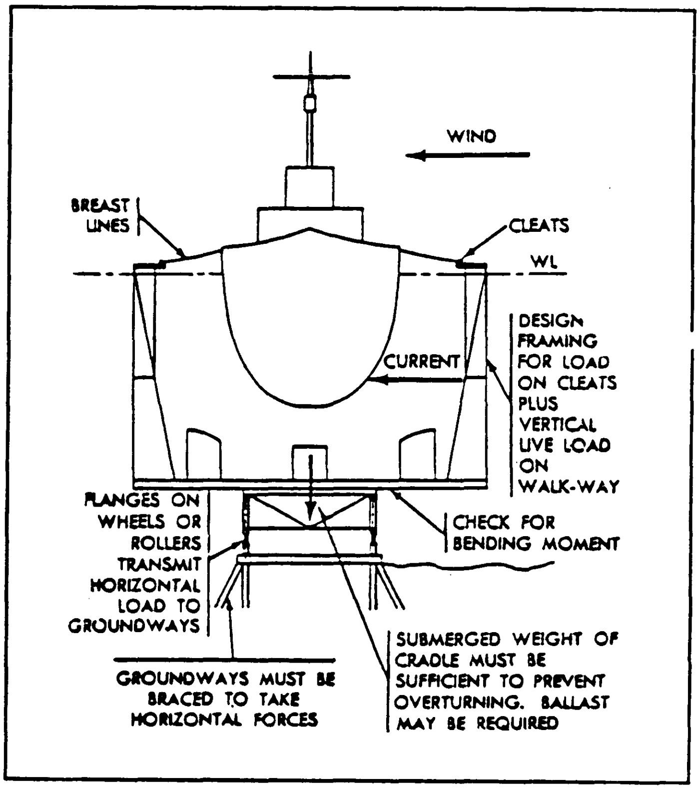

Figure 6
Stability Factors

8.3 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).

EQUATION:

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

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:

a) The amount of silt, sand-blast grit, and debris on the tracks;

b) Wear and corrosion;

c) Groundway deviations from grade and/or alignment;

d) Lack of lubrication and maintenance.

For design, a coefficient of 0.02 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.

8.4 Keel and Bilge Blocks. In general, the requirements, arrangement, and fittings for blocking correspond to those required for docking vessels in graving docks. Space keel blocks 4 feet (1.2 m) apart (6 feet or 1.83 m apart for small railways) and bilge blocks 12 feet (3.66 m) apart. When pier type keel blocks are used, they shall be spaced 6 feet apart.

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.

Consider 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.

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

a) Vertical weight of ship entirely on the keel blocks.

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

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

d) Same as c), except bilge blocks on one side take wind load in addition.

8.4.1.1 Special Cases. For 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.

8.5 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.

8.6 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 (0.9 m) 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.

8.6.1 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 6.) 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.

8.7 Cradle Trusses. Vertical members of cradle trusses are posts that transmit vertical ship and dead load from the deck framing and docking blocks to the bottom chord. The bottom chord receives loads from each post and is supported, in turn, by wheels or a roller train.

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; the aft portion will be in tension. Combine these stresses with those resulting from bending. To maintain the cradle parts in alignment, provide bracing in the plane of the bottom chord to take care of unequal resistance. The top chord of the trusses is simply a tie to hold the floor members in alignment.

8.8 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.

8.9 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.

8.10 Bootjack. A bootjack may be provided at the inner end of the cradle for use in lining up the bow of a ship preparatory to hauling. (See Figure 7.) Provide a bootjack eyebolt on each side of the railway centerline on each cradle transverse frame for the inshore half of the cradle.

8.11 Draft Gauges. Provide at least two draft gauges, one on each of the cradle walkway structures, showing the depth of water over the end keel blocks.

8.12 Fenders. Provide fenders along each inboard side of the walkway structure.

8.13 Anchors. Install anchors (pad eye for wire rope) for cradles at the inshore end of the groundways. These anchors hold the cradle in inboard position for maintenance and repair of the hauling mechanism, and for safety.

8.14 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. An alternative arrangement which avoids loss of docking length is to provide two winches, one on each side of the cradle superstructure.

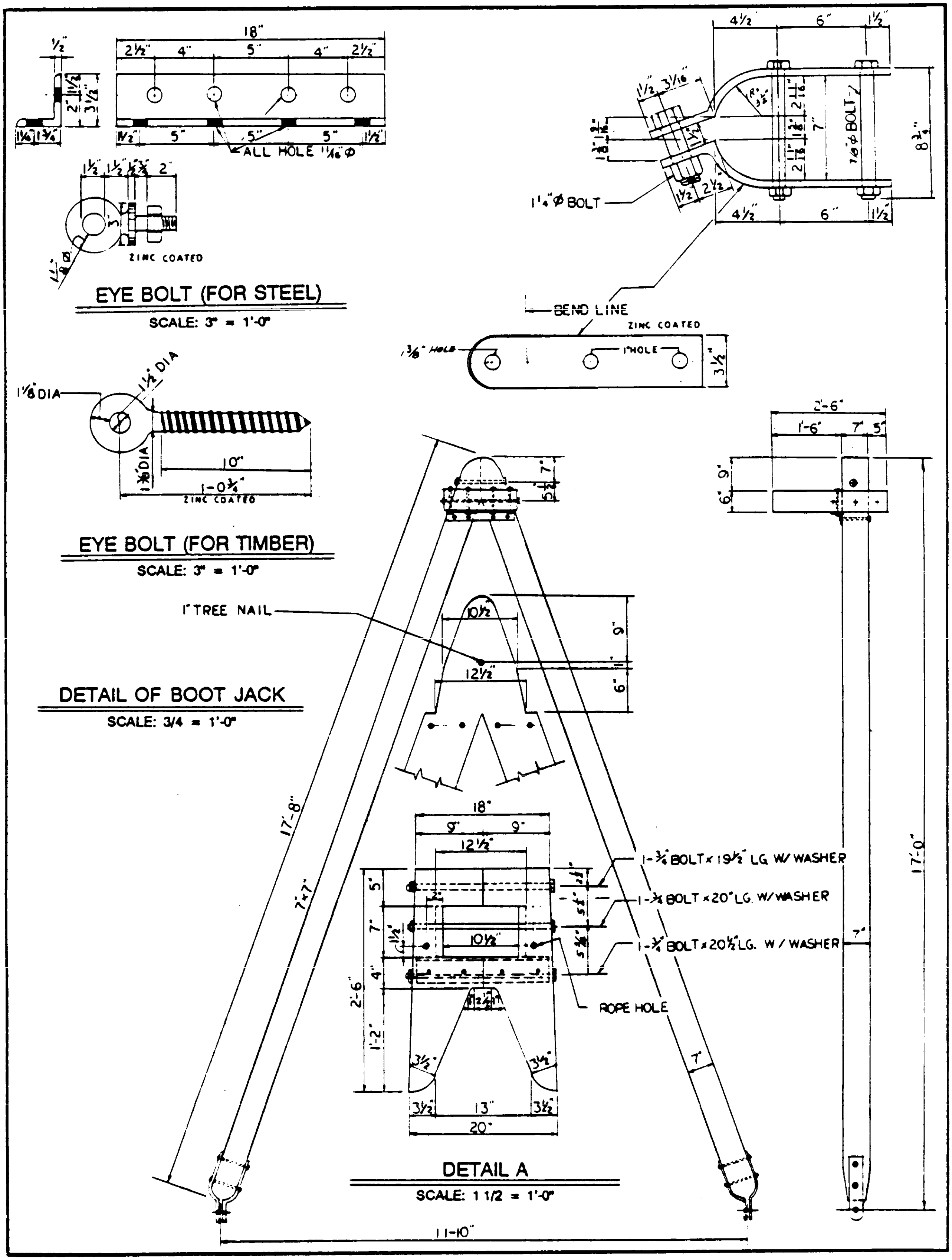

Figure 7
Detail of Boot Jack

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Section 9: MACHINERY AND HAULING SYSTEMS

9.1 Machinery/Hoist House Criteria. Design the machinery/hoist 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:

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

b) For a 2,500-ton marine railway, the house should be approximately 27 feet (8.23 m) wide and 25 feet (8.3 m) long with 9 feet (2.74 m) of headroom. For a large marine railway (3,000 tons), make the house about 29 feet (18.8 m) wide by 42 feet (12.8) long.

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

d) Provide facilities for removing machinery. These 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.

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

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

9.2 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 determined by the project specifications; therefore, the manufacturer should be furnished with all pertinent information.

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 misalignment. Misalignment subjects gears, bearings, and shafts to great overstress and the hoist may deteriorate rapidly.

9.2.1 Hoist Foundation. Design the hoist foundation to take the vertical load component and the overturning moment. Horizontal load should be transferred from hauling machinery to the track through struts.

Where hoist foundations are supported on rock, keying the concrete foundation into the rock can aid in counteracting the horizontal load. Where foundations are supported by piles, batter piles can aid in counteracting the horizontal load. (See Figure 8.)

9.2.1.1 Internal 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.

9.2.1.2 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.

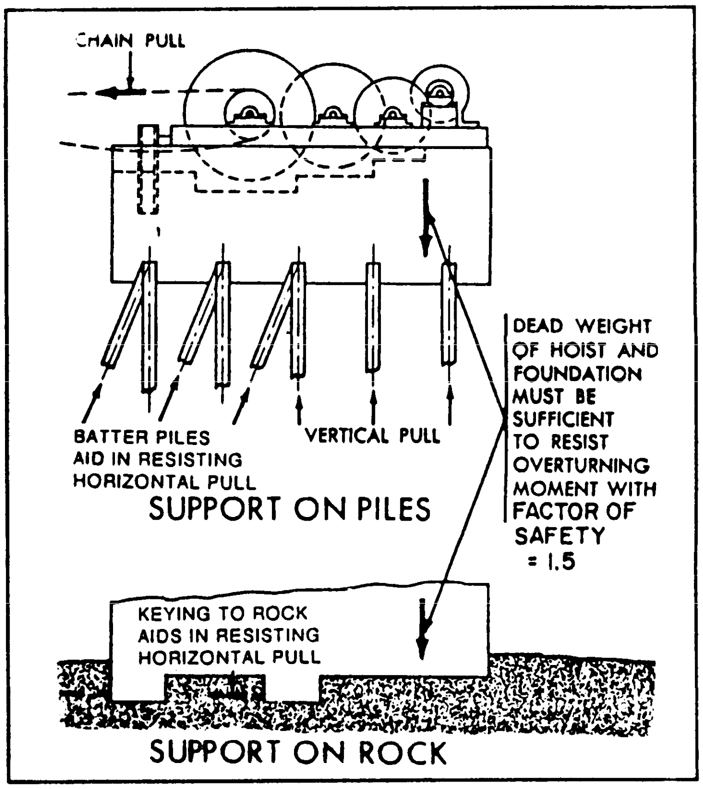

Figure 8
Hoist Foundation

9.3 Motor. T' , motor shall be of the woundrotor induction type for operation on 3-phase voltage, and of drip-proof construction. Base the horsepower rating on intermittent operation at full load with a resultant temperature rise of not more than 40 degrees Celsius (C) and having a breakdown torque of approximately 250 percent of full load torque. Select a motor of moisture resistant design, and provide space heaters of sufficient capacity to hold the temperature at approximately 5 degrees C above ambient temperature, as a protection against dampness.

9.4 Speed and Operating Time. A suitable inhaul chain speed for large marine railways is 10 feet per minute (3 m per minute). A slightly higher speed may be used on small marine railways. A speed of one vertical foot per minute is the most common present practice. Gears may be arranged 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. Two speeds usually are no longer used in designing new machines.

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

9.5 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.

9.6 **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.

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

9.8 **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 9 and 10.

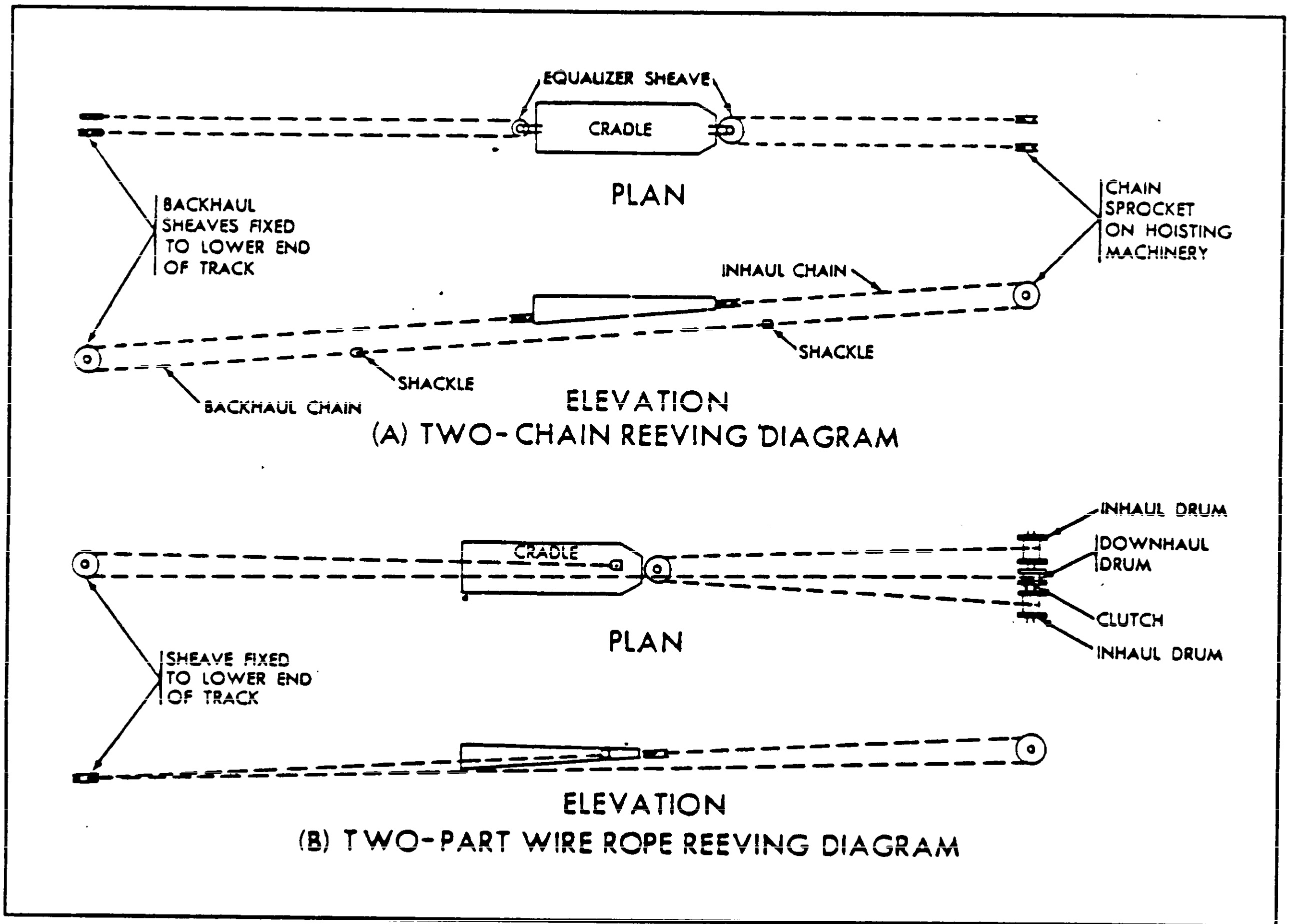

Figure 9
Marine Railway Hauling Systems

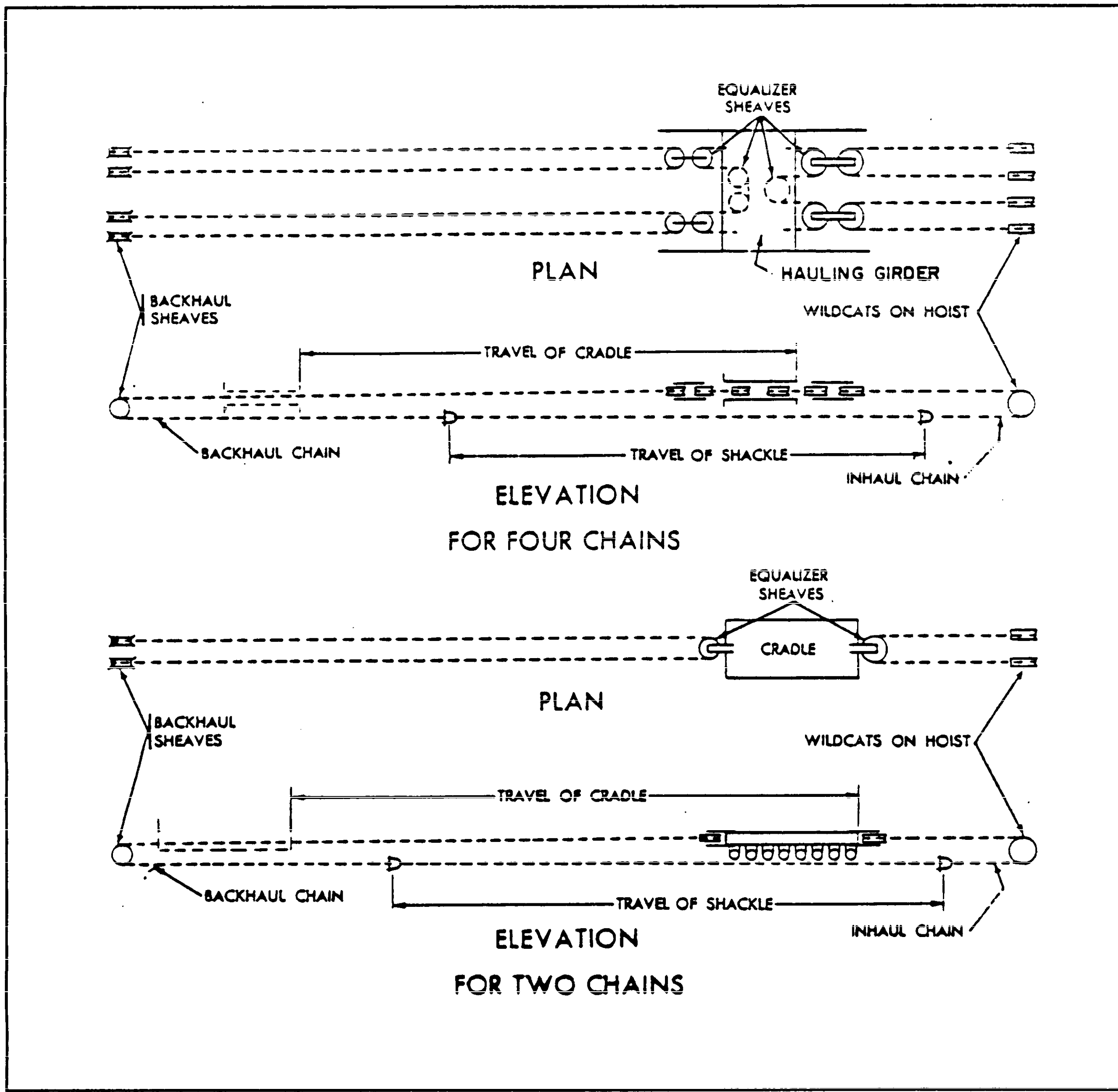

Figure 10
Chain Reeving Diagrams

9.8.1 Inhaul Chains. Use cast steel or welded steel open-link chain. Lay out the chain reeving system in the form of a closed system. (See Figures 9 and 10.) The size of the inhaul chains is determined by the load as described below.

a) Working strength. Assume the working strength of the chain to be 30 percent of its breaking strength.

b) Number and size of chains. Determine the number of chains from pull calculations. (Refer to para. 8.3, and Equation 1.) Chains larger than 2-3/4 inch (70 mm) become unwieldy. Therefore, if the load requires two 3-inch (76 mm) chains, use four 2-1/4-inch (57 mm) chains.

9.8.2 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 diameter equal to one half the inhaul size, with a minimum size of 1 inch (25.4 mm).

9.8.3 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.

9.9 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.

9.10 Control Equipment. Obtain electric power from shore distribution systems. Build control equipment as metal-enclosed units insofar as practicable.

9.10.1 Line Protective Equipment. Provide line protective equipment with proper interrupting capacity and having overload and low voltage protection. In addition, include:

a) Integrating watt-hour meter,

b) Recording wattmeter,

c) Indicator lights, and

d) Ammeter installed at master control switch location.

9.10.2 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.

9.10.3 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.

Select secondary resistors for the duty encountered in operation. Construct resistors of corrosion-resistant material.

9.10.4 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.

9.10.5 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.

9.10.6 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.

9.10.7 Brakes. Use hydraulic thruster-operated automatic brakes utilizing weights or springs for closing.

Section 10: FACILITIES

10.1 Tracks. Install a standard gauge 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.

10.2 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 can be done by means of piers, but the most common method is through dolphins or platforms installed beyond the offshore end of the groundways.

10.3 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.

10.4 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 (15 m) for the full length of the mains. The services should include those listed in paras. 10.4.1 through 10.4.6 below.

10.4.1 Fresh Water. Mains shall have a manifold at each service pit, provided with one 2-1/2-inch (63.5 mm) valved outlet with cap and chain. The residual pressure at any outlet shall be 40 to 80 psi (276 to 552 kPa).

10.4.2 Salt Water Flushing and Fire Protection. Mains shall have a manifold at each service pit, provided with one 4-1/2-inch (114 mm) 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 60 psi (414 kPa).

10.4.3 Steam. Mains shall be 4 (102 mm) inches in diameter, and have one 2-1/2-inch valved outlet, with cap and chain, at each service pit. The residual steam pressure at outlets should be approximately 150 psi (1034 kPa).

10.4.4 Compressed Air. Mains shall be 4 inches in diameter, and have a manifold at each service pit equipped with one 2-1/2-inch valved outlet with cap and chain. Outlet air pressure should be approximately 100 psi (690 kPa).

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

10.4.6 Lighting. For night lighting of the cradle, provide 250-candlepower lights (with reflectors) spaced about 60 feet (1.83 m) apart on each side. Attach these to the walkway supports. Connect the lighting circuit to the street lighting system of the yard. Provide necessary lighting for the railway and floodlighting for night dockings in addition to that on the cradle.

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Section 11: SIDEHAUL MARINE RAILWAY

11.1 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. Equalization of pulls on inhaul chains is especially important when multiple cradles are used.

11.2 3,000-Ton Facility. For this installation, there are 12 cradles, 12 sets of groundways, and 12 hoists. (See Figures 11, 12, and 13.) 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.

11.3 Design Load. Figure 12 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 12. Similarly, the various sets of groundways are designed for the two different loadings.

11.4 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.

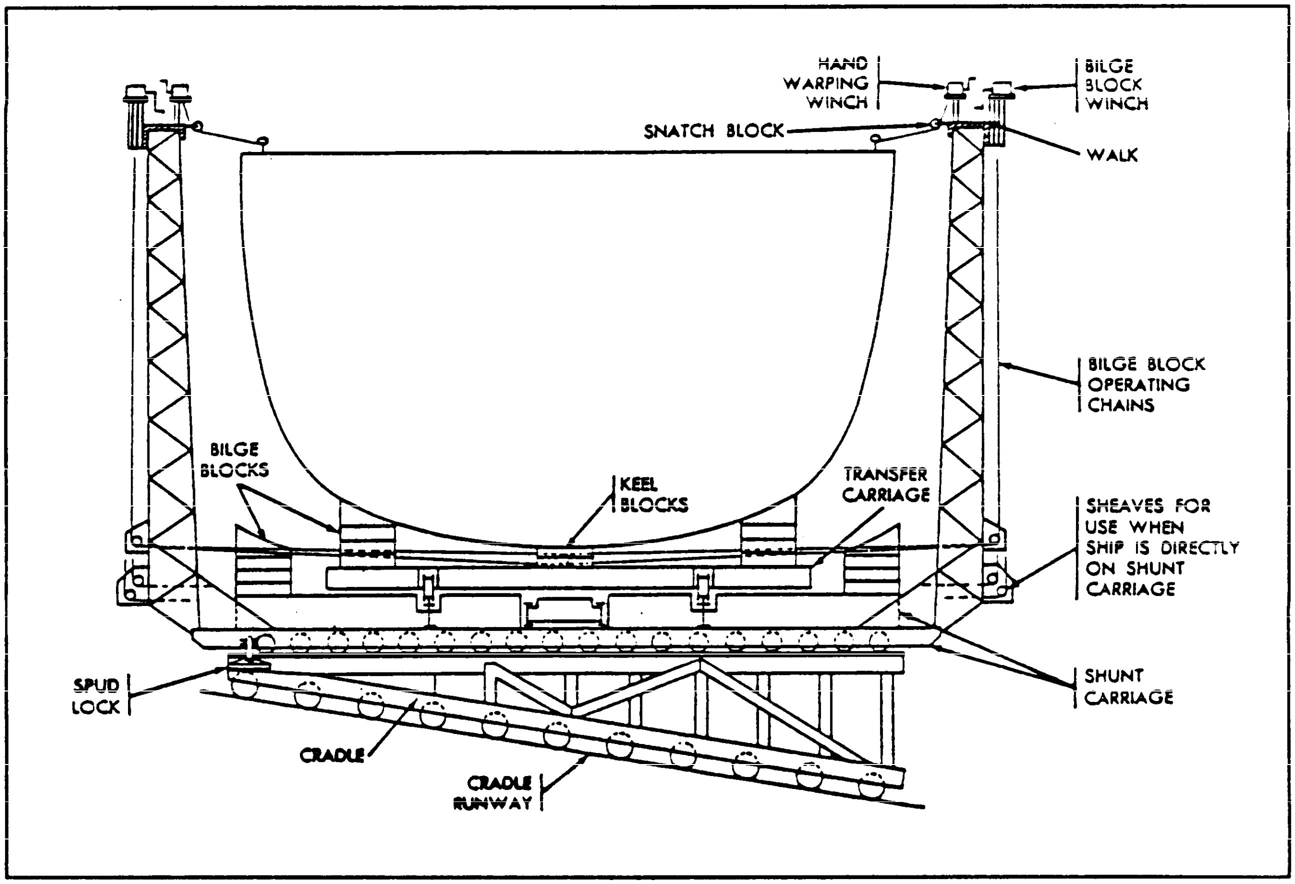


Figure 11
Section Through Sidehaul Marine Railway

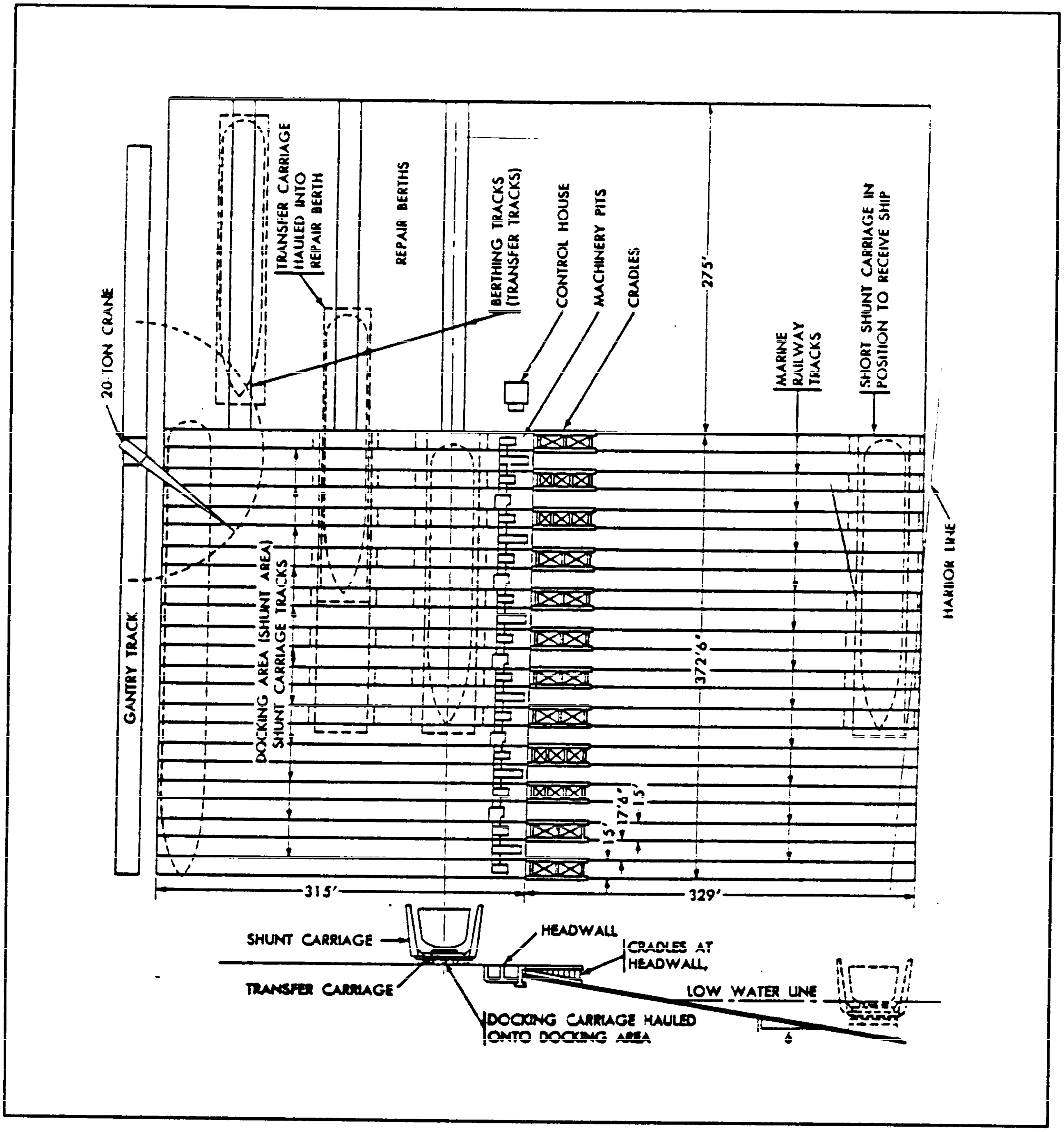
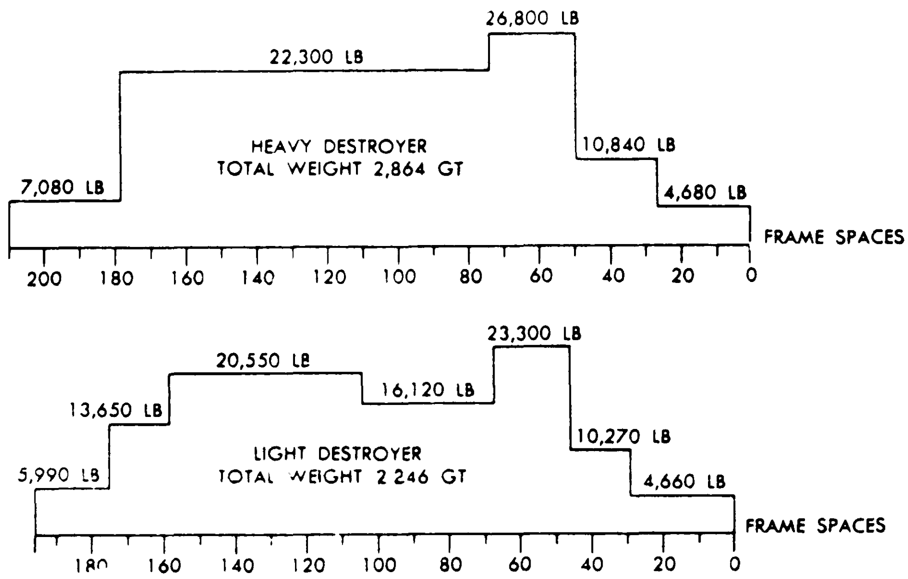
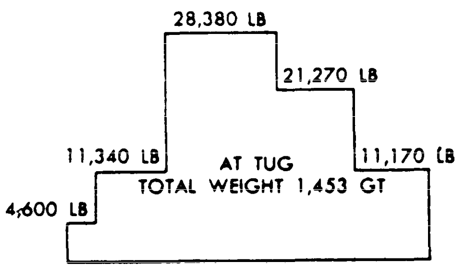


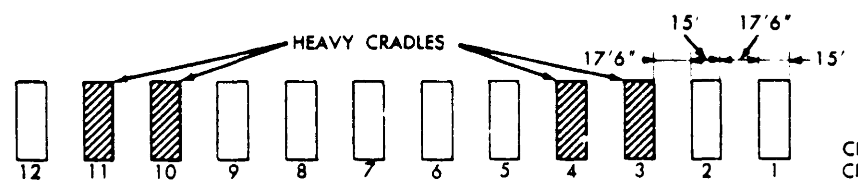
Figure 12
Plan View of Sidehaul Marine Railway





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 13
Cradle Loads and Chain Pulls

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Crandall, Stuart M., 1949, 3,000-Ton Marine Railway and Transfer, Civil Engineering, (July), American Society of Civil Engineers, New York, NY 10017.

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REFERENCES

NOTE: Unless otherwise specified in the text, users of this handbook should utilize the latest revisions of the documents cited herein.

NAVY MANUALS, DRAWINGS, AND P-PUBLICATIONS

Available from Commanding Officer, Naval Publications and Forms Center, (NPFC), 5801 Tabor Avenue, Philadelphia, PA 19120-5099. To order these documents, Government agencies must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP); the private sector must write to NPFC, ATTENTION: Cash Sales, Code 1051, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

DM-7 Series	Soil Mechanics, Foundations, and Earth Structures
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FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS, AND NAVFAC GUIDE SPECIFICATIONS

The following specification and handbook form a part of this document to the extent specified herein. Unless otherwise indicated, copies are available from Commanding Officer, Naval Publications and Forms Center, ATTENTION: NPODS, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

MIL-STD-1625	Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships.
MIL-HDBK-1029/3	Drydocking Facilities Characteristics

NON-GOVERNMENT PUBLICATIONS:

The following publication forms a part of this document to the extent specified herein.

Rossell, H. F. and Chapman, L. B., Principles of Naval Architecture, Volume I, available from Society of Naval Architects and Marine Engineers, Jersey City, NJ 07306.

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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. The forepoppet takes the concentrated loading induced when the ship rotates about this poppet as the stern is lifted by buoyancy.

Skeg. A 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.

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