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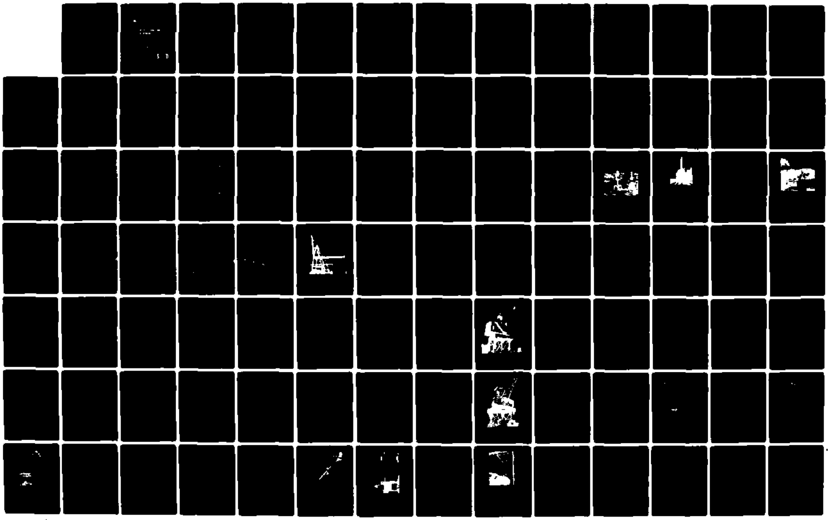

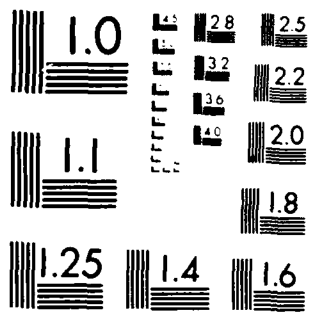

NAVFAC DM-38.1
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WEIGHT-HANDLING EQUIPMENT

DESIGN MANUAL 38.1

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Engineering criteria are presented for guidance in selection of weight-handling equipment. The contents include descriptions, design data, and operating features for equipment such as cranes, derricks, and hoists.

ABSTRACT

Engineering criteria are presented for guidance in selection of weight-handling equipment. The contents include descriptions, design data, and operating features for equipment such as cranes, derricks, and hoists.

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 SECNAVINST 5600.16.

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

WEIGHT-HANDLING EQUIPMENT AND
SERVICE CRAFT MANUAL

DM No.	Superseded Chapters in basic DM-38	Title
38.1	1	Weight-Handling Equipment
38.2	2	Dredging Equipment
38.3	3	Yard Craft
38.4	4	Pile Driving Equipment
38.5	5	Towing Nonself-Propelled Floating Structures

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FIGURES

FIGURES (Continued)

FIGURES (Continued)

TABLES

ACKNOWLEDGMENTS

Figure	Acknowledgment
7C	Courtesy Lisnave Shipyard, Portugal
10B	Courtesy Norfolk Maritime Terminals
41, 50, 51 (Part C)	Whiting Crane Handbook, Whiting Corp., Harvey, Illinois
46	Courtesy Caterpillar Tractor Company
51 (Part D)	American Electricians Handbook, McGraw-Hill Book Co., New York, N.Y.

WEIGHT-HANDLING AND LINE-HANDLING EQUIPMENT

Section 1. INTRODUCTION

1. SCOPE. This manual presents criteria for guidance in the selection of types and features of weight-handling and line-handling equipment for use at Naval Shore facilities. The scope of coverage includes cranes, derricks, hoists, monorails, capstans, winches, and windlasses. Types of equipment predominantly used for materials-handling (such as forklift trucks, platform trucks, straddle carriers, conveyors and conveyor systems, and warehouse tractors) and construction machinery such as power shovels, earth-moving scrapers, plows, tractors, etc., are not considered.

In addition to factors relating to selection of types and features, sufficient criteria are presented relating to the design of weight- and line-handling equipment so that the engineering organization of the using agency may perform the engineering necessary for the execution of repairs and/or modifications of equipment; subject to the limitation that, for modifications and alterations affecting stability or the condition of load bearing or load controlling parts and safety devices, the using agency shall consult with cognizant NAVFAC Engineering Field Division (EFD) for technical review and approval, prior to accomplishment.

This manual also presents lists of types of equipment which are available, together with a broad summary of their areas of application.

To the extent indicated herein, criteria contained in the list of references shall apply to the design of components of weight-handling equipment. Additional criteria are presented herein to supplement said references and in resolution of conflicts shall take precedence over criteria stated in the references.

This manual presents certain directions which experience indicates are advisable to suit the peculiarities of weight-handling equipment. The criteria are presented only for guidance and shall not preclude the use of any other system, device, detail, material, or construction which can be demonstrated, on the basis of generally accepted engineering principles, to provide adequate performance of the intended function, and with due consideration for elimination of excessive maintenance and for reliability of operation.

2. REFERENCES AND RELATED CRITERIA. Certain criteria related to the subject matter of this manual appear elsewhere in this DM series. See the following sources:

Subject	Source
Earthquake loadings	DM-2.2 & P-355
Wind loadings	DM-2.2
Corrosion allowances for structural components	DM-2.3
Design of crane runways and supports	DM-2.3
Design of foundation components (see also DM-7 series)	DM-2.2
Corrosion problems with mechanical components	DM-3.7
Crane rail trackage - alinement	DM-5.6

Subject	Source
Crane rail trackage - appurtenances	DM-5.6
Crane rail trackage - float calculation	DM-5.6
Foundations	DM-7.2
Fire protection engineering	DM-8
Crane rail trackage - mounting of rails	DM-25.1

Section 2. TYPES OF EQUIPMENT AVAILABLE

1. GENERAL. Figure 1 summarizes, by generic classification, the types of weight-handling equipment which are commonly available. These basic types can be obtained with numerous combinations of features and adaptations as hereinafter described (Section 4, Part 2).

2. ILLUSTRATIONS. The various types of weight-handling equipment noted in Figure 1, their basic motions, and construction are illustrated in Figures 2 to 13.

Section 3. CHARACTERISTICS OF SPECIFIC TYPES OF EQUIPMENT

1. NON-TRAVELING, ROTATING MACHINES. See Table 1.

2. TRAVELING, ROTATING MACHINES. See Table 2.

3. NON-ROTATING MACHINES. See Table 3.

4. INDUSTRIAL TYPE MOBILE CRANES. (Figure 11.) Industrial-type mobile cranes have the following characteristics:

(1) Capacities generally under 10 tons.

(2) Short reach.

(3) Highly maneuverable and versatile. Self-contained power supply. Self-propelled.

(4) Available with fixed and swinging booms.

(5) Can be furnished with convertible wheel system which allows operation on railroad tracks.

(6) Generally used for handling large numbers of small items in a diverse operation involving frequent and erratic movements.

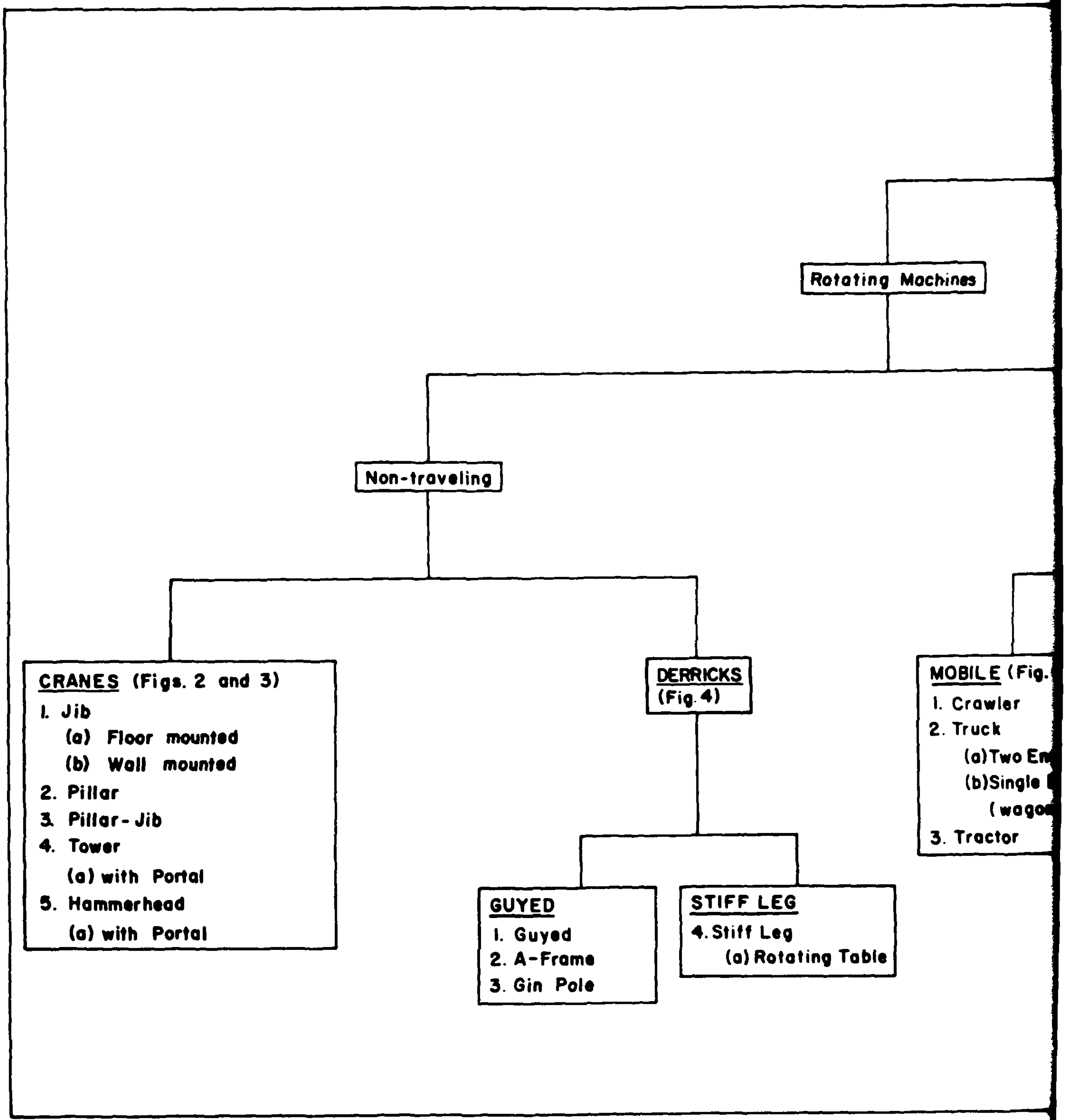
5. HOISTS AND WINCHES. (Figures 12 and 13.)

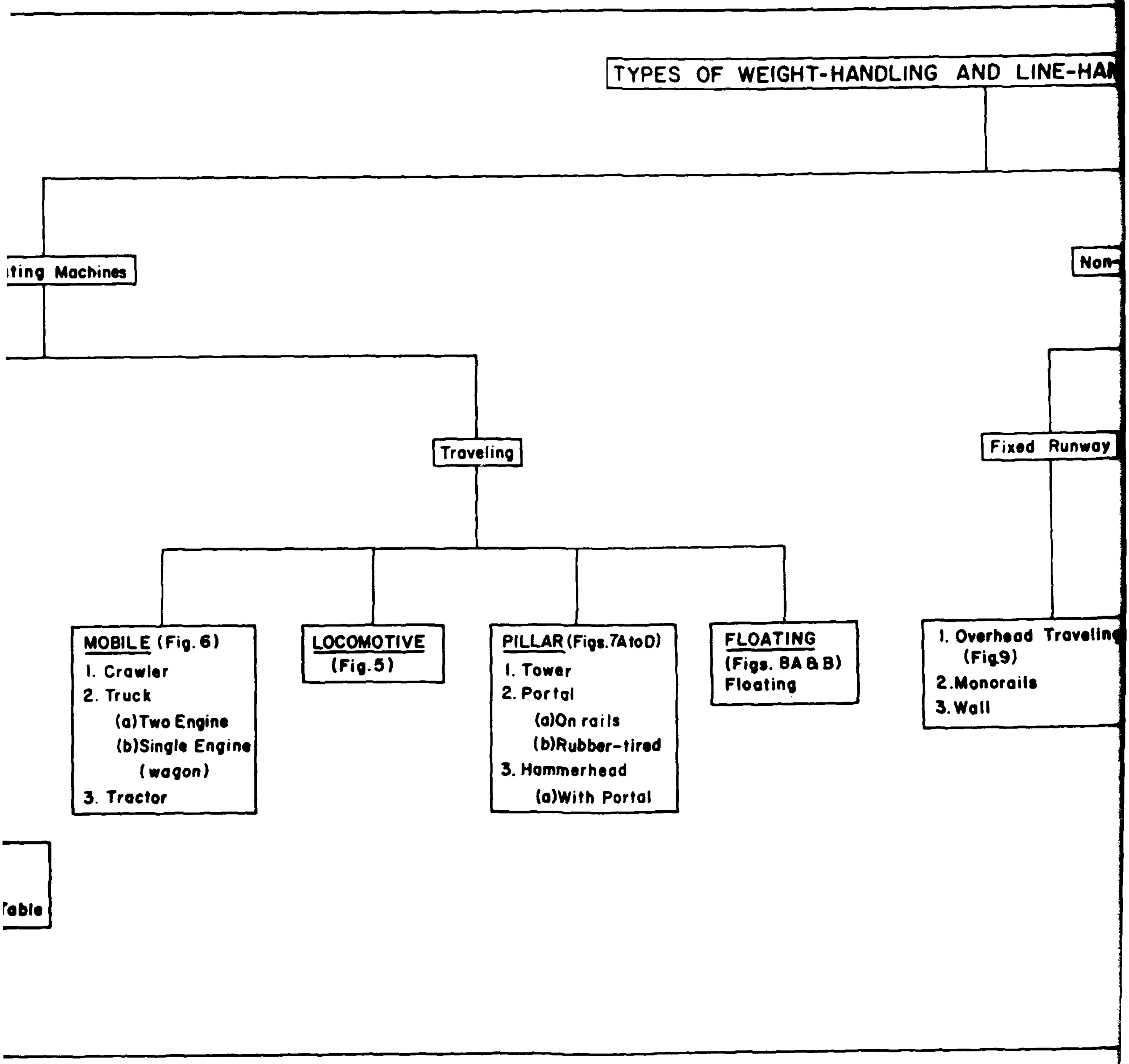
Section 4. SELECTION OF TYPE, FEATURES, AND CAPACITY OF EQUIPMENT

Part 1. GENERAL SELECTION FACTORS

1. INTRODUCTION. The general factors to be considered in the selection of the type of weight-handling equipment to be acquired for a specific project are listed in Table 4. These factors apply as follows:

a. Area of Coverage. Weight-handling equipment consists of a hoist to raise and lower the load hook and some means for positioning the hook so that the load can be picked up or set down in the desired location.


Rotating Machines
Non-traveling
CRANES (Figs. 2 and 3)
1. Jib
(a) Floor mounted
(b) Wall mounted
2. Pillar
3. Pillar-Jib
4. Tower
(a) with Portal
5. Hammerhead
(a) with Portal
DERRICKS (Fig. 4)
GUYED
1. Guyed
2. A-Frame
3. Gin Pole
STIFF LEG
4. Stiff Leg
(a) Rotating Table
MOBILE (Fig.
1. Crawler
2. Truck
(a)Two
(b)Single
3. Tractor


TYPES OF WEIGHT-HANDLING AND LINE-HA
ting Machines
Non-
Traveling
Fixed Runway
MOBILE (Fig. 6)
1. Crawler
2. Truck
(a) Two Engine
(b) Single Engine (wagon)
3. Tractor
LOCOMOTIVE (Fig. 5)
PILLAR (Figs. 7A to D)
1. Tower
2. Portal
(a) On rails
(b) Rubber-tired
3. Hammerhead
(a) With Portal
FLOATING (Figs. 8A & B)
Floating
1. Overhead Travelin
(Fig. 9)
2. Monorails
3. Wall
able

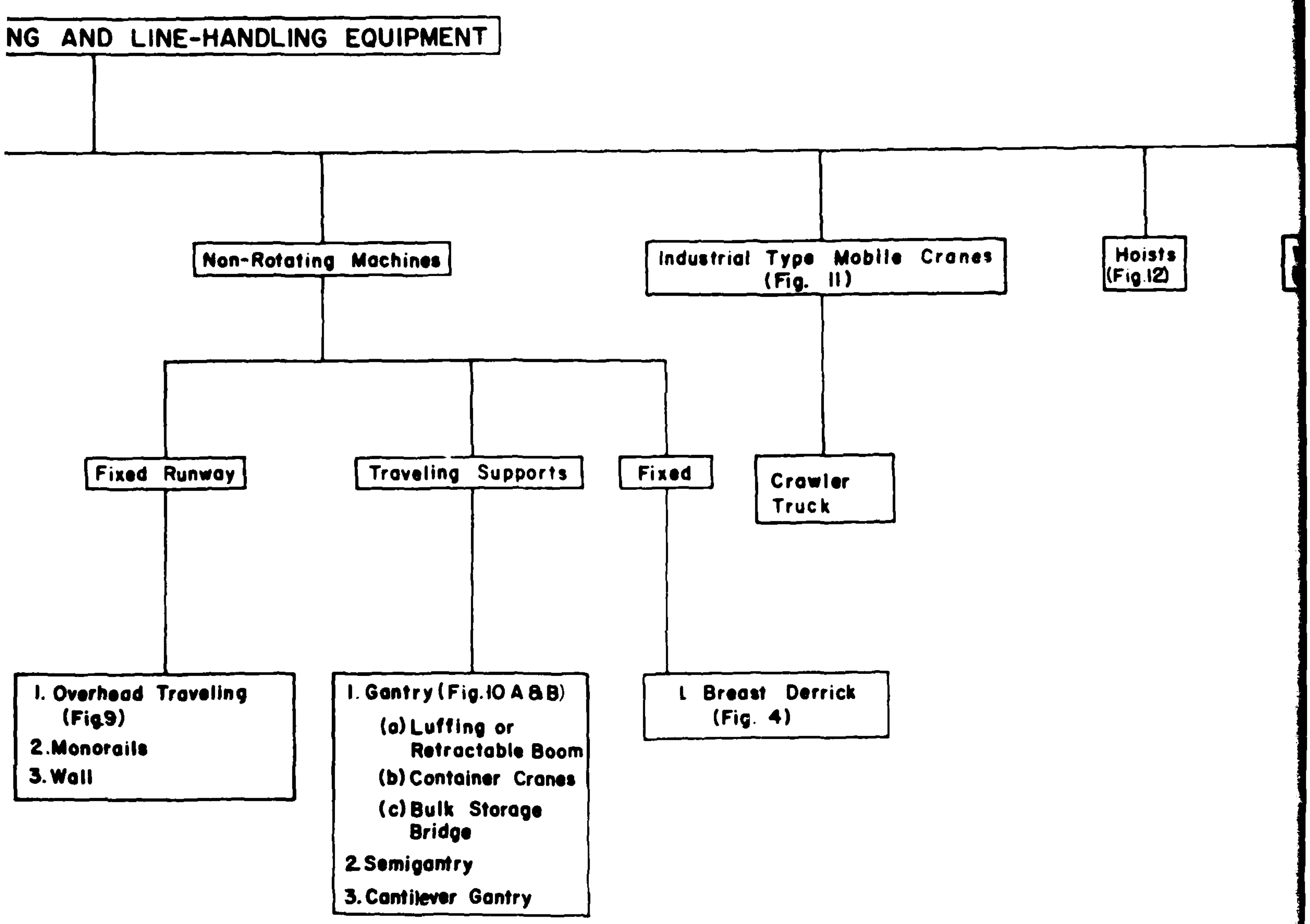


FIGURE 1
Types of Weight-Handling and Line-H

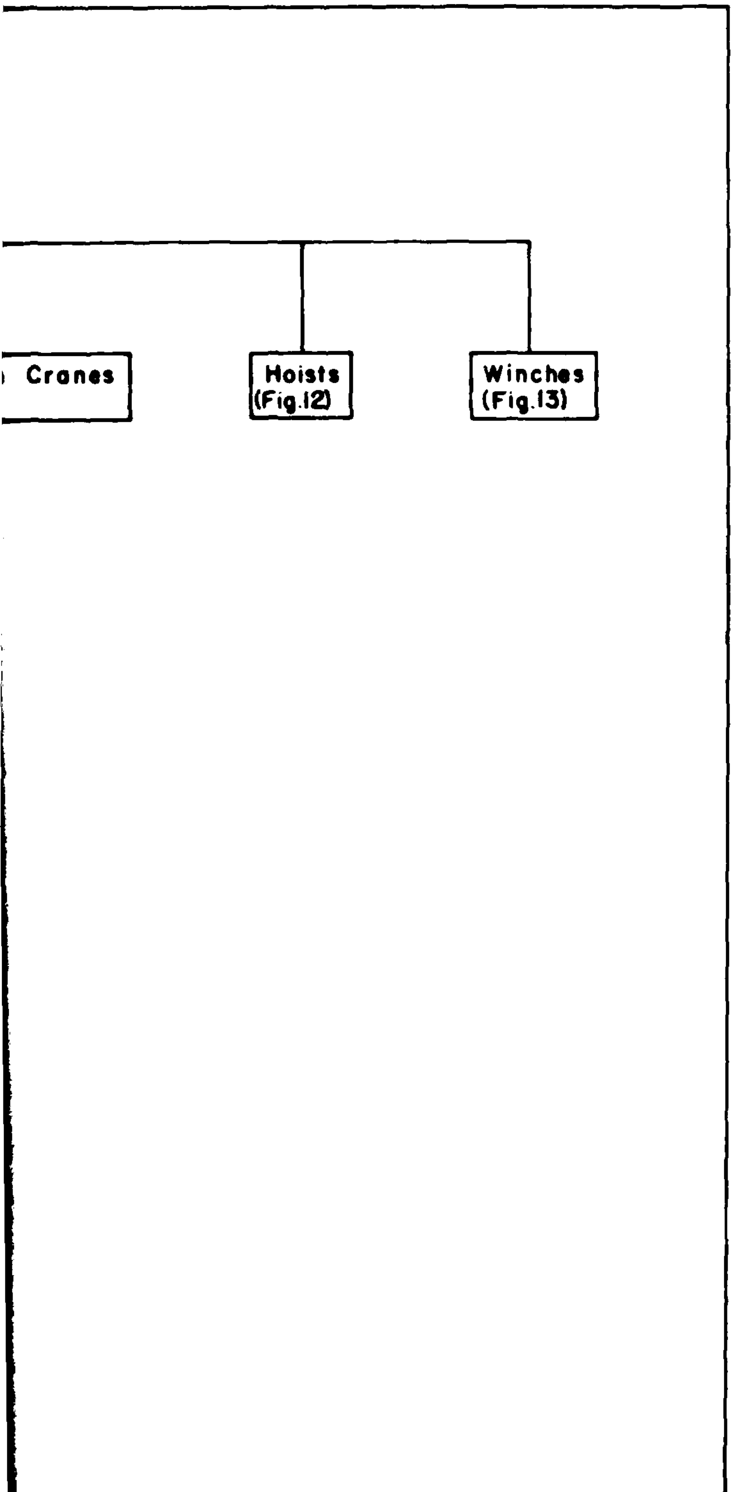
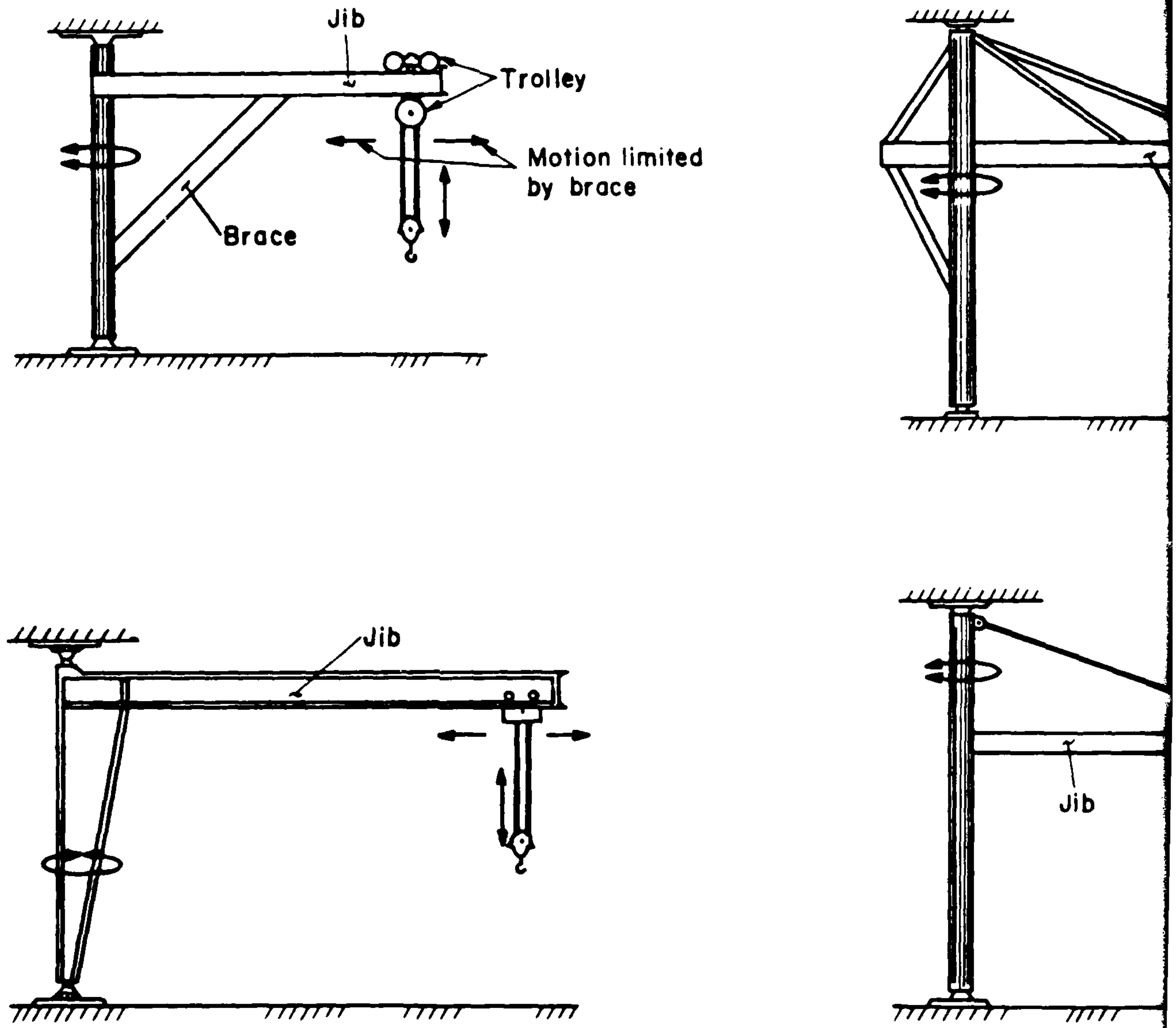
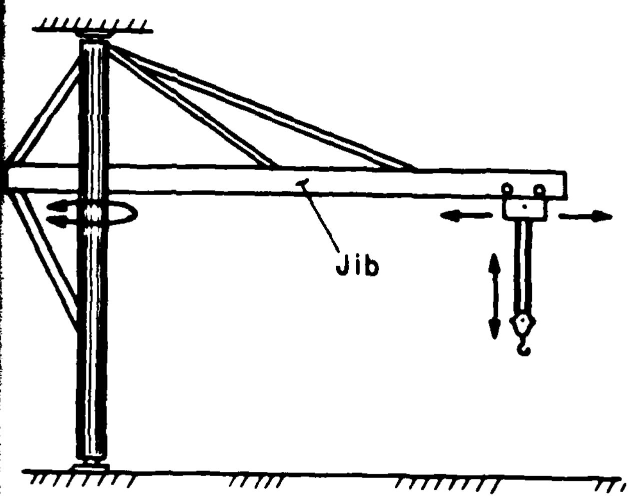
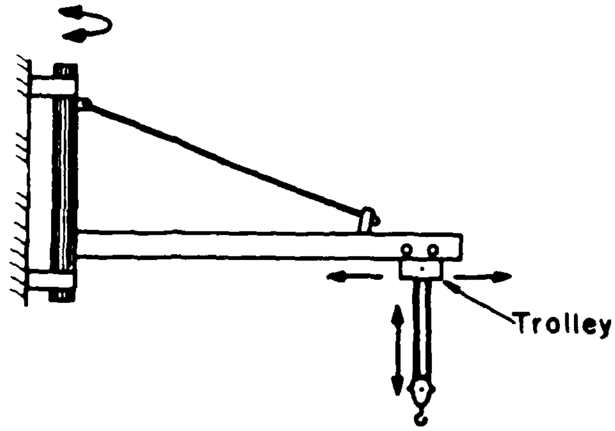


FIGURE 1
of Weight-Handling and Line-Handling Equipment

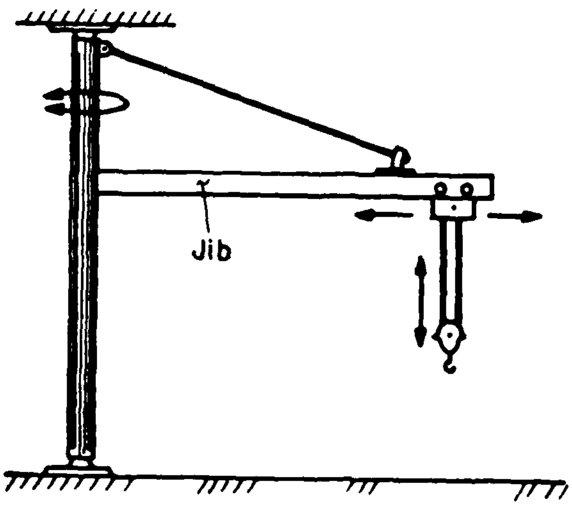


a) FLOOR MOUNTED

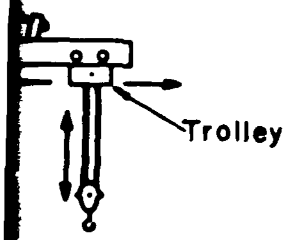


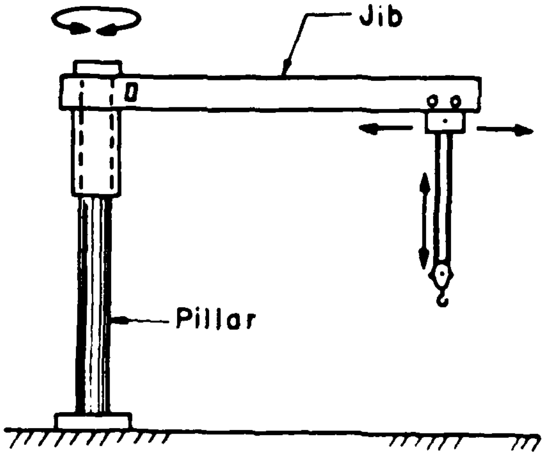


b) WALL MOUNTED

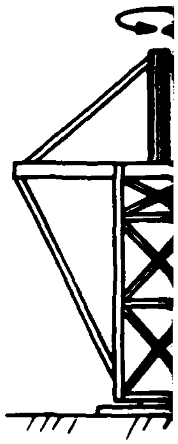


I. JIB CRANES





3. PILLAR - JIB



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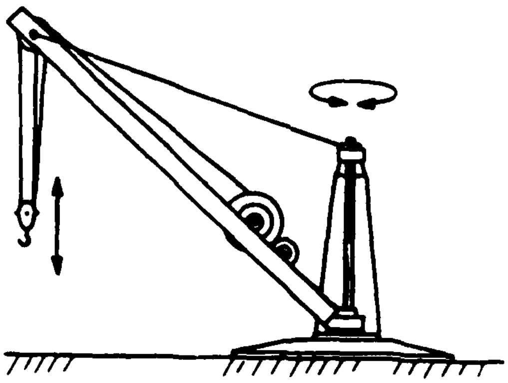
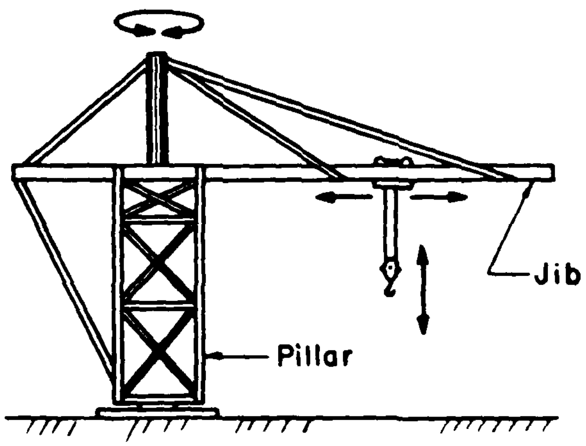


2. PILLAR

PILLAR AND PILLAR-JIB CRANES



3. PILLAR - JIB

IB CRANES

FIGURE 2
Jib and Pillar Cranes

4

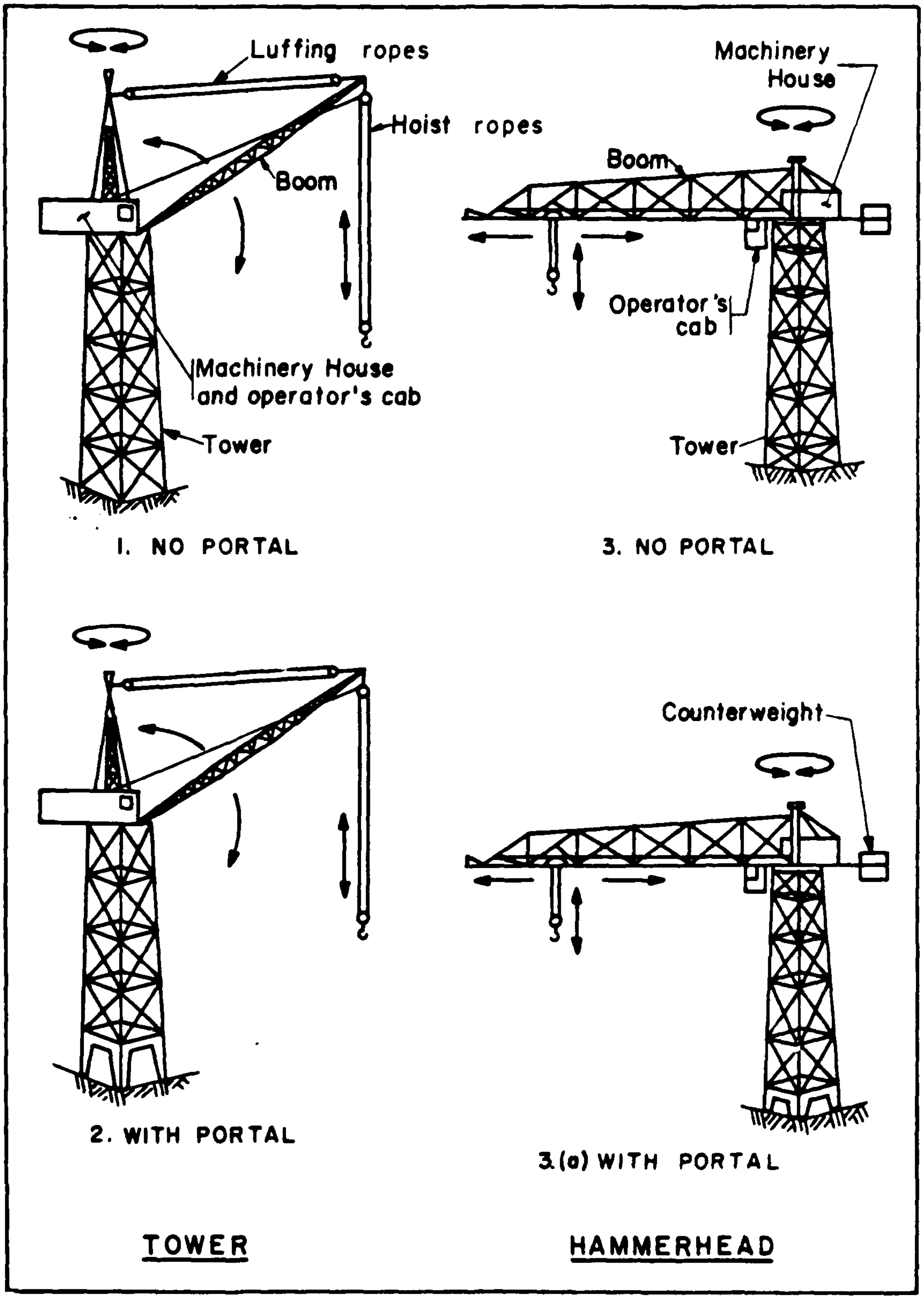


FIGURE 3
Tower and Hammerhead Cranes (Non-Traveling)

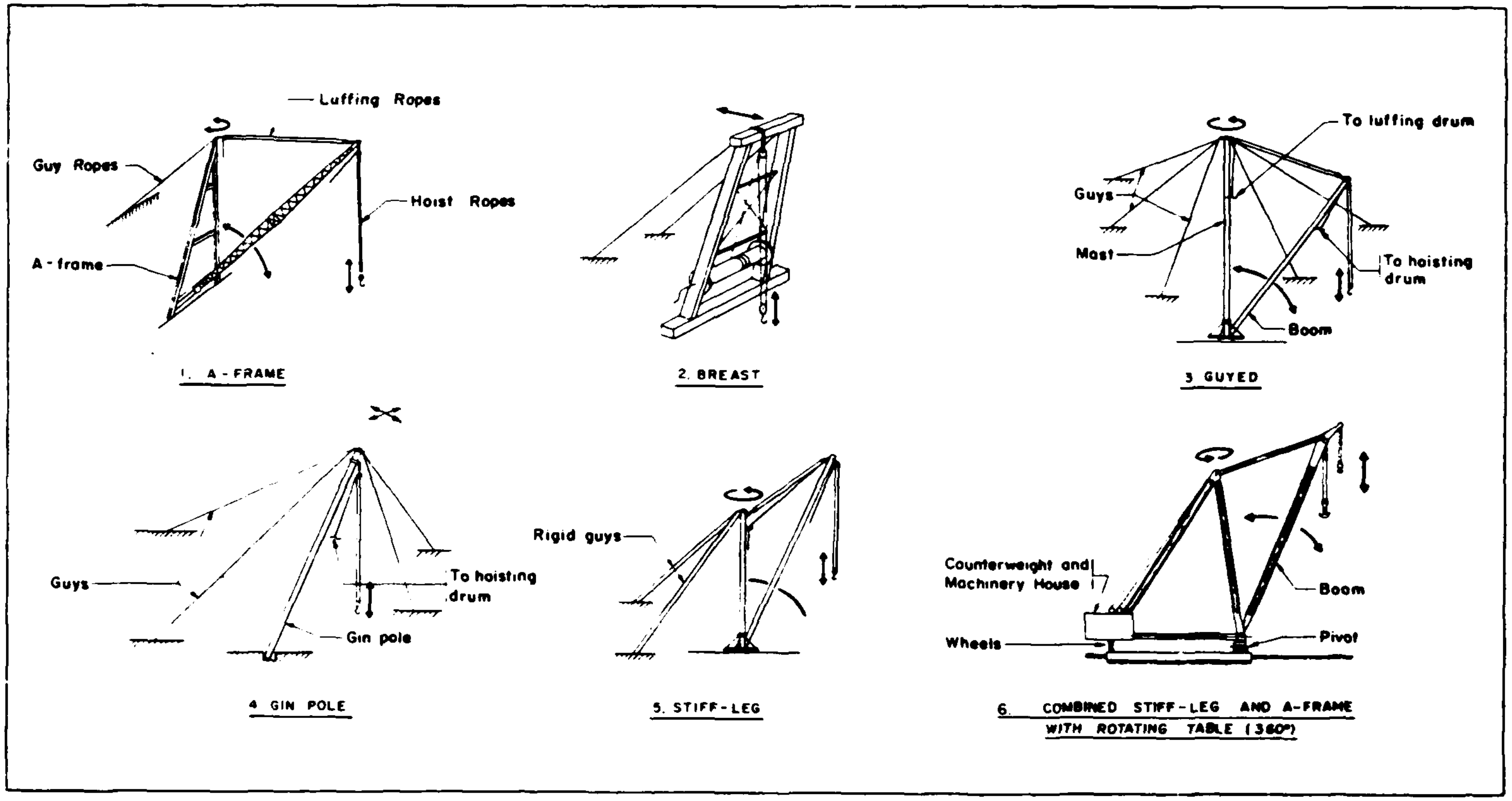


FIGURE 4
Derricks

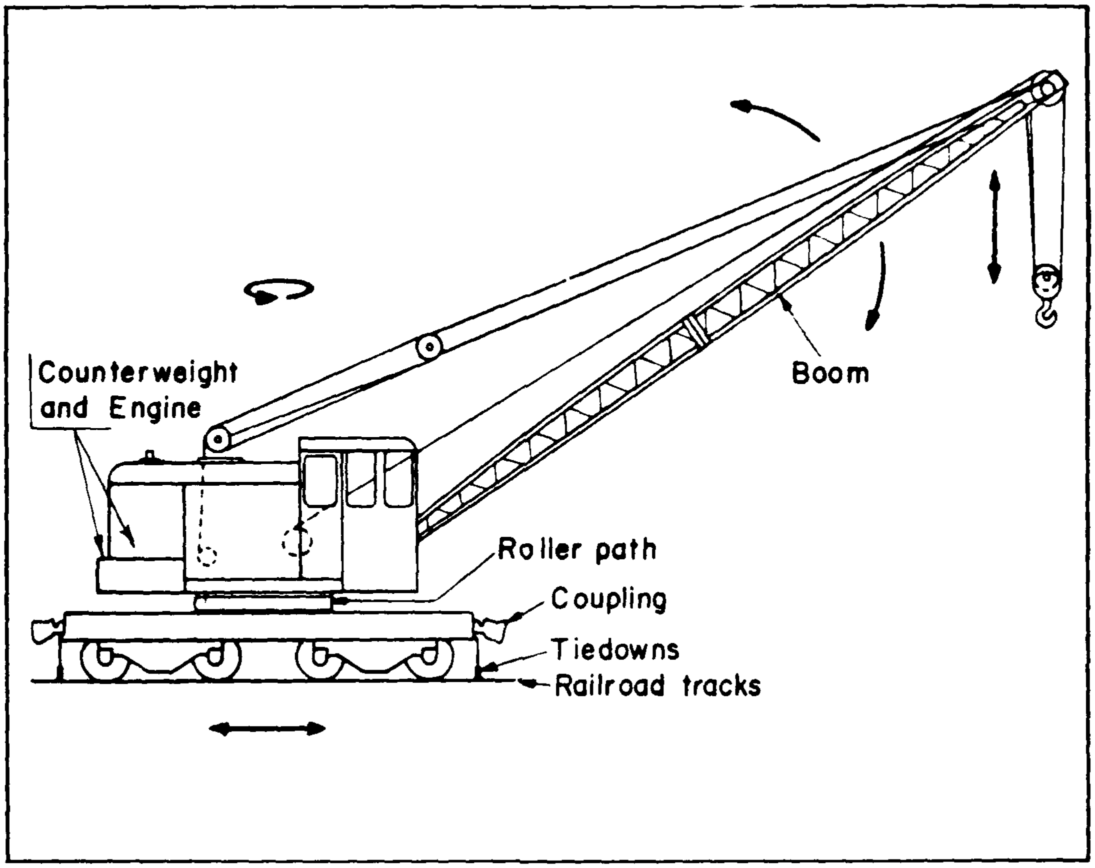


FIGURE 5
Locomotive Crane

In its simplest form, the equipment may consist of the hoist alone. The load may be brought under the hook, lifted, held aloft, and transferred to some other conveyance which also is brought under the hook, as, for example, in transferring a load from a dolly to a truck (Figure 14). For such a case, no positioning (per se) of the load hook is involved.

In most projects, however, it is necessary to "spot the load," i.e., to position the load hook over a spot in an area of some size. Mechanisms to accomplish this must be added to the basic hoist. The greater the area to be covered by the load hook and the greater the flexibility, accuracy, and speed with which this positioning is to be accomplished, the more complex and costly the equipment becomes. Thus, one of the first factors to be considered in selecting the type of weight-handling equipment required for a given task is to evaluate the area to be covered by the hook. Different types of machines afford different areas of coverage.

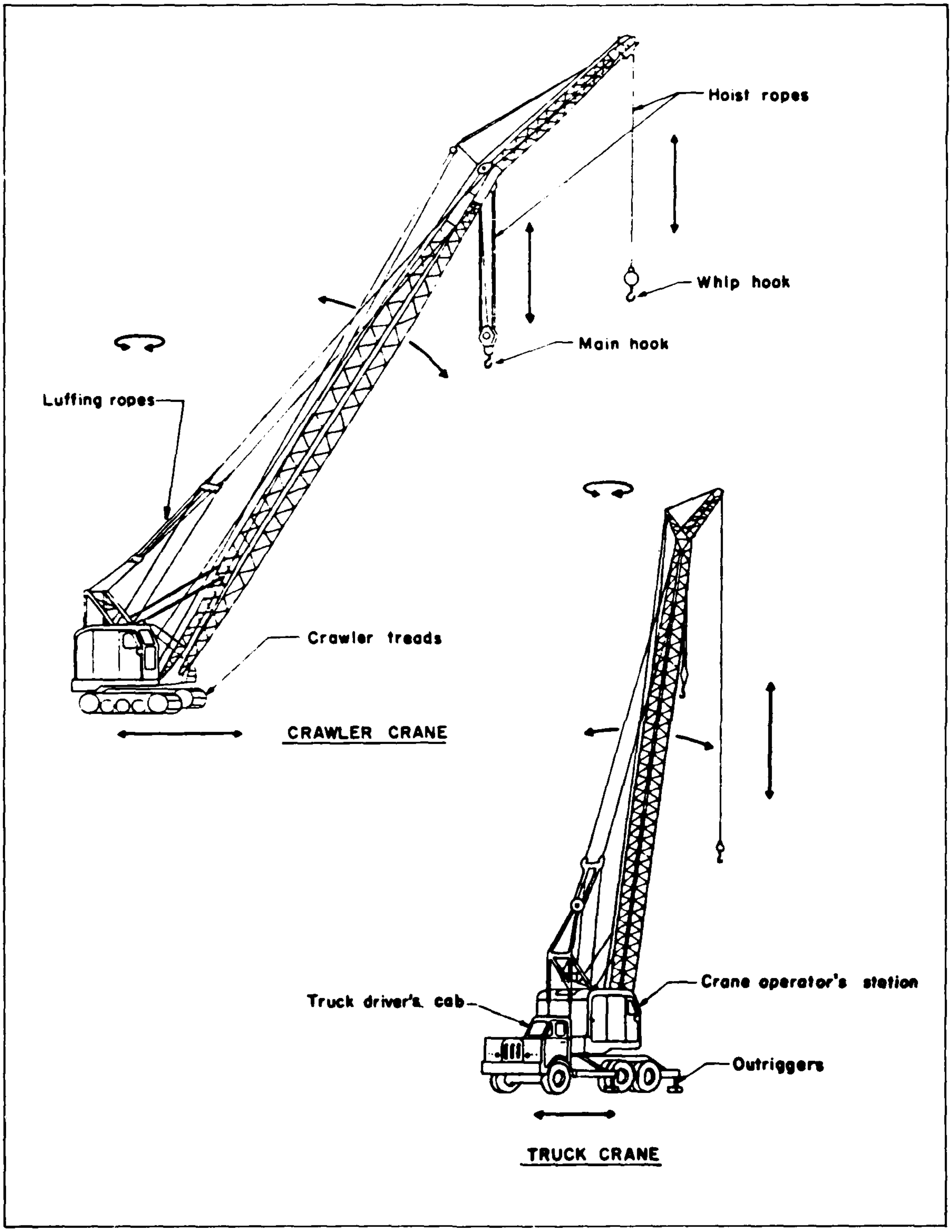


FIGURE 6A
Crawler and Truck Cranes

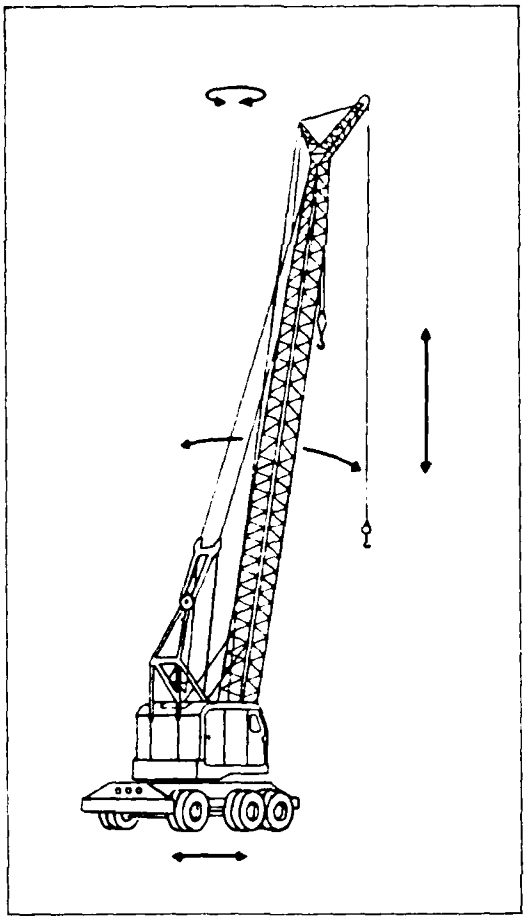


FIGURE 6B
Wheel-Mounted (Wagon) Crane
(Also Called Cruiser Crane)

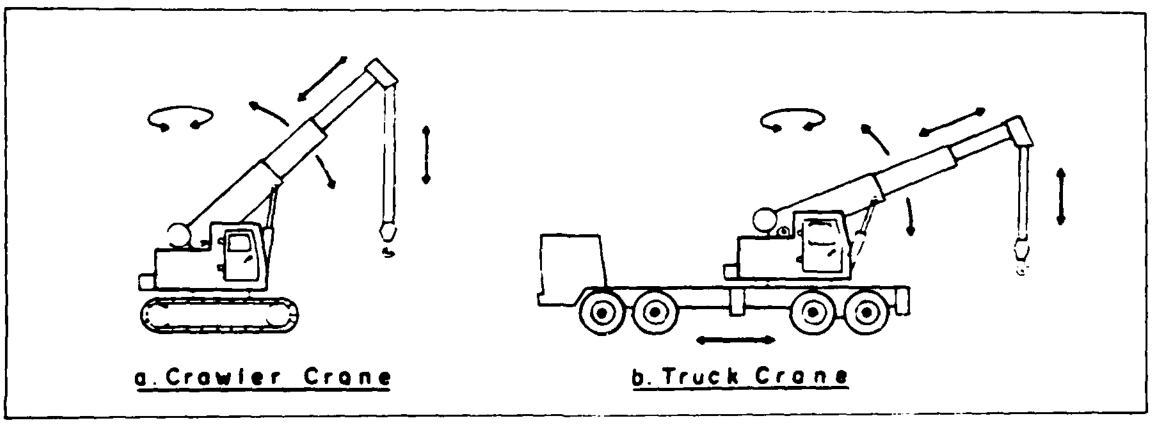


FIGURE 6C
Cranes with Hydraulic Booms

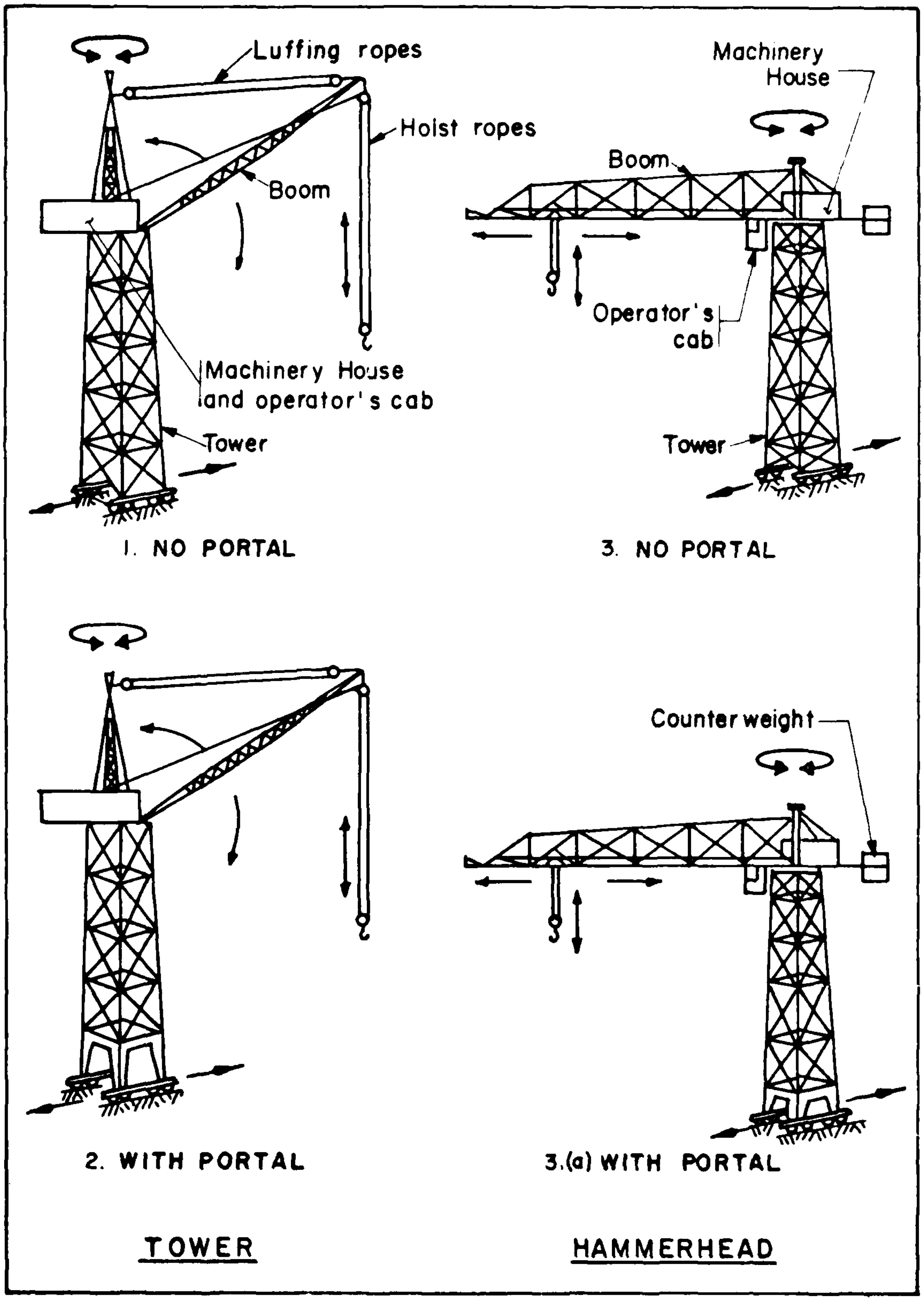


FIGURE 7A
Tower and Hammerhead Cranes (Traveling)

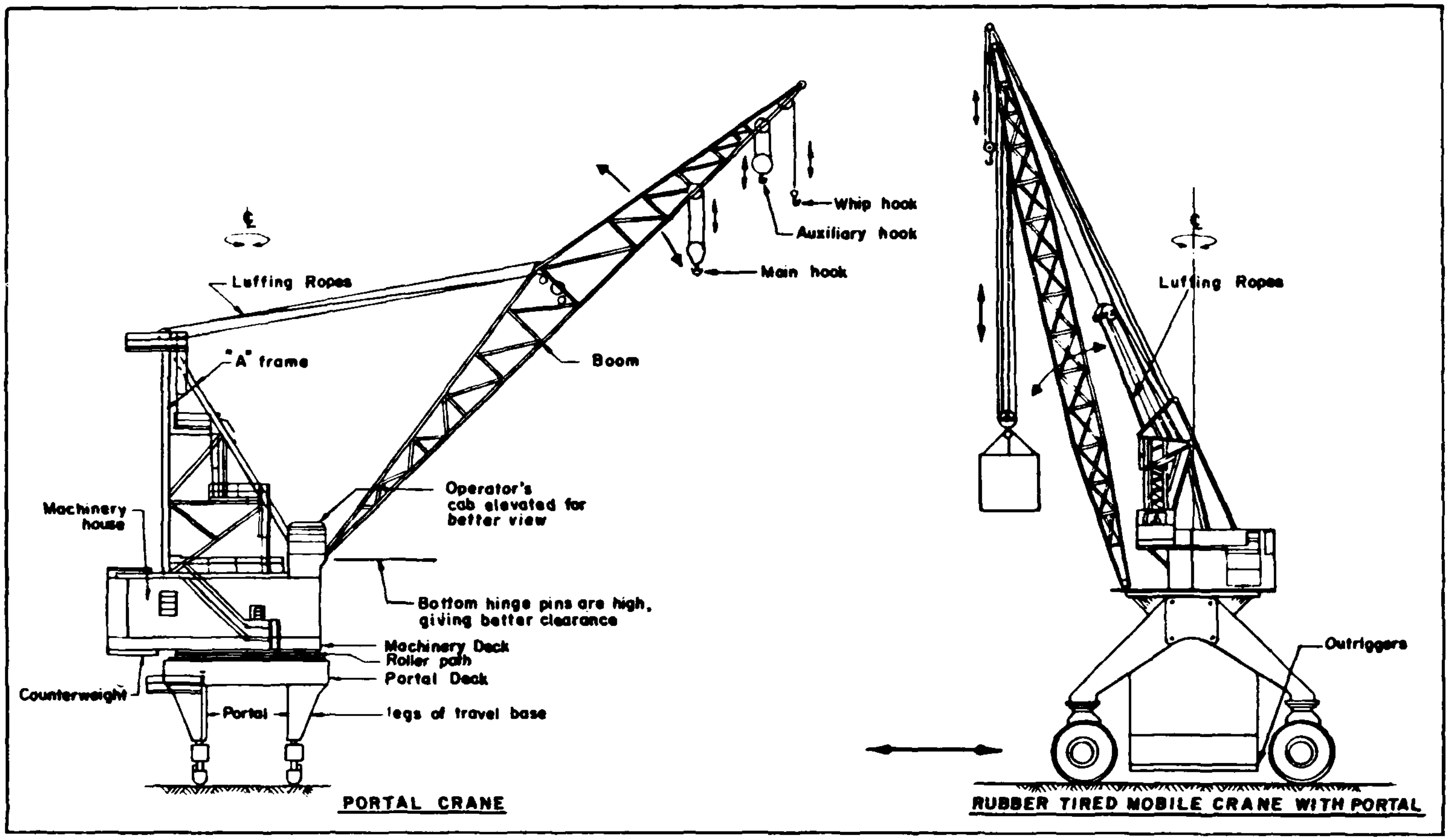


FIGURE 7B
Portal Cranes (Traveling)

FIGURE 7C
European Portal Cranes
(100-Ton Crane on Left, 50-Ton Crane on Right)

b. Capacity and Reach. The next considerations in the selection process are the weights to be lifted, and the distance from the point of support at which the load is to be handled. Within broad limits, certain types of equipment are suitable for heavy lifts and other types for light lifts. Certain types can be coupled with other cranes for extra capacity. Other types must work alone. Certain types are adaptable to working at a long distance from the point of support. Others, for practical reasons, are limited to handling objects close to the support location.

FIGURE 7D
Portal Crane (Front View)

c. Type of Work. A third major consideration is the speed and frequency with which the equipment must work or travel. Different types of machines are capable of different speeds. Some types are suited to the execution of numerous, repetitive lifts and other types are best suited for use in an intermittent work cycle.

d. Other Factors. Other selection factors include ability to travel with the load; the need for collateral facilities such as trackage, and runway structures (the cost of collateral facilities varies widely with different types of equipment and may, in fact, be more costly than the equipment); available power supply; the type and availability of support for the equipment; safety; operating costs; mobility; and clearances, all as discussed in the following subsections. Height of the lifts, and accuracy of spotting the load, also must be considered.

In effect, the selection process is one of progressive elimination of unsuitable types (too little coverage in positioning the hook, insufficiently flexible in operation, inadequate reach or capacity, etc.) until only a few remain, and eventual selection of the most suitable type from among those few on the basis of comparative cost, experience, and judgment.

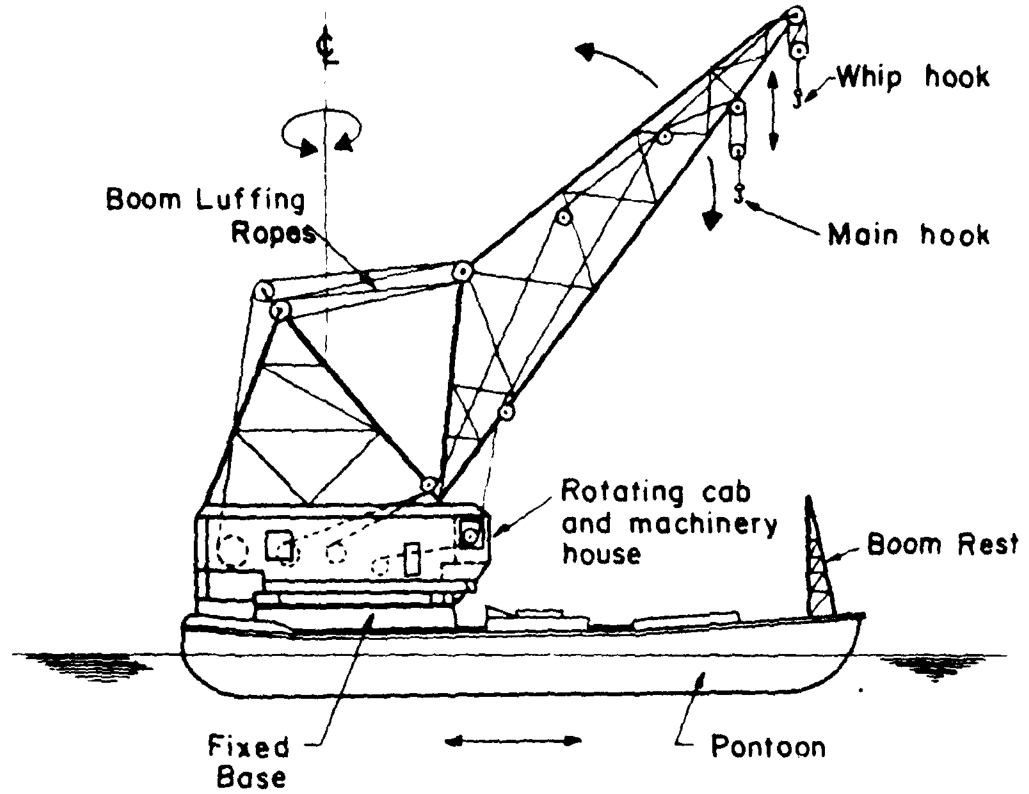


FIGURE 8A
Floating Crane

2. REQUIREMENTS FOR AREA OF COVERAGE. The first step in selecting an item of weight-handling equipment for a given application is to consider what types will provide the required coverage in positioning the hook.

a. Rotating Machines. The basic rotating (or swing) crane is shown in Figure 15a. The load can be positioned anywhere along a circular path defined by the center of rotation and the radius to the load hook. With such a crane, the load is delivered to (or removed from) some point on this circular path by a truck, dolly, or similar conveyance. This type of equipment is relatively inexpensive and is sufficient if a fixed facility is to be serviced (a machine in a machine shop, such as a lathe, for example) and if the load, conveniently, can be brought to the crane and taken away (for example, on dollies).

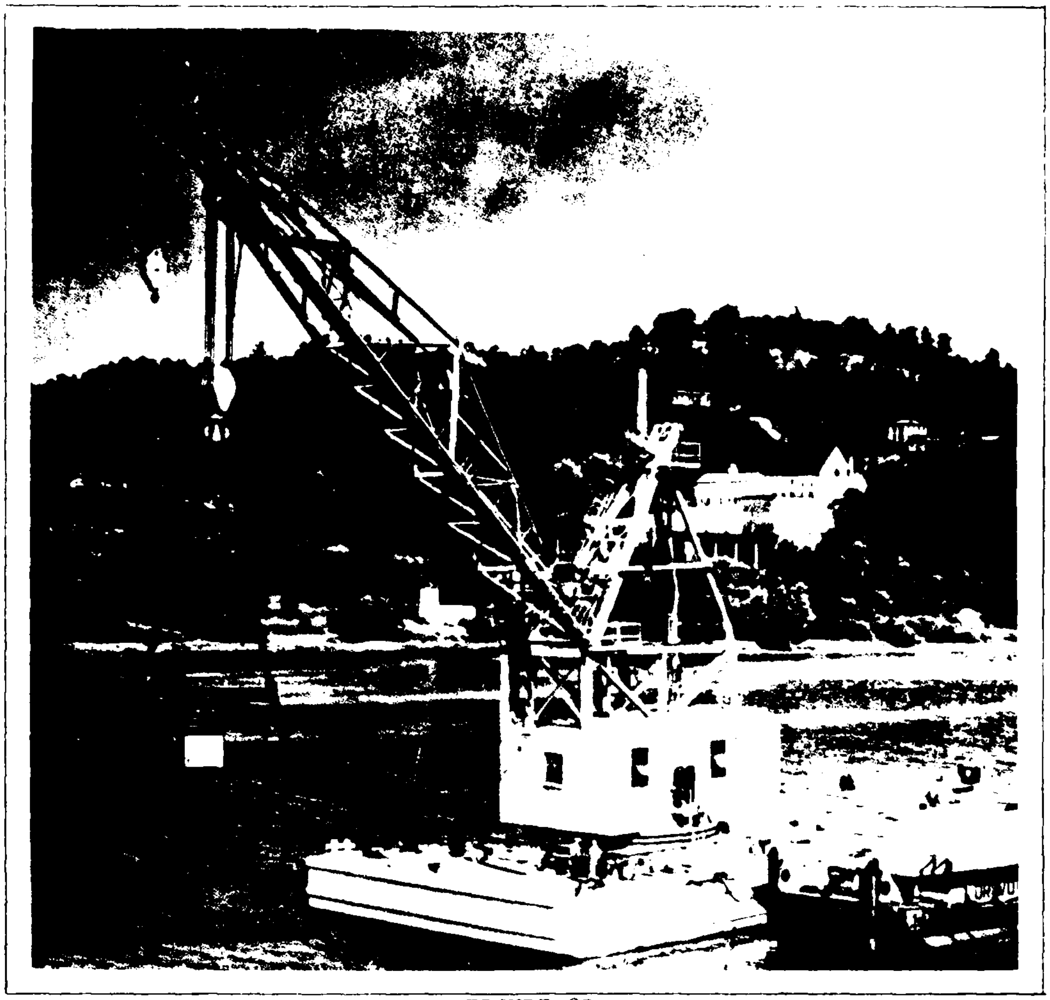


FIGURE 8B
Floating Crane

If necessary to increase the area in which the load can be positioned, either for lift or to land, a trolley may be added to the boom, as shown in Figure 15b. With such a feature, the load may be positioned not only on the swing circle, but anywhere within said circle (defined by the center of rotation and the extreme radius of travel of the trolley)--except for areas so close in to the pillar that the trolley cannot reach. This type of machine takes many forms, as shown in Figure 2.

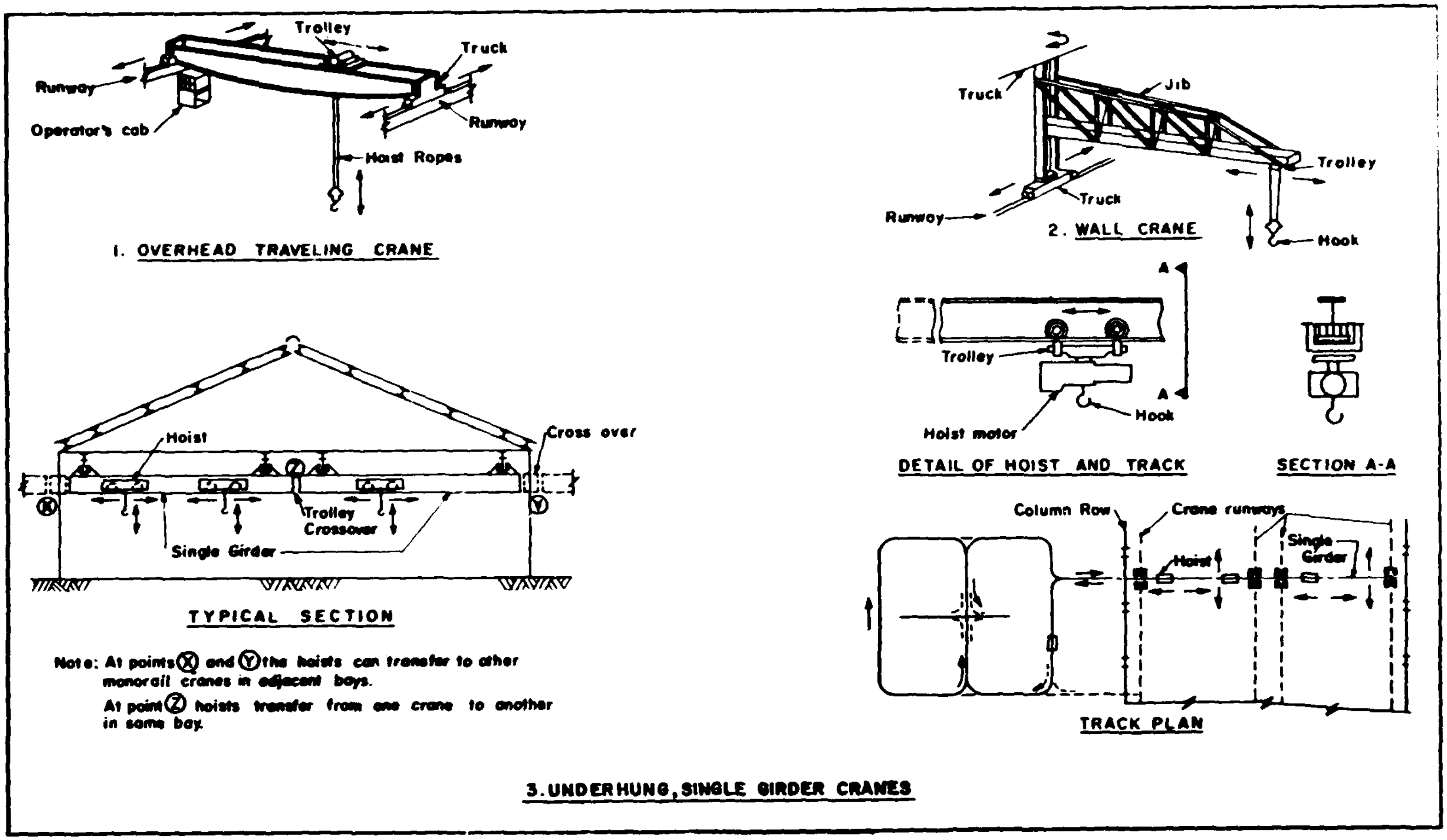
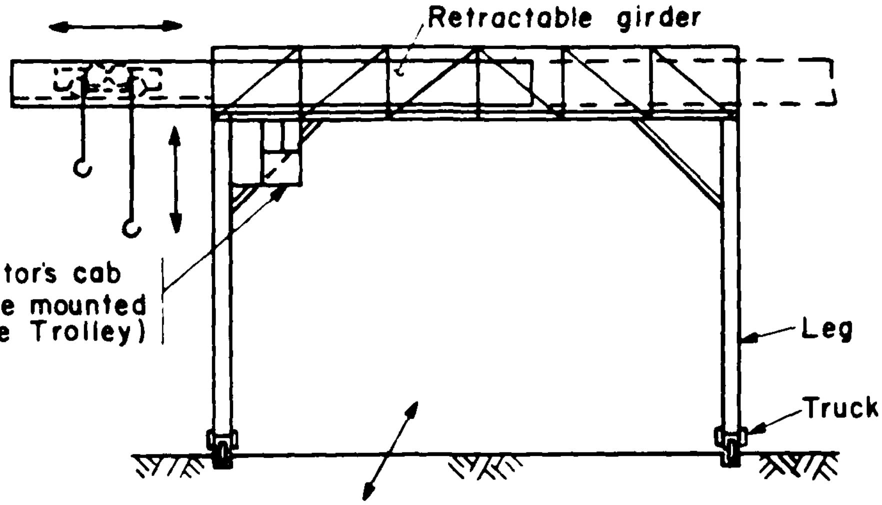
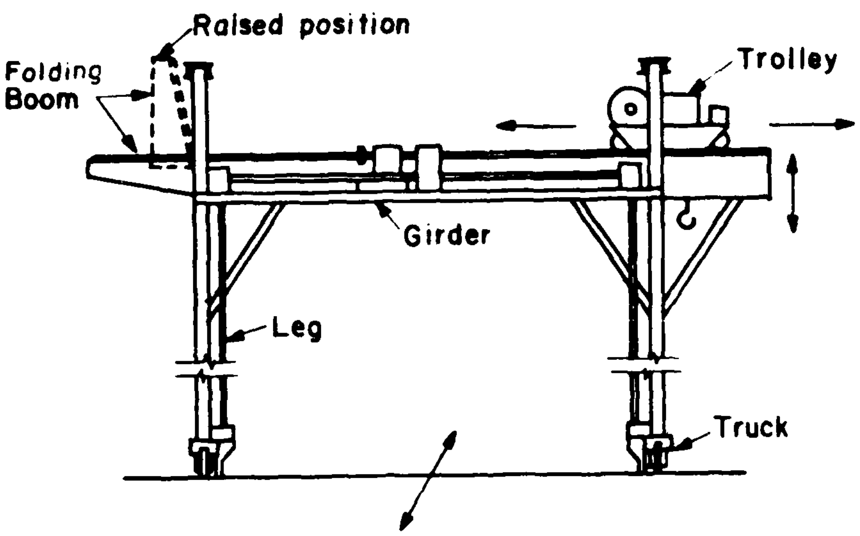


FIGURE 9
Overhead Traveling Cranes, Wall Cranes, and Underhung Cranes

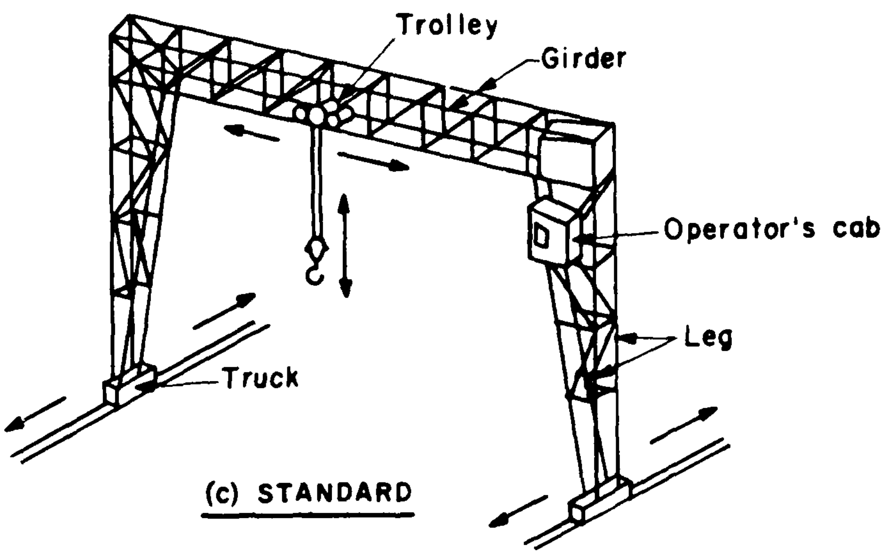


(a) WITH RETRACTABLE GIRDER

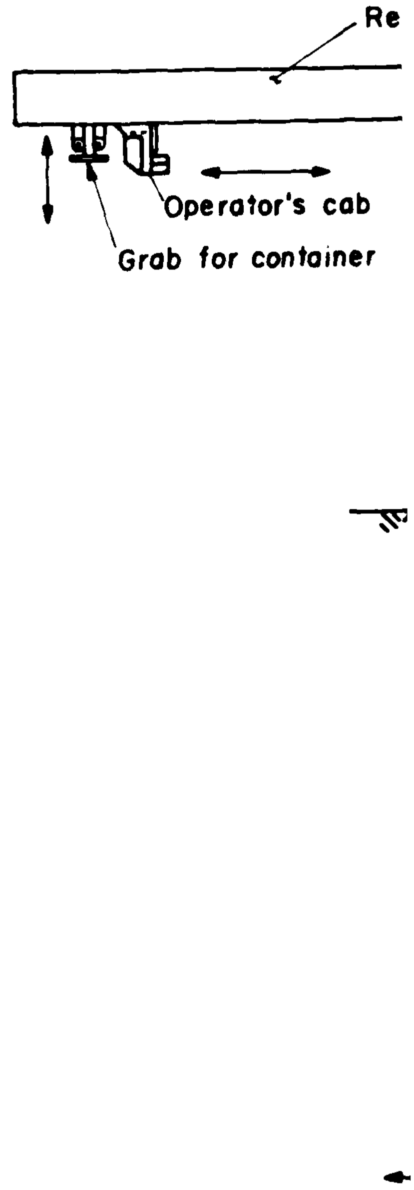
I. GANTRY



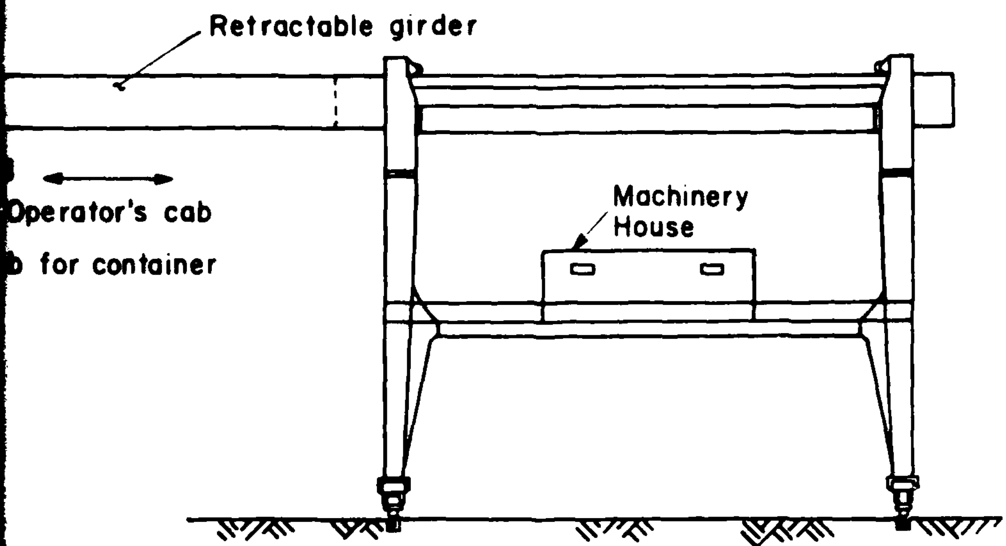
(b) FOLDING BOOM



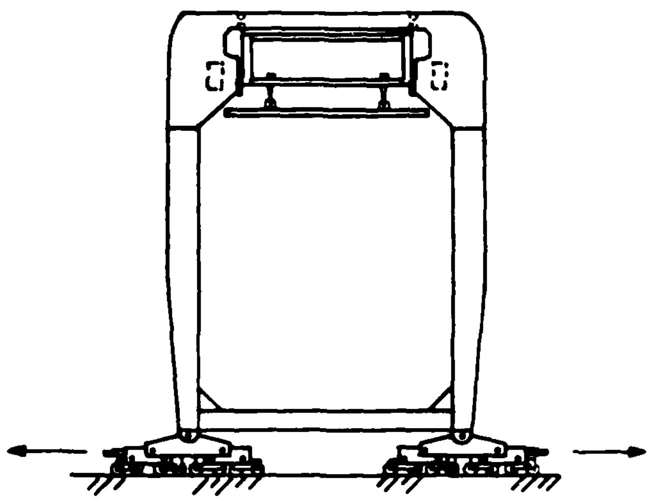
(c) STANDARD



(d) RETRA

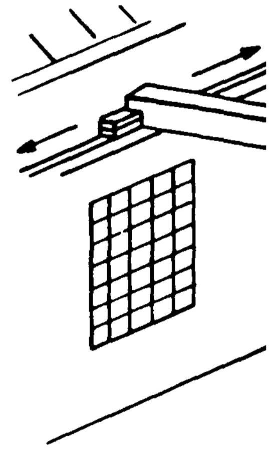


SIDE VIEW

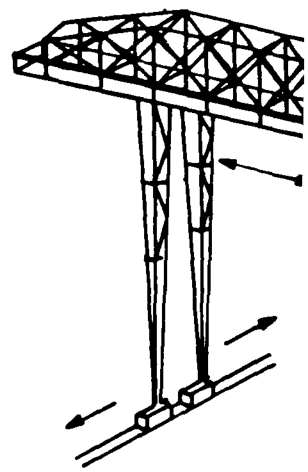


FRONT VIEW

(d) RETRACTABLE GIRDER ON REGULAR GANTRY CRANES OR CONTAINER CRANES

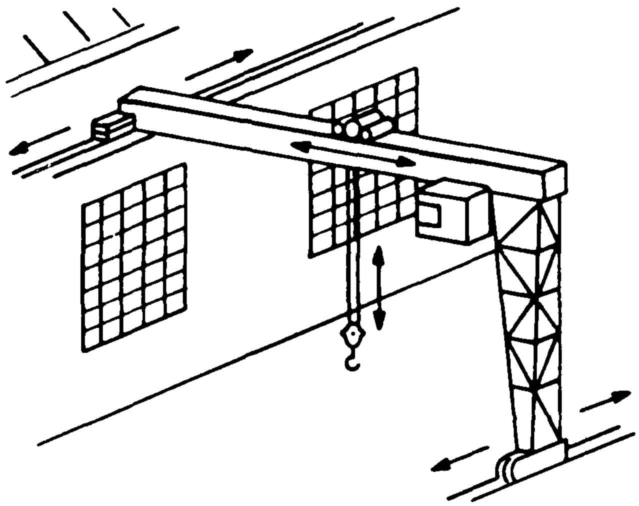


2. SEMI

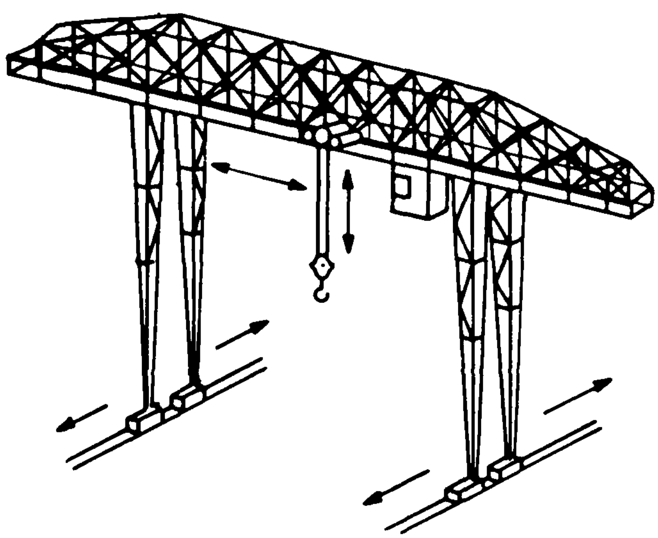


3. CANTILEVER

Gantry,



2. SEMI-GANTRY



3. CANTILEVER GANTRY

FIGURE 10A
Gantry, Semi-Gantry, and Cantilever Gantry

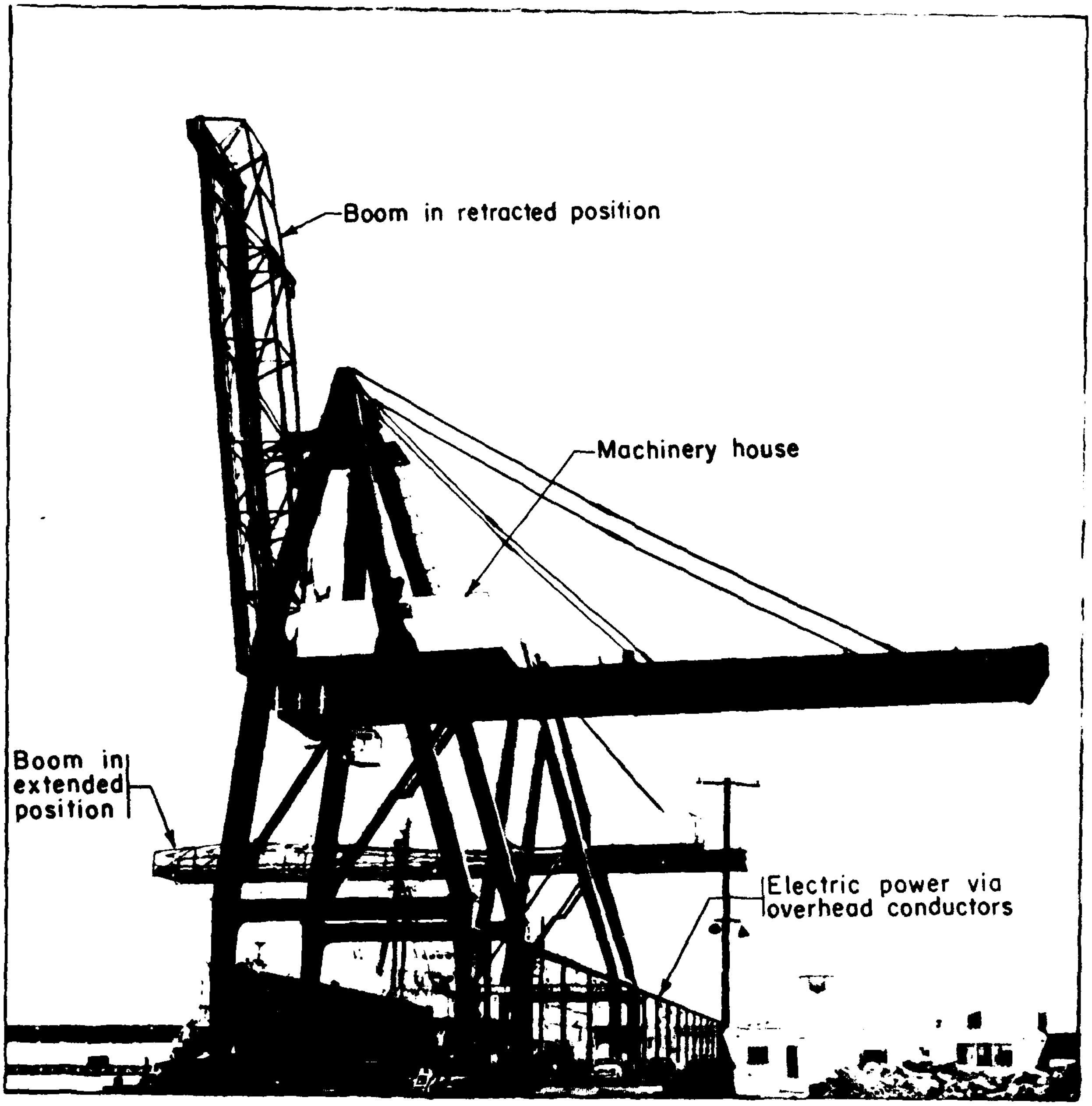


FIGURE 10B
Typical Container Cranes

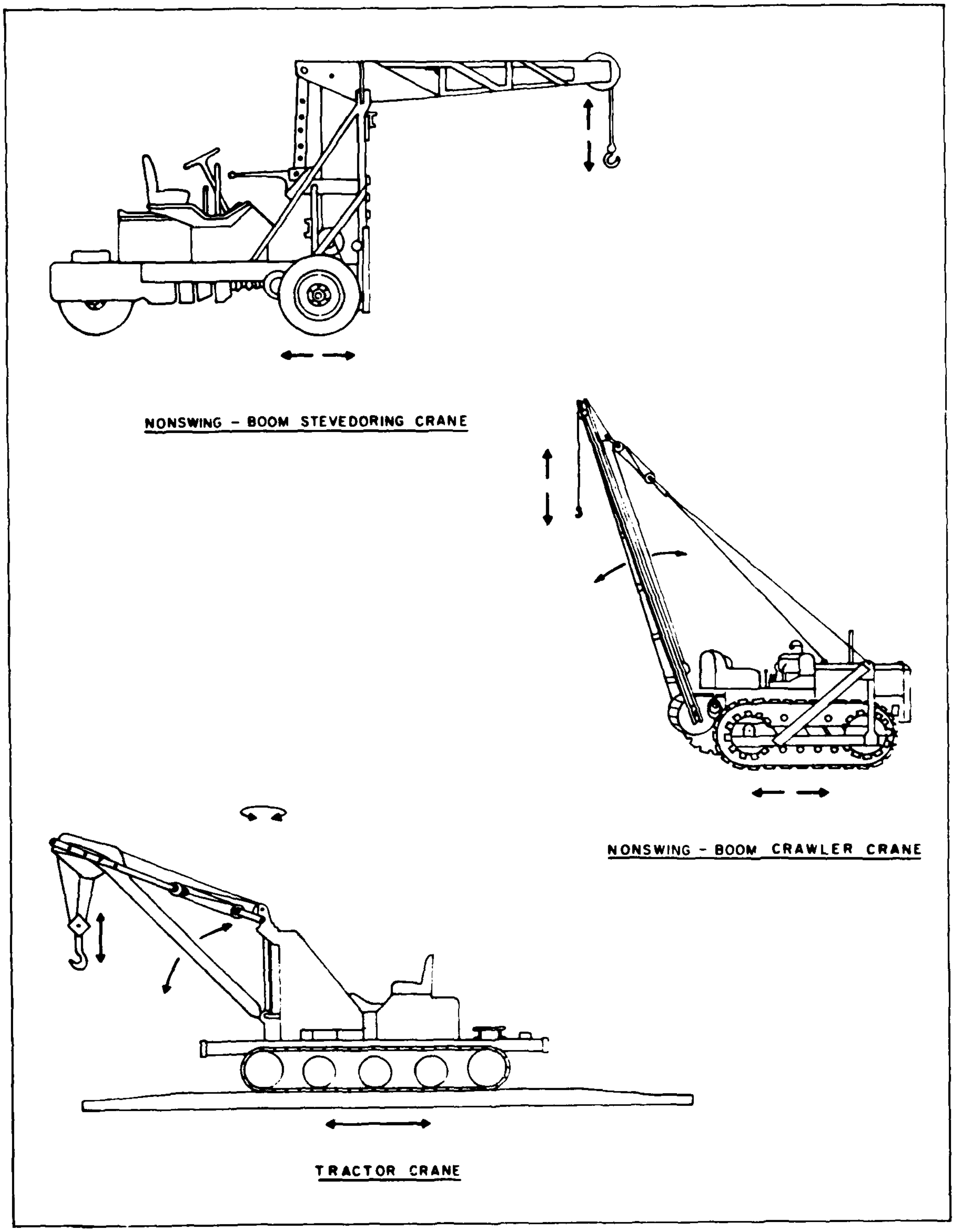


FIGURE 11
Industrial-Type Mobile Cranes

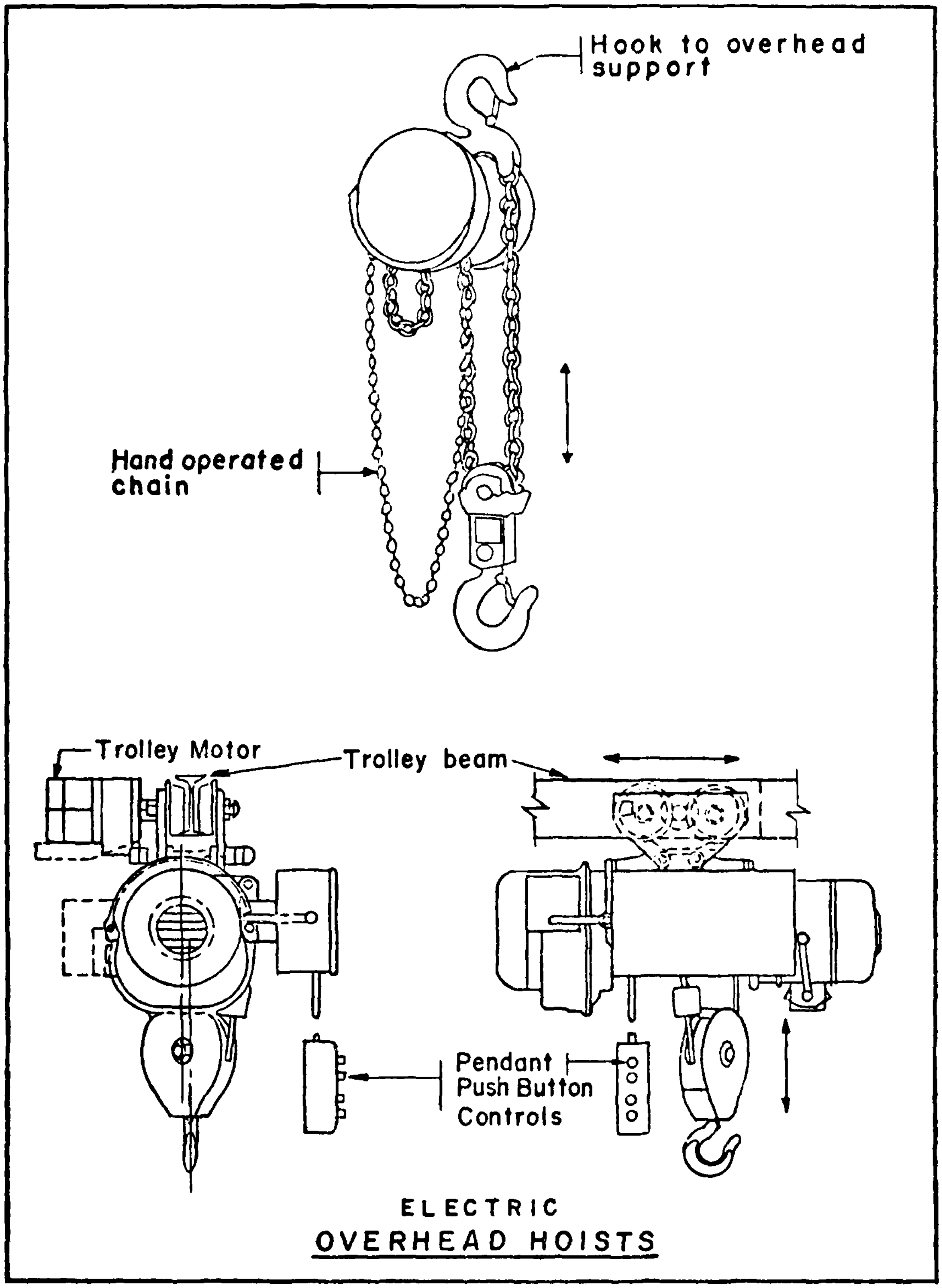


FIGURE 12
Overhead Hoists

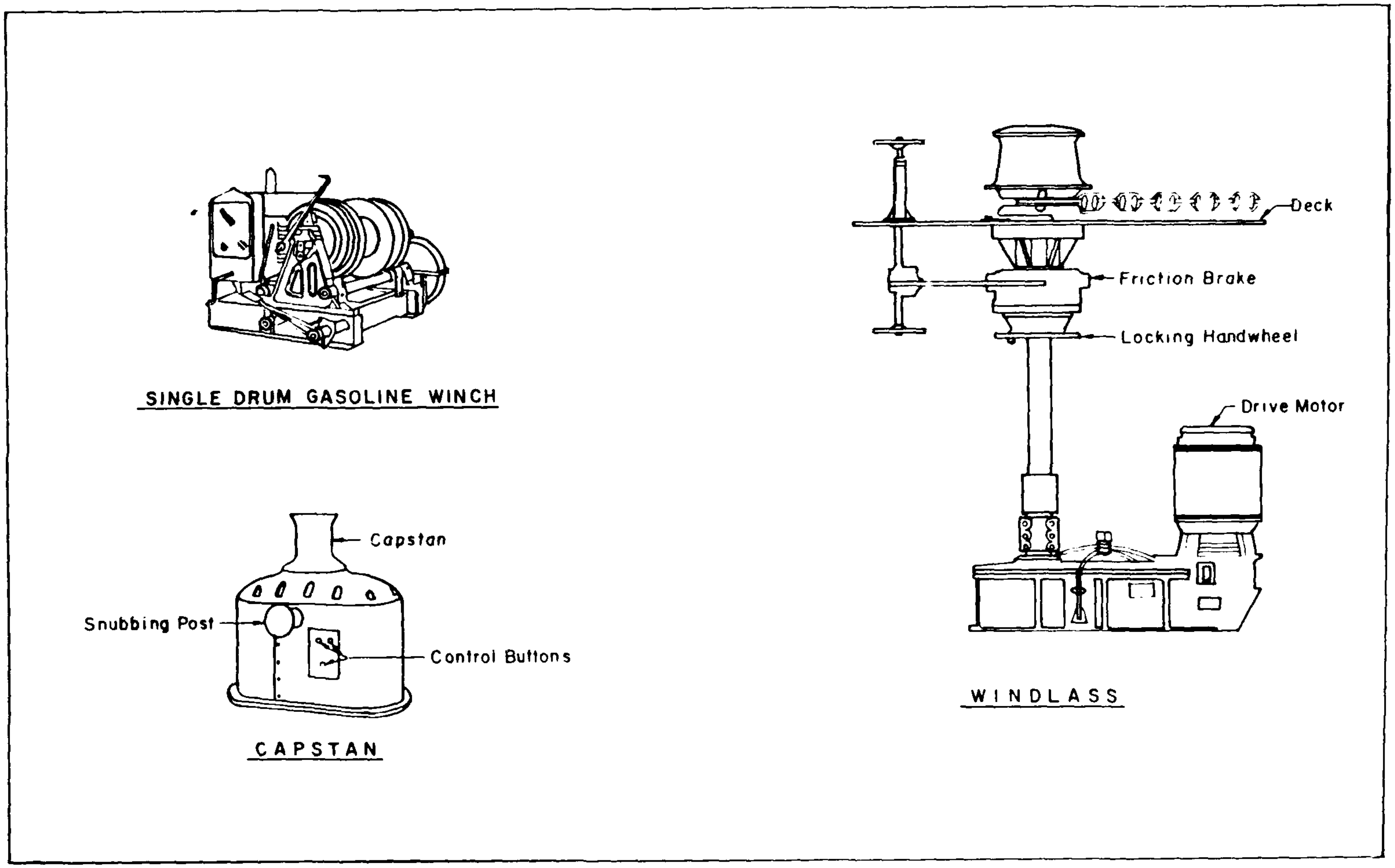


FIGURE 13
Winches

TABLE 1
Characteristics of Various Types of Non-Traveling, Rotating Machines

Jib, Pillar and Pillar-Jib Cranes (Figure 1)	Tower and Hammerhead Cranes (Figure 3)	Derricks (Figure 4)	Derricks vs. Tower and Hammerhead Cranes
(1) Capacity—over 10 to 15 tons (250-ft-tons) unusual because of lack of counterweight. (2) Reach—less than 25 ft. usual. Up to 50 ft. practical. (3) Maximum Lift—more than 25 to 30 ft. unusual. Larger values theoretically feasible. (4) Cost of Collateral Facilities—Minimal. (5) Operating Cost—Minimal. (6) Safety—Fair to good. (7) Speed of Operation—Slow. Often hand operated. (8) Generally for light capacity (indoor or outdoor) use. Usually for occasional, floor operation with manual swing and limited area of coverage.	(1) Capacity--For Cantilever cranes, 450 G.T. (35,000 ft-tons) existing. Larger capacities feasible. For luffing cranes, capacities to 50,000 ft-tons, or more, feasible. (2) Reach--Over 200 ft. existing. (3) Maximum Lift--Over 200 ft. existing. Higher practical. (4) Cost of Collateral Facilities—Moderate (principally foundations and power supply). (5) Operating Cost--Low to medium. Can be operated by one man, but may employ oiler for servicing. (6) Safety—Excellent, particularly if constant load-radius rating is provided. (7) Speed of Operation--Medium to fast.	(1) Capacity: a. Guy--more than 50 tons (5000 ft-tons) unusual. b. A-frame and Stiffleg--to 1,250 tons (150,000 ft-tons) existing. c. Gin Pole--Usually small (up to 10 tons). d. Breast--Varies. e. Floating--Generally up to 400 tons (20,000 ft-tons). (2) a. Guy--usually 50 to 150 ft. b -frame and Stiffleg--250 ft. existing. Usually 50 to 150 ft. c. Gin Pole--Short in relation to height. d. Breast--Varies. e. Floating--Similar to *Stiffleg*. (3) Maximum Lift: a. Guy--80 to 100 ft. for derrick alone. With Tower or framework--indefinite. b. A-frame or Stiffleg--220 ft. for derrick alone, existing. With tower or on framework--indefinite. c. Gin Pole--Similar to guy. d. Floating--80 ft. existing. Higher feasible. (4) Cost of Collateral Facilities--Minimal, except for floating derrick where berthing and drydocking facilities are costly. (5) Operating Costs--Generally low to moderate. (6) Safety--Generally poor. (7) Speed of Operation--Rotate motion generally very slow. Hoist and luffing motions generally medium to fast.	(1) First cost per ft-ton of capacity generally less for derricks. (2) Derrick generally a simpler machine and less costly to maintain. (3) Derrick can be more readily demounted (or dismantled) and relocated (if suitable foundations are provided) than can a fixed crane. (4) Mechanism for derrick normally mounted on ground and more readily accessible for maintenance. (5) Except for special equipment mounted on a rotating table (Figure 4 Part 6), derricks lack ability to rotate 360°. Therefore are less versatile in use. Guyed derricks are particularly cumbersome in this regard. (6) Guys and legs generally occupy more space than tower (or pillar) of crane and cause greater interference with ground level operations. (7) General use derricks for: a. High capacity lifts, i.e., lifts over 50 to 100 tons, where limited capability is not a controlling consideration. For lesser capacities, working at ground level and with sufficient room a truck or crawler crane likely is a better choice. b. For temporary work off of a tower or on a framework, as in building erection, even though lifts are light. The reason is the difficulty of putting a crane in such an area. c. Where the machine must be moved at intervals (not so often that a traveling crane is required, but often enough that the derrick's advantage of ease of demounting and reassembly is significant). d. To repair and maintain other equipment.

TABLE 2

Characteristics of Various Types of Traveling, Rotating Machines

Locomotive Cranes (Figure 5)	Motor-Truck and Crawler Cranes (Figure 6)	Traveling Towers* (Figure 7)	Floating Cranes (Figure 8)	Traveling Towers vs. "Mobile" Cranes	Locomotive vs. Truck or Crawler Cranes
(1) Self-propelled and able to travel with load. Generally only with very light loads compared to traveling tower or hammerhead cranes, but with heavier loads (for same rated capacity) than truck or crawler crane. Can be fitted with rolling outriggers which increase hook load capacity in transit (*) or can travel with capacity loads by pushing or towing loads on flat car. Can be used as an engine to switch and move railroad cars.(**) (2) Mobility--Excellent. Can travel anywhere there are suitable tracks. Except in rugged terrain, cost of trackage low to moderate and can be speedily laid. Self-contained power supply. (3) Travel Speed--Fast travel speed (among fastest of traveling cranes). This permits shuttling of single machine among several facilities. However, this capability is valuable only if travel distances are large. (4) Cost of Collateral Facilities--Moderate. Most of cost is in trackage. (5) Operating Cost--Moderate. Usually requires two man crew.	(1) Able to travel with load but only with very light loads (see Figure 18). With long boom, dangerous to travel with any load or even to travel, at all. Ability to travel with load can be increased by adding rolling outriggers.* (2) Mobility--The best. Virtually unlimited coverage on flat to rolling terrain, although may require matting or cribbing to cross, or work on, soft or loose ground. Where matting is required, laying mats is a time consuming (and costly) matter. However, despite excellent mobility, requirement to set outriggers for each lift limits use where crane must travel frequently between lifts. Also, of limited use on structures (piers, bridge decks, etc.) because of lack of provision to distribute concentrated reactions from wheels and outriggers. Self-contained power supply. Crawler cranes, having low contact pressure under treads, are more mobile than truck cranes. (3) Travel Speed--Crawlers are slow.	(1) Generally designed to travel with full rated load suspended from hook. (2) Mobility--Generally limited to prepared tracks or, for rubber tired machines, to travel paths consisting of strengthened lanes of pavement and reinforced underground structures. Because of weight of machine and concentration of corner reactions caused by suspended load, trackage and travel paths tend to involve substantial supports and cost. Therefore, extending area of coverage, while feasible, may be expensive. May have self-contained power supply or may operate off of third rail or overhead conductor. With self-contained power supply, combination of ability to traverse curve and relatively narrow track gauge (as little as 18 to 20 ft.) generally permits tracking through an entire facility (See Figure 21.) (3) Travel Speed--Slow. Usually 2-3 MPH because of practice of employing track watcher. Higher travel speeds possible. (4) Cost of Collateral Facilities--High (see above).	(1) Can travel with load by laying load on deck of barge and propelling (or being towed) to desired location. (2) Travel Speed--Slow. (3) Cost of Collateral Facilities--Low. Requires berthing space, but little else. (4) Operating Costs--Very high. Often require special crew. Require dry-docking for maintenance of hull. If not self-propelled, require tug and crew for towing. (5) Capacity--Up to 600 tons (54,000 ft.-tons) existing. Larger capacities feasible. (6) Reach--Over 200 ft. practical. (7) Lift--Over 200 ft. practical. (8) Remarks--Safety and control of load tend to be impaired by lack of stable foundation. Crane tilts with increasing load and changing vertical boom angle. Rolls and pitches in waves.	(1) For the same capacity (in foot-tons) mobile cranes are generally less costly than traveling towers. (2) The problem with the so-called "mobile" cranes is that they have very limited ability to travel with the load. In practice they function as portable derricks. Also because of the time consumed in setting the outrigger (or blocking) to make a substantial lift (anywhere from 3 to 15 minutes, depending on the equipment) they are not suitable where many lifts are to be made in a diverse area in the course of a day's operations. They are most suitable where the day's lifts are to be made in a limited area, or where only a few lifts are required, but in many, separate areas. This problem can be corrected by equipping the cranes with rolling, or crawler treads, outriggers which enable the crane to travel between lifts or with the load without retracting or re-setting outriggers, but such equipment is likely to be of comparable (or greater) cost to a tower crane of similar capacity.	Considering that all three types of machines are available in comparable capacity and reach; since the principal advantage of a mobile crane is its mobility, the locomotive crane which has the least mobility of the three (and is the most costly) generally is least favored, except for special cases where (1) railroad trackage already is available (normally, special trackage is not installed for the crane), (2) the fast travel speed is required, or (3) the ability to transport the load on flatcars (or to accompany the load) is desired (for example, in an operation involving delivery and unloading, where there are no weight-handling facilities on receiving end, i.e., where the locomotive crane can be used, in essence, as a combination truck and crane).

TABLE 2 (Continued)

Locomotive Cranes (Figure 5)	Motor-Truck and Crawler Cranes (Figure 6)	Traveling Towers* (Figure 7)	Floating Cranes (Figure 8)	Traveling Towers vs. "Mobile" Cranes	Locomotive vs. Truck or Crawler Cranes
(6) Capacity--Generally low (less than 1000 ft.-tons) without outriggers because of problem of stability when reaching over side. Capable of heavy lifts (up to 300 tons) at short reach (up to 5000 ft.-tons), with outriggers. (7) Reach--30 to 60 ft. usual, 100 ft. unusual, over 100 ft. only for very special cranes. (8) Note--Safety record is poor to fair. Because of variable reach--capacity rating and low factor of safety against tipping (and difficulty of blocking, except in paved areas), accidents are more frequent than with portal, traveling tower, or hammerhead cranes. (*) May be necessary to set boom in prescribed position to relieve load on outriggers before and during traveling. Also, rolling outriggers limited to use on firm, level ground. Use on mats of planking or steel plates acceptable. Use over open trackage unacceptable. Use on bituminous paving questionable.	Usually they are transported over any substantial distance on a truck-drawn lowboy. Motor truck cranes, however, are capable of 30-50 MPH travel speeds and are (with locomotive cranes) the fastest traveling cranes and can be shuttled to serve several facilities. (4) Cost of Collateral Facilities--Normally inconsequential. (5) Operating Cost--Low to moderate. Crawler and single engine motor (so-called "cruiser") cranes can be operated by one man. Two engine truck cranes generally operated by two man crew. (6) Capacity--Generally low (less than 1,000 ft.-tons), to moderate (to 3,000 ft.-tons), with outriggers. Very low without outriggers. High capacity ratings (up to 200 tons, 4,500 ft.-tons.) available but generally only at very short reach. Special walking cranes of large size used in stripmining operations.	(5) Operating Costs--Low to medium. Can be operated by one man, but sometimes employ oiler for servicing. (6) Capacity--Largest of Traveling, swing cranes. Capacities to 200 tons (12,000 ft.-tons) existing. Larger capacities (up to 50,000 ft.-tons, or more) feasible. Full capacity available at any swing angle. (7) Reach--Over 200 ft. practical. (8) Lift--Over 200 ft. existing. Higher practical. (9) Safety--Excellent, particularly if constant load-radius rating is provided. Excellent for tandem lifts. (10) Versatility--The luffing swing crane is the most versatile type of weight-handling equipment and is indicated where the work places a premium on this capability. (*) Includes traveling portal and traveling hammerhead cranes.		(3) Experience indicates that the service life of a truck or crawler crane is about half that for a tower crane. (4) Mobiles, as presently designed, have the operator close to the ground. His visibility is poor compared to the elevated cab of the usual tower crane. Accordingly, his efficiency and control of the lift tends to be reduced. Signal men may be required. (5) The boom hinge pins on the mobile cranes generally are low so that the reach of the crane may be restricted when working next to an obstruction. (6) The principal advantages of mobile cranes are (1) their mobility and (2) their size permits them to get into or traverse areas which are a bar to the traveling tower because of its bulk. (*) Locomotive, truck and crawler.	

TABLE 2 (Continued)

Locomotive Cranes (Figure 5)	Motor-Truck and Crawler Cranes (Figure 6)	Traveling Towers* (Figure 7)	Floating Cranes (Figure 8)	Traveling Towers vs. "Mobile" Cranes	Locomotive vs. Truck or Crawler Cranes
(**) Unless specifically provided with brakes and travel clutches sized for the purpose, locomotive cranes generally should not be used for switching engine or locomotive duties, except for occasional use on short hauls.	(7) Reach—Similar to locomotive cranes. (8) Lift—Often fitted with very long (200 to 250 ft.) booms for high lifts at short reach. (9) Notes—As with locomotive cranes, safety record is poor to fair. Crawler cranes generally unsuitable for use on asphalt or soil-cement pavement because treads tear up surface. (*) Caution is required when considering use of, or using, rolling outriggers, as follows: (1) May be necessary to set boom in prescribed (usually high) position to relieve load on outriggers before, and during traveling. (2) Limited to use on firm, level ground (see footnote under Locomotive Cranes).				

TABLE 3
Characteristics of Various Types of Non-Rotating Machines

Overhead Traveling Cranes (Figure 9)	Gantry Cranes (Figure 10)	Wall Cranes (Figure 9)	Underrunning, Single Girder Cranes (Figure 9)	Overhead Traveling vs. Gantry Cranes
(1) Mobility--Limited to fixed runway.(*) (2) Speed of Motions: a. Cab operated: Travel speed--fast. Fastest of bridge cranes. Trolleying and hoisting speeds fast. Extra-rapid lowering speed can be provided. b. Pendant operated: Travel and trolleying--etc. Hoisting--fast. c. Remote operated: Fast speeds feasible for all motions. (3) Cost of collateral facilities high. Requires runway. (4) Operating Cost--Low. One man. (5) Capacity--Over 500 G.T. existing. Larger feasible.	(1) Mobility--Limited to fixed runs of track, except for lesser capacity machines, which may be fully mobile. (2) Speed of Motions--Travel speed slow. Usually 2-3 MPH because of practice of employing track-watcher. Higher travel speeds possible. Trolley and hoisting speeds fast. (3) Cost of Collateral Facilities--Where machine is heavy enough to require trackage, the cost of trackage can vary from low to high, depending on foundation conditions. The cost of cable and reel (or third rail) for power supply also is high. In general, overall cost of collateral facilities is moderate, i.e., less than cost of runway for overhead traveling crane, but more than trackage for traveling tower.	(1) Mobility--Limited to fixed runway. (2) Speed--As for overhead traveling cranes. (3) Cost of Collateral Facilities--Moderate to high. Requires runway. (4) Operating Cost--Very low. May be operated on intermittent basis without full-time operator. (5) Capacity--Seldom over 15 tons. (6) Reach--Up to 50 ft. practical. (7) Safety--Excellent. (8) Ease of Operation--Excellent.	(1) Mobility--Good. Limited to fixed runway, but runway beam (and reactions) normally sufficiently light that runway can be readily erected, relocated, and extended. Can be arranged to transfer trolley from one bridge to other bridges in adjoining bays. (2) Speed--Fast speeds available in all motions. (3) Cost of Collateral Facilities--High relative to cost of crane, but low in absolute terms. (4) Operating Cost--Very low. (5) Capacity--2 to 10 tons usual. 20 tons available. (6) Safety--Good to fair.	(1) Runway--Overhead traveling crane requires runway structure. In interior of building, runway is not particularly costly as bracing is inherent in building and basic columns and footings are required, necessitating only added section. Therefore, overhead traveling crane is logical choice for interior use. For exterior use, the cost of the runway structure is considerable and its size and clutter of framing constitutes an interference with the flow of traffic and materials through the site. Accordingly, the gantry crane has become increasingly popular for exterior applications. However, the runway structure has certain advantages, as follows: (2) Multiple Cranes--Several overhead traveling cranes can operate simultaneously on the same runway structure. Work can progress simultaneously in several areas within the runway. The bridges can be located at different levels so that they can pass each other. Tandem lifts, up to the limit of capacity of the structure and foundation, are feasible. Of course, several gantries can operate on the same track, but the cost of several gantries will be more than the cost of a like number of bridges of like capacity and span. Also, the problem of having the gantries pass each other is difficult so that each is likely to be locked out of some area within the runway area.

TABLE 3 (Continued)

Overhead Traveling Cranes (Figure 9)	Gantry Cranes (Figure 10)	Wall Cranes (Figure 9)	Underrunning, Single Girder Cranes (Figure 9)	Overhead Traveling vs. Gantry Cranes
(6) Span--200 Ft., or more, feasible. (7) Safety--Excellent. (8) Ease of Operation--Excellent. (9) Remarks--Experience has shown the overhead traveling crane to be one of the most reliable enduring, and trouble-free types of weight-handling equipment. There are numerous instances of machines over 50 years of age which continue to give good service. (*) Underrunning crane with underrunning trolley can be arranged to transfer trolley from one bridge to other bridges in adjoining bays.	(4) Operating Cost--Low. (5) Capacity--Up to 800 tons in general use. 1,500 tons existing. (6) Span--600 ft. existing. Cantilever extensions up to 120 ft. existing. (7) Safety--Excellent. (8) Ease of Operation--Excellent. (9) Features--Can be fitted with specialized trolleys that can pass each other on different levels. Girder can cantilever beyond legs and trolley pass between legs for increased area of coverage.		(7) Ease of Operation--Good.	(3) Travel Speeds--As previously noted, the overhead traveling crane may safely operate at a faster travel speed. (4) Power Pickup--Power supply to gantry crane usually involves a third rail (Figure 22) or a reel and cable (Figure 23) near deck level. Either presents a hazard and a maintenance problem. In contrast, power pickup for an overhead traveling crane is from a conductor mounted on the runway (Figure 53), which system has proven reliable and safe. Possible provision of self-contained power supply for gantry crane is feasible and should be considered. Possible provision of overhead power supply also is feasible and should be considered. (See Figure 10B.)

TABLE 4
Weight-Handling Equipment

General Selection Factors

1. Area of Coverage (of hook).
   a. Area.
   b. Distance from point of support.
2. Capacity (weight to be lifted).
   a. Maximum value.
   b. Need for tandem lifts.
   c. Need for multiple hooks.
3. Type of Work.
   a. Speeds.
      (1) Travel.
      (2) Trolley.
      (3) Hoist.
      (4) Rotate.
      (5) Luffing.
   b. Frequency and duration of cycle.
   c. Precision of spotting loads.
   d. Sensitivity of lifts.
4. Ability to Travel with Load.
5. Cost of Collateral Facilities.
6. Available Power Supply.
7. Type of Available Supports and/or Foundation Conditions.
8. Safety Factor.
9. Operating Costs.
10. Mobility.
11. Clearances.
12. Lift (Hook height above ground or top of rail).

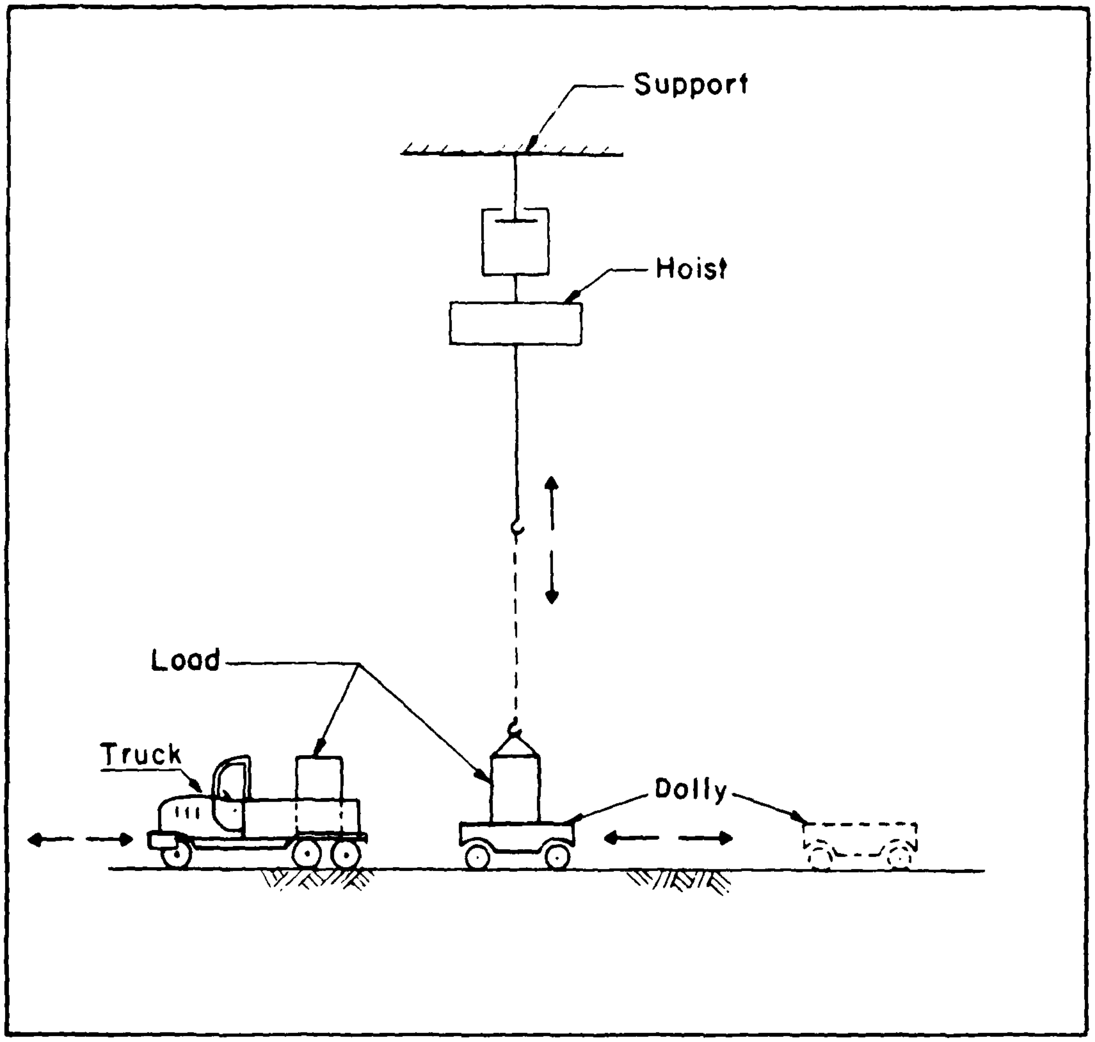


FIGURE 14
Basic Hoist Operation

An alternate means for achieving the coverage afforded by the trolley is to provide for luffing (raising and lowering the boom) as shown in Figure 15c. Again, the area covered includes the full circle, out to the limit defined by the minimum (measured from the horizontal) boom angle and restricted to the maximum boom angle. The minimum boom angle is determined by the requirement that the angle between the luffing ropes and the boom not be so acute that the boom cannot be raised. The maximum boom angle is set by the requirement that the luffing ropes always be in tension and that the boom not flip over backwards, for example, in a high wind or if there were some sudden bounce of the load (such as a break of the rope or the load suddenly releasing from its support during takeup). This type of machine also can be provided in many forms, as illustrated in Figures 3 to 8.

Finally, the area in which the load can be positioned can be further increased by fitting the machine to travel. It may travel on tracks (railroad, or wider gage crane tracks--see Figures 5 and 7) or on pavement (Figure 6A, Truck Cranes) or overland (Figure 6A, Crawler Cranes). For cranes traveling on tracks or pavement, the area of coverage is limited to the area in which trackage or pavement is laid, which involves the collateral cost of trackage, pavement, and reinforcement of travel paths and structures within the travel paths. Crawler (and, to a lesser extent, truck) cranes are limited in coverage only by the terrain.

b. Non-Rotating Machines. The two basic types of non-rotating cranes are shown in Figures 9, 10A and 10B. In both types, the hoist is mounted on a trolley, which is mounted on a traveling bridge. The bridge may ride on a fixed structure (Figure 9), in which case the assemblage usually is called an overhead traveling crane (or, if the bridge is a cantilever rather than a simple span, a wall crane), or it may be mounted on legs which travel with the bridge (Figures 10A and B), in which case the assemblage is called a gantry crane. Both types can be provided in many forms, as illustrated.

The area of coverage (of the hook) for a machine of this type is defined by the area encompassed by the fixed structure. In most cases, there is some diminution in this area because the trolley on which the hoist is mounted cannot ride beyond the end stops on the bridge. However, even this problem can be overcome by use of retractable extensions to the bridge, as shown in Figure 10 or by use of spur tracks and transfer system as shown in Figure 9 Part 3.

Theoretically, the area of coverage for a gantry crane (except for physical obstructions) is unlimited. However, the problems of steering and cornering have not been satisfactorily solved, except for small machines, so that the use of gantry cranes, in present practice, is limited to straight runs of track. The area of coverage, accordingly, is limited to the area between the tracks, plus some additional coverage which may be afforded by designing the bridge girder to cantilever beyond the supporting legs (Figure 10), or by use of retractable bridge girders (Figure 10).

3. SELECTING BETWEEN ROTATING AND NON-ROTATING MACHINES. Selection between rotating and non-rotating machines follows, primarily, from the determination of required area of coverage. However, height limitations, i.e., the requirement to clear obstructions, also must be considered together with required capacity and reach, tail swing, and need to operate in a high wind.

a. Area of Coverage. The traveling, rotating crane has a decided advantage over the non-rotating machine in terms of potential area of coverage. As noted, if enough track or pavement is available, or if the terrain is not too rough, the traveling, rotating crane can go, virtually, anywhere. Further, the area of coverage for such a crane can be expanded by adding more track or pavement and so a facility can be developed incrementally, using fewer units of equipment. Non-rotating cranes generally are limited to fixed runs of track. Therefore, where very large areas of coverage are involved (and required hook capacity is not too large), the traveling, rotating crane usually has the advantage.

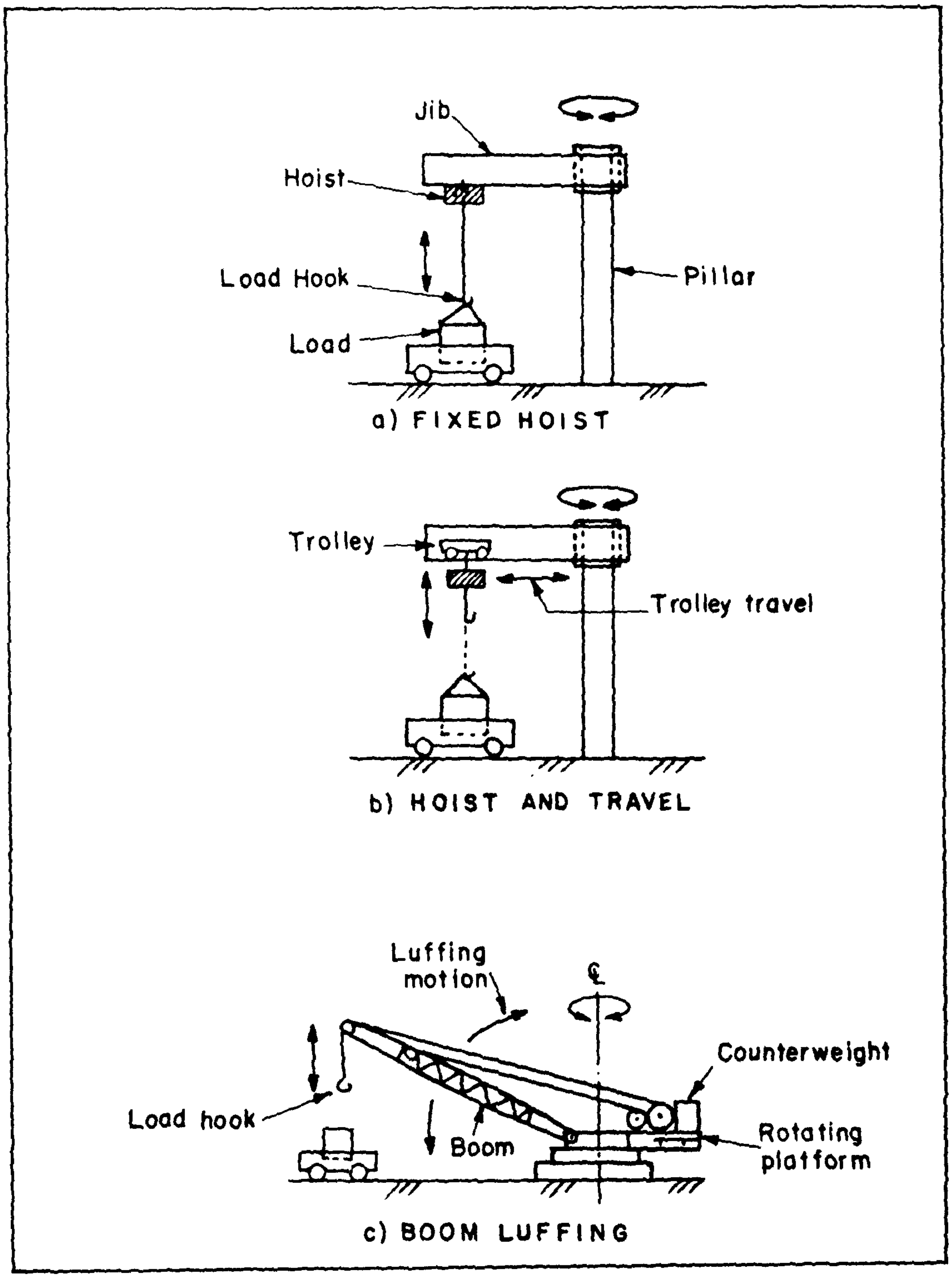


FIGURE 15
Basic Rotating Cranes

b. <u>Height Limitations</u>. A non-rotating crane must clear the top of the load to be lifted and all neighboring obstructions. For work in a plate or lumber yard, or in a shop, this is no problem since the height to be cleared is likely to be nominal to moderate. Non-rotating cranes (in the form of straddle carriers or overhead traveling cranes) are in common use to service such facilities. On the other hand, to service a ship, the clearance under the bridge required to clear the masts might be over 200 feet (61 meters).

The greater the required clearance under the bridge (which must include allowance for the trolley, hook, and rigging), the taller the legs and the more massive and costly the structure. Although very large underclearances are theoretically feasible, there is a practical limit to this height. A lift of 200 feet (61 meters) would be unusual for a gantry or overhead traveling crane, whereas 200 feet (61 meters) of lift is not uncommon with a rotating crane, equipped for luffing.

c. <u>Capacity and Reach</u>. Rotating cranes of more than 150 to 200 tons capacity would be unusual, although theoretically feasible (a rotating derrick of 1250 ton capacity has been built), whereas gantry cranes of 600 to 800 ton capacity are in general use. Reach of 200 feet (61 meters) for a rotating crane would be unusually large, whereas gantry cranes with spans greater than 600 feet (183 meters) are becoming common.

d. <u>Tail Swing</u>. Rotating cranes are not suitable where the tail swing is restricted (for example, inside of a building) unless the mast can be supported top and bottom, or cantilevered, thereby dispensing with the counterweight (see Figure 2). Normally, without a counterweight, the capacity of a rotating crane is limited. Cranes of the types indicated in Figure 2 seldom exceed 25 tons capacity. Accordingly, overhead traveling cranes are a natural choice for relatively large areas of coverage inside of a building, where the building columns and framing provide the basic framing for the runway and spans are short to moderate.

Also of occasional importance is the fact that a rotating crane, equipped to luff, can enter an area through a much narrower opening than can a non-rotating machine of comparable coverage.

4. ROTATING CRANES: SELECTING BETWEEN FIXED AND TRAVELING EQUIPMENT. Selection between fixed vs. traveling equipment (for rotating cranes) also follows from consideration of the area of coverage. If it is feasible to use fixed equipment, the cost (both first cost and maintenance cost) is less than for a machine of comparable capacity, reach, and lift which is equipped to travel. In checking the feasibility of the use of fixed equipment, it is important to give every consideration to the possibility of bringing the loads to (and taking them away from) the weight-handling device. Examples would be the hammerhead and tower cranes widely used in the erection of concrete buildings or a fixed hammerhead servicing a plate or storage yard where large numbers of relatively small pieces are to be handled in a confined area and where the pieces are funneled from various sources to the yard (and to the lifting equipment). In general, fixed equipment is used where the work involves a high duty cycle in a localized area.

In general, fixed equipment is not used where:

(1) Possible future change of use or function is anticipated. If such is likely to occur, the traveling machine is more flexible, adaptable, and more readily relocated. Most fixed equipment falls into disuse because it becomes outmoded and not because of limited service life.

(2) There is heavy traffic around the base of the machine (or tower).

(3) The intended use requires frequent testing (or repair) of the machine or its main components as, for example, a crane used for nuclear work. The machine will be out of service during the test. It is advantageous to be able to move the machine out of the way and to bring in another during the out-of-service period.

(4) Occasional heavy lifts will be required. In such case, consideration should be given to acquiring a traveling machine of lighter capacity to be coupled with another machine (or moved to make room for a heavier machine) in making the heavy lifts, in lieu of a fixed machine of greater capacity.

(5) Versatility would be an important feature of the machine. The fixed machine lacks versatility.

5. ROTATING CRANES: SELECTING BETWEEN LUFFING AND TROLLEYING. If a rotating crane has been selected, consideration must be given to the means for in-and-out motion of the hook, i.e., whether to provide for luffing the boom or to provide a fixed boom with a trolley.

This decision is based, primarily, on consideration of the need to clear obstructions when positioning the load. For a crane having a fixed boom, the boom usually is required to clear the highest obstruction in, or neighboring, the area to be serviced. The reason is that, although a skillful operator can put the end of a fixed (cantilever) boom into a tight location by progressively swinging and traveling (something like parking a car), the clearance is advisable to minimize the possibility of accidents. Thus, if there are any notable obstructions near the working area, the height of the tower for a crane having a fixed boom will be greater than that for the crane equipped for luffing. This extra height of tower is an item of added cost, first for the structure, second because, for a given structure, the higher the tower the less the stability factor under lateral loads and finally, because of the added weight which devolves on the trucks, track, and foundations. This added cost (plus the greater cost of the cantilever boom as compared to a boom supported by the luffing ropes) must be weighed against the greater cost of the luffing mechanism (hoist, ropes, sheaves, etc.) as compared to the trolleying mechanism. The balance can go either way, depending on circumstances in the individual case (required capacity, necessary height, foundation, and site conditions).

Often, the difference is not pronounced and so other considerations control, as follows:

(1) Operator Visibility. The higher tower of the fixed boom (hammerhead) crane tends to give the operator better visibility, unless the luffing crane is fitted with an elevated operator's cab, as shown in Figures 7B and 16.

(2) Costs of Maintenance and Operation. Experience indicates that, for a well-designed machine, there is no substantive difference in the costs of maintenance or operation of either type of equipment.

(3) Wind Presentment. The crane (the hammerhead) fitted for trolleying generally will have a larger, and taller, wind presentment. This means greater sensitivity and sway in a high wind, which influences control of the load. It also means a greater tendency for the wind to push the crane down the track. Normally, these are not serious considerations, but if all other things were equal, the hammerhead would have to be more amply proportioned to resist the increased wind forces, or the wind speed in which the crane could operate would be less.

(4) Versatility. Generally, the luffing machine is considered to be more versatile and finds favor where the required number of lifts per shift is low to moderate and the machine is to be used in a diverse operation. The fixed boom machine has an advantage where it must operate to transfer numerous lifts between two, more or less, fixed locations (bulk material handling, for example). But, even here, the luffing machine (if provided with the level luffing feature) is competitive.

<u>NOTE</u>: In any consideration of luffing or trolleying or of luffing mechanisms for traveling cranes, weight must be given to the number and frequency of the lifts to be made. It is feasible to position the hook by a combination of travel and swing motions without either luffing or trolleying. Indeed, this is the favored practice in types of operation where the number of lifts required is low to moderate and where the machine must be moved frequently. If such is the case, the details of the means provided for in-and-out-motion of the hook, relatively, become unimportant. That which is least expensive, or most convenient, is best.

6. CONSIDERATIONS OF REQUIRED SPEEDS.

a. <u>Travel Speed</u>. The travel speed of mobile, traveling tower, traveling hammerhead, portal, gantry, and similar cranes which travel on pavement or rails at ground level, generally, is limited to a brisk walking pace (say, 3 mph). The reason is that in most instances, for safety's sake, such equipment must be preceded by a trackwatcher, who proceeds afoot to assure that the way is clear and switches are in correct position. Therefore, where fast travel speeds are essential, an overhead traveling crane, wherein the traveling component is mounted on a high structure, clear of the lower work area, should be considered.

FIGURE 16
Portal Crane with Strut Boom and Elevated Cab

b. Transfer Speed. For loading or offloading of cargo or bulk materials the equipment operates in a temporarily fixed location where it must shuttle many lifts between two, more or less, fixed locations. For this and other applications, where fast speed is needed in a transfer-type operation, use of a crane having a fixed boom and a high speed trolley or a luffing crane which has the level luffing feature is indicated.

c. Hoisting Speed. Hoisting speed seldom is a selection factor. Virtually any type of weight-handling equipment can be fitted for a wide range of hoisting speeds.

7. CONSIDERATION OF NEED FOR ABILITY TO TRAVEL WITH LOAD. Not all traveling cranes are equally capable of traveling with the load. Overhead traveling and gantry cranes, traveling portals, traveling hammerheads, and like types are designed to travel with the rated load suspended from the hook. Indeed, this is one of the most valuable characteristics of these types of equipment. On the other hand, truck and crawler (the so-called "mobile") cranes are capable of traveling only with very light suspended loads, and then with the boom well in. One reason is that they are intended to work with outriggers down and the capacity in transit (during which time the outriggers are up) is much reduced. Figures 17 and 18 show comparative capacity-reach charts for a truck crane and crawler crane working with outriggers. Figure 19 is a comparable chart for a locomotive crane. In both cases there is a drastic reduction in capacity with increasing reach.

Several devices have been developed to improve the transit capacity of mobile cranes. One is the use of extensible side frames (Figure 20). Rolling outriggers also have been developed. Either device increases the cost of the equipment and reduces the mobility (see, also, footnotes to Table 2).

8. CONSIDERATION OF COST OF COLLATERAL FACILITIES. The cost of providing weight-handling service to a facility is not the cost of the equipment alone. The cost includes the cost of collateral facilities such as trackage and track foundations, grading and paving, reinforcement of travel paths (and buried structures), runway structures, power supply to the crane, and foundations. The operating and maintenance costs also must be considered. Evaluation is on the basis of comparison of estimated total costs. For example, it is not unusual for the cost of the collateral facilities to be a large fraction of (or even more than) the cost of the crane.

9. CONSIDERATION OF AVAILABLE POWER SUPPLY. (See, also, Section 6, Part 4, paragraph 3.) Some types of weight-handling equipment have a self-contained power supply. Truck, crawler, and locomotive cranes are examples. They are powered by gasoline or diesel engines. Most portal cranes, as utilized at the waterfront, also have self-contained power supplies. They are powered by diesel engine-generators.

Such cranes can operate independent of a central power source and are required where furnishing outside power is impractical (for field work, for example), or where the cost of connection to a central supply (including costs of pick-up and conductors, as well as connection to the source) is excessively expensive.

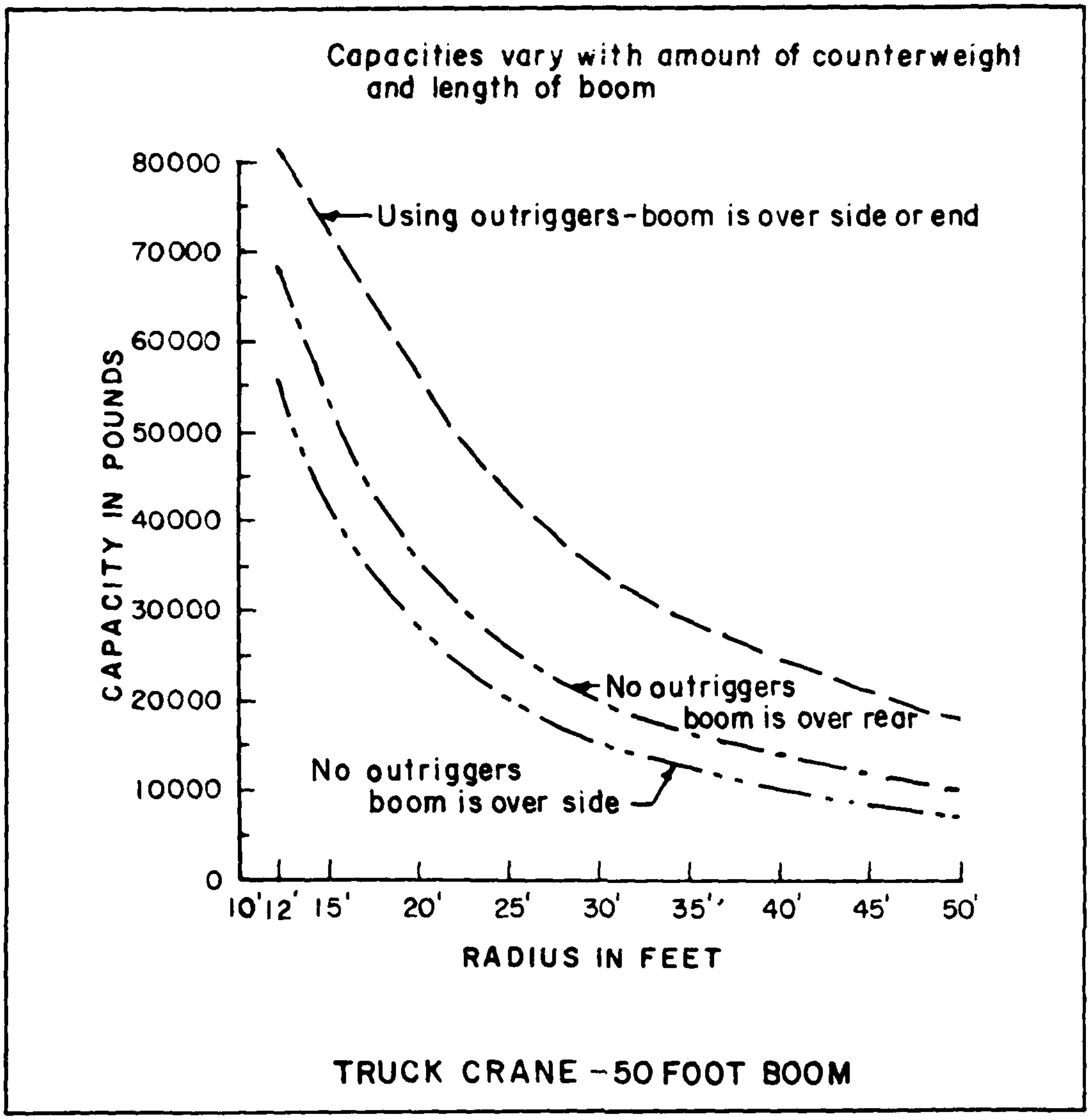


FIGURE 17
Reach-Capacity Chart: Truck Crane

Such types of equipment also find favor where they must work out-of-doors, because of problems with preventing accidental contact with the conductor (unless the conductors are set on an overhead structure) and in maintaining the conductor, particularly in a climate where there is much snow. However, experience seems to indicate that these problems may not be so serious as first appears. Power supply via a third rail is being used more frequently in modern practice, and should be thoroughly investigated. (See Figures 21, 22 and 23.)

Indoors, overhead traveling cranes find favor because a source of power is readily available and the conductors need not be protected from the elements.

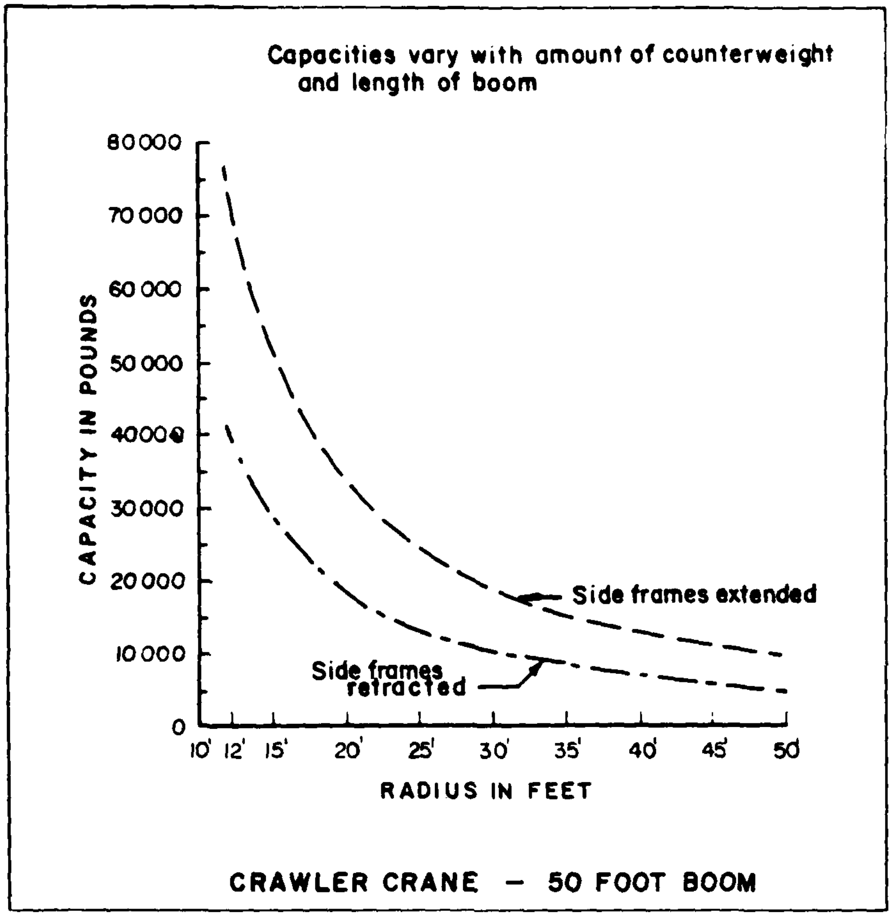


FIGURE 18
Reach-Capacity Chart: Crawler Crane

10. OTHER FACTORS. Paragraphs 2 to 9 provide the basis for selecting the basic type of equipment (rotating or non-rotating crane, fixed or traveling), i.e., within the basic divisions shown in Figure 1, and cover certain other general selection factors. Detailed selection within the subdivisions of Figure 1 involves consideration of additional factors such as the availability of supports for the equipment (the logically related use of overhead traveling and wall cranes in the interiors of buildings has been noted), safety, operating costs, mobility, and factors related to specific applications, all as set forth in Part 2. In particular, Part 2 contains several references to different features which improve the fineness of control (increased accuracy in spotting the load). An evaluation must be made of the value of this capability. This value is a matter of considerable debate. One point of view is that great fineness in spotting the load is not required. The final setting is accomplished by grabbing the load with chain falls, etc., and positioning in that manner. The other point of view is, of course, the opposite. The issue remains a matter of judgment. For some types of operation (assembling of prefabricated sections of a ship, for example) precision spotting of the load is a valuable asset. For other cases (handling cargo, for example) accuracy is not required.

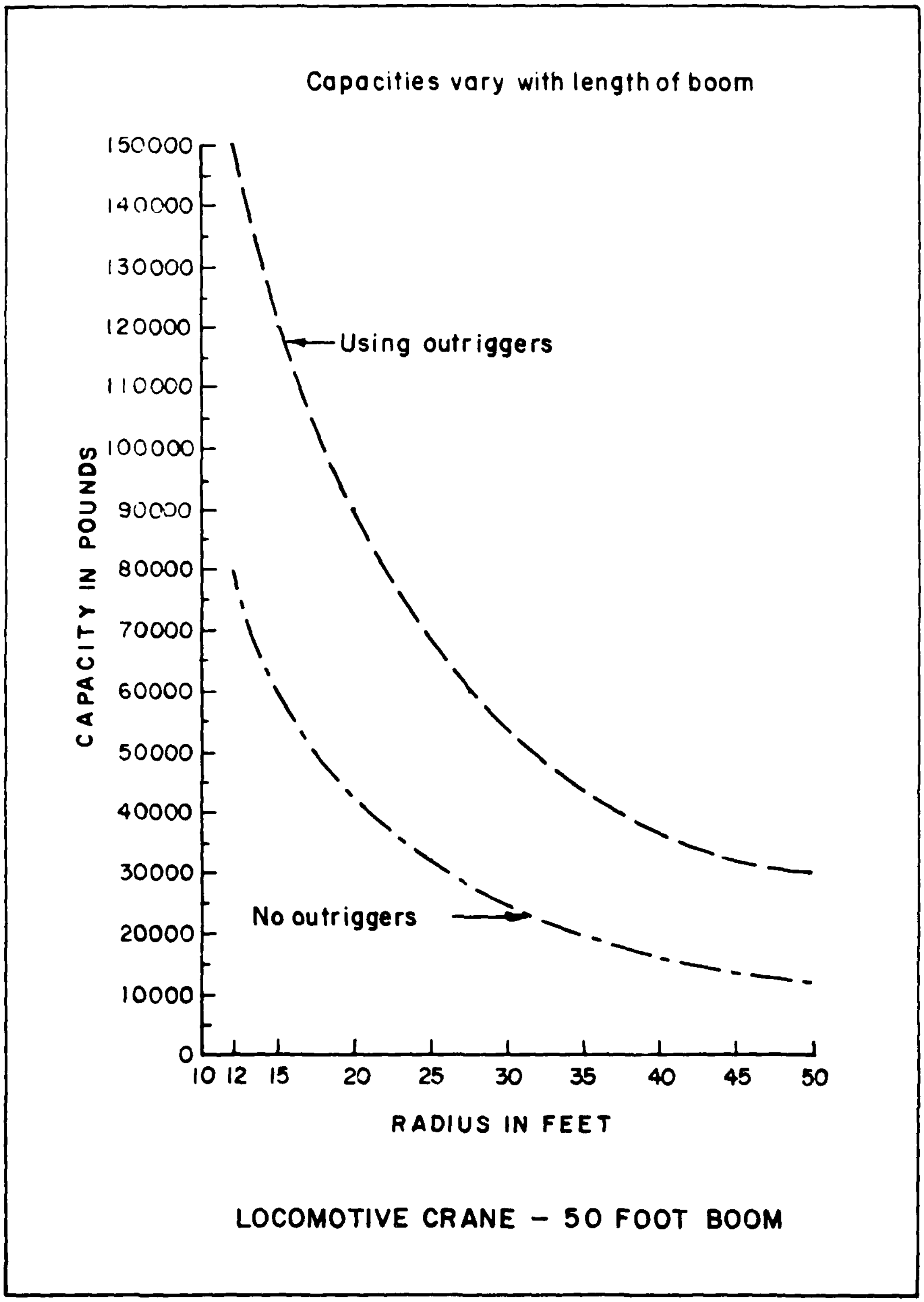


FIGURE 19
Reach-Capacity Chart: Locomotive Crane

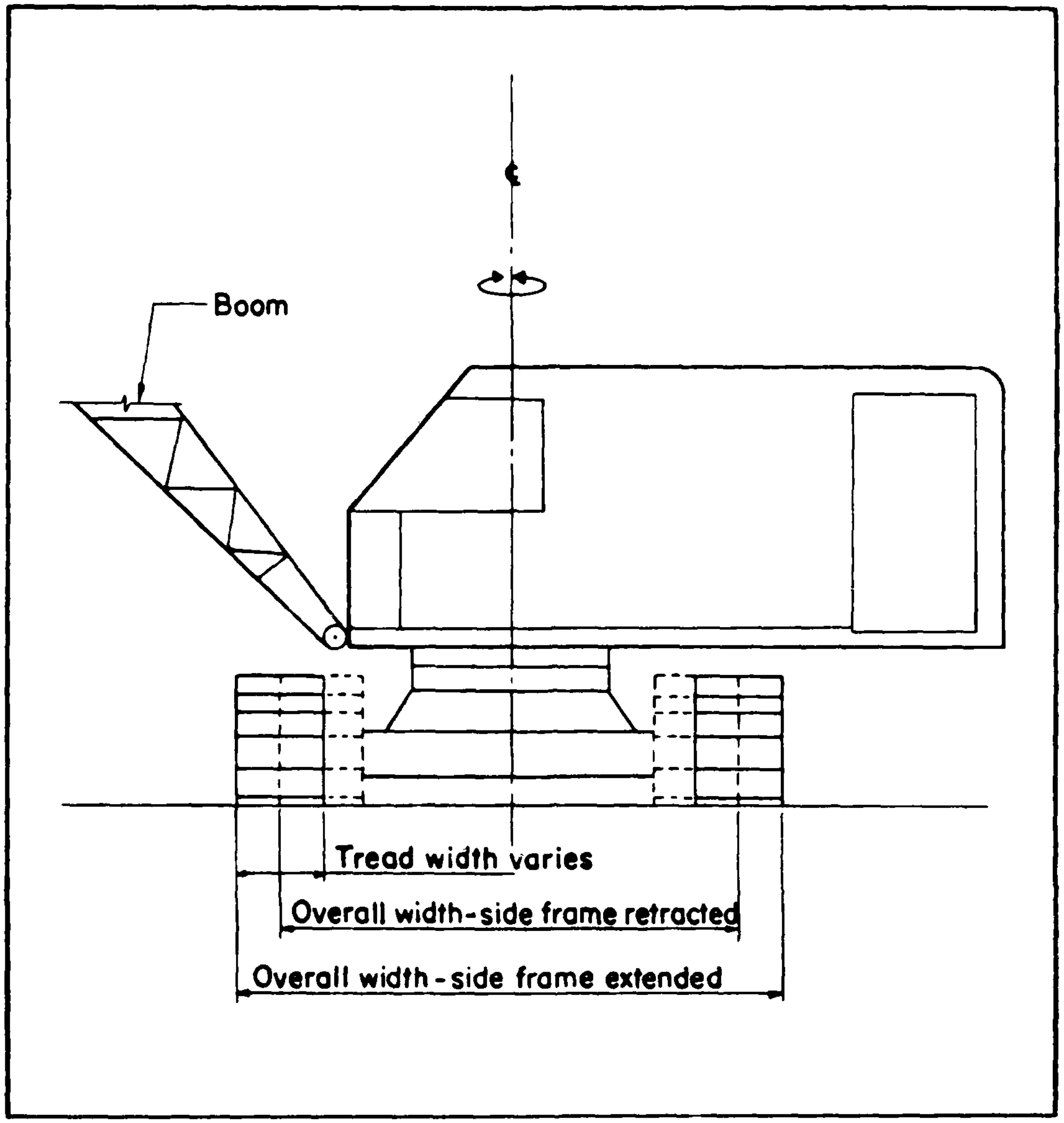


FIGURE 20
Crawler Crane--Extensible Side Frames

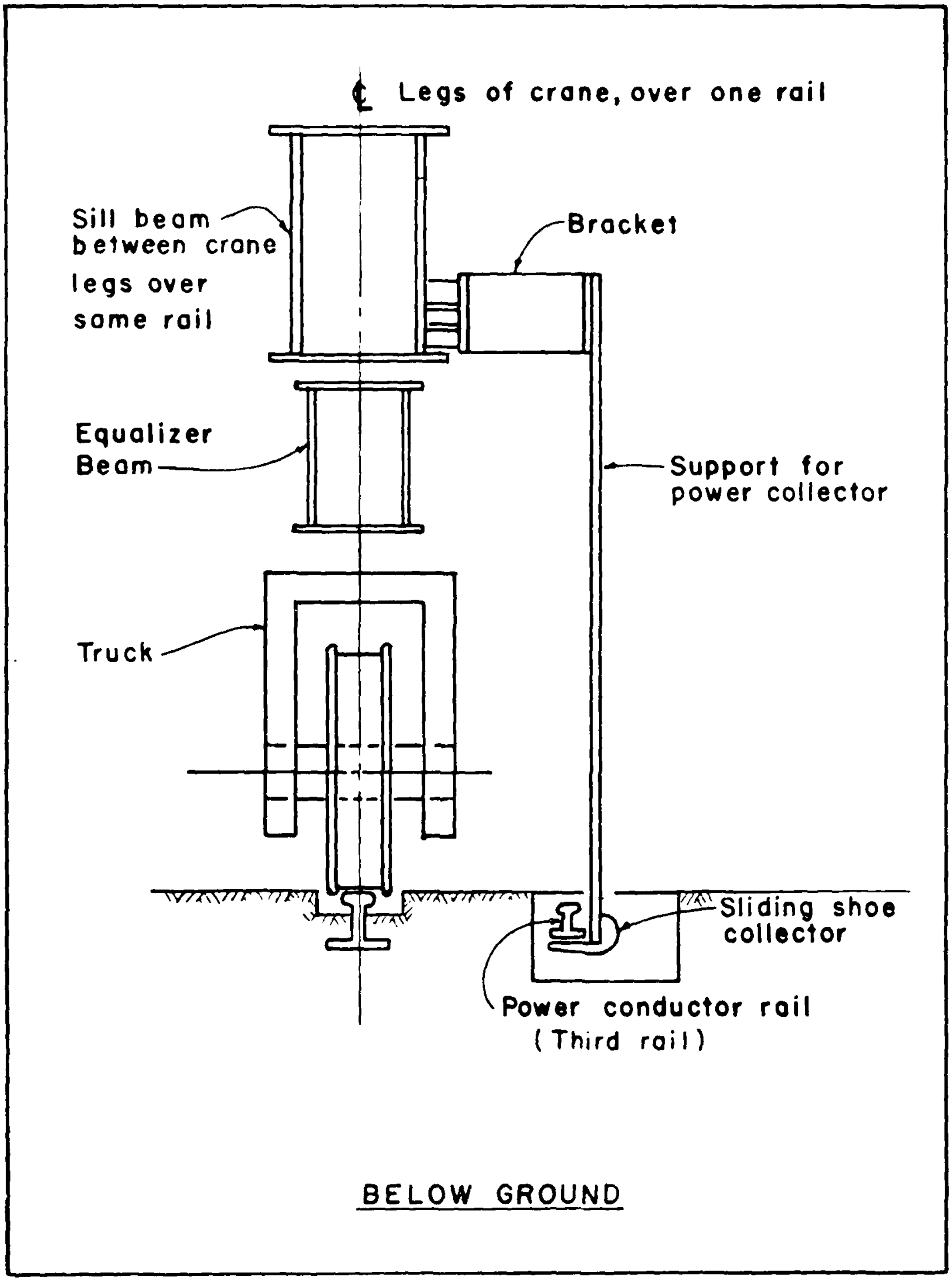


FIGURE 21
Power Conductor--Third Rail (Below Ground)

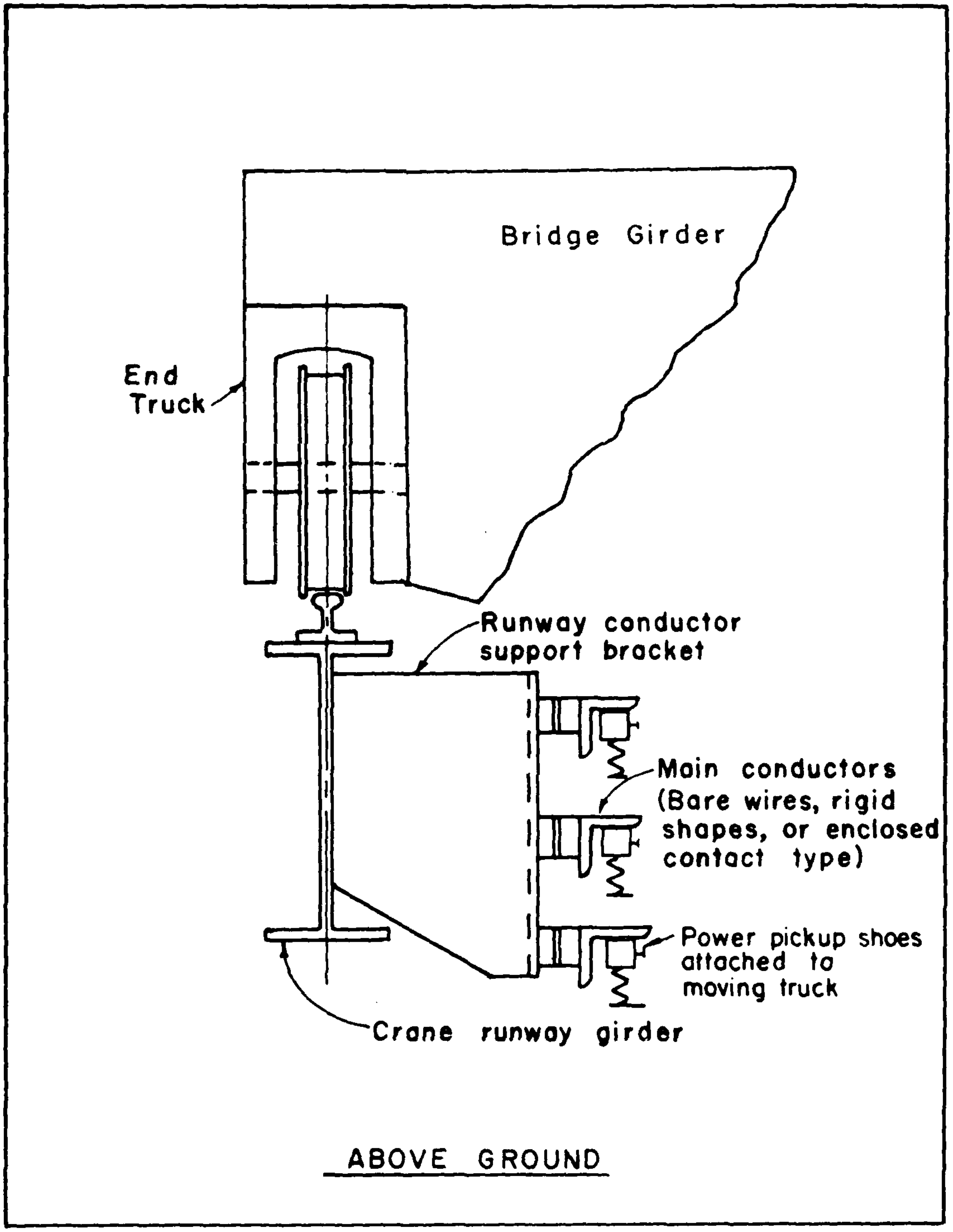


FIGURE 22
Power Conductor--Third Rail (Above Ground)

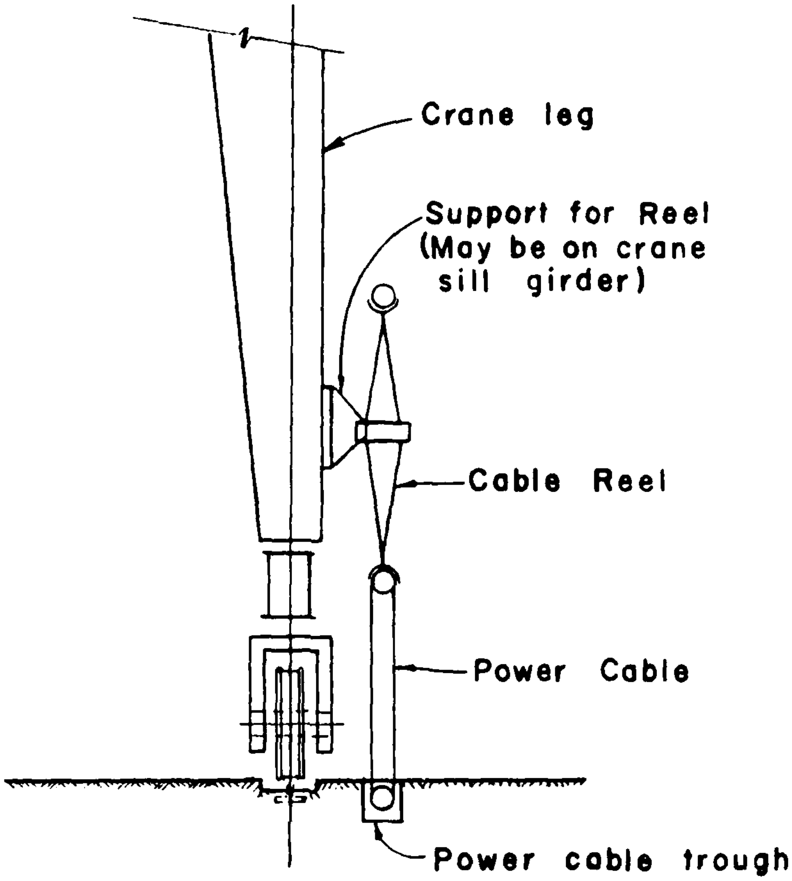


FIGURE 23
Power Conductor--Cable and Reel

Part 2. OPERATING FEATURES AND ACCESSORIES

The several types of equipment described in the previous Sections can be procured with numerous features and accessories, as follows: the requesting activity should review the need for such features and indicate those required for the proposed application. The requesting agency also may indicate a choice of type of mechanism (luffing, slewing, controls, etc.) where some particular type is especially desired.

1. PORTAL. Any tower crane can be designed with a portal (see Figure 7C and 7D). The function of the portal is to provide for passage of traffic (pedestrians and vehicles) under the crane, or for passage of the crane over stored

materials or obstructions (buildings, etc.). However, provision of the portal is likely to increase the cost of the tower because the framing is less efficient than bracing down to the ground (or the trucks). Therefore, a portal should not be specified unless there is a functional advantage to it.

2. HOOK CAPACITY RATING.

a. Rotating Cranes and Derricks. The capacity of a rotating crane (and of many derricks) is governed by three basic considerations: (1) the capacity of the hoist unit; (2) stresses in the structure, rigging, and the machinery; and (3) stability.

The power of the hoist operating a load block is a fixed quantity giving a constant hook capacity rating, independent of reach. However, the stability factor (factor of safety against overturning), and to a lesser extent, the stresses in different components is not a constant, but varies with the reach (i.e., angle of boom or position of the trolley) so that the hook capacity rating (as governed by stability) decreases as the reach increases. These facts give rise to two different types of capacity rating for rotating cranes, the so-called straight-line and variable capacity ratings.

(1) In the straight-line rating, the structure and equipment is proportioned for the desired capacity at maximum reach, the hoist is powered for this capacity, and the rigging and engine power similarly proportioned. The structure of the machine could support a greater hook load at lesser reach, but this heavier load cannot be lifted because of the limited power of the hoist and the limited capacity of the rope. The straight-line rating results in reduced first cost for the machine and should be adopted where maximum capacity is required at maximum reach. The straight-line rating also provides for a safer machine, because inadvertent overloads due to misjudgment of reach or load are minimized.

(2) In the variable capacity rating, the machine is designed to lift increasingly heavier loads at lesser reaches, i.e., the capacity at long reach controls the design for stability (and certain other considerations), but the hoists, rigging, and the power supply are proportioned to provide for heavier lifts at short radius. This type of rating is advantageous where it is required to lift heavier loads at lesser radii and lighter loads at maximum reach. It has the disadvantage that overturning by operator misjudgment is an increased possibility.

Caution: Locomotive, crawler, and truck cranes and some portal, tower, and floating cranes are designed for a variable capacity rating. Conventionally truck, crawler, and locomotive cranes are rated at a standard 10 to 12 foot (3.05 to 3.65 meter) reach. Usually, the capacity falls off drastically with increased radius (see Figures 17, 18, 19, and 24). It is important that the rating at the desired operating reach be specified for procurement. Also, some larger machines cannot operate at the standard 10 to 12 foot (3.05 to 3.65 meter) reach rating so that the manufacturer's rated capacity may be a normal designation only. Also, different types of equipment, conventionally, are proportioned for different safety factors. Refer to Section 6, Part 1 and note that locomotive and mobile cranes usually are proportioned for lesser safety factors than are other types of weight-handling equipment.

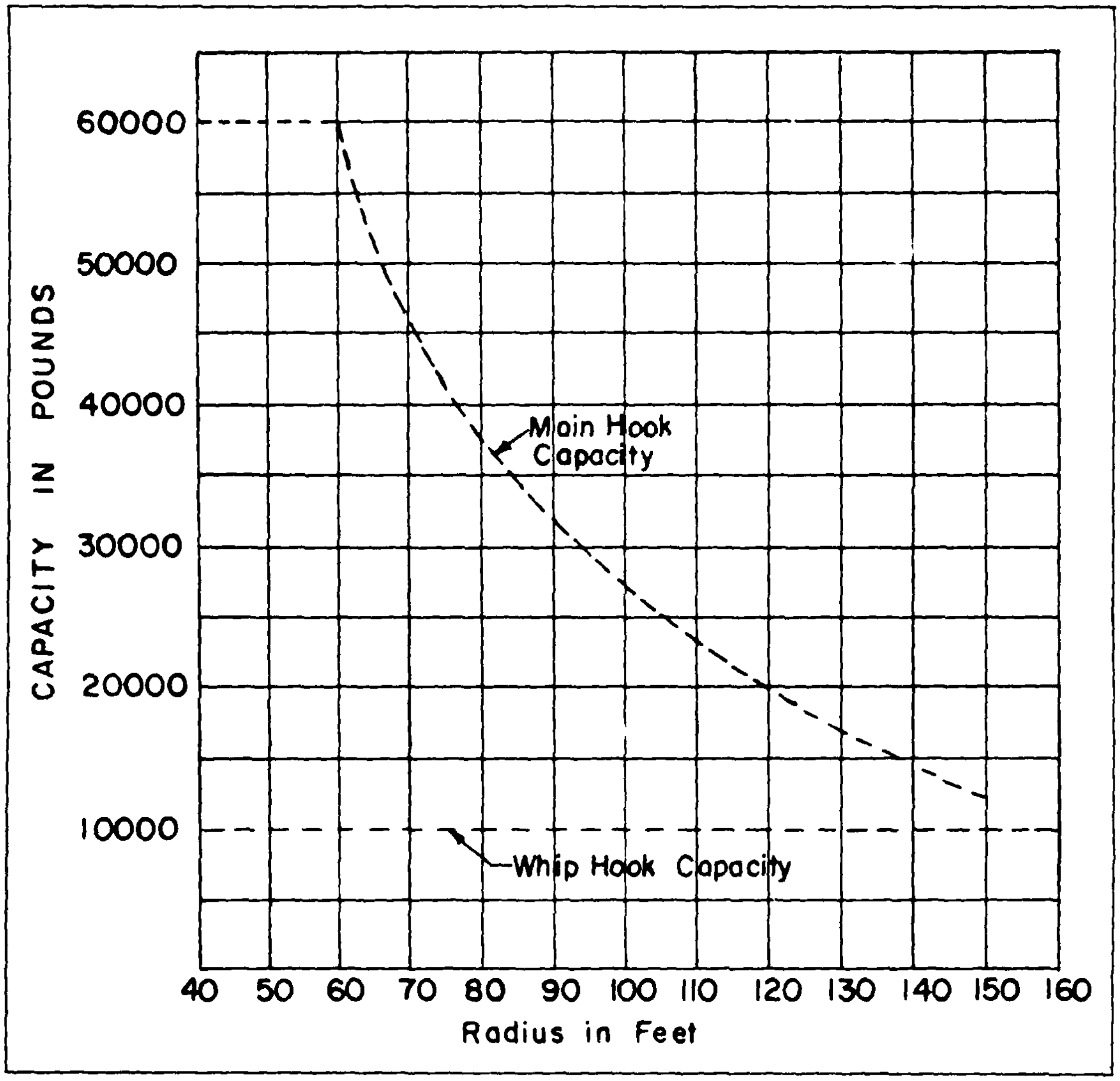


FIGURE 24
Typical Reach-Capacity Chart for Variable-Capacity Portal Crane

b. Non-Rotating Cranes and Derricks. Non-rotating (overhead traveling and gantry) cranes normally are designed to lift the full rated load at any location in the span and will be so furnished unless the requesting agency indicates some special requirement.

3. GOOSENECK BOOM. (Figures 25 and 26.) This device may be specified where a straight boom would result in unacceptable interference, either with a wide load, close-in (Figure 25) or with some obstruction (Figure 26). However, for the same length of boom, whereas the reach is increased, the lift is reduced. Therefore, where a close-in obstruction is the problem, an alternate, and often better, solution is to raise the boom hinge pins (Figures 27 and 28).

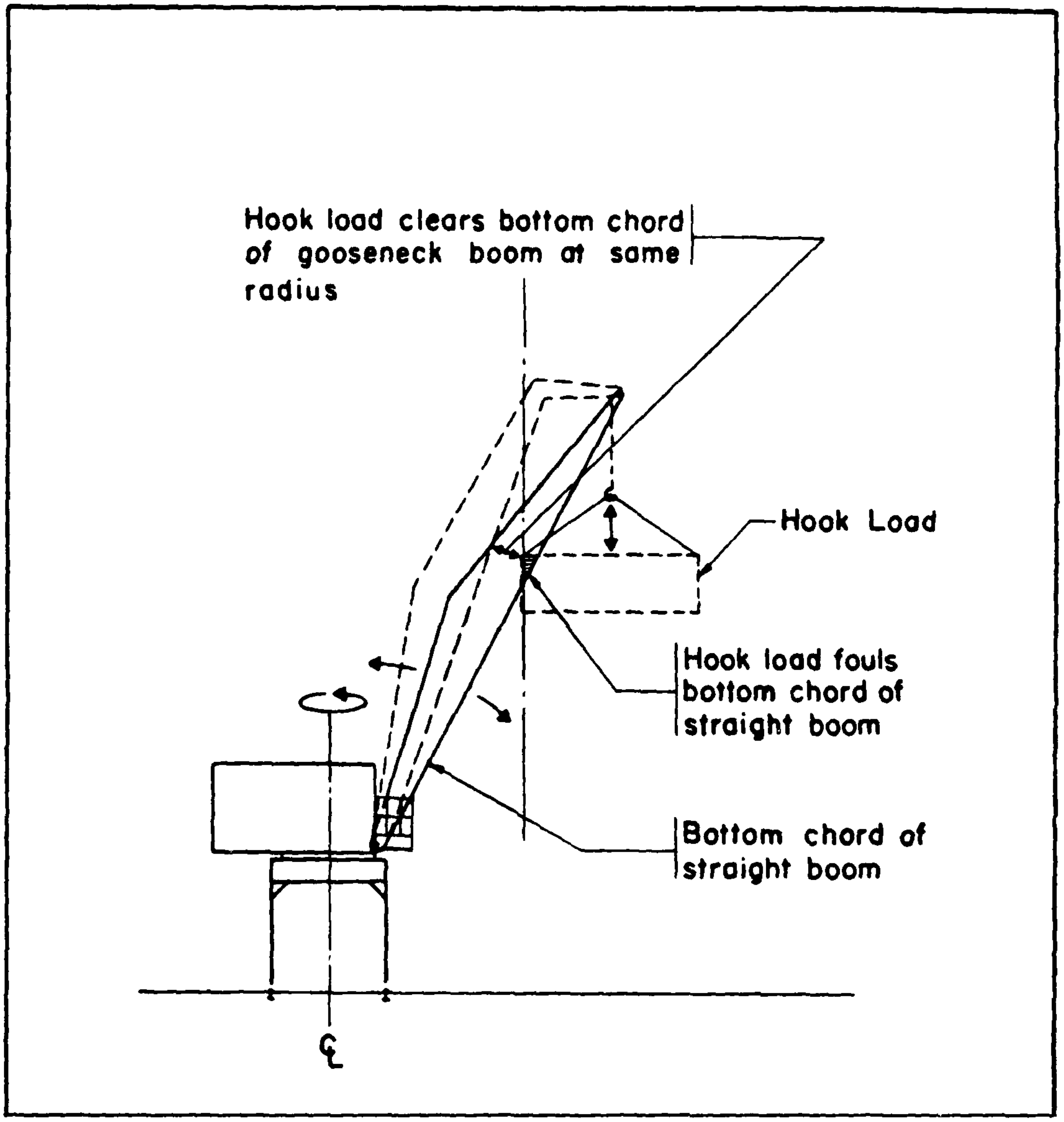


FIGURE 25
Advantage of Gooseneck Boom when Handling Wide Load

4. OPERATOR'S CAB. The operator's cab can be provided with a wide range of features and creature comforts, including the following:

a. Visibility. Good operator visibility is essential and, within reason, is worth additional cost.

In an overhead traveling or gantry crane, the cab normally is positioned to provide full view of the area of coverage and no problem exists.

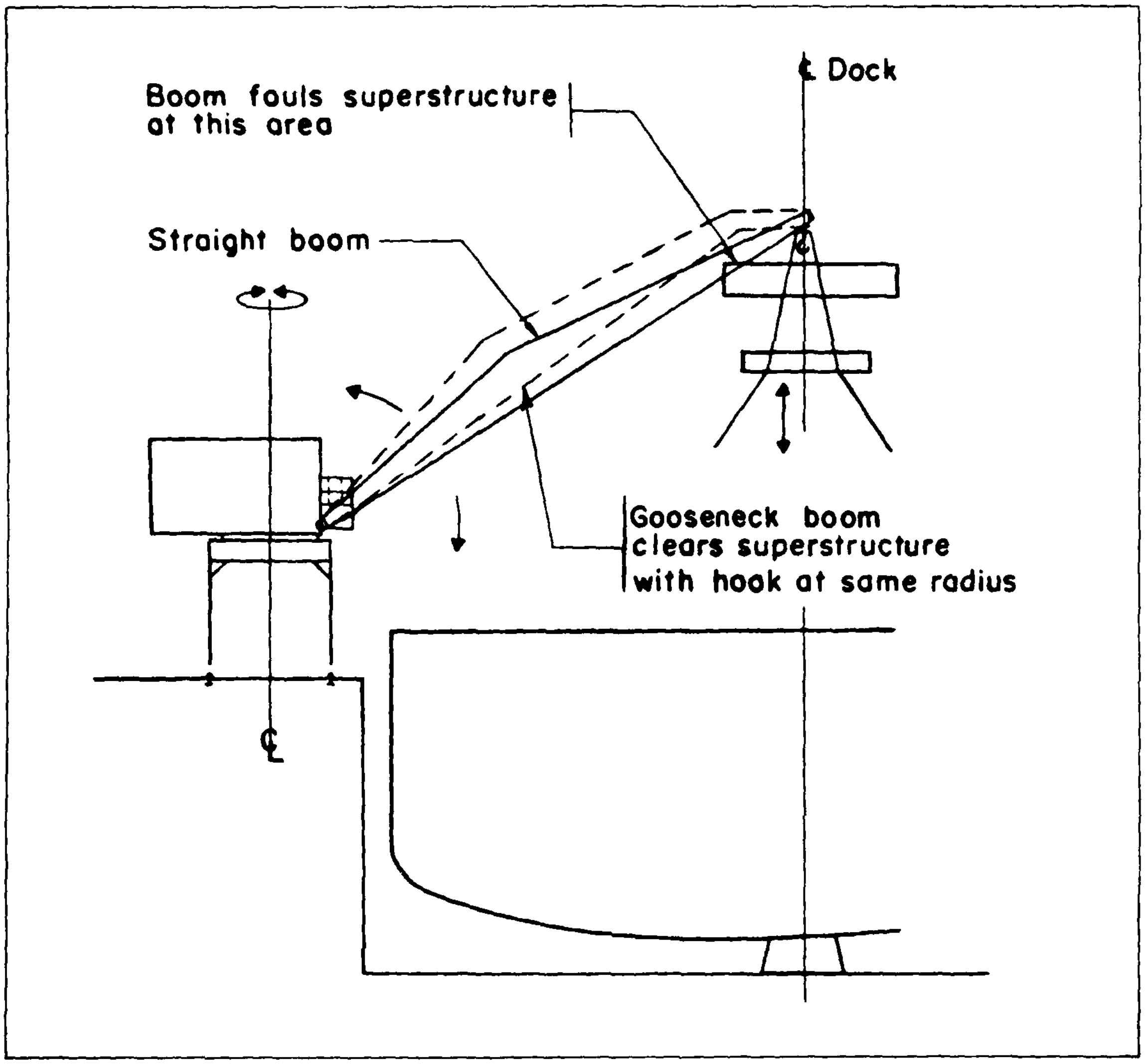


FIGURE 26
Advantage of Gooseneck Boom in Clearing Obstructions

However, in a rotating crane, the view from the cab often is partially obstructed because the level of the cab is not above the level of the work. Consideration should be given to raising the cab as high as practical, even if this means an elevated extension above the machinery house (Figure 28). It is not necessary that the operator be able to run back into the machinery house. Overspeed trips, remote sensing fire extinguishing apparatus, and similar devices are available to handle crises in the machinery room and should be indicated if a remote operator's cab is stipulated and if provision of an individual, more or less full-time, in the engine room is not anticipated.

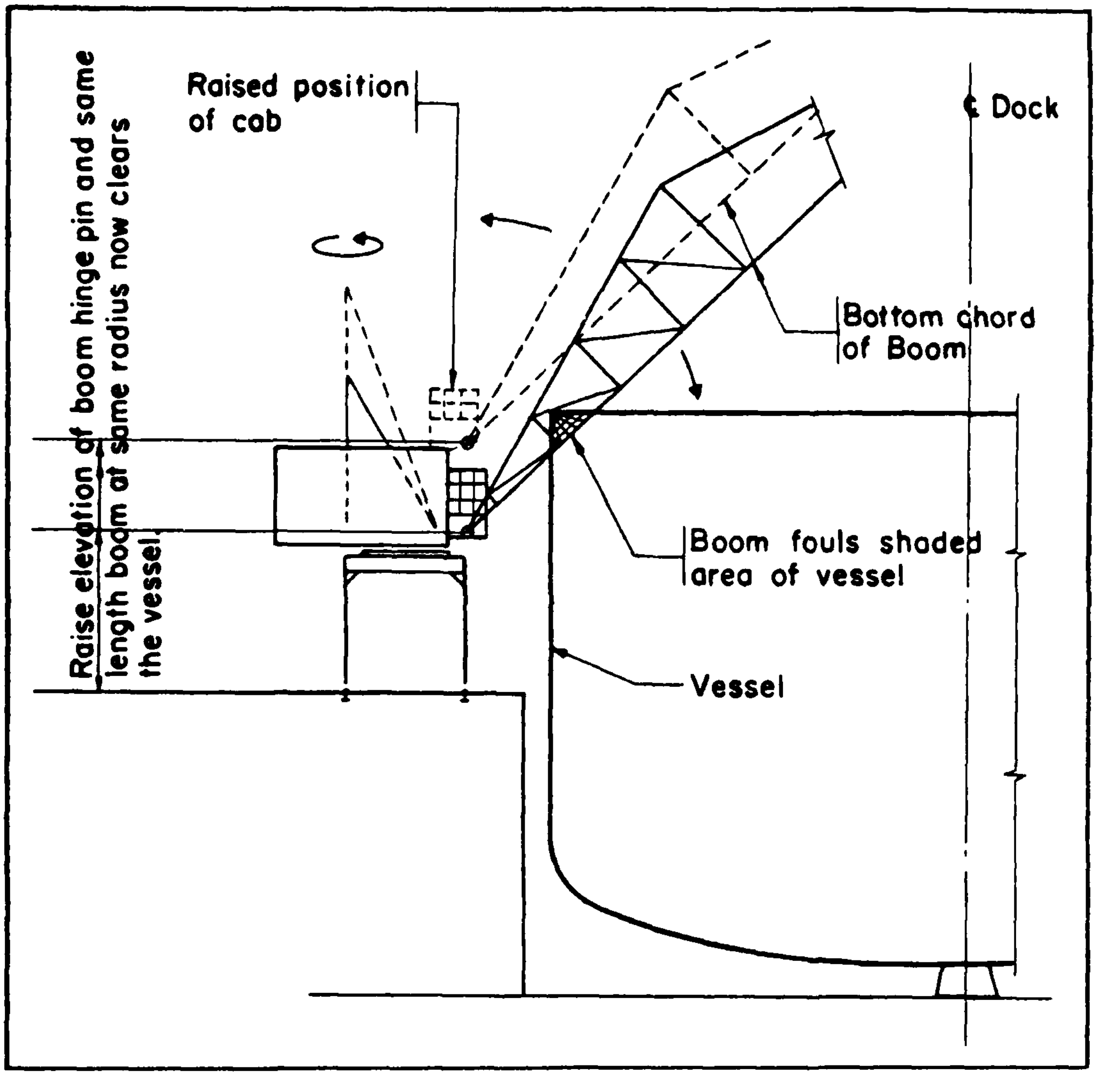


FIGURE 27
Advantage of Elevated Boom Hinge in Clearing Obstructions

b. Emergency Egress. Two means of egress should be provided to allow for contingencies such as a fire in the machinery house. This applies to overhead traveling cranes (consider possibilities of electrical fire on crane, fumes, or fire in building), as well as to rotating machines. Means of egress include:

(1) Overhead Traveling Crane:

(a) Ladder to walkway.

(b) Knotted life line (with or without exit via trap door).

(2) Rotating Machines:

(a) Ladders down opposite legs of tower or other support.

(b) Knotted life line.

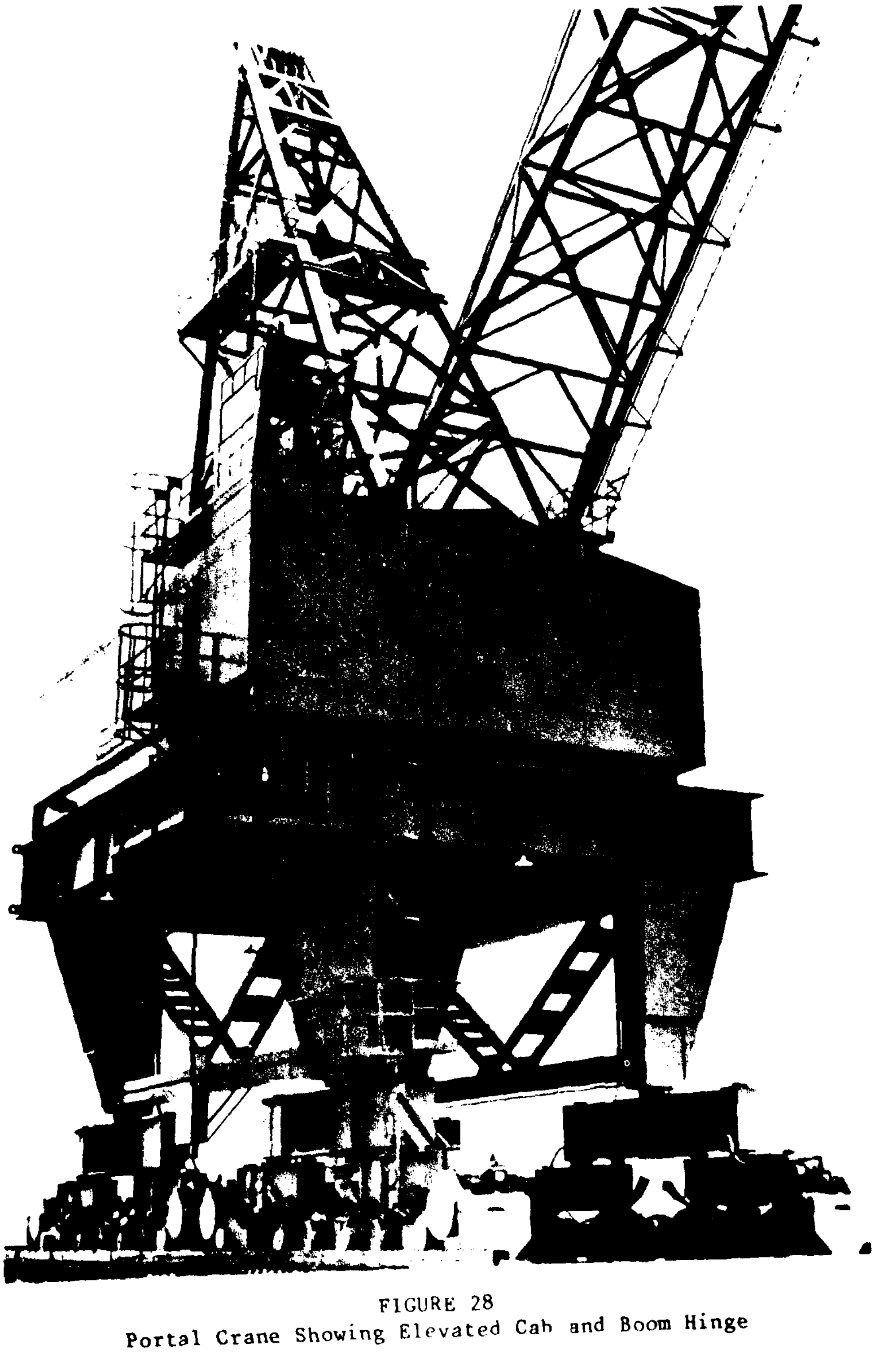


FIGURE 28
Portal Crane Showing Elevated Cab and Boom Hinge

c. Heating, Ventilating, and Air Conditioning. Specify geographic location and desired interior temperature.

d. Sunshade. An overhang to the roof of the operator's cab may be stipulated. Use of tinted glass may be considered. Where night work will be common, provision of shades may be preferable to use of tinted glass.

e. Elevator. (Figure 29.) Requirement subjective, but a rudimentary elevator generally desirable where, because of use of fixed equipment or other reason, it is expected that one operator will be required to climb several cranes in the course of a shift.

f. Chemical Toilet. May be specified where it is anticipated that long hours of continuous attendance will be required. However, chemical toilet involves problem of disposal of residue. Propane gas and electric disposal units eliminate this problem and are of proven efficiency and safety.

g. Sample Layouts. (See Figures 30 and 31.)

5. MOTOR CONTROLS. Select category of operation:

(1) Cab (control station located in operator's cab).

(2) Floor (control station hung as pendant below machine).

(3) Remote.

(a) Can operate via radio or wires.

(b) Can be linked to computer for pre-programmed cycle, or cycles of operation.

6. LEVEL LUFFING. Virtually any luffing crane (or derrick) can be designed for level luffing (see Figures 32 and 33). With the level luffing feature, as the name implies, the load is maintained at a fairly constant height as the boom is luffed (raised or lowered).

The advantages of the level luffing features are: (1) in positioning the load, the horizontal and vertical movements can be achieved independently, i.e., the operator needs to concern himself with only one motion at a time; (2) the luffing hoist need not be so powerful (and can be smaller and less costly) because it does not have to raise the suspended load at the same time it raises the boom; and (3) for a repetitive operation in a fixed position, the crane works rapidly.

a. Positioning the Load. The crane use survey noted in Praeger, Kavanagh & Waterbury Reports, Oct. 1971, showed that, except for certain operations (cargo handling, for example), the operators of traveling cranes do little luffing. They position the load by travel and swing, operating each motion independently. The operation is easy and rapid. It is questionable whether the level luffing feature has a pronounced advantage in a traveling, rotating crane, capable of traveling with the load. For a fixed crane, or one incapable of traveling with the load, the advantage is more significant.

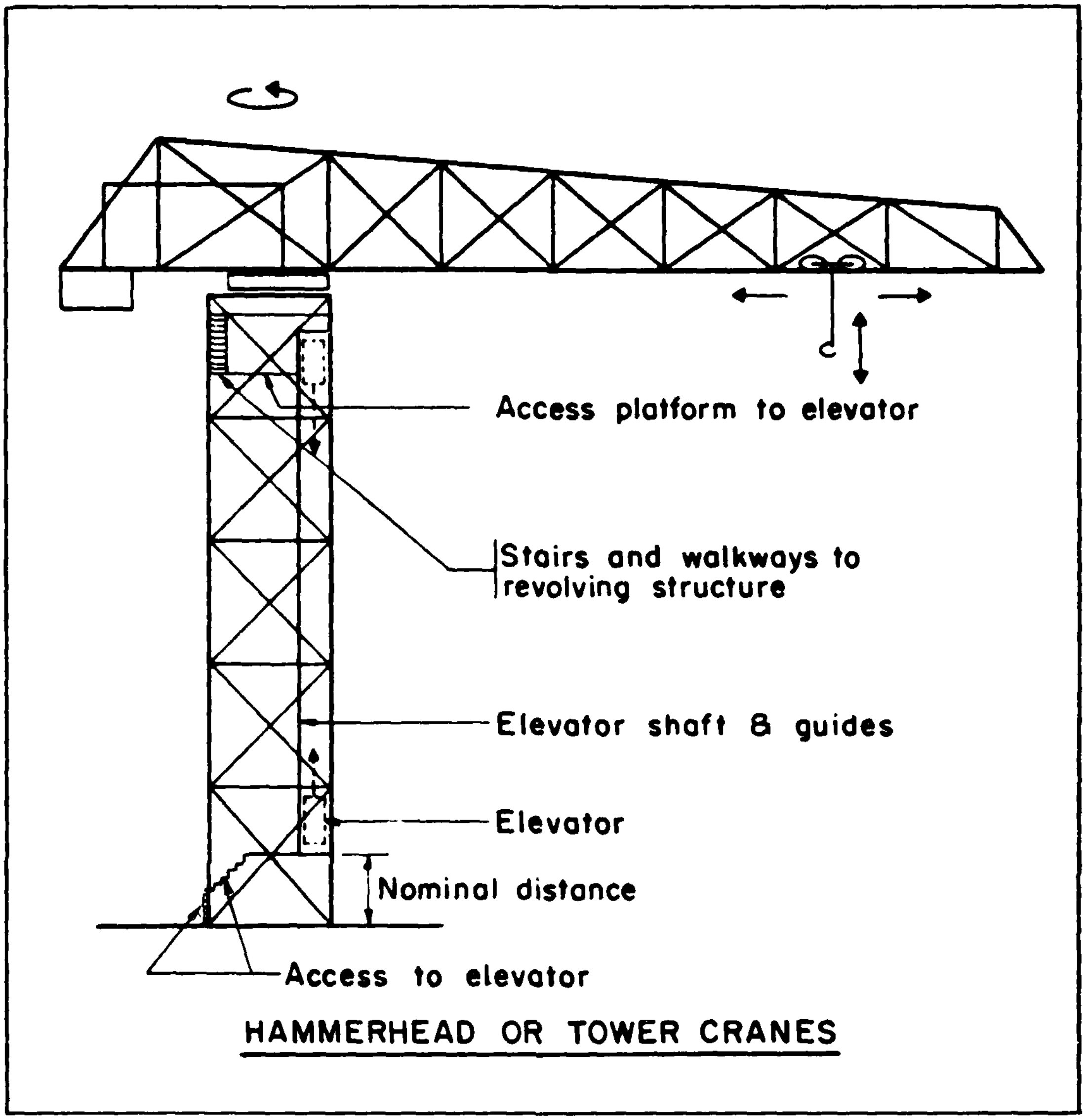


FIGURE 29
Elevator

b. Cost. While the luffing hoist, ropes, and appurtenances can be less costly (for a given capacity and radius) in a level luffing crane than one lacking the feature, the mechanism for accomplishing the level luffing is an added cost. At the present time, the overall result is that, in the United States, the level luffing crane (again, for the same capacity and reach), is more costly.

c. Rapidity of Operation. Cranes having the level luffing feature are well suited for jobs requiring rapid and repetitive load handling, in a fixed position (such as handling cargo and, to a lesser extent, in ship building).

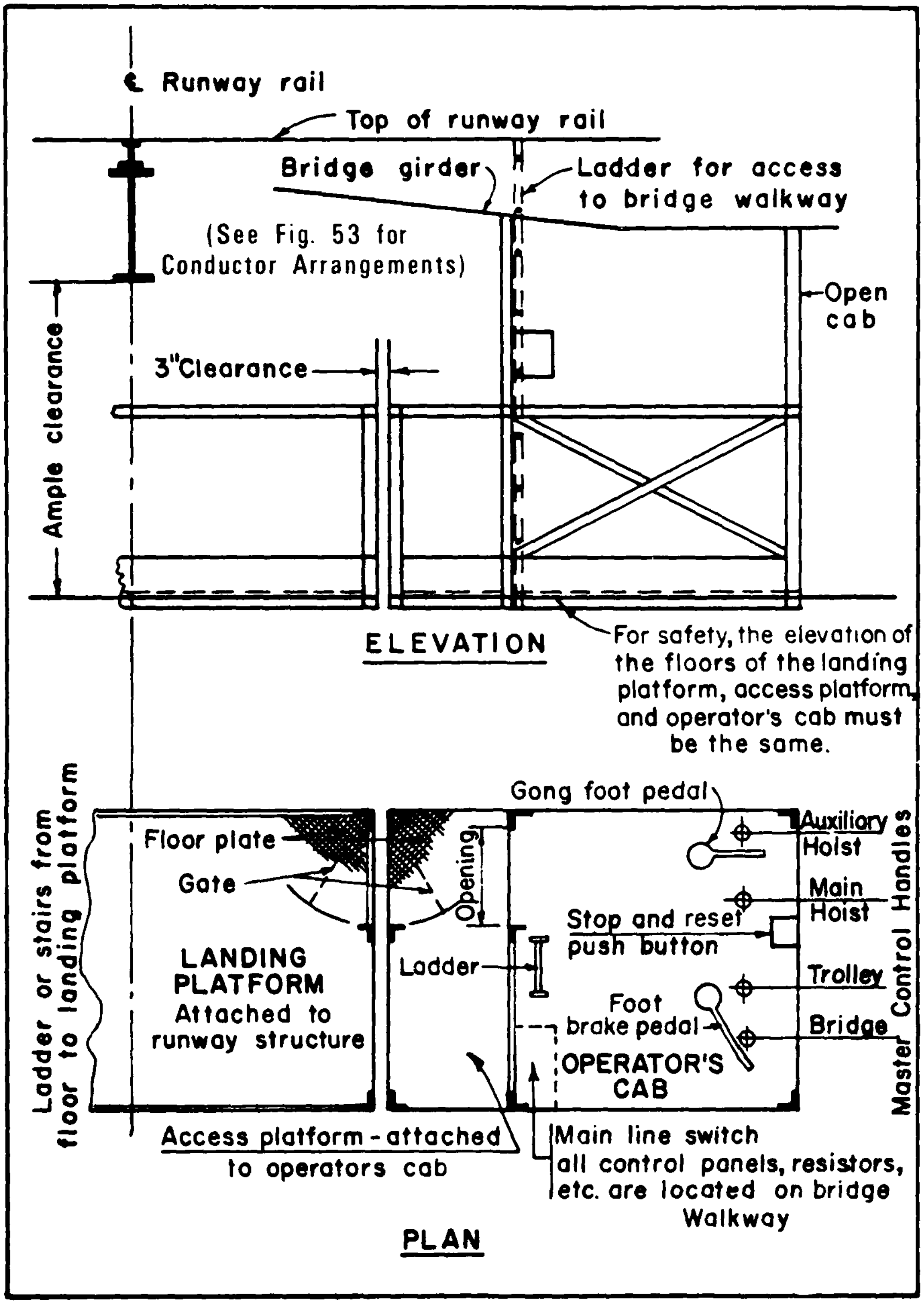


FIGURE 30
Typical Arrangement of OET Crane Operator's Cab

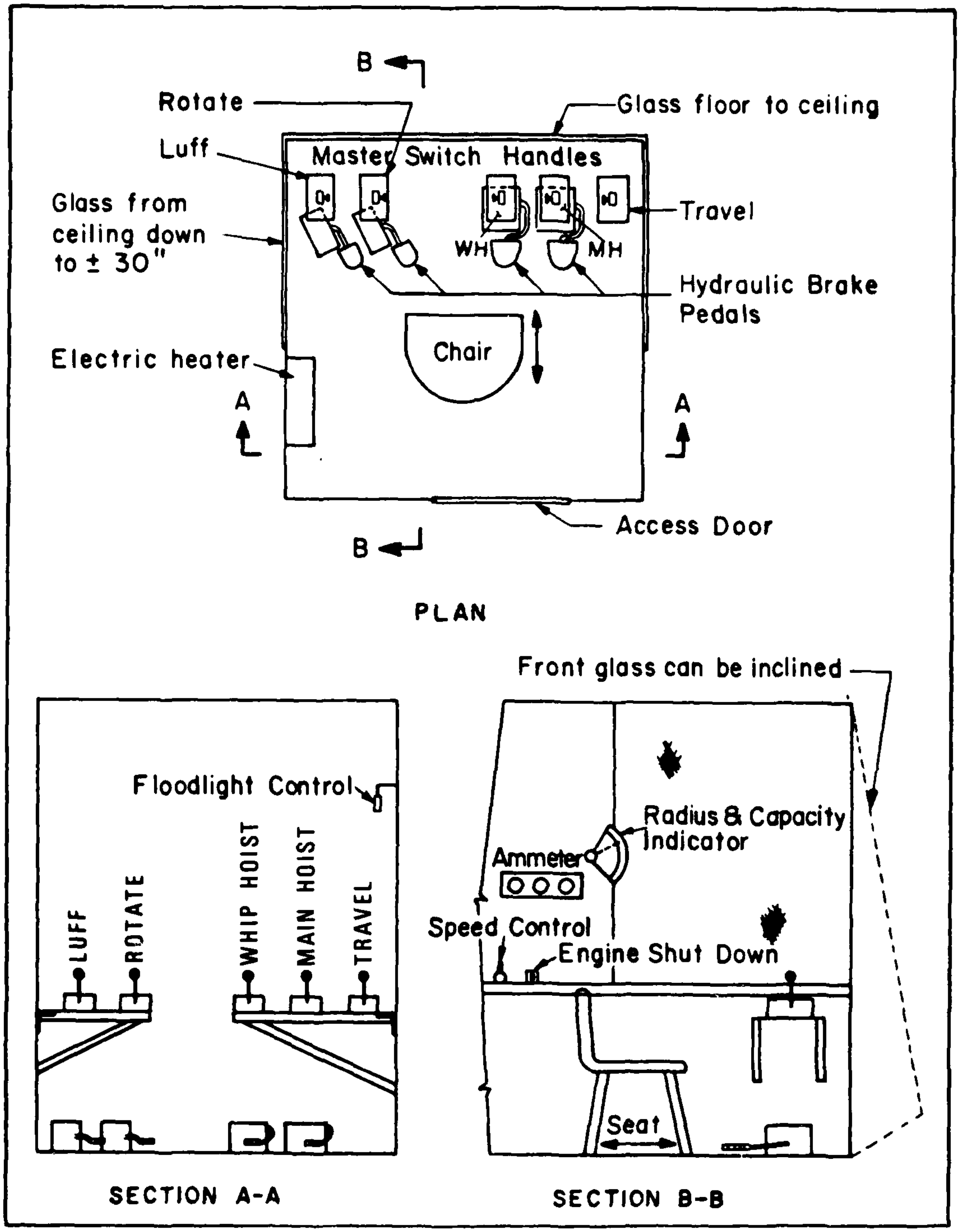


FIGURE 31
Typical Arrangement of Revolving Crane Operator's Cab

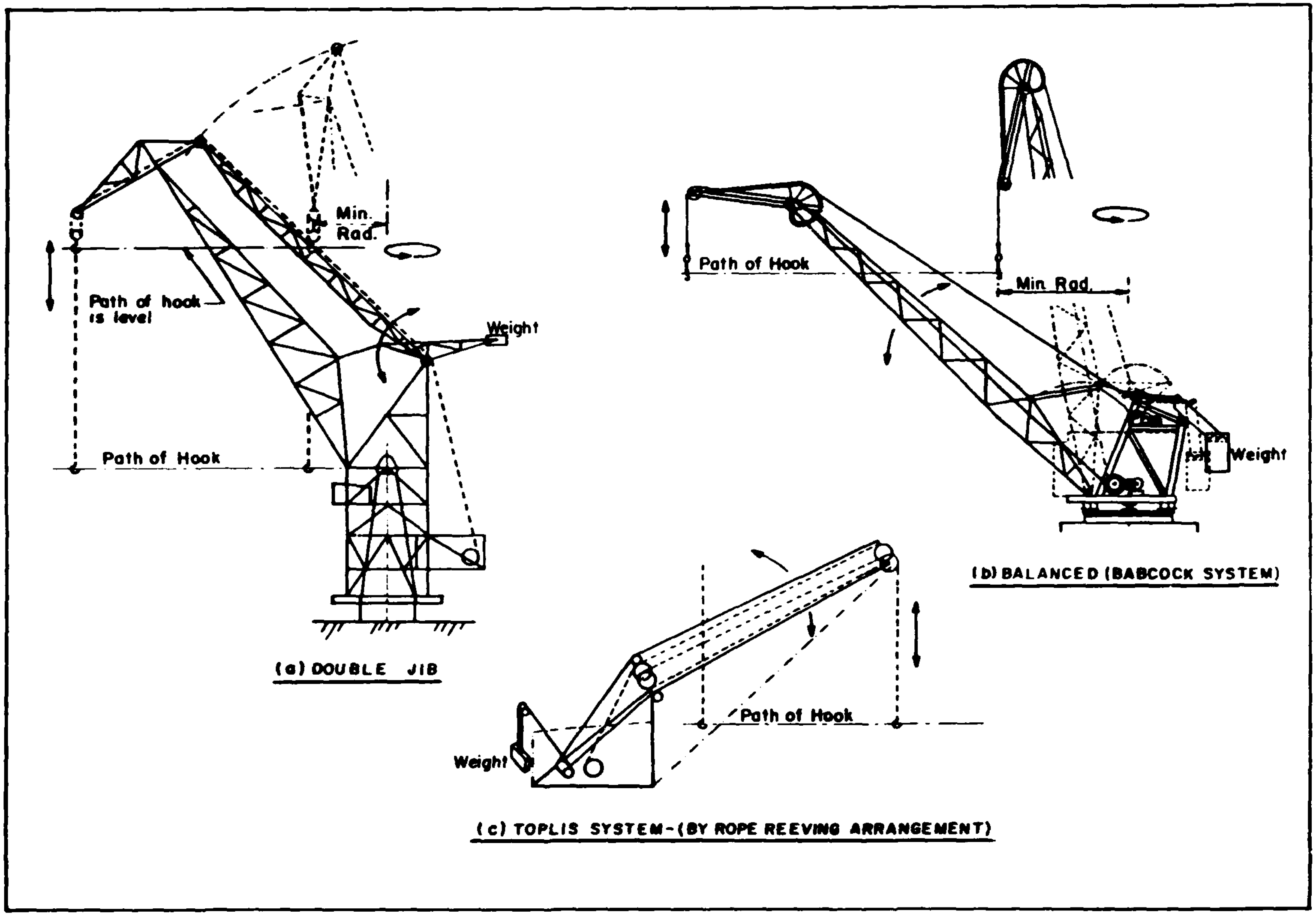


FIGURE 32
Level Luffing

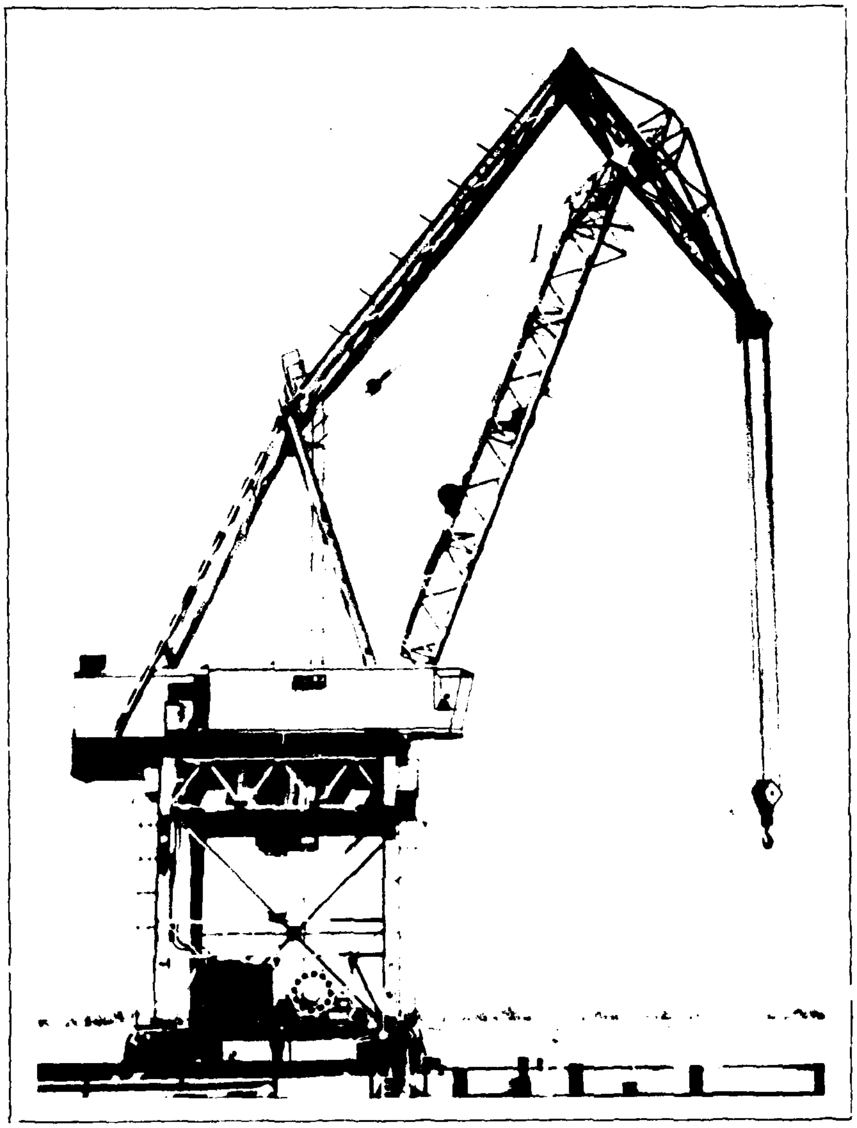


FIGURE 33
Level Luffing Crane

7. HOOKS.

a. Types Available.

(1) Single Barbed Hook (Figure 34).

(2) Double Barbed Hook (Figure 34).

b. Selection Factors.

(1) Single barbed hook for general usage.

(2) Double barbed hook usually for heavy loads (40 tons, or greater).

8. NUMBER OF HOOKS.

a. General. In addition to the main hook (for making full capacity lifts) consider provision of:

(1) Auxiliary hook (multiple part line) for making lifts of intermediate weight, at faster speed and/or;

(2) Whip hook (single part line) for making lifts of light to intermediate weight, at fast speed.

b. Discussion.

(1) More than one hook seldom justified for crane capacities less than 15 tons unless some special circumstance (turning load, for example) prevails. Three hooks rarely justified.

(2) The greater the number of hooks in a single piece of equipment: (a) the less the floor coverage for any one hook (because other hooks interfere); (b) the greater the weight on the boom and on the machine; (c) the more maintenance required; (d) the greater the power requirement; and (e) the more machinery which must be put into the machinery house, cab, or carriage. The extra cost far exceeds the cost of the hook and the hoist. Within limits, it is much less costly to increase hoisting speed by use of proper controls and hoist motor than by providing extra hooks. The number of hooks should be the minimum requirement consistent with the use.

9. BOOM.

a. Telescoping (Hydraulic) Boom. Cranes having telescoping booms are illustrated in Figure 6, and may be selected if the requirements of the work so dictate.

b. Select between (1) Use of Pipe vs. Structural Shapes and (2) Use of Welding vs. Bolting. On occasion, booms are damaged due to hitting an object. This is an occurrence of sufficient frequency to be a consideration in selecting the type of construction. There is little doubt that the repair of welded pipe fabrications is more costly than the repair of fabrications consisting of structural shapes. This relates to the complexities of welding and the need for vapor sealing the pipes. On the other hand, the pipe fabrication often weighs less for the same strength which reduces the overall weight (and cost) of the machine, and is less susceptible to corrosion attack, which results in a lesser maintenance cost.

c. Extensions. Demountable boom extensions (for occasional light lifts at long or high reach) are available (Figures 35 and 36).

d. Special Configurations. Specify as need dictates (see Figure 37, for example).

10. EQUALIZER BEAM. Where the requirement for occasional tandem lifts is anticipated, an equalizer beam (two, three, or four point pickup--see Figures 38 and 39) may be specified.

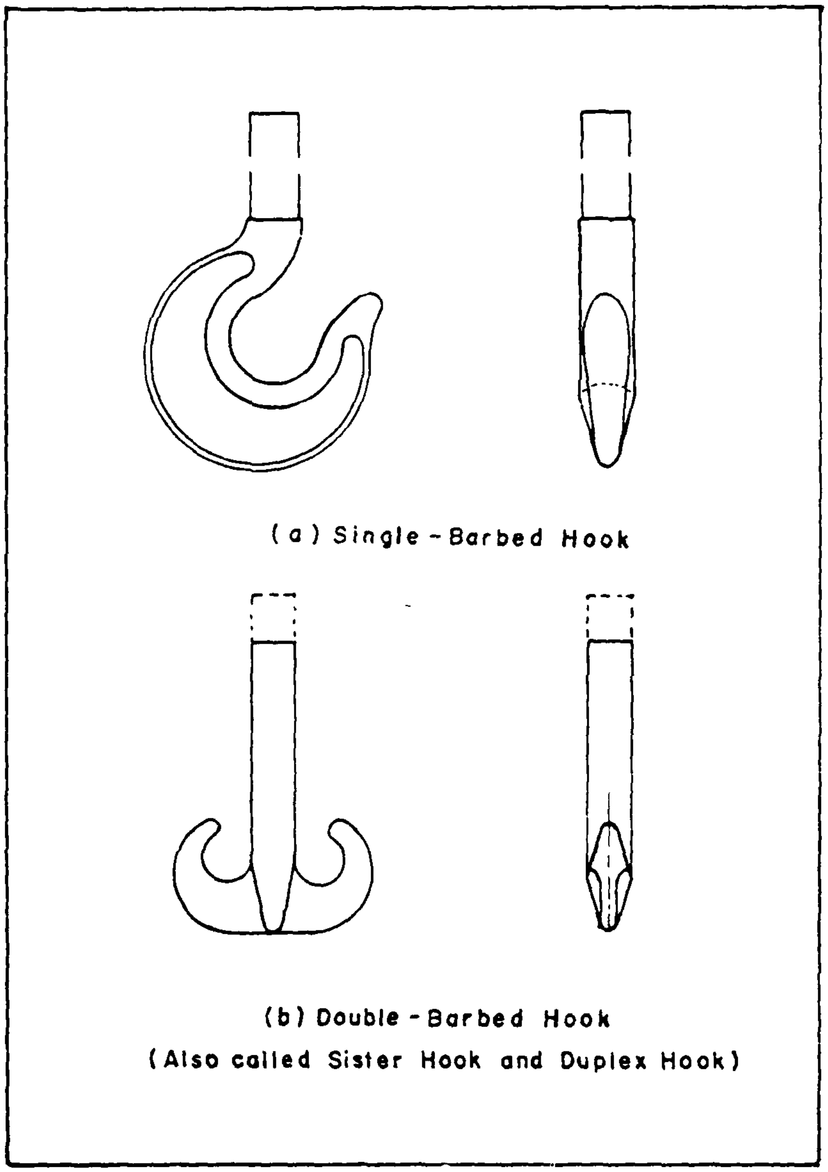


FIGURE 34
Hooks

11. PASSING TROLLEYS. If required, equipment utilizing a trolley for in and out motion of the hook (hammerhead, bridge, gantry) can be fitted to accommodate several trolleys. For overhead traveling cranes, two trolleys can be arranged to pass each other (see Figure 40).

12. HOOK BLOCK. Attention is directed to the requirement for disassembly of the hook from the block to permit non-destructive testing of the hook. The hook block (and blocks and sheave assemblies, in general) should be detailed with this in mind.

13. SELF-PROPULSION. (Floating Cranes.) Floating equipment can be towed or self-propelled. The relative economics should be carefully studied, considering the probable frequency of use and movement, the availability of tugs, cost of additional engine room personnel, and costs of fueling and maintenance.

14. CREWS' QUARTERS. For floating cranes, the need and economics of crews' quarters should be evaluated based on frequency of need and means of access to work in remote locations.

15. SIGNAL, COMMUNICATION, AND SAFETY DEVICES. Where required, equipment can be provided with the following types of devices:

a. Telephone Communication from Operator to Station at Ground Level. Where the work may involve a delicate, or complex, series of steps or movements, provision of this relatively inexpensive device should be considered.

b. Radio Communication to Operator.

c. Audible Warning Devices.

(1) For traveling portal, tower, or gantry cranes some form of audible warning normally will be provided at ground level to clear the travel path. Similarly, truck or locomotive cranes will be equipped with horns, bells, or other devices. Any special requirements may be indicated, but with the understanding that these devices get continuing usage and must be simple and rugged.

(2) Audible devices also can be provided in the operator's cab to warn of intruders, problems in the machinery room, and many other comparable problems.

d. *Warning Lights*. Where applicable, warning lights may be provided in lieu of audible warning devices.

e. Load Indicators. Some provision should be made to indicate to the operator when the lifting machine is being operated near its safe capacity. Many devices are available for this purpose. For example, for a crane with a boom, a radius-capacity chart can be posted in the operator's cab and a radius indicator (an arm and indicator attached to the boom in a position readily visible to the operator) provided. The operator is advised by whomever may be supervising the lift, of the weight to be lifted and he positions the lifting machine, or the load, so that the allowable radius for that load is not exceeded. Accuracy of load and radius indicating devices are covered by Society of Automotive Engineers (SAE) J159, J375, J376 and J1150.

For a crane without a boom, the rated capacity of each hook is known and should not be less than the load to be lifted.

The trouble with these simple devices, however, is that the load to be lifted often is not known or may be incorrectly evaluated (due to misinformation, forgetting the weight of the container, miscalculation, failing to unfasten the load from its supports, etc.). Therefore, a device for weighing the load, as it is being lifted, is desirable. A number of such devices are available and should be considered a requirement when the crane will handle loads whose weights are estimated and the estimates approach the crane's rated capacity. The best protection against damage remains an alert operator and rigger.

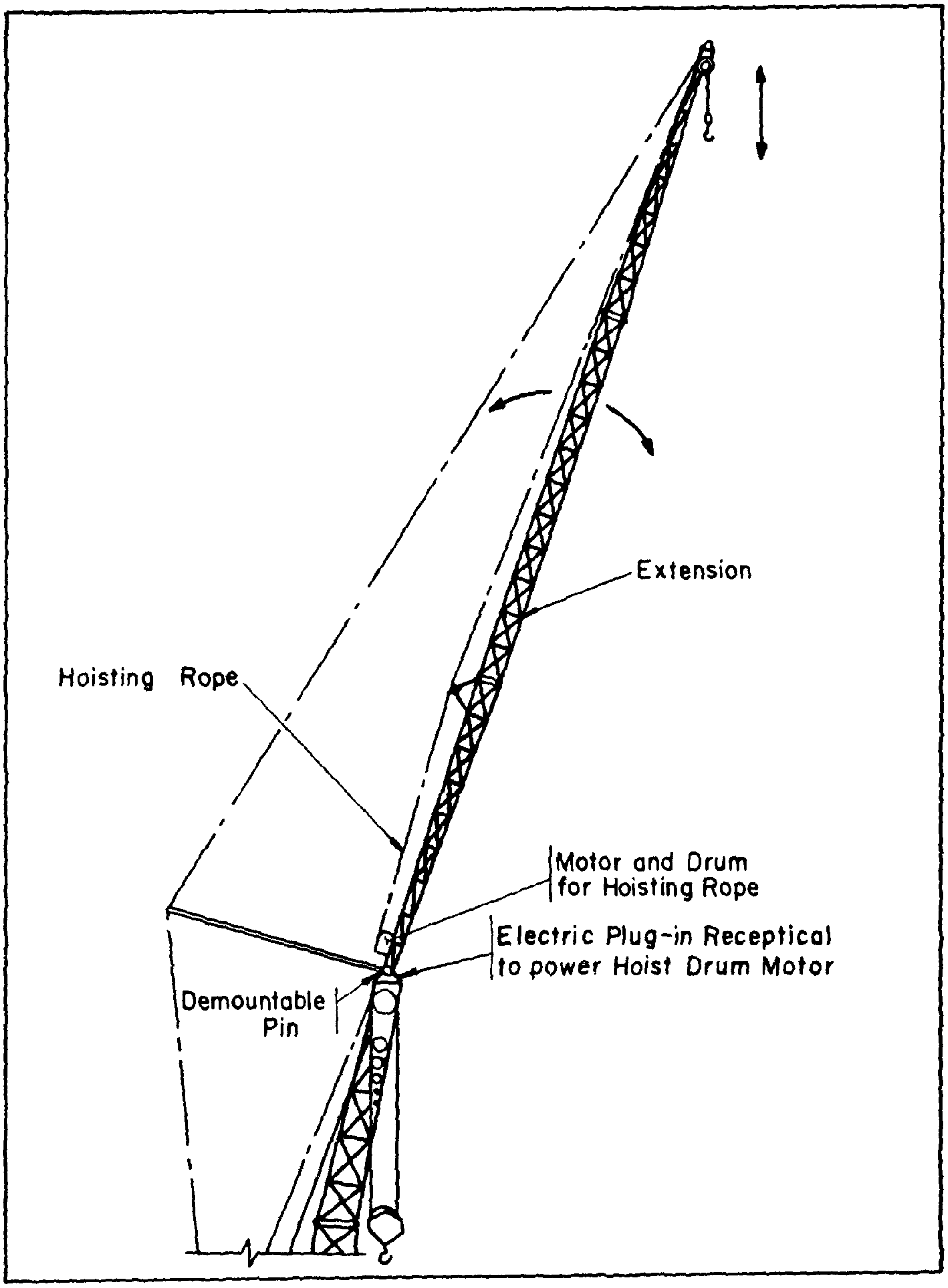


FIGURE 35
Self-Contained, Demountable Boom Extension

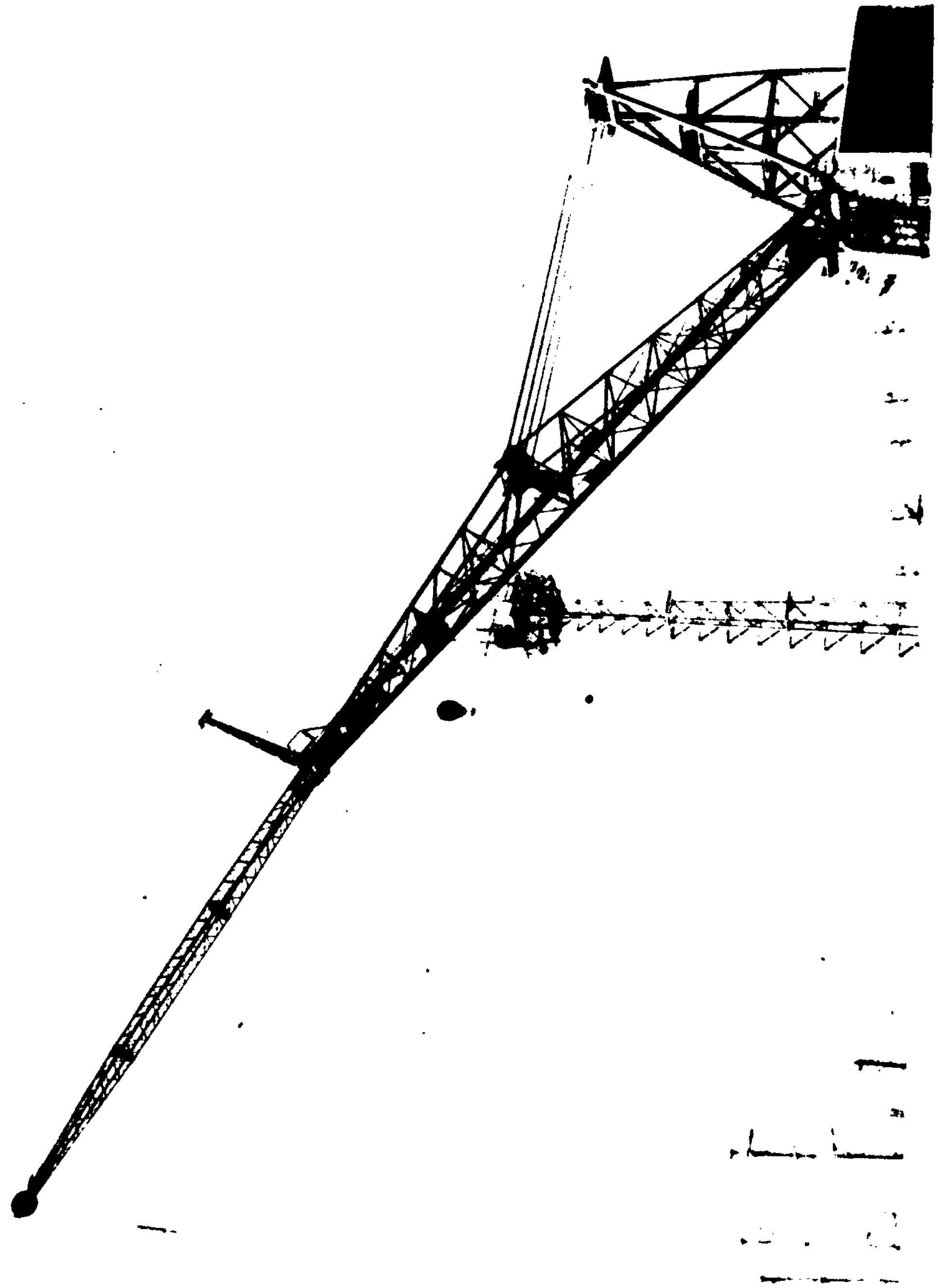


FIGURE 36
Boom Extension on Portal Crane

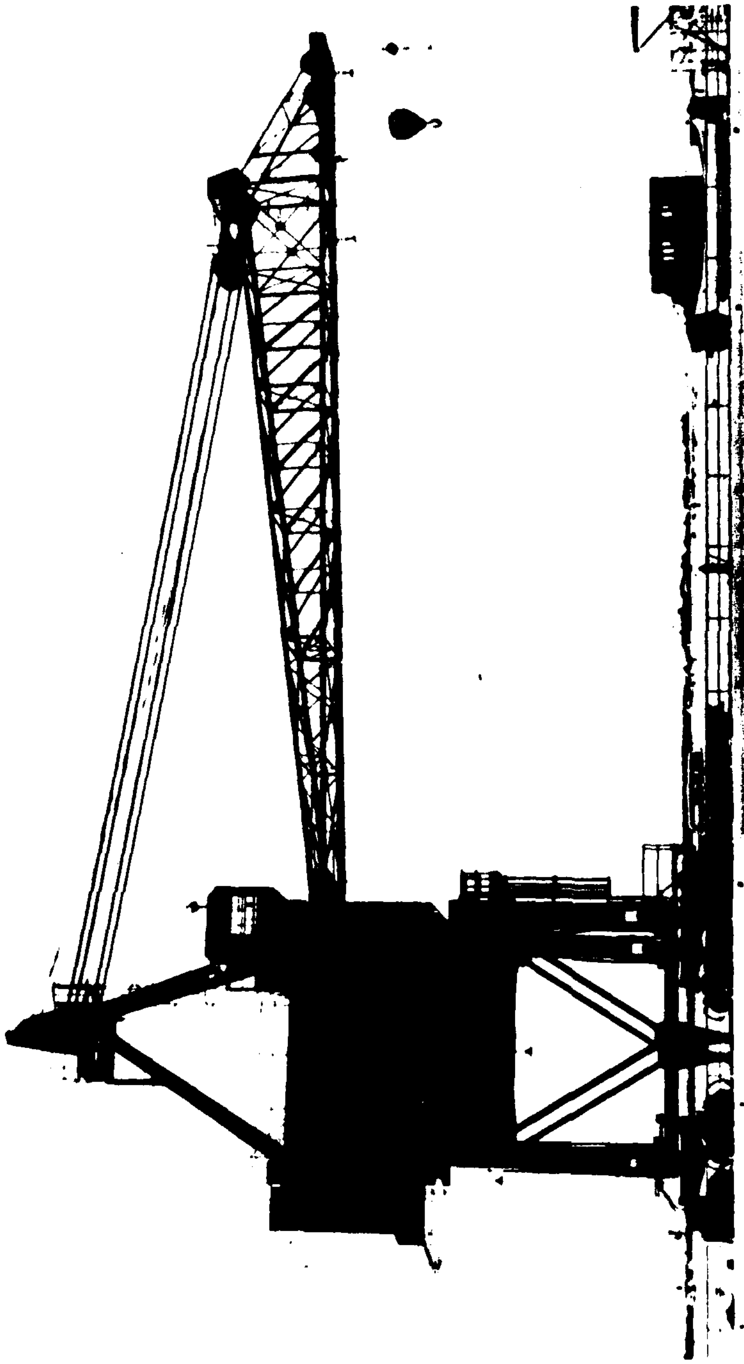


FIGURE 37
Portal Crane--Special Boom

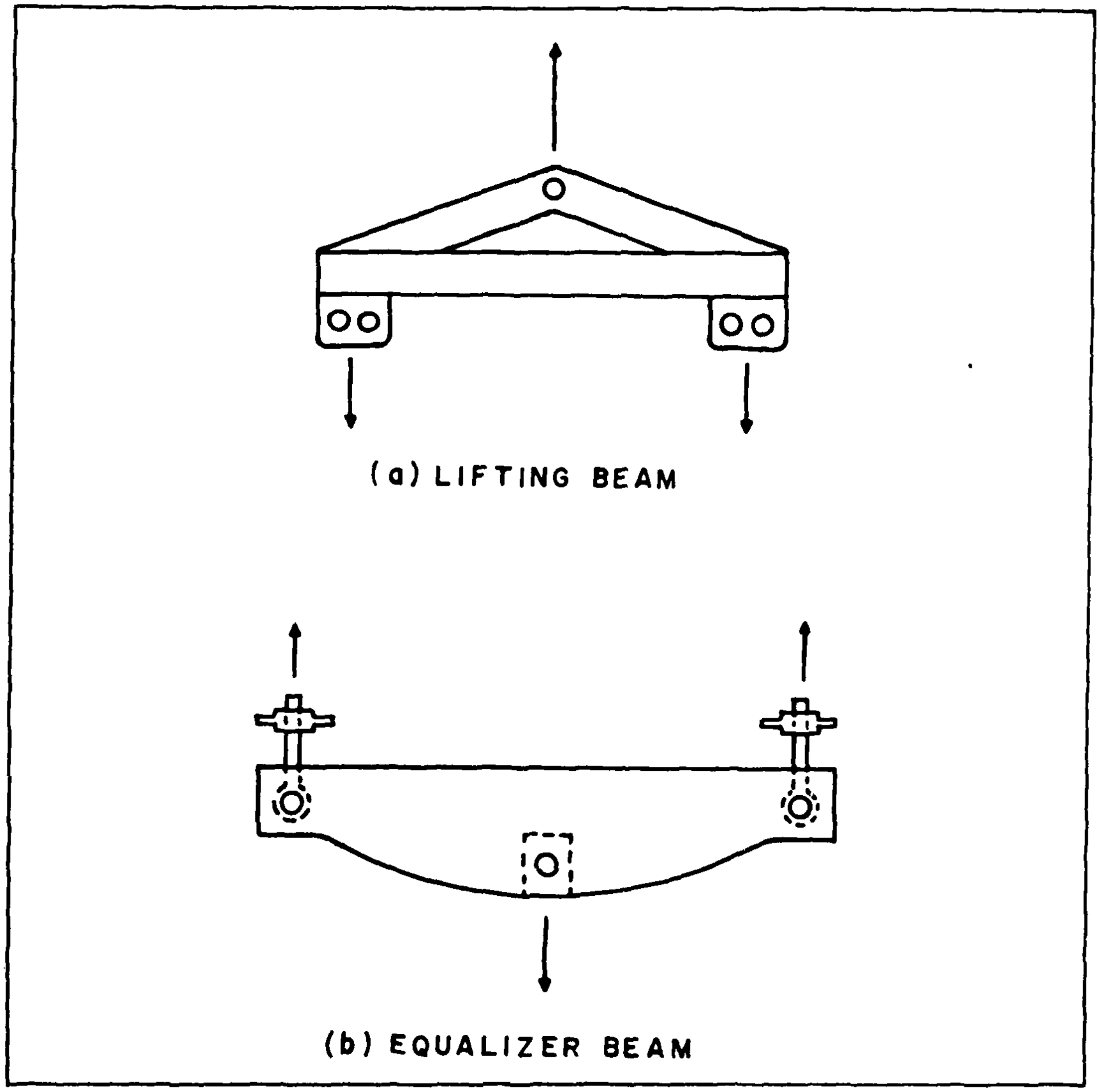


FIGURE 38
Lifting and Equalizer Beams

f. Dead-Man Safety Device. This device provides for stopping and holding the motions of the lifting machine should the operator suddenly become incapacitated. Uncontrolled motions are prevented. It is recommended for use on all machines handling critical materials.

16. FLOODLIGHTS. The need for floodlights or other provisions for external illumination and night work should be determined. In particular, consideration should be given to the need for lights (both marking lights and floodlights) at the boom tip and for underportal lighting. Equipment will normally be provided with emergency lighting necessary for access or egress when the main lighting power is off.

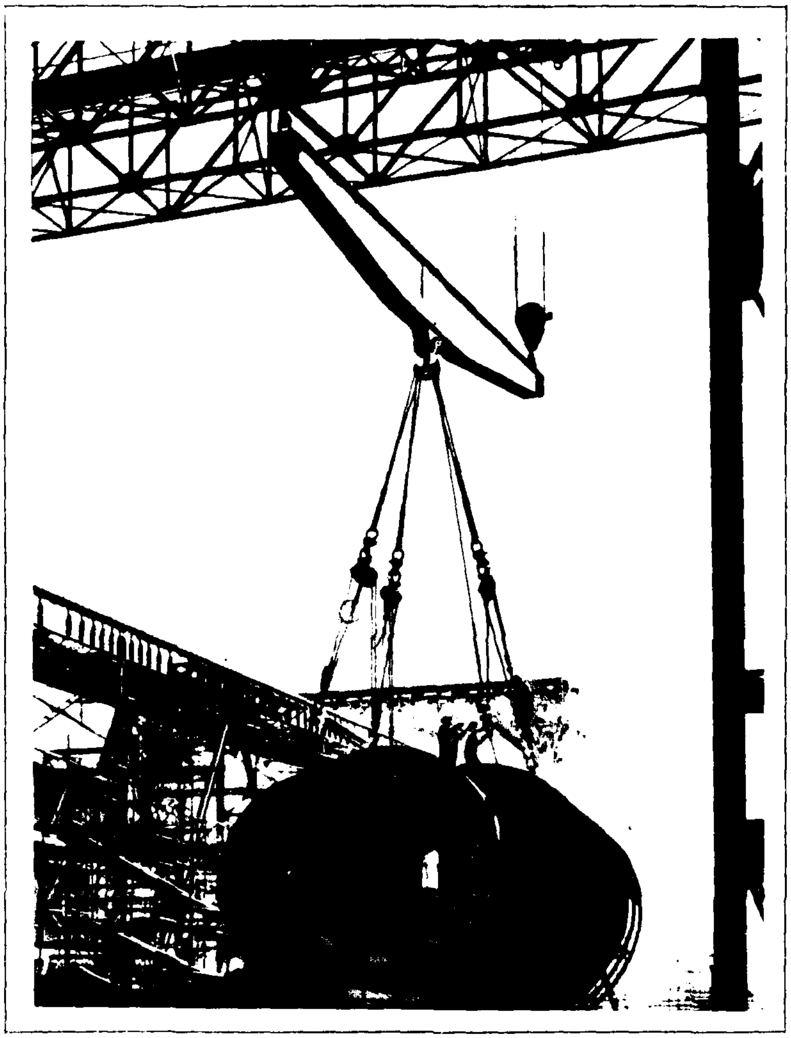


FIGURE 39
Equalizer Beam

17. MISCELLANEOUS.

a. Crane and Trolley Stops. These should be provided at the limits of travel for all traveling cranes. On traveling cranes with a trolley, stops for both the trolley and crane are necessary. A stop which engages the crane or trolley bumper shall be used. Stops which engage the wheels only are not permitted, because they create excessive shock loading on the wheel bearings.

b. Bumpers. (Figure 41.) Bumpers should be provided on all cranes and trolleys which travel on rails. Bumpers are used as energy-absorbing devices when the crane or trolley reaches the end of its permitted travel, to reduce impact between two moving cranes which come into contact. In general, the use of a "bumper" which hits a "stop" at the end of a runway is preferred. A user should be careful that all bumpers on cranes which operate on identical tracks are of equal height.

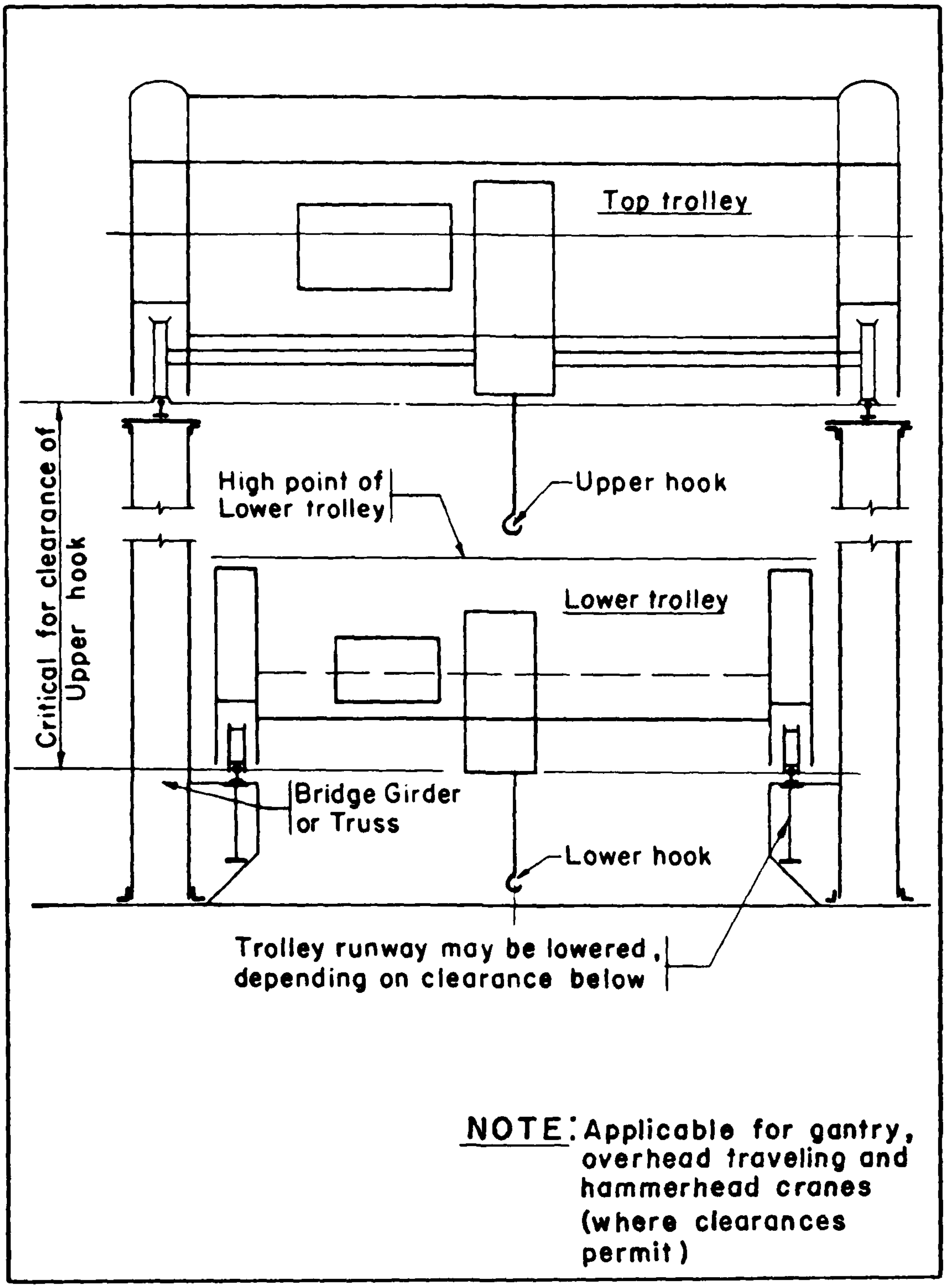


FIGURE 40
Passing Trolleys

c. Fencing. Provide where access is to be restricted to work site, to prevent people from walking under the machine, or to protect runways.

d. Boom Rests. (Figure 8A.) These are required when luffing ropes must be replaced or repaired or if the boom (or heel pins) must be repaired or replaced. They may be permanent, built-in features or, simply, a portable stand such as sections of pipe scaffolding or similar temporary device. Built-in boom rests normally are provided only for floating cranes (secure stowage when under tow), or for truck cranes (secure stowage in transit), but can be provided for other types.

e. Stowage Space. Indicate requirements (including approximate size or volume) of desired storage spaces for:

(1) Oil, gasoline, or cleaning fluids and maintenance implements and supplies.

(2) A place where parts may be placed and worked on.

(3) A storage bin accessible to riggers for slings, blocking, shackles, etc.

f. Radius Indicator. This normally will be provided. Any special type desired should be indicated.

g. Fire Fighting Equipment.

(1) Crane operator cabs normally will be provided with an extinguisher. Care should be observed that location is prominently marked and easy access is available and maintained.

(2) Machinery house also normally will be equipped with extinguishers. Again, location should be of easy access and prominently marked.

(3) Floating cranes.

(a) Power plant in pontoon. Hand-operated extinguishers normally will be provided. Consider the additional need for a piped CO_2 system with valve to flood entire compartment.

(b) Deck. Hand-operated extinguishers normally will be provided. Generally, this is sufficient. For large cranes, consider additional protection via the salt water system.

(4) Reference. See DM-8 for criteria on extinguishing equipment.

h. Parking Brake, Rail Clamps, or Other Securing Device. Some form of securing device normally will be provided for machines used in exterior operations, for periods when they are unattended. Selection is a matter of circumstances and individual preference and should be indicated if some particular type is desired.

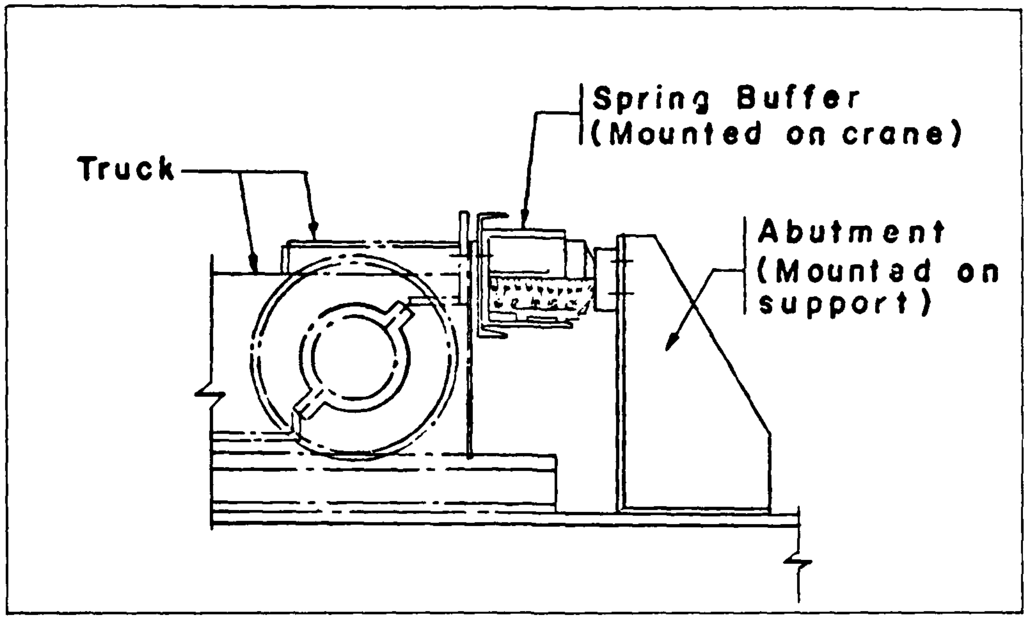


FIGURE 41
Bumper Stop

i. Grease and Oil Catchers (Drip Pans). These devices can be used to assist in preventing drip of lubricant, particularly from wire rope and from sheave bearings, on work personnel, floor, or materials, but can be installed practically anywhere, if they are needed. When used on load blocks, they also provide greater safety in situations where work personnel could come in contact with moving cables and sheaves.

j. Devices for Capturing Fasteners. Devices also can be provided to capture or secure potential falling objects (principally nuts, bolts, etc.) under conditions where such security is required.

k. Insulated Links. Occasionally (on machines handling ordnance, for example) it is necessary to prevent transmission of stray electric currents from the weight-handling machine to the load. Insulated links, above the hook, or as part of the rigging, can be provided for this purpose (see Section 6, Part 3, paragraph 18d).

l. Rigging and Rigging Accessories. The machine, normally, will be provided with necessary rope, a weight ball, and swivels (for use above and below weight ball). If desired, indicate need for shackles, pins, slings, and similar accessories and the hook capacity for which these accessories will be used.

m. Other. Other features which normally will be provided include: ratchets and pawls for luffing drums, windshield wipers, special maintenance tools, and guards for machinery. Additional optional features include wear gages, track sanders, and a weight-handling system in the machinery house to assist in handling equipment for repair.

Part 3. DATA REQUIRED FOR PROCUREMENT OF NEW EQUIPMENT

1. USE. This part presents a summary of information required to permit proper procurement of weight-handling equipment. A general description is required of the use to which the equipment will be put.

2. DESCRIPTION OF WORK TO BE DONE. Give brief description of type of work. What is to be lifted? How often (how many lifts per shift; per 24 hour day)? How many days per month (average)? How often must machine move? Must it travel with load? How often? How far? Give detailed description of operating procedure. Are loads to be lifted particularly sensitive to shock or rough handling? Are they particularly expensive or difficult to replace? Are they particularly dangerous to handle? Is machine to be used for precision assembly? If so, describe.

3. REQUIRED SPEEDS. Give desired high and low speeds for each motion and each hoist. The number of lifts or movements (generally in terms of lifts or movements per 8 hour shift and per 24 hour day), and the speed define the selection of several components of the design; for example, bearings, motor rating (insulation), cross drive shaft, resistors, etc. Speed and frequency of operation should be separately defined for each motion and hook. If machine is for standby service, so indicate. For equipment having fixed, repetitive, and continuing cycle of operation, the required speeds of motion can be derived from the duty cycle.

Determination of required speeds of motion for cranes involved in heterogeneous or sporadic operations is a matter of judgment and experience for which Section 5 (equipment for use at waterfront in shipyards) and Tables 5 to 9 (for equipment for use in other areas) are provided for guidance. Note that:

(1) The precision of handling increases as the speed is decreased.

(2) Initial and maintenance costs increase with speed increase (i.e., engines, motors, and gearing are larger and heavier; control systems are more complicated, etc.). For equipment infrequently used (e.g., standby) use slow speeds.

(3) Total output is dependent on both human and mechanical factors, and is not proportionately increased by higher speeds.

(4) For cranes that require track watchmen or riggers to accompany the load, limit travel speed to a brisk walk, i.e., 3 mph (264 fpm.) (4.8 km/h).

(5) Fast acceleration rather than speed is preferred for cranes with short movements of crane travel, trolley, or swing travel, or with constantly recurring duty cycles.

(6) Speed studies of the working cycle are recommended when selecting the speeds of each motion.

Where high, light-load speeds are desired (up to 350 percent of normal speed), consideration should be given to provision of an adjustable voltage control which provides such a feature. Control options also are available to provide for extended slow speed operation (see Section 6).

4. CAPACITY (WEIGHTS OF LIFTS). The required capacity of each hook, if several hooks are to be provided, must be determined. Recommendations relating to machines for use at the waterfront in Naval Shipyards are presented in Section 5. For other locations and uses, the following general recommendations apply:

a. Main Hoist. Economy dictates that, where feasible (and except where all lifts are in the same weight category), a facility should be serviced by weight-handling equipment capable of handling a large percentage (but not all) of the required lifts. Some auxiliary means should be provided for handling the occasional, heavier pieces. This auxiliary means should be capable of being transported from facility to facility, as need dictates. One such means is to provide for tandem lifts (i.e., lifts by two, or more cranes). It is axiomatic that two smaller machines will do more work than one large one. With care, tandem lifts can be safely executed and need not be feared. Other devices include provision of a single, portable machine (crane or derrick) of heavier capacity, skidding, jacking, etc., limited only by the ingenuity of the riggers. Under such circumstances, the main hoist should have capacity for making heaviest lift of common occurrence (tentatively defined as more than 5 percent of time), and not for making the heaviest lift.

If such auxiliary means are lacking, or if all the lifts are of substantially the same weight, then the main hoist should have capacity for making the heaviest, anticipated lift.

b. Whip or Auxiliary Hoist. Should have sufficient capacity to make 80 to 85 percent of all required lifts. If heavier equipment can be moved in readily to make occasional heavier lifts, consider providing whip or auxiliary hoist capable of making 90 to 95 percent of all lifts.

c. Allowable Overloads. The rated capacity of a lifting machine incorporates a factor of safety. However, the operating crew shall never be permitted to load any weight-handling equipment in excess of its rated lifting capacity, without specific authorization from the officer responsible for the operation of the unit. Every instance of exceeding the rated capacity shall be treated as a special problem and all the conditions involved shall be duly considered. In such cases, decisions as to the safe lifting capacity within the overloads just listed shall be made by the Public Works Officer.

d. Caution. For some cranes, the weights of rope reeving, blocks, and hooks must be deducted from the capacity when determining the load which can be lifted. The rated capacity of a machine does not necessarily include allowance for these items.

e. More Than One Hook. The number of hooks desired should be indicated, together with the required capacity of each. If two hooks (or trolleys) will be required to handle lifts simultaneously, indicate in what combinations and, for rotating machines, at what radius.

5. REACH AND HOOK HEIGHT.

a. Equipment to be Used at Waterfront Activities in U.S. Naval Shipyards. For recommendations see Section 5.

AD-A123 624 WEIGHT-HANDLING EQUIPMENT DESIGN MANUAL 381(U) NAVAL FACILITIES ENGINEERING COMMAND ALEXANDRIA VA JUN 82 NAVFAC-DM-38.1

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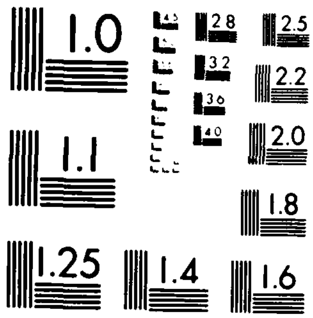


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

TABLE 5

Speeds for Portal, Tower, Hammerhead, and Floating Cranes and for Fixed and Floating Derricks[1,2]

Hook Capacity (tons of 2,240 lb.)	Hoist			Luffing			Trolley			Rotate			Travel		
	Slow	Moderate	Fast	Slow	Moderate	Fast	Slow	Moderate	Fast	Slow	Moderate	Fast	Slow	Moderate	Fast
5.....	100	150	200	25	50	75	100	150	200	150	300	450	200	350	450
10.....	60	90	120	25	45	65	100	150	200	150	300	450	200	350	450
15.....	40	60	80	25	35	55	100	150	200	150	300	450	200	350	450
25.....	20	30	50	15	25	35	80	130	175	125	250	400	200	350	400
50.....	10	15	25	8	14	20	70	120	150	125	250	300	200	300	400
75.....	10	15	25	8	12	15	70	110	125	125	200	250	200	300	400
100.....	10	14	20	6	9	12	60	90	125	125	200	250	200	300	400
150.....	8	12	18	5	8	12	45	65	90	125	200	250	...	...	...
200.....	6	10	15	5	8	12	30	45	60	125	200	250	...	...	...
250.....	5	8	12	5	8	12	25	40	50	125	200	250	...	...	...
350.....	5	7.5	10	5	8	12	15	30	45	125	200	250	...	...	...
400.....	5	7.5	10	..	..	..	15	30	45	125	200	250	...	...	...
450.....	5	7.5	10	..	..	..	15	30	45	125	200	250	...	...	...

[1]All speeds are in f.p.m. maximum running for hoist and travel, average for luffing, and peripheral for rotate.
[2]For use in areas other than at waterfront in naval shipyards.

TABLE 6
Speeds for Level-Luffing Cranes[1,2]

Hook Capacity (tons of 2,240 lb.)	Hoist Moderate	Hoist Fast	Luffing Moderate	Luffing Fast	Rotate Moderate	Rotate Fast	Travel Moderate	Travel Fast
5..........	150	300	200	300	500	800	250	350
10..........	100	200	160	200	450	700	250	350
15..........	80	120	120	150	400	600	250	350
20..........	60	80	100	125	350	500	250	350

[1]All speeds are in f.p.m. maximum running for hoist, trolley and travel, average for luffing, and peripheral for rotate.

[2]For use in areas other than at waterfront in naval shipyards.

TABLE 7
Ranges of Maximum Speed for Locomotive Cranes

Nominal capacity (tons of 2,000 lb.)	Main Hoist (f.p.m.)	Luffing minutes to radius	Rotate (r.p.m.)	Travel (m.p.h.) Diesel-mechanical	Travel (m.p.h.) Diesel-electric
25........	50-60	2-2.5	2.5-3.5	7.5-14	7.5-15
30........	40-60	2-2.5	2.5-3.5	7.8-15	10-15
40........	30-70	2-2.5	2.5-3	7.8-15	10-15
50........	30-60	2.5-3	2-4	8-15	10-15
60........	30-60	2.5-3	2-4	8-15	10-15
80........	30-60	2.5-3	2-4	8-15	10-13

TABLE 8
Ranges of Maximum Speeds for Crawler and Motor-Truck Cranes

Nominal capacity (tons of 2,000 lb.)	Main hoist (f.p.m.)	Rotate (r.p.m.)	Travel (m.p.h.)		
			Single-engine motor-truck cranes	Two-engine motor-truck cranes	Crawler cranes
7.5	160	5-5.5	7.8-15	33	1-2
10	170	4-5	7.5-10	30-40	1-2
15	150-170	4-5	4.2-7.5	30-40	.75-1.6
20	150-160	3.5-5	5.2-13	30-50	.75-1.5
25	150-200	3-5	2.5-7.2	30-35	1.2-1.4
30	....	3-5	7.7	30	.8-1.5
35	....	3-4	5.3	30	.9
45	....	3.5-3.7	4.2	18	1.5
50	....	2.5	....	.....	.8
65	....	2.3	....	.....	.8
110	....	2.1	....	.....	.8

b. Equipment to be Used in Other Areas.

(1) General. Reach and height depend on the layout (geometry) of facility, clearances, size of piece to be handled, height of boom hinge pins, and other variables. Each case must be separately derived.

(2) Maximum Reach. The hook shall be able to reach out to the farthest limits to be served (with a little to spare to reduce maneuvering and provide a margin for limit stops).

(3) Minimum Reach.

(a) The minimum reach shall be as small as possible, consistent with the stability of the boom under conditions of wind, list, uneven ground, or rebound on sudden loss of load.

(b) The closest reach position of the hook is of particular importance on fixed cranes and derricks.

(4) Upper Limit of Hook Travel.

(a) The hook must be able to handle loads at the required elevations plus a vertical clearance of a foot or more.

TABLE 9
Operating Speeds for Overhead Traveling Cranes (ft. per min.)[1]

Capacity (tons of 2,000 lb.)	Hoist			Trolley			Bridge		
	Slow	Moderate	Fast	Slow	Moderate	Fast	Slow	Moderate	Fast
3..........	12-30	45	75	125	150	200	250	350	450
5..........	16-25	40	65	125	150	200	250	350	450
10..........	16-22	35	55	125	150	200	250	350	450
15..........	18	30	45	125	150	200	250	350	450
20..........	15	25	35	100	140	175	250	350	450
25..........	15	22	30	100	140	175	250	350	450
30..........	12	18	25	90	130	160	250	350	400
40..........	10	15	20	80	120	140	200	250	350
50..........	10	14	18	70	110	140	150	225	300
60..........	9	13	18	70	100	130	150	225	300
75..........	8	12	16	60	90	120	125	200	250
100..........	8	10	12	40	80	100	125	175	250
125..........	6	8	10	40	80	100	100	175	250
150..........	5	8	10	40	60	80	100	150	250
175..........	4	6	8	40	60	80	100	150	250

[1]For floor-controlled cranes, Military Specification MIL-C-22137.

(b) Make allowance for height of pickup point on the load, length of slings, dimensions of hook, relative drop of load in relation to the boom on luffing, drift of hook on operation of limit stops, and a safe margin against contact of upper and lower blocks (two-blocking).

(c) There should be an upper limit switch to guard against this event.

(5) Lower Limit on Hook Travel.

(a) The hook should be able to get close enough to the bottom of ships, drydocks, pits, excavations, and other low working areas for convenient slinging of any probable load.

(b) Allowance for close slinging and operation of limit stops, i.e., drift of load after tripping switch, should be made.

(c) Not less than two dead wraps should remain on the drum of any hoist at the lower limit of hook travel.

(d) A lower limit switch is a desirable feature on any crane or derrick, but is mandatory only on a crane with a luffing boom, except for USN number equipment which are covered by commercial standards.

6. SPECIAL CONSIDERATIONS. What is anticipated temperature range (extreme temperatures) of environment in which machine must work? (This is related to design of motors and electrical components and dictates need for cab and machinery house insulation and requirement for heaters.) Any special requirements relating to use of the equipment in aggressive environment (special steels, painting, or use of aluminum to prevent corrosion; cold regions; controlled environment or atmosphere in operator's cab; explosion proof electrical fixtures; acid resistant coatings; dustproofing; etc.) should be stipulated. For example:

(1) Special attention should be given to areas having an explosion hazard. If such hazard exists, the National Electrical Code Class, Group, and Division should be determined and electric equipment selected to conform. Spark resistant construction may be required.

(2) The existence of corrosive atmospheres will influence the selection of construction materials and coatings (aluminum, instead of steel, use of asphalt coatings, etc.).

(3) Noisome or poisonous atmosphere will require environmental isolation of operator's cab (by shielding against radiation sources, for example) or remote control.

(4) Dusty environment introduces explosion hazard and need to seal gears, etc., in protective enclosures.

(5) Proximity to sand blast operations introduces need to seal gears in protective enclosures to prevent damage due to intrusion of grit.

7. SITE LAYOUT. Indicate using activity. Where is project? Give site (or interior) layout and sections showing locations and nature of obstructions. Show nearby railroad or crane tracks or roadways which will be active when equipment will be in operation. Clearances which must be considered include:

(1) Tail swing (for full 360 degree swing).

(2) Overhead.

(3) Side (to nearest obstruction. Obstructions include: conduits, rivet heads, fire hydrants, light fixtures, etc.).

(4) Under portal.

(5) Under hook (in raised position).

(6) Under counterweight.

(7) Under bridge.

(8) Under chassis.

Some details:

(1) Bumper heights of adjacent cranes to match.

(2) Pickup shoes to match locations of existing conductors, if any.

(3) On floating cranes, back of structure (or tail swing) should not extend beyond edge of pontoons.

8. TRACK AND RAIL DATA. If the desired equipment is to be mounted on existing track give gage and size of rail. (Center to center of rails for wide gage cranes. Clear distance between rail heads for locomotive cranes.) Give data on curves (radii, transitions, P.T., P.C., and P.C.C.'s). If new track is to be provided, give corresponding data for proposed installation.

With regard to new track, if a choice of gages is available, the range should be indicated. The gage provided will be derived from the design of the new machine and any existing machines that will use the tracks. The size of the rail is derived from the design wheel loads.

For curved track, the larger the radius the less the amount of float required in the trucks. (Particular attention must be devoted to providing a proper easement curve.) For cases where the requirement to traverse the curve is infrequent, consider the use of swivel trucks with no float, and provision for jacking, as per Figure 42.

Indicate grade (inclination) of tracks, if any, and geometry of vertical curves.

9. ALLOWABLE WHEEL AND TRUCK LOADS. Any limitations on wheel or truck (set of wheels) loads due to conditions other than the size of the rail must be indicated. For example, if the machine is to traverse an existing runway, what are the design loads for the runway (without impact) and the wheel spacings?

Within reason, the load of the machine can be distributed by increasing the number of wheels in, and the length of, the trucks (with more tiers of equalizers). Total reactions on the trucks can be reduced by use of lightweight alloys (principally aluminum) or of high strength steels. Both are items of extra cost which are justified only if corresponding savings can be effected in the supporting structure. The design requires coordination of both facets in order to minimize the cost of the total system. To this end, one or more preliminary, comparative designs often are desirable.

10. LOADS. Provide the following information regarding loads for which the machine must be designed:

a. <u>Wind</u>. Indicate any sheltering which would reduce wind effect. Indicate elevation of machine above ground since wind speed varies with height.

b. <u>Live Loads</u>. Used for catwalks, machinery house, and other occupied areas. Indicate design live load, only if special.

c. Wave and Sea Conditions (for floating cranes and derricks). Indicate maximum anticipated wave and sea conditions in which machine will have to operate: (1) with load and; (2) with boom secured. Unless otherwise stipulated, design will provide for minimum 2 degree list and 1 degree out of trim under operating conditions; design wave equal to length of pontoon; and, for seagoing use, wave height = L/30.

d. Dragging or Snaking Loads. Normal design of weight-handling equipment is for vertical weight lifting. Indicate occurrence of dragging or snaking when known to be incident to the purpose of the machine.

11. POWER SOURCE. Indicate if independent power source is required (i.e., power source to be part of machine). If independent source is required, an emergency or temporary plug-in to shore power usually is desirable. Indicate characteristics (kind, voltage, frequency, and phase) of shore power and locations at which it may be tapped.

If shore power is to be used for primary power, again indicate characteristics and location at which it may be tapped.

12. FEATURES. Indicate desired features, as per Part 2. Environmental considerations (hazardous conditions, in particular) should be fully described.

13. MISCELLANEOUS.

a. Access. Indicate desired points of access to crane. Limit access to one location so that operator has better chance to keep track of oiler, or other personnel, and thereby avoid accidents. See Section 4, Part 2, paragraph 4b, regarding emergency egress.

b. Other Cranes on Same or Adjacent Track or Runways or Servicing Same Facility. This data is required to avoid interferences (clearance), to evaluate possible concentrations of reactions, and to evaluate potential for tandem lifts.

c. Passage Through Doors. If crane will be required to pass through doors indicate any special clearances. Is some form of trip required so crane cannot be run through closed door?

d. Drips. Indicate if oil or grease tight gear cases are required to prevent drips.

e. Fungus Control. Is fungus resistant treatment of electrical components required?

f. Radio Interference Suppression. Indicate, if required.

g. Security. Indicate which means of access need to be secured and how (lock, removable key, or part, etc.).

14. SAMPLE FORMS. Copies of the following NAVFAC forms for use in procurement are presented in Appendix A: "Information Form for Overrunning, Overhead, Traveling Cranes" and "Information Form for Traveling, Rotating, Portal Crane with a Boom."

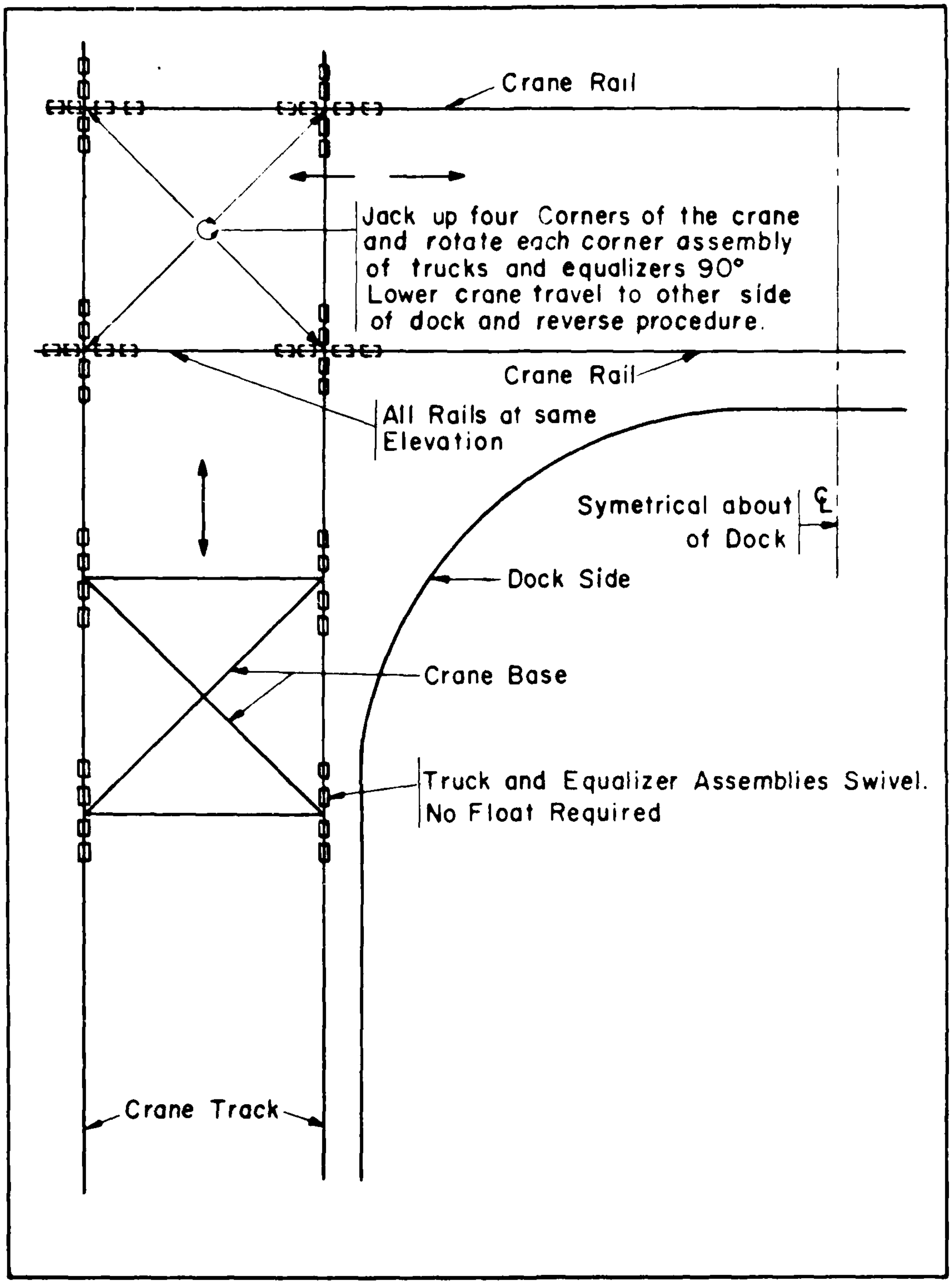


FIGURE 42
Method for Traversing Curve Using Swivel Trucks Without Provision for Float

Section 5. RECOMMENDED CAPACITIES, REACH, HOOK HEIGHT, AND SPEEDS FOR PRIMARY WEIGHT-HANDLING EQUIPMENT SERVICING DRYDOCKS, PIERS, AND WHARVES IN NAVAL SHIPYARDS

1. GENERAL. The following summary of recommendations is based on a survey and study of needs for shipyards engaged in a primary function of overhaul and repair and relate to portal and floating cranes. They are recommendations only, and shall be modified as dictated by local need, conditions, and the dictates of economy.

2. CAPACITY.

a. Complex of Four or More Drydocks. Three cranes having 50 gross ton capacity on main hook and 7.5 gross ton capacity on whip hook (single part line). Remainder of portal cranes to be divided one-quarter (with minimum of two) having 15 gross ton capacity on main hook and 5 gross ton capacity on whip hook, and three-quarters having a single (whip) hook of 5 gross ton capacity.

b. Complex of Two or Three Drydocks. Two cranes having 50 gross ton capacity on main hook and 7.5 gross ton capacity on whip hook. Other portal cranes to be divided as per paragraph 1.

c. Single Drydock. This type of complex is to be avoided.

d. Complex of Drydocks Plus Pier or Quayside Berths. Provide cranes of 50 gross ton capacity on main hook as described in paragraphs 1 and 2 and based on number of drydocks in complex. Remainder of portal cranes to be divided into two groups: (1) one-third having 15 or 20 gross ton capacity in main hook and 5 gross ton capacity on whip hook; and (2) two-thirds having a single (whip) hook of 5 gross ton capacity. The group of cranes having 15 and 20 gross ton capacity on the main hook to be divided between these two classes in proportion to the total number of crane work stations at the drydocks vs. the total number of crane work stations at the piers plus quays.

e. Complex of Pier or Quayside Berths, Only. One-third of portal cranes to have 20 gross ton capacity on main hook and 5 gross ton capacity on whip hook. Remainder to have single (whip) hook of 5 gross ton capacity.

The provision of an auxiliary (third) hook is not required for any portal crane.

Floating cranes should be of minimum 100 gross ton capacity on the main hook and equipped with a whip hook of 10 ton capacity at the reach consistent with moments imposed by the main hook capacity. An auxiliary hook is not required. The provision of floating equipment having less than 100 gross tons of capacity is not recommended.

3. SPEEDS.

a.	Travel:	200 to 250 fpm (1 to 1.5 m/s)	
b.	Rotate:	50 G.T. cranes (50 Mg)	- 0.6 rpm (.063 rad/s)
		15 G.T. (15 Mg) and 20 G.T. (20 Mg)	- 1.5 rpm (0.157 rad/s)

c.	Main Hoist:	50 G.T. capacity (50 Mg)	-	40 fpm (0.2 m/s)
		15 G.T. (15 Mg) and		
		20 G.T. (20 Mg)	-	100 fpm (0.5 m/s)

d. Whip Hoist: 250 fpm (1.5 m/s) with provision of field weakening or rapid lowering gear to increase lowering speed.

4. REACH AND HOOK HEIGHT.

The main hook of portal cranes servicing a complex of drydocks, at the maximum working radius, should reach slightly (say 5 feet or 1.5 meters) beyond the centerline of the widest dock. In some cases (particularly if the boom hinge pins are low) at the maximum working radius the boom may not clear the ship to be serviced, or there may be insufficient clearance for the hook. These conditions must be checked.

The whip hook on portal cranes servicing a complex of drydocks should be positioned so that, with the boom elevated at 45 degrees 0.78 rad, the whip hook will reach 5 feet (1.5 meters) beyond the centerline of the widest dock. This criterion is for the boom hinge pins at a level 40 feet (12 meters) above the level of the drydock coping. If the boom hinge pins are higher or lower, the length of boom should be adjusted so that the whip hook will reach the corresponding location.

At least one crane of those servicing each complex of two, or more, docks should be fitted to receive a demountable boom extension of sufficient length that the whip hook can reach across the width (measured at floor level) of the dock.

For single berthing at pierside or quayside, the main hook, considering all requirements for fendering and camels, should (at maximum working radius) reach to the centerline of a vessel of AE class (or its equivalent). The whip hook, at the maximum working radius, should be capable of reaching the outboard side of the ship. This condition should be checked to assure that the boom will clear the design vessel at this minimum inclination.

For multiple berthing at pierside or quayside, the reach on the main hook should be as for single berthing. However, if the requirement for multiple berthing will be a long term requirement and provided that the requirement is for servicing the ships and not merely inactive berthing, it is recommended that the whip hook, at maximum working radius, be capable of reaching the outboard side of the outer vessel. In this case, however, the design vessel should be assumed to be DD's (or their equivalent).

Section 6. BASIC DESIGN DATA RELATING TO MODIFICATIONS AND ATTACHMENTS

This section presents basic criteria for the selection and design of those components of weight-handling equipment which, experience indicates, using agencies most frequently find occasion to modify. The intended use is in the preparation of plans and specifications for said modifications; i.e., of equipment previously procured. All such modifications are to be approved by the cognizant NAVFAC Engineering Field Division.

Part 1. GENERAL DESIGN CRITERIA

Except as supplemented or amended in this Section, ANSI Standards, series B30 (ANSI B30.1, et. seq.) shall be followed in the design and execution of alterations to weight-handling equipment previously procured.

Unless specifically noted otherwise, the criteria noted hereinafter pertain to overhead traveling, portal, tower, hammerhead, gantry, and floating cranes and derricks. Some criteria and guidelines are indicated for the following: locomotive and mobile cranes; commercial packaged unit hoists; wall, jib, pillar, pillar-jib, and similar cranes; and winches, windlasses, and capstans. Complete detailed design criteria for such equipment have not been included in this manual. In general, if detailed design criteria are not noted hereinafter for the components of the aforementioned equipment, determine the applicable manufacturer's criteria for which the equipment was originally designed and meet or exceed these criteria in determining the adequacy of the component(s); or, the criteria established hereinafter for other equipment may be used as a guide.

The provisions of this Section are not intended to prevent the co[illegible]nued use, nor to necessitate modification of, any existing situation which performing satisfactorily. Accordingly, for purposes of this Section, "replacement-in-kind" will not be considered as a modification. Also, [illegible]e criteria presented are not, necessarily, the best, nor the only metho[illegible] [illegible]ch will provide satisfactory performance. They represent procedures whi[illegible] perience indicates are of reasonable efficacy and simplicity, and provi[illegible]e durable service. They are not intended to preclude the development, or use, of any other system, device, detail, material, or construction which can be demonstrated, on the basis of generally accepted engineering principles, to provide adequate performance on the intended function, with due consideration for durability and maintenance. However, all such deviations from criteria presented herein, shall be subject to approval by NAVFAC Headquarters.

1. ALLOWABLE STRESSES AND GENERAL DESIGN STANDARDS.

a. Structural Elements. (See Part 2.) Analysis of adequacy (and reinforcement, if required) of existing components shall conform to the design standards indicated in the original contract (or on the plans) for the existing equipment. For new components, or existing equipment where original design standards are not available, design shall conform to the following:

(1) Portal, Hammerhead, Tower, Pillar, Jib, and Pillar-Jib Cranes, Derricks. Design shall conform to the provisions of the American Institute of Steel Construction "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings." Consideration of fatigue shall provide for the most critical of the following conditions:

(a)	Lifts of 40 tons or more (including test loads, see paragraph 3)	- static loading.
(b)	Lifts between 10 tons and 40 tons	- 100,000 cycles of loading.

(c) Lifts of 10 tons, or less - 500,000 cycles of loading.

(2) Overhead Traveling and Gantry Cranes. Design shall conform to MIL-C-22137, MIL-C-28613, or MIL-C-28546.

b. Mechanical Elements. (See Part 3.) NAVFAC practice is to accept retained, existing components with regard to strength and durability and to accept manufacturers' ratings of cataloged items. Non-cataloged items shall be designed in conformance with the applicable publications of the American National Standards Institute, National Electrical Manufacturers' Association standards, and standards cited herein for particular components. The design factors listed below are overall and apply to ultimate strength. Ultimate strength is chosen to insure more conservative stresses in highly heat-treated parts, for which there is a relatively small margin between the yield point and the ultimate strength. For cataloged components, ascertain the manufacturers' safety factors, and whether or not they apply to ultimate strength. Make appropriate adjustments if they apply to yield point or if the manufacturer's factor of safety is less than that required.

(1) Design Factors. In practice, design factors (frequently referred to as safety factors) range from 3 to 15, but are more commonly from 4 to 8. The design factors generally account for normal amounts of vibration, impact, shock, abuse, corrosion, manufacturing and maintenance tolerances, acceleration, misalignment, deflection, and minor stress concentration. Such loadings and effects must, however, be accounted for in the computations when they are unusually large. Recommended minimum general design factors (and the material property on which based) for mechanical elements of various types of weight-handling equipment are as follows:

Type of Equipment	Design Factor (based on ultimate strength)
Portal, tower, floating, and hammerhead cranes. Derricks.	
a. Running ropes	6
b. Standing ropes (other than rotation resistant)	4
c. Hooks	5
d. Shafts, axles, pins	(See Part 3, paragraph 3)
e. All other elements	5
Overhead traveling crane.	See MIL-C-22137
Monorail, wall, jib, pillar, gantry, pillar-jib cranes. Monorail hoists.	5
Locomotive cranes.	
a. Ropes (other than rotation resistant)	4
b. Hooks	5
c. Alloy steels, steel castings	4
d. All other elements	As per manufacturer

Type of Equipment	Design Factor (based on ultimate strength)
Mobile cranes.	
a. Running ropes (other than rotation resistant)	3.5
b. Standing ropes (other than rotation resistant)	3.0
c. Hooks	4.0
d. All other elements	As per manufacturer
Hoists or winches.	5
Rotation resistant ropes.	5

(2) Stresses. Except in unusual cases, the above recommended factors of safety allow for (without direct stress computations), the usual amounts of vibration, shock, abuse, corrosion, manufacturing and maintenance tolerances, mild acceleration, inadvertent misalignment, deflection, and minor stress concentrations. For unusual cases, stress computations shall be made and the stresses shall provide the above-recommended factors of safety. For such cases, dynamic loading shall be computed in accordance with recognized standards. In all cases, stresses shall be well below the endurance limit of the material.

2. DESIGN LOADINGS.

a. Dead Load. Include the weight of all parts of the structure, machinery, and fixed equipment, and its contents.

b. Vertical Live Load.

(1) Hook Load. Include the weight of the object lifted and of all slings and auxiliary devices suspended from the hook. Consider as a vertical, static load. Do not design for out-of-plumb hoisting unless such type of hoisting is a specific requirement of the crane function. In general, out-of-plumb hoisting is not allowed.

(2) Hook-Load Reactions. The hook load produces reactions throughout the structure and the machinery. These reactions are considered as static loads on the affected parts. In stability calculations for floating cranes and derricks, the hook load, plus all other suspended weight, reacts at the top block as though actually located at that point.

(3) Rope Load. Design for Lead Line Factor as set forth in NAVSHIPS 0900-008-9010, except that Lead Line Factor may be neglected in design of structural components, provided that design provides for impact loads, hereinafter described.

(4) Machinery House and Similar Floors. Where floors are not occupied by fixed equipment, design for a uniform load of 100 psf (4.8 kPa) or a concentrated load of 750 pounds (340 kg), whichever produces the greater stress.

(5) Stairways, Walkways, Ladders, and Similar Parts. Use a uniform load of 50 psf (2.4 kg) or a concentrated load of 350 pounds for design purposes.

(6) Roof Load for Outdoor Cranes. Design roofs for snow load as per DM-2.2, or for a concentrated load of 250 pounds (160 kg), whichever is the greater. Snow loads shall be a minimum of 20 psf (1 kPa).

c. Horizontal Loads.

(1) Revolving Cranes.

(a) Calculate the forces applied in accelerating the live and dead loads on the basis of an assumed acceleration from standstill to full speed in 8 seconds, for both rotation and travel. Calculate the forces incident to deceleration caused by panic stopping (for both rotation and travel) on basis of ratings of brakes, assuming no permanent deformation of any component.

(b) Allow for the forces applied in braking the trolley and the centrifugal forces on the dead and live loads during rotation.

(2) Overhead Traveling and Gantry Cranes.

(a) Lateral and longitudinal loading shall be taken as a minimum of: 2-1/2 percent of the total of the lifted load plus the dead load (not including the weight of trucks and end ties) for Class A cranes; 5 percent for Classes B, C, D cranes; and as 10 percent for Class E cranes, applied one-half to each of the two runways or crane girders. The lifted load shall be considered as a concentrated load.

(b) Higher loadings may be applicable for select cranes.

d. Impact Loads. Provide for an equivalent static increase in the shock-load and the hook-load reactions, as per Table 10.

e. Wind Load.

(1) Non-operating Condition. See DM-2.2 for design velocities in various localities and for formulae relating velocity to pressure.

(2) Normal Operating Conditions. Use 5 psf (240 Pa) for design purposes.

f. Squeezing and Spreading Forces on Legs of Traveling Cranes. For traveling speeds of up to 350 fpm (1.8 m/s), use 12 percent of maximum wheel load (10 percent if crane operates on straight track only) due to dead load plus hook load. Apply horizontally to each wheel, at the elevation of the rail head. Consider total effects of load on all wheels.

g. Seismic Loads. For seismic loads, see NAVFAC P-355.

3. TEST LOADINGS. Except for motor-truck, cruiser, crash, and locomotive cranes, all weight-handling equipment should be capable of lifting (on a periodic test basis) 125 percent of their rated load. Motor-truck, cruiser, crash, and locomotive cranes should be capable (on same periodic test basis) of lifting 110 percent of their rated load. These requirements notwithstanding,

however, no piece of weight-handling equipment shall be loaded in excess of any limitations imposed by the manufacturer's specifications.

4. COMBINATIONS OF LOAD (FOR DESIGN). Design for the following combinations of loads:

(1) Dead, vertical live, impact, horizontal, and operating wind loads.

(2) Dead and non-operating wind loads.

(3) Dead, vertical live, and earthquake loads. Earthquake loads shall include the effects of vertical live load, but may omit the horizontal effect of live load on the crane due to pendulum motion of ropes and hook. Increase allowable stresses 50 percent for this loading condition.

Horizontal loads to include squeezing and spreading forces, acceleration and deceleration (including acceleration and deceleration of boom), centrifugal forces due to rotation, and lateral loads as described under paragraph 2c above, combined on the basis of a simultaneous occurrence of all possible coincident motions.

For jib cranes (including portal and tower cranes) and for derricks, assume boom at minimum radius under application of non-operating wind load.

For floating cranes, in addition to loads enumerated above, consider list and trim forces in combination with other load combinations, as described. List and trim forces induce horizontal components of the vertical dead and live loads on all parts. These forces can be especially serious on the boom (producing torsion), on the rotating mechanisms' strength and control, and on stability.

5. STABILITY OF DERRICKS AND OF PORTAL, HAMMERHEAD, TOWER, AND FLOATING CRANES. In general, NAVFAC practice is as follows:

The horizontal distance from the C.G. of the revolving structure of the crane to the center of rotation at the plane of the top of the lower path for machines having full circle roller nests shall not be greater than the radius of the roller path; for machines employing bogies, the horizontal distance from the C.G. of the revolving structure of the crane to the center of rotation at the plane at the top of the lower track shall not be greater than the distance from the center of rotation to the chord line connecting the bogie equalizer pins; under the following conditions:

(1) Overload of 125 percent of normal load on the main-hoist hook at the maximum full load radius, in any direction.

(2) Boom at minimum radius, no hook load, and non-operating horizontal wind pressure.

The distance of the C.G. of the entire crane (thrust line of all forces above the rails) from the center of rotation, under the following loadings, shall not be greater, at the elevation of the rails, than 0.50 of the track gage.

TABLE 10
Percentages of Increase for Impact

Hook Capacity (tons of 2,000 lb. 2,205 lb. 2,240 lb.)	Hammerhead, Jib, Pillar, Pillar-Jib Cranes			Portal, Tower, and Floating Cranes			Derricks	
	Trolley	Revolving Structure	Tower, Portal, Pillar, Bearing, Trucks	Revolving Structure	Portal, Tower, or Base Bearing Trucks	Boom	Mast or Frame	Base Bearing
25 or less	50	35	18	35	18	50 ..	40	25 ....
26 to 50	45	30	15	30	15	45 ..	35	20 ....
51 to 80	40	25	12	25	12	40 ..	30	18 ....
81 to 120	35	20	10	20	10	35 ..	25	15 ....
121 to 180	30	15	10	15	10	30 ..	20	12 ....
181 or more ...	25	15	10	15	8	25 ..	18	10 ....
All magnet and bucket cranes.	....	....	....	....	....	.....	....	....

(1) Overload of 150 percent of normal load on the main-hoist hook at the maximum full load radius, in any direction.

(2) Boom at minimum radius, no hook load, and non-operating horizontal wind pressure (but not more than 20 psf) (1 kPa). Provision shall be made for adequate, temporary tiedowns where non-operating wind exceeds 20 psf (1 kPa).

List of Floating Cranes and Derricks is limited as follows:

(1) Cranes 25 ton and less--maximum list allowable is 4 degrees (70 mrad).

(2) Cranes over 25 ton--maximum list allowable is 7 degrees (120 mrad). Recommended allowable list is 5 degrees (90 mrad).

(3) Derricks--list shall be limited to 10 degrees (175 mrad).

(4) Moving counterweights or use of water ballast to reduce list is not permitted.

Part 2. STRUCTURAL DESIGN CRITERIA (MODIFICATIONS)

Crane elements considered to be structural for design purposes include, but are not limited to, bridges, booms, platforms, walkways, cabs, machinery houses, jibs, trolley frames, A-frames, portals, truck frames, equalizers, truck rocker pins, wind locks, trolley rails, stairs, ladders, and railings.

1. SELECTION OF MATERIALS. Structural carbon steel (ASTM A36) is most commonly used for structural components of weight-handling equipment. Higher

strength steels, including ASTM A242 (weldable alloys), A441, and A529, find use where the need to reduce weight is of special importance. Such materials should not be used without consideration of obtaining adequate fracture toughness and through thickness ductility, however.

Similarly, aluminum alloys and aluminum-steel combinations are used to reduce weight. However, such use is made at the expense of ductility and stiffness, or with the introduction of an isolation problem (between the dissimilar metals). Therefore, aluminum alloys, particularly cast aluminum, shall not be used for structural components of weight-handling equipment without approval of NAVFAC Headquarters.

Accordingly, in applications involving alteration, replacement, or strengthening of existing components, unless some special problem of availability or other consideration exists, best practice is to match the existing materials.

Cast iron shall not be used for structural components.

2. SPECIAL CONSIDERATIONS IN DESIGN.

a. Stiffness. Stiffness is a prime requisite to hold working alignment of machinery and must be considered in addition to stresses.

b. Welded Construction. Preferred for medium and large cranes. Seal against moisture penetration. See NAVFAC P-956 for welding requirements.

c. Connections. Body-bound and high strength bolts shall be considered as the equivalent of rivets of equal size.

d. Loads on Trucks of Portal or Tower Cranes. Loads shall be determined on the basis that the tower, or portal, is flexible, i.e., use the "beaming" method rather than the "moment of inertia" method.

Part 3. MECHANICAL DESIGN CRITERIA (MODIFICATIONS)

Crane elements considered to be mechanical for design purposes include, but are not limited to, shafts, axles, bearings, keys, gears, sheave pins, blocks, hooks, hook trunnions, roller paths, rollers, wheels, wire rope, drums, sheaves, couplings, spring bumpers, diesel engines, brakes, and pawls.

Wherever practicable, all elements and assemblies shall be constructed so that they may be easily assembled or disassembled, adjusted, and repaired and shall be readily accessible for inspection, cleaning, and lubrication. Supporting surfaces for motors, gearcases, brakes, bearing housings, and similar machine components shall be planed in place. All welding, except that for attachment of alignment devices and shims, shall be completed on all parts of the machinery supporting structure prior to planing of surfaces. All motors, gearcases, brakes, bearing housings, and similar components shall be held in alignment with tight fitting dowels, shear bars, or chocks (in pairs) securely welded to the supporting structure after final alignment is complete. When shims are used for alignment perpendicular to the supporting structure, they shall be a minimum of 1/8 inch thick, machined on both sides, and shall be permanently secured to the supporting structure by welding. All weldments, including gearcases, drums, gears, and similar fabricated mechanical components shall be stress relieved prior to finish machining. Steel retaining rings may be used on brakes, but shall not be used on or in conjunction with any other mechanical elements.

1. SERVICE LIFE. The following factors shall be considered when selecting rated parts:

a. Strength. The design factor included in the published rating of a part or commercial assembly should be ascertained and a part, or assemblage, selected having sufficient rating to provide the required design factor hereinbefore listed.

b. Life. Some parts, particularly antifriction bearings, are rated in terms of expected hours of life under definite loading conditions. These parts shall be selected to meet the required life. Other parts are often chosen on the basis of life even though there are no published ratings in terms of time. Wire rope and internal combustion engines are examples whose selection is partially governed by judgment of economical or safe life before breakage from fatigue.

c. Wear. Many mechanical components, such as gears, engines, and bushed bearings, are selected for resistance to wear. They may be rated in terms of wear, but not definitely in hours of life. In general, the lower the rating in terms of horsepower or applied load for a given component, the higher the rating in terms of wear and the longer the useful life of the part.

d. Heat Dissipation. Torque converters, brakes, gearing, and similar units shall be checked against the thermal rating to insure against overheating. The heat-dissipating capacity always should be checked.

e. Service Factors. Service factors shall be applied as hereinafter described. Service factor standards have not been established for locomotive, crawler, and truck cranes. Service factors for all other cranes and derricks are as follows:

Hoists	1.00
Rotate Mechanism	1.25
Trolley Travel	1.25
Crane Travel	1.50

2. LIMITATIONS ON USE OF CAST IRON AND ALUMINUM.

a. Cast Iron and Aluminum shall not be used in the hoist power transmission train for shafts, gears, couplings, keys, and hoist drums. It is recommended that steel be used for support components, e.g., gear cases, bearing supports, etc., of the hoist power transmission train. However, cast iron and aluminum may be used to support components of the hoist power transmission train provided they are of a high quality casting with an elongation of not less than 10 percent in 2 inches and stress levels which do not exceed 1/5 of the ultimate tensile strength.

b. Service Use. When cast iron or aluminum is used for such items as gear cases and bearing supports for cranes handling critical loads, these items must be non-destructively tested initially for cracks.

c. Brakes. Automotive gray iron castings (ASTM A159) for heavy duty brake service or ductile cast iron recommended by a brake manufacturer that exhibits wear characteristics in the form of powdered wear particles and is resistant to heat checking shall be used for brakes.

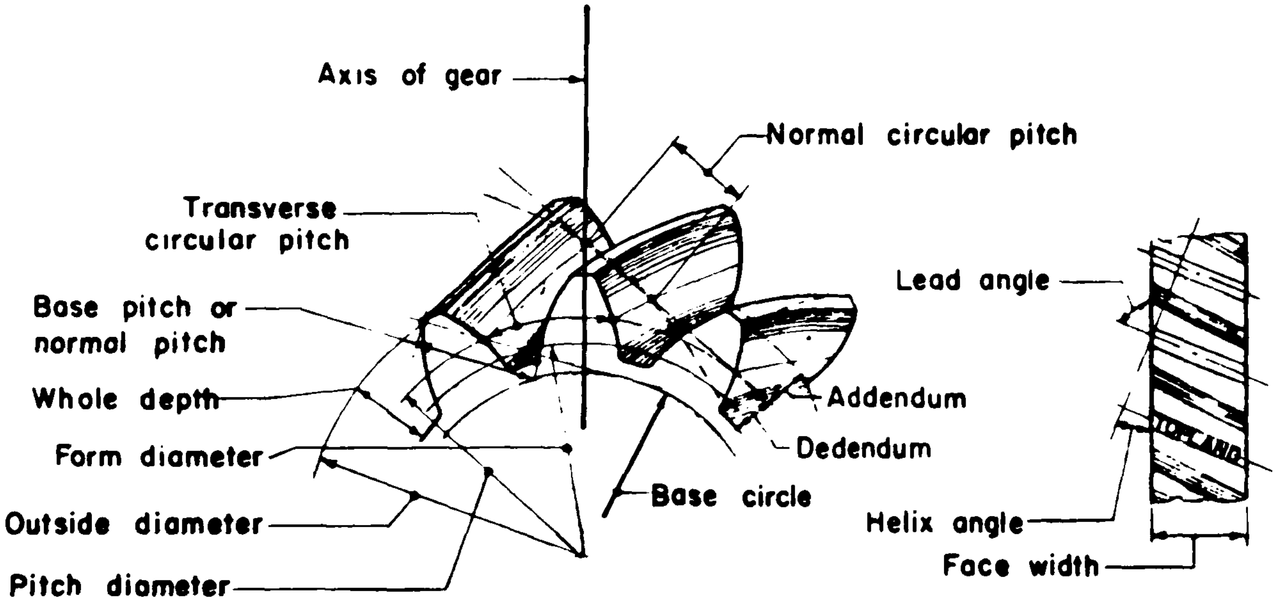
3. MECHANICAL DESIGN LOADINGS. Loads, bending moments, torques, and speeds used in determining component stresses, sizes, and required ratings, except as modified hereinafter, shall be computed using the combination of the following which results in the most conservative design: (1) dead and hook loads, (2) the 30-minute rated speed of the driving motor, and (3) the 30-minute rated torque or horsepower of the driving motor multiplied by the appropriate service factor as delineated hereinafter, and associated torque reactions. Normal impact, shock, vibration, or acceleration loads need not be considered in component computations unless otherwise required. Such loadings must, however, be included in the computations when they are unusually large. All hoist drive components shall be designed for motor torque and/or horsepower (the line pull off drums, for drum and related component calculations, shall be taken to be that necessary to balance torque due to full rated motor torque).

4. TRAVEL DRIVE MECHANISMS. Where travel drive mechanisms are employed, each mechanism drives two closely spaced wheels mounted within a single truck frame through an interconnecting gear train consisting of wheel gears and one or more meshing idler gears; the idler gear(s), wheel gears, and associated shafts, axles, and bearings shall be designed for the loadings noted in paragraph 3, except that if the slipping torque is greater than the torque due to the 30-minute rated torque of the motor multiplied by the required service factor, slipping torque shall be used in the computations. The slipping torque shall be taken as that required to slip one wheel on the rail in relation to the other wheel assuming the coefficient of friction between wheels and rail of 0.20. The wheel axles and axle bearing of all traveling portal, tower, hammerhead, gantry, and semi-gantry cranes shall, in addition to the load conditions noted hereinbefore, be designed for vertical forces due to acceleration, and spreading and squeezing forces.

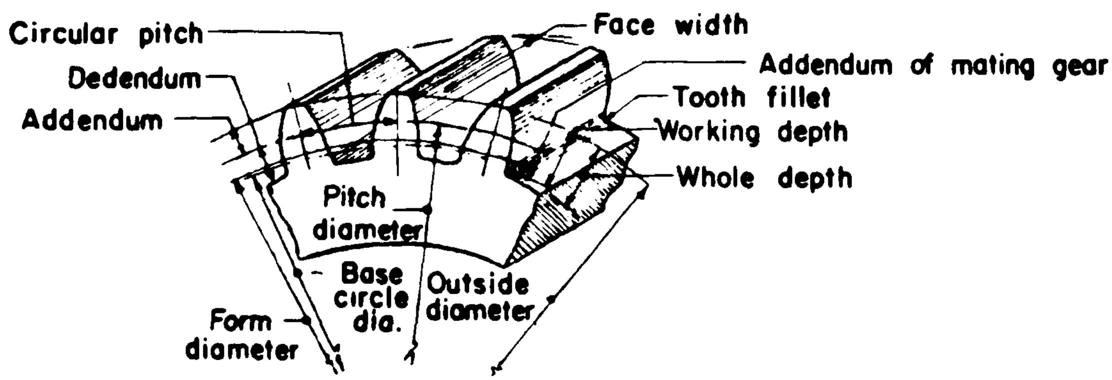
5. LUFFING HOIST MECHANISMS. Luffing hoist mechanisms shall be designed for not less than 75 percent of the maximum torque produced by hook load and dead load or the 30-minute rated torque of the driving motor, whichever is greater, and the corresponding speed of the driving motor.

6. GEARING.

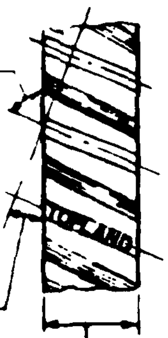
a. Types. (See Figure 43.)

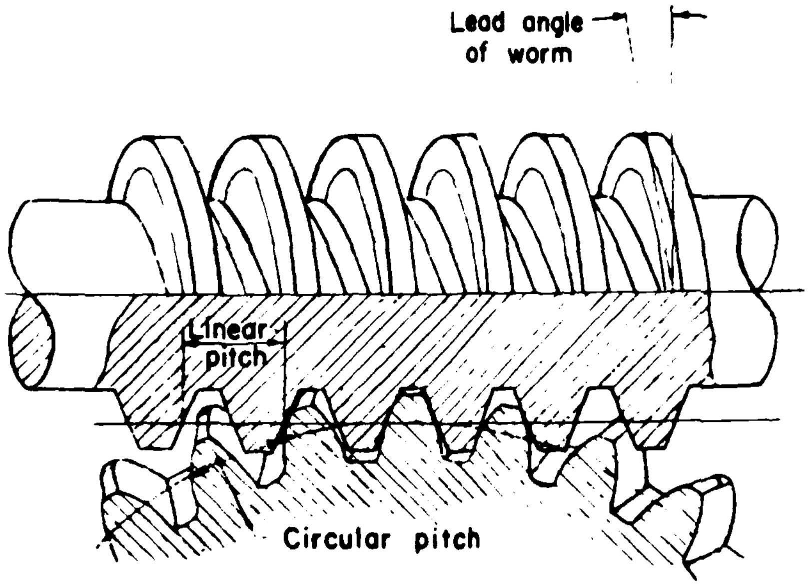


(a) HELICAL GEAR

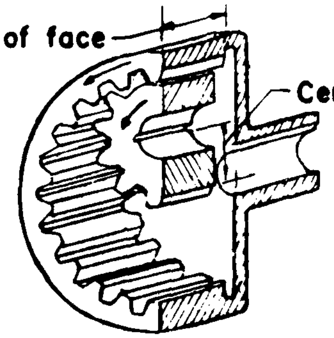


(b) SPUR GEAR





(c) WORM GEAR



(d) INTERNAL GEAR & PINION

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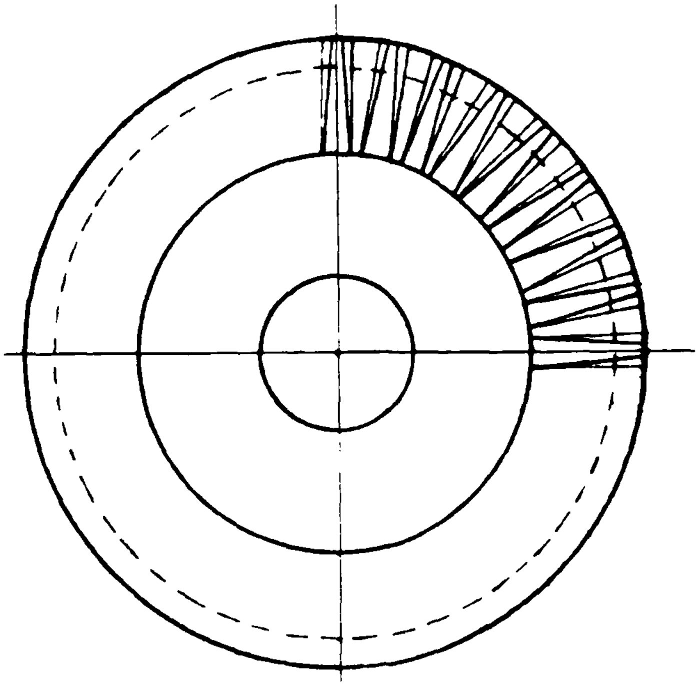
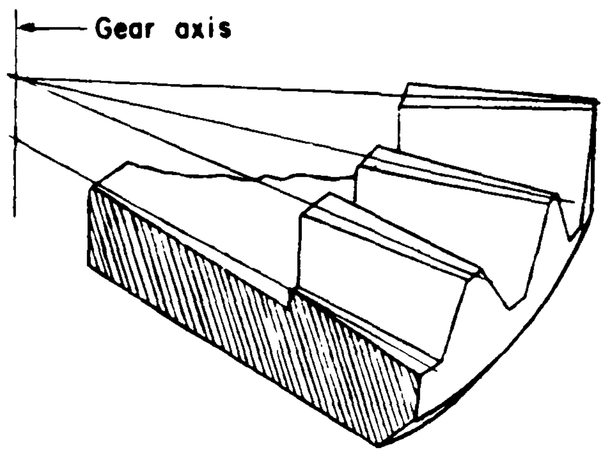
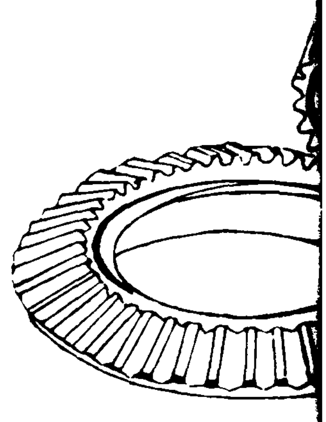


PLAN



(e) FACE GEAR



(f) BEVEL GE

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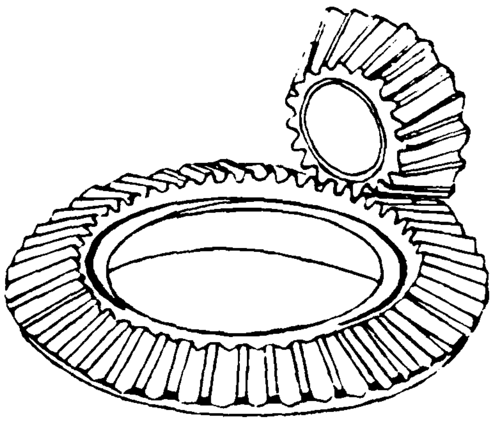

(f) BEVEL GEARS

FIGURE 43
Types of Gears

b. Applications. No dogmatic rules apply. Selection is a matter of weighing several conflicting advantages and disadvantages. In general, however:

(1) Spur gears are used wherever design requirements permit.

(2) Helical gears generally for higher speeds, and if noise is a problem.

(3) External helical gears used when both high speed and high horsepower are involved.

(4) Bevel gears normally used on right-angle drives where high efficiency is required.

(5) Worm gears used on right angle drives where very high gear ratios are required.

c. Design Standards. Formulas and procedures for gear design, standards of tolerance, and backlash are given in American Gear Manufacturers Association (AGMA) publication (see Criteria Sources).

d. Gear Rating.

(1) General. Base the horsepower ratings for gears for cranes on the number of hours of operation expected per year for the mechanism and on the strength and durability rating. No rating shall be higher than the strength rating. If the durability rating is lower than the strength rating, the rating to be applied shall be as follows:

0 to 500 hours: Normal strength horsepower.
501 to 1000 hours: durability horsepower plus 75 percent of the difference between the strength and durability horsepower.
1001 to 2000 hours: durability horsepower plus 50 percent of the difference between the strength and durabilty horsepower.
2001 to 3000 hours: durability horsepower plus 25 percent of the difference between strength and durability horsepower.
3001 to 4000 hours: durability horsepower.

(2) Specific.

(a) Portal, tower, level-luffing, hammerhead, and floating cranes. Select horsepower rating for bull pinions and bull gears for strength only.

(b) Overhead traveling cranes. Select gears and gear ratings in accordance with the following table:

Crane Class	Rating Basis
A, all motions. B, all motions except single hoist.	Normal strength horsepower.
B, single hoist. C, trolley, main and auxiliary hoist.	Durability horsepower + 75 percent of the difference between strength and durability horsepower.
C, bridge and single hoist. D, trolley, main and auxiliary hoist and single hoist. E, auxiliary hoist.	Durability horsepower + 50 percent of the difference between strength and durability horsepower.

Crane Class	Rating Basis
D, bridge. E, trolley, main hoist, and single hoist.	Durability horsepower + 25 percent of the difference between strength and durability horsepower.
E, bridge.	Durability horsepower.

For average conditions for portal, tower, hammerhead, and floating cranes and derricks use rating basis for Class C. Rating of all rotate drive bull pinion-gear sets for all classes of portal, tower, hammerhead, and floating cranes and derricks shall be based on the gear set strength horsepower in lieu of that noted above.

7. SHAFTS, AXLES, AND PINS. Shafting on a majority of the Navy's weight-handling equipment has been designed for combined torsion and bending plus stress concentration factors up to 33-1/3 percent in accordance with the following formula:

$$S = \frac{5.1}{d^3} \left(M + \sqrt{M^2 + T^2}\right) \qquad (1)$$

Where:

	Customary Units	Metric Units
S = Resultant bending stress	(psi)	Pa
M = Bending moment	(inch-pound)	N·m
T = Torsional moment	(inch-pound)	N·m
d = Solid Shaft diameter	(inch)	m

Where:

Maximum allowable S = 1/5 the ultimate tensile strength of the shafting material.

The above criteria with its large factor of safety (sometimes referred to as a factor of ignorance) has provided the Navy with reliable weight-handling equipment. However, advances in engineering technology since adoption of equation (x - fx) by the Navy show that the Mise Criterion of Failure (sometimes referred to as the Shear Energy Theory or the Octhahedral Shear Theory) will more accurately predict failure of shafts and pins under fatigue loading. For future modification and in cases where there is doubt as to the adequacy of an existing design the Mise Criterion of Failure shall be used (see Stress Concentration Design Factors by R. E. Peterson, published by John Wiley & Sons and Mechanical Engineering Design by J. E. Shigley, published by McGraw-Hill). For shaft design subjected to steady plus alternating torsion and single plane steady plus alternating bending stress, use the following formula:

$$N = 3 \leq \frac{1}{\sqrt{\left[\frac{\sigma_o}{\sigma_u} + \left(K_t{}^1{}_f \frac{\sigma_a}{\sigma_f}\right)\right]^2 + 3\left[\left(\frac{\tau_o}{1.33\sigma_y}\right) + K_{tfs}\frac{\tau_a}{\sigma_f}\right]^2}} \qquad (2)$$

Where:

σ_o = Steady (or average) normal stress, kips per square inch, KSI (MPa).

σ_a = Alternating (or completely reversed) normal stress, KSI (MPa).

τ_o = Steady (or average) shear stress, KSI (MPa).

τ_a = Alternating (or completely reversed) shear stress, KSI (MPa).

σ_u = Ultimate tensile strength, KSI but not greater than $1.7\sigma_y$.

σ_y = Yield strength, KSI (MPa).

σ_f = Fatigue strength for axial load or bending of unnotched element, KSI (MPa).

σ_{f1} = Bending endurance limit of a .3 inch (7.6 mm) diameter mirror polished test specimen.

K_{t1f} = Estimated fatigue notch factor for normal stress taking account of theoretical normal stress concentration fact, Mise Criterion of Failure, and notch sensitivity factor.

K_{tfs} = Estimated fatigue notch factor for shear stress taking account of theoretical shear stress concentration factor and notch sensitivity factor.

N = A design factor against failure.

For shafts subject to bending in more than one plane, resolve the stress into principal stresses and use the shaft design procedure outlined for shaft designed in Association of Iron and Steel Engineering (AISE) Number 6. AISE Number 6 may also be used for single plane bending and torsion both steady and alternating. Shafts, sheave pins, and axles 6 inches and less in diameter shall be of forged, hot-rolled, cold-rolled, or cold-drawn steel. Shafts and axles greater than 6 inches in diameter shall be of forged steel. The class or grade designation as applicable, yield point, ultimate strength, and Brinell Hardness Number of each shaft, pin, or axle shall be shown on the design and detail drawings.

Values for steady and alternating normal and shear stresses should be obtained as applicable from the usual equations for axial, bending, and shear stresses in bars of the applicable cross-section. In general, shafts and axles which are rotating in relation to an applied bending moment (as in the case of gear shafts and wheel axles) shall be calculated for completely reversing normal stress. Shafts and axles subjected to completely reversed driving torque (as in the case of most travel drives) shall be calculated for completely reversed shear stresses, even though the frequency of cyclic reversing shear stress may be considerably less than the frequency of the cyclic reversing normal stress. Shafts subjected to torque which varies from zero to a maximum (such as in most hoist drives) shall be calculated for average and alternating shear stresses of the proper proportion of the maximum shear stress. In the case of stationary pins subjected to varying bending moments, both steady (or average) and alternating (or completely reversed) normal stresses of the proper proportion of the maximum normal stress shall be taken into account. In most cases, torsional stresses will not be present on stationary pins and as a result, τ_o and τ_a will vanish. Values of K_{t1f}

and K_{tfs} shall be obtained from expressions and charts contained in Stress Concentration Design Factors by R. E. Peterson, published by John Wiley & Sons, Inc., New York. Values for σ_u may be obtained from any of the many sources of such published data, but should always take account of mass effect for heat-treated components, and whether component is heat-treated prior to or after machining, as applicable. For cold-drawn and surface-hardened steel, the value of σ_u should be taken as the ultimate strength of the interior steel. Since it is rarely possible to directly obtain values for σ_f by fatigue testing of a similar actual part, such values may be estimated as follows:

$$\sigma_f = C_D\, C_S\, C_M\, \sigma_{f1} \tag{3}$$

Where:

σ_f and σ_{f1} are as previously defined.

C_D = Size factor, dimensionless.

C_D = $0.907 \div (d)^{0.079}$

Where:

d = Shaft diameter, inches.

C_S = Surface finish factor, dimensionless for machined, cold-drawn or cold-finished steels use:

C_S = $0.88 - (.001236\sigma_u)$.

For other finishes, consult references such as Mechanical Engineering Design by J. E. Shigley, published by McGraw-Hill. If the endurance limit (σ_{f1}) of a test specimen (usually 0.3 inches diameter, mirror polished specimen) of the material is not known, the value ($0.45\ \sigma_u$) may be used.

C_m = Factors affecting the endurance limit such as temperature, corrosion, internal and directional stresses (see Mechanical Engineering Design by Shigley).

Stress concentrations shall be avoided wherever practicable. Shafts and axles shall be formed to avoid large or sharp changes of section, and such changes as are made shall be provided with large fillets, fillet rings, or stress reducing grooves. Extreme press or shrink fits shall be avoided to keep stress concentrations to a minimum. Shaft diameter at each coupling seat shall be not less than 90 percent of the shaft diameter at adjacent bearing seat. All shafts and axles should be of solid section. Shafts and axles shall be machined at bearing, gear, wheel, and coupling fits. Gear seats shall be close to bearings to reduce the effect of deflections on shafts, gears, and bearings. Shaft, axle, and pin material shall be tough and ductile.

Diameter range, and hardness of that portion of shafts and axles in contact with lip type seals shall conform to the seal manufacturers' published recommendations.

8. SPECIAL SHAFT AND AXLE REQUIREMENTS FOR OVERHEAD TRAVELING CRANES. Squaring shafts and associated mechanisms for single motor bridge drives shall be designed for two-thirds of the design torque to each end of the crane. Squaring shafts and associated mechanisms for cranes employing a motor drive at each end of the bridge shall be designed for one-third the combined total design torque of the motors. The torsional deflection of squaring shafts, including as applicable floating shafts from end reducers to wheels on single motor drives, shall not exceed 0.08 degrees per foot based on the specified design torque except that for Class A and B cranes the torsional deflection shall not exceed 0.10 degrees per foot. Squaring shafts of ground and polished, turned, or cold-drawn rounds need not be machined at bearing or coupling seats if the tolerances on shaft diameter are within those recommended by bearing manufacturer and/or such as to provide the specified fit in coupling bore. Wheels shall be fixed to rotating axles except that for Class A and B cranes with maximum wheel loads of less than 30,000 pounds, wheels may rotate on roller bearings on a stationary axle which is secured by keeper plates to both webs of end truck.

9. SPECIAL AXLE REQUIREMENTS FOR TRAVELING PORTAL, TOWER, HAMMERHEAD, AND GANTRY CRANES. Axles for Class C, D, and E cranes shall be of the rotating type. Axles for Class A and B cranes may be of either the stationary or rotating types.

10. KEYS AND KEYWAYS. Key sizes shall conform to ANSI Standard B17.1 for the respective shaft diameter. Keys may be of cold finished low carbon steel key stock or heat treated alloy steel. Keys and keyways shall be dimensioned, with tolerances, on the applicable drawings. Keys shall be machined or ground to size, or selective fitting may be employed for keys of cold finished low carbon key stock, to provide the required fit in the keyways. Heat treated key stock shall be sufficiently oversized to allow for cleaning and truing the surfaces by grinding. Keys shall be designed to provide the indicated design factors based on the applicable material property. The ultimate shearing strength shall be taken as equal to 70 percent of the ultimate tensile strength of the material. The compressive yield strength shall be taken as equal to 100 percent of the tensile yield strength of the material. Surface compressive stresses on keyway sides in shafts or axles and hubs of mating components shall also be calculated on the above basis to account for differences in material.

11. WHEELS AND ROLLERS.

a. Loading. Determine design (not necessarily actual) loadings as follows:

(1) Limber Roller Path Supports. Assume that only the rollers in the forward and rear quadrants of the roller circle are acting and that all rollers in each of these quadrants are equally loaded. Consider the loads on these two groups to be equal to the reactions of a beam loaded with the total dead, live, and hook loads above their level, acting as a concentrated load at

its calculated center of gravity, and that the rollers react at the geometric center of pressure of the group of acting rollers (see Figure 44).

(a) Overhead traveling cranes. Wheels for operation on lower flanges of I beams or special built-up inverted T rails (underrunning overhead traveling cranes) shall be single flanged with treads contoured to match rolling surface of track, or may be flangeless provided each wheel is guided by two guide rollers operating against side of lower flange. All travel wheels shall have hardened treads, ground or machined true to diameter and width. Cylindrical driving wheel tread diameters shall be matched within 0.001 inches per inch (.001 mm per millimeter) of diameter, but not exceeding 0.010 inches (.25 mm). Wheels shall be rim toughened to a minimum 320 Brinell Hardness Number. For severe duty, wheel treads shall be deep carburized to not less than 550 Brinell Hardness Number with a gradual decrease of hardness with depth. Wheels on rotating axles shall be pressed on, and driving wheels shall be keyed to the axle. Hub ends of wheels on nonrotating axles shall be ground and polished to mate with bronze thrust washers at truck side members. All wheels shall have cylindrical treads except as otherwise noted. Overhead traveling crane bridge drive wheels shall have treads tapered either 1 inch in 20 inches (5 mm in 100 mm) or 1 inch in 25 inches (4 mm in 100 mm). Fillet radii between tread and flanges of wheels shall be 1/16 inch (1.6 mm) less than corner radius of rail head. Outside diameter of wheel shall be from 1-1/2 inches (38 mm) to 2-1/4 inches (57 mm) greater than tread diameter. Nominal flange thickness shall be not less than 1 inch (25 mm). Trolley wheel treads should be equal to the width of the railhead plus 1/4 inch (7 mm) for 8 inch (203 mm) and smaller wheels and plus 1/2 inch (13 mm) for wheels larger than 8 inches (203 mm) in diameter. Tread widths for bridge wheels should be equal to the width of the railhead plus 1 inch (25 mm) for 16 inch (406 mm) and smaller wheels and plus 1-1/2 inches (38 mm) for wheels larger than 16 inches in diameter. Special conditions may necessitate tread widths other than noted.

(b) Cranes traveling on ground surface rails. Outside diameter of wheel shall be equal to the tread diameter plus twice 1/8 inch (3 mm) greater than the rail flangeway depth at the center of existing rigid frogs that the crane will operate on. This depth is usually 1 inch (25 mm). Trolley wheel treads for gantry and hammerhead cranes shall be the same as for overhead traveling cranes. Tread widths for wheels traveling on ground rails shall be not less than the effective rail width plus 1/2 inch (13 mm) for curved track or 3/4-inch (19 mm) greater than the rail head width whichever is greater. All replacement wheels shall have minimum tread widths compatible with 135 pound crane rail (CR). Effective rail width is computed using the following equation:

$$Re = Rn + R - \sqrt{R^2 - \left(\frac{C}{2}\right)^2} \qquad (4)$$

Where:

Re = Effective rail width

Rn = The width that results in minimum wheel clearance (for 135 pound CR with flanges tapered outward equal to or greater than the rail taper, R_n = 3 inches (76 mm))

R = Radius of sharpest curve

C = Center to center distance between wheels of one truck.

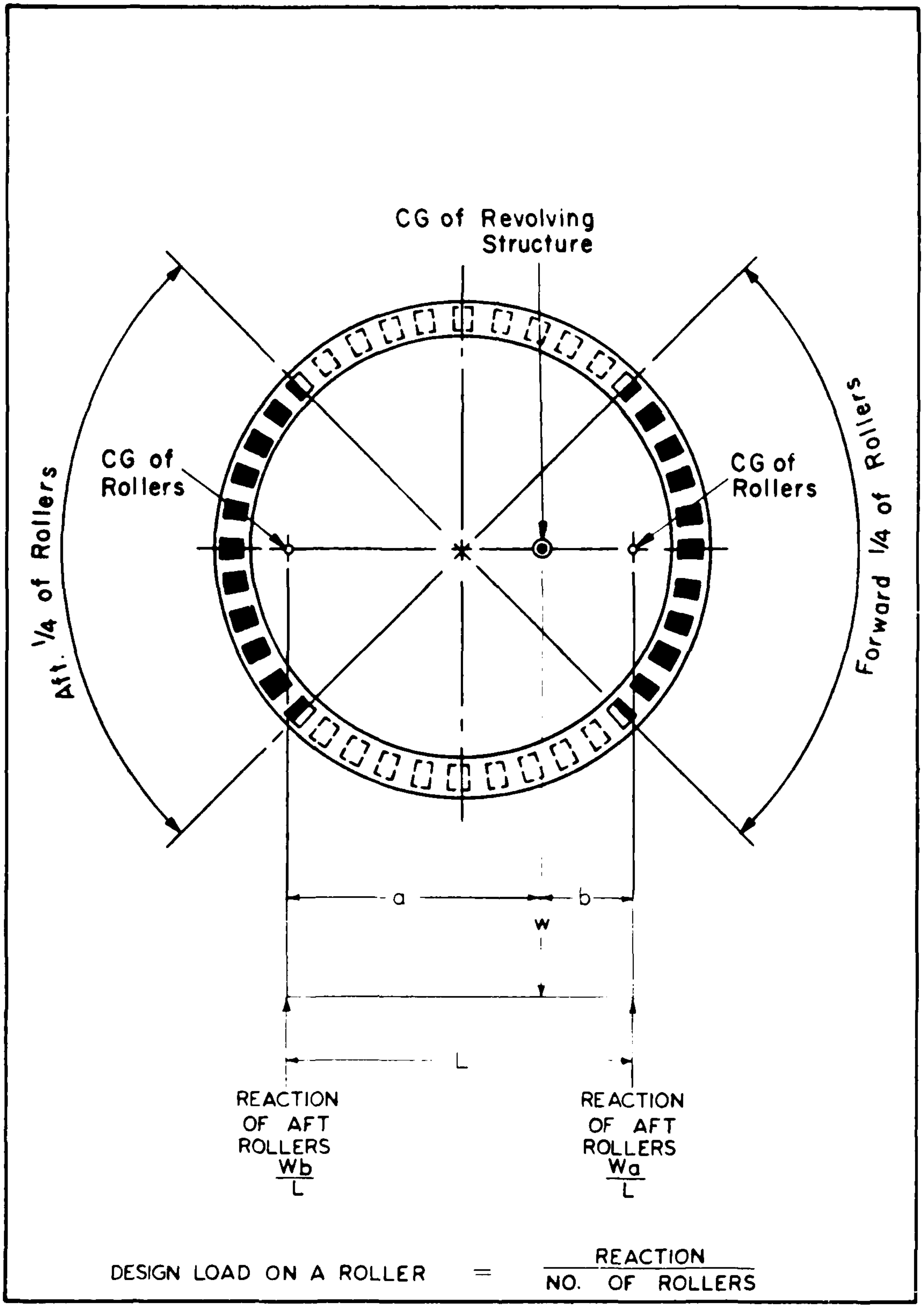

FIGURE 44
Limber Roller Path Loading

b. Allowed Loading. The allowed loading on wheels and rollers shall be:

	Customary Units	Metric Units	
P =	KWD	.069 KWD	(5)

Where:

	Customary Units	Metric Units
P = Allowed wheel or roller load	lb.	Newtons
K = A factor based on the material and kind of service		
W = The effective width of the rail for wheels, or width of roller or track, whichever is less for rollers	in.	mm
D = Diameter of tread of wheel or roller	in.	mm

(1) For portal, tower, level-luffing, hammerhead, and floating crane roller paths, K shall not exceed 2-1/2 times the sum of the Brinell Hardness Numbers (BHN's) of the wheel or roller and of the supporting path or rail, and must never be greater than 1,500. The hardness of roller or wheel treads shall be in the BHN range 325 to 375 and that of rails or paths shall not be less than 300 for rails and 200 for cast or rolled segmental paths. If necessary to produce the hardness by heat treating, it should be done by quenching and drawing or, in the case of wheels, by the rim-toughening process.

(2) The K factor for locomotive cranes has been established in NAVFAC practice as three times the sum of the BHN's (indicated above), but not to exceed 1,500.

(3) The factor K for crane track wheels running on rails at the surface of the ground (including gantry cranes) is established as 1,500. These wheels should have a tread hardness in the BHN range of 325 to 375, obtained by quenching and drawing or by rim-toughening.

(4) For trolley travel and crane travel wheels, as applicable to overhead traveling, monorail, wall, jib and pillar-jib cranes, the allowable wheel load shall be in accordance with Crane Manufacturers Association of America (CMAA) Specification No. 70.

12. ANTI-FRICTION BEARINGS.

a. Type Standardization. The most commonly used anti-friction bearings have been internationally standardized as to bore, outside diameter, and width. Standardized bearings should be used.

b. Numbering System. For the use of the Armed Services in procurement, stocking, and replacement of the tens of thousands of sizes and types of anti-friction bearings, an all-embracing numbering system has been devised. It does not identify by manufacturer, but is descriptive as far as all the major points of engineering importance are concerned. These points are type, size, type modifications, retainers, tolerances and fits, and lubrications. This system is embodied in MIL-STD-102. These numbers shall be used on design and detail drawings and stamped on or near the bearing housings on all weight-handling equipment procured.

c. Classes. Anti-friction bearings are classed as rigid or self-aligning.

(1) Rigid bearings, which have the greater capacity, shall be used when the mounting or base is rigid and where the shaft can be held rigidly in alignment. Undesirable eccentric loading of the bearing otherwise results.

(2) When the mounting or the shaft is relatively limber and deflection is likely to be large, self-aligning bearings shall be used. Except for the purpose of aiding in the initial alignment during assembly, rigid bearings in so-called self-aligning housings should not be used. They seldom align under load without being subjected to unacceptable high, eccentric loadings.

d. Rating. Select anti-friction bearings on basis of manufacturer's rating. Rating is a function of load, at a definite speed, for a definite life. Rating data, conversion formulas, and various service factors are published by each manufacturer for his own bearings.

(1) Life. Hours of expected life are expressed in two ways--average life and minimum life (B-10 Life). Because the latter is only one-fifth the former, the specifications or design criteria should definitely state which is intended or desired.

(a) Average life is the number of hours to failure of 50 percent of all bearings of a large group.

(b) Minimum life (B-10 Life), as used in bearing terminology, is the number of hours at which 90 percent or more of a large number of identically loaded bearings will still be operating.

13. SELECTION OF BEARINGS.

a. Anti-friction Bearings. All bearings, except those subject only to small rocker motion and certain running bearings as hereinafter permitted, shall be of the anti-friction type with the balls or rollers retained in a cage. Bearings shall be the product of a manufacturer making a specialty of manufacturing standardized bearings to commercial precision limits. They shall be installed in accordance with the manufacturer's recommendations. Allowable load computations for anti-friction bearings shall be in accordance with published engineering data of the bearing manufacturer, except as otherwise specified herein. Anti-friction bearings, except gudgeon, hook thrust, and similar bearings, shall be designed for dead load, direct reactions of the hook load (applied as a dead load), and torque reactions of the values noted under Mechanical Design Loadings. Loads and reactions shall be reduced to percentages not less than as shown in the following table, with normal impact, shock, and similar loadings omitted. Anti-friction bearings shall be designed for the speeds resulting from operation of the driving motor at its 30-minute rated speed and shall provide not less than the minimum number of hours of B-10 life shown in the following table (Table 11) for the applicable equipment class and application. For average conditions for portal, tower, hammerhead, and floating cranes and derricks use Class C life requirements.

b. Life. Anti-friction bearings shall be selected (on the basis of B-10 life) to give a minimum life expectancy of 10 years under the service conditions for which the crane is intended. The total number of cycles shall be based on that which the bearing is expected to undergo during a 10-year life expectancy.

(1) Constant loads. Where the loads are essentially constant the bearings must meet the required life expectancy, considering 100 percent of the maximum load at rated speed.

(2) Varying loads. Where loads are not constant (such as bearings for bridge and trolley track wheel assemblies and sheave bearings) design shall be based on a load which is equal to 75 percent of the maximum load which can be applied to the bearing, with the crane loaded in such a manner as to apply the maximum load condition to that particular bearing. Sheave bearings shall be based on 75 percent of the maximum load which can be applied to the bearing (the "lead" sheave rpm at full rated speed shall be used to size all sheave bearings).

(3) Locomotive cranes. Hours of bearing life and loadings are assigned in the corresponding Military Specifications (see Section 4) at those amounts complying with the best commercial practices.

(4) Crawler and motor truck cranes. No definite hours of bearing life or loading have been established for crawler and motor truck cranes because the practice in the industry is difficult to determine and is known to vary widely.

TABLE 11
Minimum Hours of Life (B-10 Life) and Applicable Percentage of Various Loads for Bearing Design for Overhead Traveling, Monorail, and Wall Cranes

	Bridge		Trolley		Main hoist		Auxiliary hoist		Single hoist	
Crane class	Life	Percent load	Life	Percent load	Life	Percent load	Life	Percent load	Life	Percent load
A	3,000	75	2,500	75	2,500	75	2,500	75	3,500	75
B	5,000	75	4,000	75	4,000	75	5,000	75	5,000	85
C	10,000	85	8,000	85	8,000	75	10,000	75	10,000	75
D	20,000	85	15,000	85	15,000	75	15,000	75	20,000	75
E	25,000	85	20,000	85	20,000	85	20,000	85	25,000	85

(5) Bearings for static and rotating loadings. Allowed static loadings on anti-friction bearings shall be determined by the load that causes objectionable forming of permanent indentations in the bearing races by the balls or rollers (Brinelling). Means for determining this load are given by manufacturers. It is usually from six to ten times the rated load capacity of the bearing. In some applications, the statically loaded portion of the race is not the same as that dynamically loaded, and a greater amount of "Brinelling" under static conditions may consequently be acceptable.

(a) Bearings subject mainly to static loading and yet required to rotate somewhat under load cannot be consistently rated for hours of life. Hook bearings (thrust type) and trunnion and gudgeon bearings for travel trucks are examples of such bearings. Allow these bearings to be loaded to their basic rating at 10 rpm for the hours of life specified for the particular crane function for which they are used, or allow loads as computed by (Equation 6) and (Equation 7).

For roller bearings,

	Customary Units	Metric Units	
$P =$	9,000 DLN	1,576 DLM	(6)

For ball bearings,

$P =$	$4{,}000\ ND^2$	$27.58\ ND^2$	(7)

Where:

P = Allowed loads in	pounds	Newtons
D = Diameter of roller or ball in	inches	mm
L = Length of roller in	inches	mm

N = Total number of rollers or balls for thrust bearings or 1/5 the total number for radial bearings.

(b) Alignment. Anti-friction bearings, self-aligning or not, require close alignment. Consequently, bronze bearings in combination with anti-friction bearings should never be used wherever wear of the bronze may change the alignment.

14. SPECIFIC REQUIREMENTS FOR BEARINGS.

a. Portal, Tower, Floating, Hammerhead, Level-Luffing, Gantry Cranes. Under average conditions, use the design loadings and design minimum hours of life of bearings of these cranes as given in the following tabulation (see paragraphs (1), (2), (3), and (4) below for explanation of load):

Motion	Hours	Percent Load
Travel	10,000	85
Rotate or trolley	7,000	85
Luffing hoist	5,000	75
Main hoist	5,000	75
Auxiliary hoist	7,000	75
Whip hoist	8,000	75

(1) Travel motion. The load is that from whatever weight is on the bearing plus that from the driving or braking torque, computed as equal to 1.5 times the full load torque of the motor at its 30-minute rating.

(2) Rotate or trolley motion. The load is the same as for the travel motion, except that the torque multiplier is 1.25.

(3) Luffing hoist motion. The load is from the maximum torque on the motor in any luffing cycle.

(4) Motion of main, auxiliary, and whip hoists. The load is from the torque of the motor at its 30-minute rating.

b. Overhead Traveling Cranes. For overhead traveling cranes that are not designed to meet a specific duty cycle, anti-friction bearings shall be selected to meet the requirement of the applicable class of crane noted in Table 11.

15. BRONZE BUSHINGS. Bearings subject to small rocker motion shall be of the bronze bushing type. Bearings supporting vertical bull pinion shaft and rotate center bearings on portal, tower, hammerhead, and floating cranes shall also be of the bronze bushing type. Bushings shall be full circle of ample size to insure cool running, shall be of substantial construction with wide bases attached to the supporting structure, shall be of adequate thickness, and shall be dust tight. The projected area of running bushings shall be such that the load in pounds per square inch multiplied by the square root of the rubbing velocity in feet per second will not exceed 900. For running bushings the maximum allowable bearing pressure as computed by the projected area shall in no case exceed 1,000 pounds per square inch (6,900 kPa) of bearing pressure as computed by the projected area. Bearings subjected to only a small rocker motion shall not exceed 20 percent of the elastic limit as commercially determined nor more than 4,000 pounds per square inch (27,600 kPa), except that for gudgeon pin bushings which are required to "float" on gudgeon pins the maximum bearing pressure shall not be more than 1,500 pounds per square inch (10,300 kPa). Gudgeon pin bushings shall be of aluminum bronze and shall have two separate grease groove systems, one on loaded area of bushing, the other on unloaded area. The grease grooves in loaded portion of bushing shall have sufficient area to lift the loading structure under minimum dead load conditions with grease at a pressure of 8,000 psi (55,100 kPa). All other bushings and thrust washers shall be properly grooved to satisfactorily distribute the lubricant to all areas. All bushings shall have integral flanges except that

flanges may be omitted if bushings are securely retained by other means and are equipped with thrust washers (if necessary). Bearing caps, if used, shall be of rolled or cast steel, shall be located in accurately machined tight-fitted chocks, and shall be held securely in place. Bearing housings for vertical bull pinion shafts and rotate centers shall be steel castings or weldments bushed at each end and shall be rigidly supported.

16. ROPE DRUMS. Rope drums shall be of welded rolled structural steel, cast steel, or seamless steel pipe. Drums shall not be stressed in combined crushing and bending in excess of 8,000 psi (55,100 kPa) for steel having an ultimate tensile strength of approximately 60,000 psi (413,700 kPa). Allowable stress for steels having higher ultimate strengths shall be proportionally higher. In addition to the combined crushing and bending stress limitation, drums shall be calculated to insure that the external pressure as applied by the wire rope layer(s) does not exceed 1/5 the collapse pressure as determined by:

$$P_c = \frac{2.6E\sqrt{\left(\frac{t}{D}\right)^5}}{\frac{L}{D} - 0.45\sqrt{\frac{t}{D}}} \qquad (8)$$

Where:

			Customary Units	Metric Units
P_c	=	Collapsing pressure	psi	kPa
E	=	Modulus of elasticity	psi	kPa
t	=	Drum thickness under grooves	inches	mm
D	=	Drum tread diameter	inches	mm
L	=	Drum length between diaphragms	inches	mm

The external pressure exerted by a single layer of wire rope is determined by:

$$P = \frac{T}{R\,b} \qquad (9)$$

Where:

	Customary Units	Metric Units
P = External pressure on drum	psi	Pa
R = Tread radius of rope and drum	inches	meters
T = Rope pull	pounds	Newtons
b = Rope pitch for grooved drums and rope diameter for smooth drums	inches	meters

The external drum pressure for multiple layer drums shall be determined from the data contained in NAVSHIPS 0900-008-2010.

Annular welds of drums fabricated in two or more lengths and longitudinal welds of the drum barrel shall be complete penetration welds. Welds carrying drum driving torque shall not be stressed in shear due to combined torsion and bending in excess of 6,000 psi (41,370 kPa), and, if weld is of the fillet type, the weld size shall not be less than that specified in American Welding Society (AWS) D1.1 based on material thicknesses. Drums shall have through shafts or stub shafts. Stub shafts or hubs for through shafts shall be set in and welded to two widely spaced diaphragms, a single thick diaphragm, or one diaphragm with not less than six stiffeners radiating from stub shaft or hub to drum barrel. Single layer drums for double reeved hoists shall have flanges at each end, and shall have helically turned grooves cut right and left hand to receive, in a single layer, the full winding length of the rope plus not less than two dead turns on each end. Single layer drums for single reeved hoists shall be similar to that for double reeved hoists except that grooving shall be either right or left hand as suits the application. Grooving for two layer drums shall be helical or counterbalance type. Grooving for three or more layer drums shall be counterbalance type. Grooves for single layer drums shall be smooth and well rounded, and shall have a depth not less than 0.4375 times the rope diameter, a pitch of not less than 1.125 times the rope diameter and a radius in accordance with Figure 45.

Drum ends for multiple layer drums shall be fitted with flanges and risers and filler strips of the configuration noted in NAVSHIPS 0900-008-9010. Drum groovings for multiple layer drums shall have a pitch as noted in NAVSHIPS 0900-008-9010. If multiple layer drums are used for double reeved hoists, the center of the drums shall be fitted with flanges, riser, and/or filler strips as necessary. All flanges shall have an outside diameter at least four rope diameters greater than the outside diameter of the top layer of rope. Rope dead ends shall be anchored to single layer drums by means of rope clamps or swaged or speltered rope sockets and to multiple layer drums by means of rope sockets. Rope clamps shall have two grooves mating with grooves in the drum barrel and shaped to securely clamp the rope. The rope shall pass under the first groove and be doubled back or wrapped around drum to pass under the second groove. Fastener holes shall be located between the clamp grooves. A minimum of two fasteners shall be provided for each rope clamp. Fasteners shall be cap screws with heads wired together or through studs welded to inside of the drum barrel with slotted or castellated nuts locked to studs by means of cotter pins. When rope sockets are used, end grooves of the drum barrel shall be turned into the anchor point with a radius of not less than six rope diameters. The rope socket shall be anchored inside the drum barrel or on the outside of the flange against a rigid surface which is welded in place. The holes in the drum barrel for insertion and removal of the socket and rope shall be closed with pipe plugs. Drum pitch diameters shall be not less than as shown in Table 12 for the applicable equipment class, with the drum and sheave diameters given in rope diameter units.

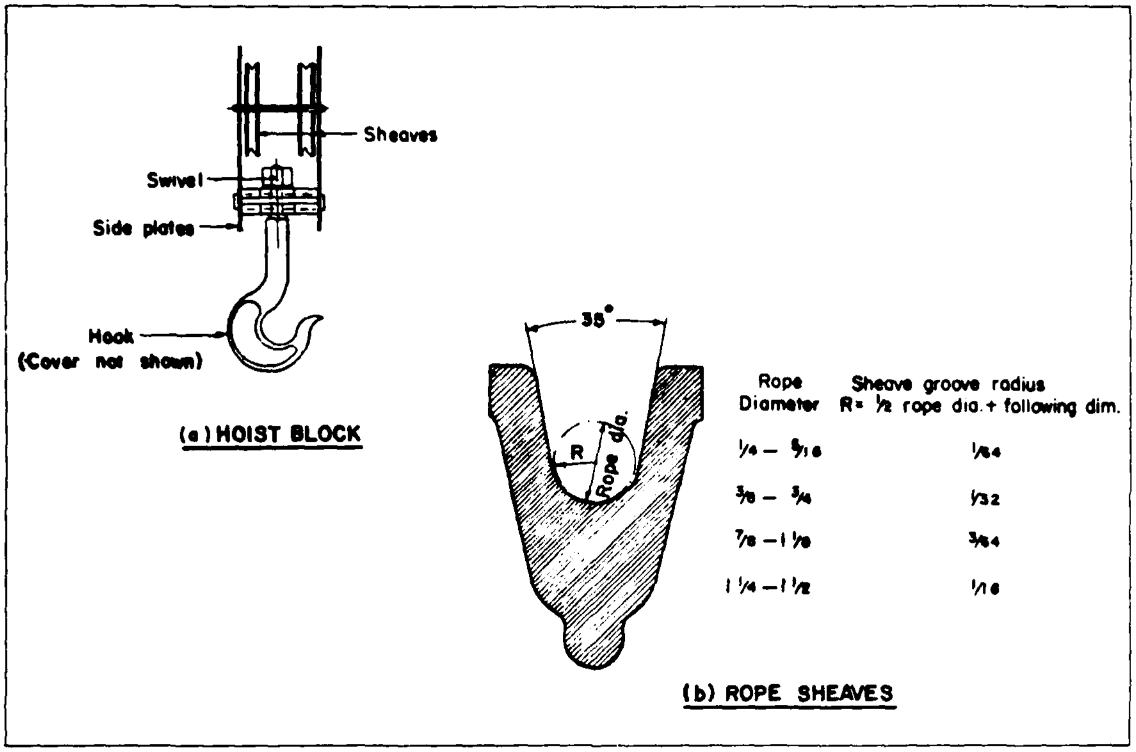

FIGURE 45
Hoist Block and Rope Sheaves

TABLE 12
Drum and Sheave Pitch Diameter/Rope Diameter Ratios

Type of Drum	Weight handling equipment type	Wire Rope classification	Drum and Running Sheave Ratios Minimum	Drum and Running Sheave Ratios Recommended	Recommended Equalizer Sheave Ratio
Single layer type	Portal, hammerhead, tower, and floating cranes and derricks.	6 x 19 Seale	24	36	30
		8 x 19 (spin-resistant)	24	30	
		6 x 25 Type B Flattened Strand			
		6 x 30 Type G Flattened Strand			
		6 x 21 Filler wire	24	36	30
		6 x 25 Filler wire	24	30	26
	Portal, hammerhead, tower, and floating cranes and derricks.	All ropes in 6 x 37 classification	24	30	24
		18 x 7, 19 x 7 (non-rotating)	34	40	
	Overhead traveling and gantry cranes, class A.	6 x 37 classification having 41 or more wires per strand	20	24	18
	Overhead traveling and gantry cranes, class B.	All ropes in 6 x 37 classification	24	24	18
	Overhead traveling and gantry cranes, classes C, D, and E.	All ropes in 6 x 37 classification	24	30	18

For Multiple Layer Drums See NAVSHIPS 0900-008-9010

17. HOIST ROPES. The maximum rope load or drum line pull shall be computed in accordance with the following formula:

$$P = \frac{W(K)^{S/2} \quad (K-1)}{2\ (K^{N/2} - 1)} \quad \text{for double reeved systems.} \quad (10)$$

or

$$P = \frac{W(K)^{S} \quad (K-1)}{(K^{N} - 1)} \quad \text{for single reeved systems.} \quad (10)$$

Where:

P = Drum line pull

W = Total weight supported

S = Number of running sheaves in system

N = Number of parts of line supporting load

K = 1.04 for anti-friction type running sheave bearings (friction factor)

K = 1.09 for bronze bushing type running sheave bearings (friction factor). (The inclusion of this value is for purposes of determining rope loads in existing bronze bushed sheave reeving systems and is not to be construed as permitting new bronze bushed sheave reeving systems.)

The drum line pull shall be divided into the nominal breaking strength of the wire rope to obtain the design factor. Hoist rope shall be of the type noted in Table 12 for the respective drum and weight-handling equipment type and shall be preformed, uncoated. Ropes for multiple layer drums and for cranes used for handling molten materials shall have independent wire rope cores. Ropes for other applications shall have cores suitable for the intended service. All rope shall conform to the applicable requirements of Federal Specification RR-W-410. Rope lead angles between sheaves and from single layer grooved drums to first sheaves in reeving system shall not exceed 2 degrees. Rope lead angles from multiple layer drums and smooth drums to first sheaves in reeving system shall not exceed 1-1/2 degrees. Also, the lead angle between sheaves shall not exceed 3 degrees. Refer to NAVSHIPS 0900-008-9010 and 0900-008-2010 for additional information concerning wire rope.

18. ROPE SHEAVES AND HOIST (LOAD) BLOCKS. The basic parts of a block are shown in Figure 45a. Hoist blocks preferably should be enclosed for safety and to permit adequate lubrication without dripping of lubricant on workmen, materials, or onto floor. A flange at the hook opening also should be provided for this purpose.

a. Sheaves. Diameter of running sheaves should conform to the requirements for rope drums as set forth in paragraph 16. Recommended diameter of equalizer sheaves are given in table 12. Flanges shall have depth not less than 1.15 x rope diameter. Upper hoist blocks shall be provided with sheave side plates with rounded edges to prevent ropes leaving grooves under excessive rope leads. Grooves should conform to minimum dimensions shown in Figure 45b. Sheaves and sheave pins of blocks shall be readily accessible and capable of being removed. Sheave pins shall be drilled to provide a separate individual lubrication passageway to each sheave bearing. Sheaves shall be of cast, roll forged, or rolled and welded structural steel with all grooves machined or ground to contour with tread hardness of not less than 320 Brinell.

b. Lower Hoist Blocks for Other than Single Part Single Reeved Systems. Blocks shall be provided with a forged steel trunnion separate from the sheave pin. The trunnion shall be bored for swivel mounting of the hook and shall be securely retained in the block side plates. The adequacy of the trunnion shall be verified by the application of the shaft design formula contained in paragraph 7. For blocks over 5-ton capacity, the trunnion shall rotate about its horizontal axis in holes bored in the side plates. Bearing pressure of trunnion on plates shall not exceed 6,000 psi (41 370 kPa). The lower block weight, including the load hook, shall be sufficient to overhaul and accelerate all rope and all mechanisms not subject to positive drive down from the motor. Sheave bearing lubrication fittings shall be recessed within the sheave pin or otherwise protected. Lower blocks shall be constructed so that they may be easily and completely disassembled into component parts without damage to any part. Welding or peening over of fastener threads to preclude loosening of fasteners is not acceptable.

c. Lower Hoist Hook Arrangement for Single Part Single Reeved Systems. End of whiphoist wire rope and other single part single reeved systems shall be socket connected to chain which is in turn attached to a swivel hook assembly. Approximately 4 feet (1.2 meters) above the hook bearing, a cast iron ball consisting of two hemispherical-shaped halves shall be through bolted or clamped by means of through bolts to the chain. Weight of ball shall be sufficient to overhaul the wire rope with hook being onloaded. Optionally, a combination ball-swivel hook assembly may be employed. Hooks shall swivel on anti-friction thrust bearings.

d. Fiberglass Insulated Links. When fiberglass insulated links are used on weight-handling equipment, they should meet the following criteria:

(1) Have a minimum breaking strength of five times the rated load;

(2) have ends constructed of steel;

(3) end magnetic particle tested for cracks before covering with fiberglass; and

(4) meet the electrical isolation characteristics specified by the using activity.

19. HOOKS.

a. Materials and Manufacture. For capacities up to 50 tons, usually forged and of carbon or alloy steel. For capacities over 50 tons, consider cutting from steel slab and machining to contour.

b. Stresses. Compute stresses on the basis of a vertically applied load for single-barbed hooks and of applicable components of the load applied 30 degrees from vertical for double-barbed (sister) hooks. The cross section of the curved part should be designed to minimize the difference between compressive and tensile strengths.

Hook opening and shank length shall be such that when the hook is mounted in the block, sling placement will be facilitated. Sling bearing portions of the hook shall be well rounded. Each hook shall swivel on, and be centered by, an anti-friction thrust bearing mounted within a counter bore in the lower block trunnion.

c. Details. Rope bearing portions should have smooth, rounded surfaces. Material and heat treatment should be stamped on the end of the shank.

20. BRAKES. To assure safety and accuracy of control, there should be two independent systems of braking for each hoisting and luffing motion.

a. Friction Brakes. Common types of friction brakes used for weight-handling equipment include the shoe and disc types.

(1) Shoe brakes. Consist of a friction shoe which is pressed against rotating drum producing braking friction. Easy to adjust, minimum drag, and good heat dissipation.

(2) Disc brakes. Consist of moving plates or discs sandwiched between fixed discs. Usually high first cost. More difficult to get adequate heat dissipation. Good holding power if adequate bearing area is provided.

(3) Mode of operation. Actuation of force between shoe and drum or between moving and fixed discs may be accomplished mechanically (toggles and levers), hydraulically, or by use of an electromagnet. Selection is a matter of convenience and preference.

(4) Materials. Brake linings should be materials which provide a high coefiicient of friction, are heat-resisting, and provide a long life. Discs shall be of a material that does not readily score and of sufficient diameter and face to provide low braking pressures.

Brake wheels shall be a brake manufacturer's standard high strength ductile cast iron wheel (provided that the material exhibits wear characteristics in the form of powdered wear particles and is resistant to heat checking).

(5) Operation. Electric-hydraulic brakes shall be wired so that the brake will release upon movement of the master switch handle from the "off" position and shall set upon return of the handle to the "off" position, and by operation of stop push-button, or power failure. Hydraulic and electric-hydraulic brakes shall be equipped with remote control bleeders operable by

push-button and foot pedal. Electric brakes shall conform to NEMA Standard ICS. Hoist brakes may be arranged so that they can be released by hand and the load allowed to gradually descend by gravity. Operator controlled brakes (normally of the band type) may be used for small amounts of speed control as well as an emergency back-up to the automatic brake. Using an operator controlled brake for speed control is seldom warranted or satisfactory as large amounts of heat must be dissipated rapidly. Holding brakes shall be automatically applied and capable of stopping and holding the load. Control brakes (may be operator applied) shall be capable of maintaining safe lowering speed of the rated load under all operating conditions including loss of power.

b. Electric Brakes. (See Part 4.)

c. Brake Ratings. Brakes shall be rated at not less than the hereinafter noted percentages of the torque due to the 30-minute full load motor torque, at the point where the brake is applied. If, however, a duty cycle is to be performed, or a great deal of energy is to be repeatedly absorbed, the energy absorbing capabilities of the brakes must not be exceeded.

(1) Travel and rotate brakes. For travel and rotate drives, one or two braking systems per drive shall be provided as best suits the application. When one braking system is provided, it should generally be of the automatically applied type and shall be used for stopping and holding. When two braking systems are provided, the first is an automatically applied type used for holding (parking) and, on occasion, stopping. The second brake system provided is normally an operator controlled hydraulic or air activated type and is used for controlled slowing and stopping of the motion in conjunction with a drift point in the control (free wheeling--no power applied to motor, automatic brake released).

(a) Rotate brakes for portal, tower, hammerhead, and floating cranes and derricks. As a minimum, a single 100 percent electric brake shall be provided for each rotate drive. Preferably, a 100 percent electric-hydraulic brake shall be provided for each rotate drive where feasible and a drift point shall be provided.

(b) Travel brakes for portal, tower, hammerhead, and gantry cranes. A single 100 percent electric brake shall be provided for each travel drive equipped with travel motions.

(2) Hoist brakes. Two 100 percent electric holding brakes, one of which shall be adjustably delayed in setting from one to three seconds, shall be provided for each hoist drive except as hereinafter specified. Hoist drives employing a mechanical load brake and hoist drives employing emergency control braking means that limit the lowering speed to not more than 30 percent of the full load speed under conditions of simultaneous power and electric brake failure may be equipped with a single 125 percent electric holding brake, except for hot metal and other critical load handling cranes. Hot metal handling crane hoist drives shall be equipped with two 125 percent electric brakes.

(3) Hoist and luffing brakes for portal, tower, and floating cranes and derricks. Hoist and luffing brakes for portal, tower, and floating cranes and derricks may be as specified or may be as follows: one 150 percent

electric brake plus an air or hydraulically operated brake with service torque rating of 100 percent capable of holding a 50 percent overload.

(4) Trolley and bridge brakes. A single 50 percent electric trolley travel brake shall be provided for each trolley drive except that a 100 percent trolley brake shall be provided on an outdoor crane and a 100 percent electric-hydraulic trolley brake shall be provided on a man-trolley. A single 50 percent electric bridge travel brake shall be provided for each motor of the bridge drive on floor-controlled cranes, except that a 100 percent bridge brake shall be provided for each motor of the bridge drive on outdoor floor-controlled cranes and on man-trolley cranes. A 100 percent electric-hydraulic bridge travel brake shall be provided for each motor of the bridge drive on cab-controlled cranes.

21. COUPLINGS. Coupling rating shall be not less than that determined by the coupling manufacturer's published selection method, based on the operating speed, design horsepower, and the coupling manufacturer's published service factor. All couplings shall be located immediately adjacent to the bearings. Couplings between closely spaced bearings shall be of the full flexible type. Couplings for floating shafts and for shafts of lengths more than 16 and less than 32 shaft diameters between coupling and farthest bearing shall be of the half-flexible type having pilots. Flexible couplings shall be of forged steel and shall transmit torque either by means of external gears on hubs engaging internal gears in coupling sleeves, or (for full flexible couplings only) by means of a steel spring grid fitted into grooves in the periphery of the coupling hubs. Flexible couplings shall be enclosed and sealed to retain the lubricant under both dynamic operating and static conditions. Couplings for shaft lengths exceeding 32 shaft diameters between the coupling and the farthest bearing shall be of rolled, forged, or cast steel and shall be of the solid safety compression or safety flange type. Compression type couplings shall be of the axially split type with not less than three bolts per side. Flexible couplings with brake drums shall have the drum attached to the driven hub.

22. BUMPERS. Trolleys for gantry, hammerhead, and overhead traveling cranes and overhead traveling bridge end trucks shall be provided with spring or hydraulic type bumpers, except that bumpers for crane classes A and B of small capacity may be of the polyurethane type. Spring bumpers may be provided, as applicable, for traveling portal, hammerhead, tower, and gantry cranes, and shall be designed to absorb the travel energy of the crane striking at 50 percent of rated travel speed. Bridge and trolley bumpers shall be designed to absorb the travel energy of the crane and trolley, respectively, when striking bumper stops at 50 percent of rated travel speed, except that hydraulic bumpers shall be designed to absorb the travel energy of the crane or trolley striking at 100 percent rated travel speed. The rate of deceleration from the indicated travel speeds for all bumper types shall not exceed 7.0 feet (2.13 meters) per second per second. The design of all bumpers shall be based on a power off condition and shall not include the lifted load if free to swing. Sufficient bumpers shall be provided and located to stop the crane, or trolley, when traveling in either direction. Where two or more cranes operate on the same runway, or two trolleys operate on the same bridge, bumpers shall be mounted on each structure to provide proper clearance between structures when bumpers are fully compressed and shall be identical to bumpers at other ends of cranes, or trolleys, as applicable. Bridge bumpers shall be located vertically above

the runway rail centerline at the indicated or specified height and shall be mounted to permit easy removal of bridge wheels. All bumpers shall be capable of being easily disassembled, and shall be provided with safety cables to prevent parts from dropping to floor. Bumpers shall be mounted in a manner which precludes shear in attaching bolts.

23. LUBRICATION. Lubrication means shall be provided for all moving parts which require lubrication. Oil levels in gear cases should, in general, be below the elevation of all oil seals. Oil lubricated gears shall be lubricated by means of at least one gear of each mating set dipping into the oil reservoir, except that gears which are remote from the free surface of the oil shall be lubricated by means of a pump discharging oil onto the gear teeth. Oil pumps shall be of the reversible type capable of being driven in either direction while maintaining the same oil flow direction. Pumps shall be driven from a gear reducer shaft at such speed as to provide sufficient oil to gears and bearings for proper lubrication. Slow-speed grease lubricated gears, where permitted, shall be lubricated with grease of the adhering type. Bearings shall be oil or grease lubricated as best suits the application. Oil lubricated bearings in gear cases shall be positively lubricated by means of an oil bath. Bearings remote from the free surface of the oil shall be provided with an assured path of oil flow by means of troughs or pumps as specified hereinbefore. Grease lubricated bearings in gear cases shall be sealed to prevent entry of grease into gear oil. Grease lubricated bearings shall be lubricated through an individual passageway to each bearing. Each passageway shall be fitted with a pressure lubrication fitting conforming to MIL-F-3541. Fittings shall be easily and safely accessible from walkways, floors, or platforms, or when such are not available, from a reasonable, safe point. Completely sealed bearing housings in which seals are oriented to retain lubricant shall be provided with pressure relief fittings. Each lubrication fitting and relief fitting shall be located so that when fresh grease is inserted, the grease will pass through bearing. Except as otherwise permitted, bearing housings of bearings lubricated with an oil bath or pressure applied grease shall be sealed through shafts with seals of the spring-loaded leather or synthetic lip type, suitable for the rubbing velocity and lubricant provided. Grease lubricated sheave bearings shall be shielded or sealed as noted hereinbefore. Oil seals shall be oriented to retain the lubricant. Grease seals shall be oriented to insure that fresh grease will pass through the bearings except that when lubricant drops cannot be tolerated, seals shall be oriented to retain the lubricant. Where grease retention is not a necessity, grease lubricated bearings may be sealed with a labyrinth-type seal. The labyrinth-type seal shall contain at least three annular grooves, each having a depth of 3/16 inch (5 mm), width (at widest point) of 1/8 inch (3 mm), and an included angle between sides of groove equal to 30 degrees. Distance between centers of grooves shall be 3/16 inch (5 mm). Oil seals which are submersed in an oil bath shall be of the double lip type with both lips pointed towards the oil reservoir.

24. FINISHES. Finish roughness height ratings indicated are maximum. Bearing seats on shafts, pins, and axles (unless the bearing manufacturer specifically recommends otherwise); coupling, gear, and wheel bores; and all seats on shafts or axles to which couplings, gears, and wheels are press-fitted shall be finished to a roughness height rating of 63 microinches (1600 micrometers). Surface finish of that portion of shafts, drums, hubs, and axles in contact with lip type seals shall be 16 microinches (400 micrometers) roughness height

rating with no machine lead. Portions of pins in contact with bronze bushings shall be finished to 63 microinches (1600 micrometers) roughness height rating. Keyways shall be finished to the roughness height rating corresponding to required keyway tolerances and standard industry practice. In general, all shaft, axle, pin, or bore surfaces not specifically covered herein shall be finished to 125 microinches (3200 micrometers) roughness height rating. The surface of bronze bushings on which motion takes place shall be finished to 125 microinches (3200 micrometers) roughness height rating. Bearing housing bores shall be finished to 125 (3200 micrometers) and 63 microinches (1600 micrometers) roughness height ratings for fixed and floating outer race bearings, respectively. Drum and sheave grooves shall be finished to 125 microinches (3200 micrometers) roughness height rating.

25. FITS. All gears, pinions, wheels, and couplings shall be interference fitted to shaft or axle, as applicable, in addition to being keyed as noted. Interference fits shall conform to the force fit requirements prescribed in ANSI B4.1 and shall be medium-drive fits unless length of engagement, material, or imposed loading dictates otherwise. Bearings and seals shall be fitted in accordance with the manufacturer's recommendations. Keys shall be fitted in keyways so as to produce a metal-to-metal fit to a light-drive fit, shall fit snugly to bottom of shaft keyway, and shall fit with maximum clearance of 0.005 inch (0.13 mm) to bottom of hub keyway.

26. RATCHET AND PAWLS. A ratchet and pawl shall be provided on all luffing hoist drums and all drums of multiple drum (water fall) hoist units. Pawls shall engage ratchets so as to hold against applied rope pull and shall be electrically interlocked to prevent application of lowering power when engaged. Pawls should be electrically operated or manually operated through stiff pull rods from the operator's cab and shall be counterweighted to help maintain both the set and released positions. Design load for ratchets and pawls shall be that due to a 50 percent overload.

27. DIESEL ENGINES. (See Part 4, Paragraph 5c.)

28. HORSEPOWER COMPUTATIONS.

a. Hoist-Power.

(1) Assumptions:

(a) Friction losses in the bearings and gears or chains vary from 5 to 35 percent, depending on the number involved and the quality of their construction. (Consult mechanical engineering handbooks and manufacturers' literature.)

(b) Power loss in bending the rope around sheaves (including sheave bearing loss) is 2 percent for bronze-bushed sheaves and 1-1/2 percent for sheaves on anti-friction bearings for each 180-degree bend in the rope system.

(c) Values assumed shall be liberal in computing hoisting power, and conservative in computing brake holding torque.

(2) Hoist-power computations. The stabilized power for hooks or the instantaneous power for luffing hoists shall be determined by Equation 11.

$$\text{Horsepower} = \frac{(\text{drum-line pull}) \times (\text{drum-line speed})}{33{,}000 \times \text{hoist efficiency}} \qquad (11)$$

Where:

Pulls are in lb., speeds in fpm, and efficiency is expressed as a decimal.

$$\text{Joules} = \frac{(\text{drum-line pull}) \times (\text{drum-line speed})}{\text{hoist efficiency}} \qquad (11a)$$

Where:

Pulls are in Newtons, speeds in meters per second, and efficiency is expressed as a decimal.

Hoist efficiency shall be assumed not higher than .90 for unit hoists and .85 for hoists with spur and similar type gear speed reducers and external drum gears.

b. <u>Travel Drive for Portal, Tower, Hammerhead, Level-Luffing, and Gantry Cranes</u>.

(1) Assumptions. The tractive effort required to overcome running friction shall be assumed as follows:

(a) 12 to 14 lb. per short ton (1.3 to 1.6 N per kN) of total crane weight for trucks with all anti-friction bearings.

(b) 22 to 28 lb. per short ton (2.4 to 3.2 N per kN) of total crane weight for trucks with all bronze bearings.

(2) Horsepower for steady speed (running horsepower) is given by Equation 12.

	Customary Units	Metric Units	
Horsepower =	$\frac{S \times E}{33{,}000}$	$S \times E$	(12)

Where:

	Customary Units	Metric Units
S = Speed	fpm	m/s
E = Total tractive effort	lb.	N

(3) Horsepower required for acceleration is given by Equation 13:

	Customary Units	Metric Units	
Horsepower =	$\frac{M \times a \times S}{33{,}000}$	$M \times a \times S$	(13)

Where:

	Customary	Metric
M = Total mass accelerated =	$\frac{W}{g}$	kg
a = Acceleration	fps/sec.	m/s^2
S = Speed (instantaneous for actual horsepower or terminal or rated speed for nominal horsepower).	fpm	m/s

(4) Acceleration rate shall be assumed as uniform between zero speed to full-rated speed in the following times:

Time	Crane Size
4 sec.	Small
8 sec.	Medium
12 sec.	Large

(5) Note: if DC series or compound-wound motors, with a 30-minute horsepower rating equal to the running horsepower plus one-fourth to one-third the nominal accelerating horsepower, are selected, the performance and life of the motor will be satisfactory under normal circumstances.

c. Trolley Drive for Gantry and Hammerhead Cranes and Bridge and Trolley Drive for Overhead Traveling and Wall Cranes. Trolley and bridge motor ratings shall not be less than those determined by Equation 14.

$$HP = \frac{TV\ [1 + (0.3 + 0.002V)]\ Fc \times Fa}{33{,}000} \qquad (14)$$

$$\text{Joules} = TV\ [1 + (0.3 + .0366V)]\ Fc \times Fa \qquad (14a)$$

Where:

T = Tractive effort in pounds (Newtons).

V = Rated velocity in fpm (m/s).

Fc = 1.0 for class A and B overhead traveling cranes and for all gantry and hammerhead cranes.

= 1.1 for class C overhead traveling cranes.

F_c = 1.15 for class D overhead traveling cranes.

= 1.2 for class E overhead cranes.

F_a = 1.0 for all DC drives.

= 1.2 for AC trolley drives.

= 1.3 for AC bridge drives.

The tractive effort in pounds, including allowances for friction in drive mechanism gears and bearings, shall be based on 15 pounds per short ton (1.68 N per kN) of the trolley and hook load or of the entire crane and its hook load for antifriction bearing indoor cranes. Cranes for outdoor service shall be additionally computed with a 5-pound wind load per square foot (240 Pa) of projected area, added to the tractive effort. For this condition, the allowance for acceleration (0.3 + 0.002V) may be omitted, and the 15-minute motor rating shall be used. But in no case shall the motor rating be less than that obtained by Equation 14. For bridge drives on jib type wall cranes the effort shall include the cantilever effect of the dead load plus hook load.

Part 4. ELECTRICAL DESIGN CRITERIA (MODIFICATIONS)

1. STANDARDS. Electrical equipment for cranes, hoists, and derricks should be in accordance with the applicable industrial standards of the Institute of Electrical and Electronic Engineers (IEEE), the National Electrical Manufacturers Association (NEMA), the American National Standards Institute (ANSI), the Diesel Engine Manufacturers' Association (DEMA), and the Engine Manufacturers Association (EMA). Installations shall comply with the requirements of the National Electrical Code, with particular attention to Article 610.

a. Mill-type Motors and Mill-type Brakes. Mill-type motors and mill-type brakes should also comply with the standards of Association of Iron and Steel Engineers (AISE).

b. Control and Protective Panel Equipment. The control and protective panel equipment should be the product of the same manufacturer.

2. PLANNING. It is the Navy's practice that cataloged commercially available items should be used wherever suitable. Control systems found to be inadequate or otherwise unsatisfactory should be replaced in their entirety (except resistors) by commercially available control systems. Modifications to existing control systems should be avoided except for compelling reasons.

3. POWER SOURCE.

a. Available Sources.

(1) Shore power.

(2) Engine driven generators.

(3) Mixed (as discussed below).

b. Selection Factors.

(1) Portal, floating, locomotive, gantry, and tower cranes are generally provided with their own power plants.

(2) Other types of cranes should be provided with power from external sources, except where distances are prohibitive. Where DC is required and readily available from an external source, it should be used. Where DC is required for auxiliary systems (as discussed below) and is not available from an external source, consideration should be given to obtaining it from an external AC system by conversion, preferably by static converters.

4. CURRENT CHARACTERISTICS.

a. General Comparison of AC vs DC. The service classification of the crane and the power available in the local area are prime factors in determining which current should be used.

Direct current systems are, by virtue of the characteristics of DC motors and controls, most suitable for most crane applications. Even in those "AC systems" that are the equivalent to DC systems for the more demanding types of crane use, DC sub-systems are the means of obtaining such equivalence, as in adjustable-voltage DC systems operated from AC power sources. DC motors have unique ability to operate at very slow speeds for extended periods without heating-up as much as would an equivalent AC motor. DC motors and controls can provide the often desirable characteristic of inverse rates of speed to load, a characteristic conducive to safety. However, no new DC distribution systems are being installed and the cost of AC equipment is usually significantly less than the cost of DC equipment. Therefore, infrequent use, restricted ranges of load or speed, or absence of a requirement for precise handling may indicate the use of AC for economic reasons.

b. Special Applications. The advantages of both AC and DC may be realized by driving some motions with AC and others with DC. This arrangement has been used satisfactorily on some cranes by driving those non-overhauling motions suited to AC drives with AC, and driving the hoists with an adjustable-voltage AC system as described below. Direct current, provided by rectifiers, is often used on AC cranes to improve the performance of control elements and automatic brakes.

5. ENGINE-GENERATOR SETS.

a. Capacity of Set.

(1) The net kW output rating of main engine-generator sets for cranes should be sufficient to start and operate any motions required to be simultaneous (generally three motions) plus all accessories such as heaters, lights, ventilation systems, etc. For certain special-purpose cranes, two simultaneous motions may suffice. The use of the crane should be carefully investigated. Ratings of generators need not match the entire connected load of the crane but should take full account of the requirements for starting, due consideration being given to mitigating factors such as adjustable-voltage control systems and the use of fluid clutches. AC generators are usually

rated at 0.8 power factor. Further qualifications of generator and engine capacity are discussed below under those headings.

(2) For portal, hammerhead, large gantry, and tower cranes, an auxiliary generator should be provided with capacity as required to furnish power for lighting and auxiliary systems.

(3) Consideration should be given to the selection of a larger generator, as opposed to a larger engine-generator set, for applications involving frequent starting of large motors, short-term overloads, low-power-factor loads, or combinations thereof. A requirement for unusual cyclic heating of the generator does not necessarily require increased engine capacity.

b. Generators.

(1) As a source for DC motors, AC generators plus static conversion equipment represent the trend, particularly if an adjustable-voltage control is to be used. There is little reason to incur the maintenance associated with rotating conversion equipment. Consideration should be given to AC generators even for travel and rotate motors.

(2) Generators. AC generators should be of the synchronous type built to NEMA standards and wye-connected for neutral grounding. Single-bearing or two-bearing generators may be used, but the latter should have a coupling which tolerates both parallel and angular misalignment. The coupling should be able to withstand torsional shock. Single-bearing generators should be coupled to the engine flywheel through a flexible steel disc or equivalent elastic means of adequate radial stiffness. The drive should be direct. If sleeve bearings are used for generators on floating cranes with 5-degree lists, they should be arranged so that lubrication can be maintained. Open, drip-proof, protected generator frames should be provided. Generators serving load magnets should be selected in consultation with the manufacturer's engineering staff to be compatible with the special characteristics of the load.

(a) Exciters. Exciters should have a capacity to provide field current for generators at 125 percent of the generator's rated capacity and should be capable of carrying, without injury, momentary loads of 150 percent of their own rated current. Exciters are available in a brushless type, using a rotating rectifier bridge circuit. This type of exciter requires less maintenance and is subject to less downtime.

(b) Voltage Regulators.

(i) Voltage regulators are available in the transistorized type, using silicon-controlled rectifiers and Zener reference diodes. The regulator should include protection against shorting of power rectifiers. The voltage-adjustment rheostat should be mounted on the generator control panel, as described below.

(ii) Voltage adjustment range should be at least $\pm$ 7 percent of rated voltage. Under steady-state conditions, the voltage regulation should not exceed 3 percent for any load between no load and full load, at any constant ambient temperature between minus 20 degrees F and 90 degrees F (minus 6.67 degrees C and 32.22 degrees C). Upon application of full-rated load in one step, the voltage should vary by not more than 25 percent and should recover to within the steady-state modulation band within 5 seconds.

(3) DC Generators. DC generators should be shunt-wound or flat-compound-wound or overcompounded to provide voltage-regulating characteristics suitable for the loading patterns and should be built to NEMA standards.

(4) Voltage Dips. Voltage dips resulting from high momentary current draws depend not only on the characteristics of the generator but on the inertial characteristics of the entire set. This aspect of performance is further discussed under Engines.

(5) Overload Capability. Generators should be able to sustain an overload of 10 percent in excess of full load rating with safe operating temperatures for two continuous hours but only a total of 2 hours out of any 24 consecutive hours of operation.

c. Engines.

(1) Full diesel engines of the single-fuel type should be used. This criterion does not preclude the use of starting aids other than spark ignition (e.g., glow plugs).

(2) Standard Rating. The Diesel Engine Manufacturers Association (DEMA) has established a general rating known as sea-level rating for diesel engines which is based on an altitude of not over 1,500 feet (457 meters) above sea level, an atmospheric temperature not over 90 degrees F and a barometric pressure of not less than 28.25 in. (718 mm) of mercury. Refer to the Association's handbook for further definition of the rating.

(3) Manufacturer's Ratings. Individual manufacturers of diesel engines usually give three ratings for their engines, as follows:

(a) Maximum Rating. The maximum horsepower output of the engine which can be demonstrated within 5 percent at the factory under standard conditions. Warning--Engines should not be used at this rating without the approval of the manufacturer.

(b) "Standby" Rating. The manufacturer's recommendation (not standardized): usually 80-90 percent of maximum rating. It is intended as the horsepower which can be supplied with reasonable overhaul intervals when the engine is not used continuously. It should be realized that this is an arbitrary rating set by the manufacturer without respect to a specific application and that the basis for the rating has not been standardized in the industry.

(c) "Continuous" ("Prime Power") Rating. The manufacturer's recommendation (not standardized): usually approximately 90 percent of "standby" rating. It is intended as the horsepower which can be supplied with reasonable overhaul intervals when the engine is used continuously. It should be realized that this rating is set by the manufacturer and that the basis for the rating has not been standardized in the industry.

(4) Selection of Engines.

(a) For weight-handling equipment, a "continuous" rating to match the generator input plus a factor for recovery from short-term overloads (as defined under frequency variation below) is recommended, except for cranes permanently designated as standby, for which "standby" ratings may be considered.

(i) For generators with the usual 25 percent overload capability, a reasonably conservative criterion for the selection of an engine for continuous duty is that the engine shall have a useful shaft output (power for all direct-driven accessories subtracted) of not less than 135 percent of the generator input requirement at nameplate rating (output/certified efficiency) based on the engine's cataloged and certified continuous horsepower or 83 percent of its cataloged and certified maximum horsepower, whichever is less. Such excess capacity is intended to restrict the operating temperature of the engine, favorably affecting maintenance. The engine's ability to recover from slowdown is dependent on such factors as lugging capability, governor response time, and engine-generator inertia. The restriction of operating temperature is a factor in the basis for the distinction between the "continuous" and "standby" ratings of the same engine.

(ii) In the cases of portal, hammerhead, large gantry, and tower cranes, consideration should be given to the ratio of accelerated-hoisting power to all other loads that are simultaneous with hoisting. If an engine's lugging capability (see following paragraph) is marginal (peak torque below rated speed less than 112 percent of torque at rated speed) for high-ratio hoisting loads, a small increase in required engine horsepower should be considered. Any uncertainty as to the ability of a set to handle this characteristic of loading should be checked with the manufacturer's engineering staff.

(b) Lugging Capability. For weight-handling equipment, engines with good lugging capability (that is, with peak torque occurring at a speed below, but not too far below, normal operating speed) should be selected.

(c) Voltage Dip--(See Generators). When the largest motor exceeds the equivalent of 35 percent of the rated "continuous" capacity of the engine-generator set (31 percent of "standby" capacity), the manufacturer's engineering staff should be consulted regarding the proper selection of a set. Figure 46 shows one manufacturer's curves for checking voltage dip on diesel engine-generator sets. Contrary to popular belief, modern lighter engine-generator sets with speeds of 1,200 or 1,800 rpm and without heavy flywheels "ride out" heavy current draws quite well. For example, 1,800-rpm sets generally exhibit better voltage-dip characteristics than do 1,200-rpm sets (see Figure 46).

(d) Frequency variation with AC Generators. Upon application or removal of full-rated load in one step, the set should recover to stabilized speed within 5 seconds after full rated load is applied in one step and the frequency should vary by not more than 5 Hertz. Under steady-state conditions, the maximum frequency minus the minimum frequency should not exceed 0.25 Hertz.

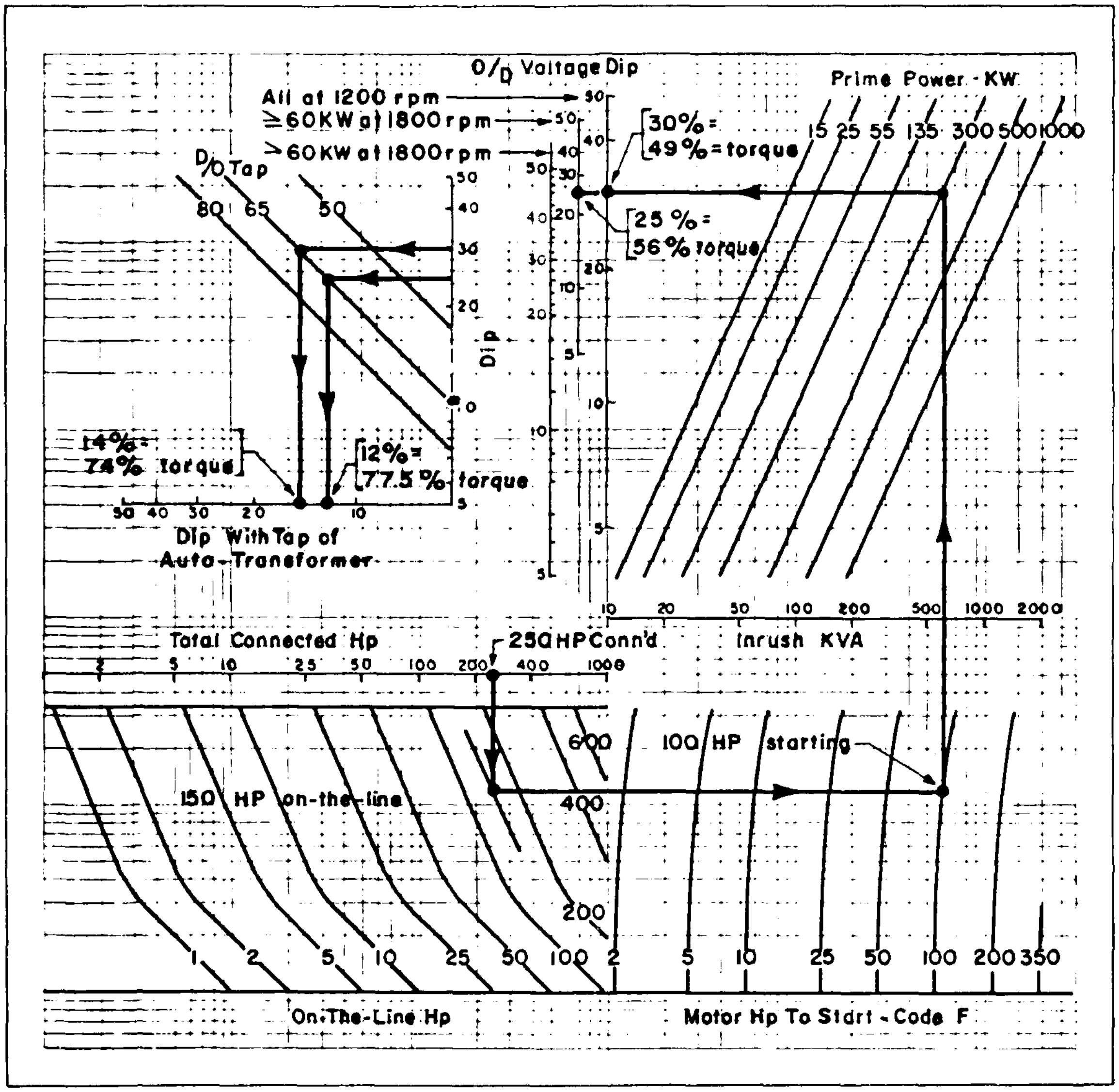

FIGURE 46
Voltage Dip of AC Engine-Generator Sets (Representative)

(e) Speeds.

(i) Engine technology has progressed to the point where medium-speed units (1,200-1,800 rpm) are entirely practical, on a conservative basis, for application to generator drives on cranes. Most portal, tower, hammerhead, and floating cranes procured during World War II have diesel engine-units with speeds of 600 to 720 rpm. They should be replaced with units having a speed of 1,200 rpm. Where the weight of the engine-generator set constitutes a significant component of a crane counterweight, the replacement set should be carefully positioned, equilibrium rechecked, and counterweight added as necessary.

(ii) Derricks, hoists. Derricks and hoists are generally light-duty machines with a relatively small amount of use per year. If so, 1,800 rpm engines are reasonable and the use of "standby" units should be evaluated.

(iii) Locomotive and mobile cranes. Because practices vary widely within the industry, the crane manufacturer should be consulted about replacement engine-generator sets.

(f) Supercharging. Supercharged engines are becoming increasingly common for crane use. Their inherently lower exhaust emissions reduce the need for pollution control devices to meet the National Emission Standards. The most popular form is a turbo-supercharger driven by the exhaust gases. This type of supercharger and electrically driven types with no availability of local auxiliary power or external power, cannot be of assistance in starting since they depend on the operation of the engine.

(5) Protection of Engine. While running, the engine-generator set should be protected against the following malfunctions: overspeed, low oil pressure, high cooling water temperature. An alarm should be sounded for each in advance of shutdown. On starting, the set should be protected against overcranking. A red "MALF SHUTDOWN" indicator should be illuminated for each function if shutdown is caused by malfunction. Restart should be possible only after manual resetting.

d. Controls.

(1) Main Generators. Provide the following control equipment on a suitable panel:

(a) Field rheostat or "voltage-adjust" rheostat (static exciter) to set desired full-load voltage.

(b) Field switch that grounds through discharge resistors (DC generators).

(c) Trip-free air circuit breaker, mechanically and electrically tripped. Breaker should be electrically tripped from the operator's position. This is used not only to protect the generator but also to stop all crane motions when an overload occurs on any motion or a short circuit occurs anywhere beyond the breaker. Breaker should be reset locally (manual) and from the operator's position (electrical).

(d) Under-voltage protection, requiring a complete new start after a slowdown or shutdown.

(e) Voltmeter and ammeter with phase selector switches.

(f) Automatic ground fault protection with indicating lights. Sensing should be on ground connection. Note--If throwover to an alternate source of power is provided, protective devices should be operational in either mode of operation. Ground fault protection should be checked for by-passing of sensing elements if 3-pole automatic throwover switches are used.

(2) Auxiliary Generators. Controls for auxiliary generators should be the same as for main generators except that the circuit breaker need not be electrically tripped and reset from a remote position.

(3) Engine Control Panel. In addition to items mentioned under Protection of Engine, the panel should bear the following:

Engine speed adjust (governor reset)
Speed indicator (tachometer)
Fuel pressure gauge
Lube-oil thermometer
Lube-oil pressure gauge
Circulating water thermometer
Running time meter for each motion
Running time meter for each engine.

Items requiring physical contact or mechanical connection are usually placed on this panel. With certain types of governors, remote electrical speed adjusting controls are placed on the electrical panel. Engine panel should be adequately isolated from vibration.

e. Precautions During Shutdown. If the set is not to be located in a heated room, an electric immersion heater should be provided to keep the block warm. If feasible, crane parking locations should have shore power available to serve this heater and anti-mildew heaters.

f. Noise Abatement. The requirements of the Occupational Safety and Health Administration (OSHA) relative to the permissible sound levels in the operator's cabs of cranes should be followed. In designing attenuation of noise between engine and cab, due weight should be given to solid-borne transmission.

g. Torsional Analysis. Each engine-generator set should have a torsional analysis made by a competent authority and a certificate of freedom from critical speeds in the operating range should be obtained from the manufacturer.

6. MOTORS. Two types of alternating current (AC) motors: squirrel-cage and wound-rotor, and three types of direct current (DC) motors: series-wound, compound-wound, and shunt-wound (adjustable-voltage systems) are employed for crane service. Motors of 2 hp and larger should run no faster than 1,200 rpm (AC synchronous speed) or 1,150 rpm (DC base speed). Motors of 50 hp and larger should be limited to 900 rpm (AC synchronous speed) or 850 rpm (DC base speed). Since motor speed is reduced in typical crane applications, crane motors should have speeds permitting economical gear selection.

a. DC Motors.

(1) Series-wound. These are preferred for heavy-duty traction or hoist motors. Series-wound motors should be used for all hoist, travel, and rotate motions, except those with adjustable-voltage drive. Mill-type motors are usually used for heavy-duty crane service, as described below. These motors develop very high starting torque and can rapidly accelerate heavy loads. They handle overloads far above their rated capacity. Split-frame

motors are specified by the AISE. Solid-frame crane- and hoist-duty motors are usually used for medium- and light-duty service.

(a) Advantages.

(i) Permits dynamic braking; safe; excellent starting torque and acceleration.

(ii) Speed control over a wide range of speed; accomplished by varying the amount of resistance connected to the armature and field.

(iii) The speed of a series motor when handling a light load will be considerably higher than when handling a capacity load. It is safe and time-saving for a crane to lift or travel at a faster speed when operating with no load or only handling a light load as compared to its speed with a heavy load.

(b) Disadvantage. These motors run away at no load. This is critical for hoisting but not for trolley and bridge travel where the dead load to be moved is always a significant part of the total load and, therefore, these motions are not subject to speed-up at no load as is the hoist motion.

(2) Compound-Wound. For light duty 50 percent-compound-wound motors are used on cranes to limit the no-load speeds of each motion. Such motors are similar to series-wound motors in construction and characteristics, except that they are wound so as to prevent the no-load speed from exceeding 150 percent of full load speed. Disadvantages are the lower torque and higher current draw at low speeds.

(3) Shunt-wound. Not suitable for weight-handling functions, except with adjustable voltage controls, as described under that heading.

(4) Speed-torque curves for DC motors can be obtained from all manufacturers.

b. AC Motors.

(1) Induction Motors. In induction motors, no electrical contact is made between the line and the rotor. About 90 percent of induction motors are of the type known as squirrel-cage motors, which have power factors, varying from approximately 0.70 to 0.92 depending on size, speed, and type. For a given horsepower, the power factor increases significantly with speed, particularly in the lower range of horsepowers. Do not use AC motors for travel drives on curved tracks.

(a) Squirrel-cage motors are often used for intermittent service where frequent starts, stops, and reversals are encountered; where fast starts are tolerable; and where no elaborate speed control is required. The type selected should have high starting torque, low starting current, and high slip at full load (NEMA Design D). The speed-torque curves for this design of squirrel-cage motor can be obtained from any manufacturer.

(i) Squirrel-cage motors for crane hoists should be limited to those applications requiring only one or two hoisting speeds and requiring not more than 10 horsepower and should be provided with a straight reversing control and automatic mechanical load-lowering brake. Resistance is sometimes used in the primary winding to control acceleration, but this is not a speed control. Provide fluid drives on motors to be used on travel drives for small cranes.

(ii) Speed selection can be improved by using a two-speed, two-winding motor with slow speed 1/3 or 1/4 of high speed. Two-speed squirrel-cage motors should be used on small hoists where hook or travel speed is slow and operation of hoists is by unskilled personnel. Effective control of starting, acceleration, and deceleration can be obtained at reasonable cost in the form of solid-state, reduced-voltage equipment.

(iii) Single-speed squirrel-cage motors should be used when speed is to be constant and starting load is light. Use on motor-generator drives for adjustable-voltage control or AC-DC control (AC hoist and DC dynamic-braking lowering).

(b) Wound-rotor motors.

(i) Heavy-duty cranes using AC motors should have motors of the wound-rotor (slip-ring) induction type with speed and acceleration control by means of secondary resistor banks, as described below. Their starting current will be significantly less than for squirrel-cage motors.

(ii) Wound-rotor motors are well suited for crane use. Their basic torque-speed curve (no external resistance in the rotor circuit), shows nearly constant speed with varying load (torque) up to about 200 percent to 275 percent full load. Speed control can be accomplished from zero to full (see NEMA standard) speed by means of the controller and resistances. Used with light loads or no load, this type approaches, but will not reach, its synchronous speed. Under full load, these motors develop a "slip" of approximately 5 to 10 percent, the slip varying inversely as the square of the applied voltage. Since this type of motor stalls at about 275 percent torque (see NEMA standard), extreme overloads on the crane are obviated.

(iii) Resistors connected in series with the armature (secondary) provide high resistance when starting, thus reducing the current demand in starting yet providing high starting torque. Further reduction of resistance in the secondary circuit increases the motor speed. Wound-rotor motor controls are discussed below.

(iv) Disadvantages of wound-rotor motors. Inability to control speed through a useful range with light loads and the lack of effective regenerative motor-braking except at supersynchronous speeds present control problems. All speed-torque curves pass through the synchronous speed point at no load so that, at zero torque, no speed control by secondary resistance is possible.

(v) The danger of using the steeper curves to obtain some speed control with light loads is sometimes overcome by further altering the basic curves through changes in the primary (stator) current, or by automatically loading the motor with an artificial load simultaneously with the hook load. These modifications are discussed under Motor Control.

(vi) Speed-torque curves for wound-rotor motors can be obtained from any manufacturer.

(2) Synchronous Motors. These motors are not suitable for crane traction or hoisting functions.

c. Special Mechanical Features Applied to Motors.

(1) Gear Motors. Motors that combine a motor and a gear case in a single unit are available in a range of horsepower ratings and output speeds in various types of either AC or DC motors. Gear motors are used in crane design for light duty trolley or bridge travel drives, for micro-drive (very slow drive) components, and for drive applications where space is severely limited.

(2) Fluid-Drive Motors. As a power source of both crane bridge and trolley drives, squirrel-cage motors can be used with fluid couplings to provide satisfactory single-speed operation with positive but gradual acceleration to operating speed. The motor starts under no-load and comes up to about 85 percent of full speed before starting the load.

d. Multiple Motor Drives.

(1) Rotate drives or travel drives on straight track may consist of two or more motors, mechanically connected through the gearing. In these cases, they may be 230-volt motors (DC) or 460-volt motors (AC) or they may be two 115-volt motors (DC) or 230-volt motors (AC) connected in series.

(2) Travel drives on curved track must use 115-volt motors (DC only) connected in series in pairs. In each pair, one motor operates on the rail on one side of the crane, the other on the rail on the other side. In traversing a curve, the motors over the inner rail slow down and those over the outer rail speed up. The two motors divide the total supply voltage of 230-volts in accordance with their overall resistances, including their counter-electromotive forces so that, in effect, they operate on two torque-speed curves, the slower on the lower voltage curve and the faster on the higher voltage curve, but both at the same torque abscissa.

e. Motor Enclosures. Refer to the NEMA standards for types of motor enclosures and their application. Hazardous areas may require explosion-proof motors. Self-ventilated fan-cooled motors are generally impractical for crane applications because of intermittent use and variable or multiple speeds. It is essential, where special or unusual operating conditions exist, that the details be provided to the crane manufacturer so that motors designed to operate under these special conditions can be provided. Conventional motors that have enclosures that are substantially closed (such as "totally enclosed," explosion-proof, and dustproof motors) have rated maximum temperatures of 95 degrees C with Class A insulation and 115 degrees C with Class B insulation. More open types (such as dripproof) have rated maximum temperatures of 90 degrees C with Class A insulation and 110 degrees C with Class B insulation.

Temperature rise has been abandoned by NEMA as a basis for rating. Unobstructedly open enclosures are no longer manufactured, having been supplanted by dripproof enclosures, which category has generally absorbed the splash-proof designs. This type of enclosure affords a 15 percent service factor on the motor. More restrictive enclosures do not afford any service factor in standard designs. However, service factors of 15 percent can be obtained at a premium even on totally enclosed motors (severe duty).

f. Time Ratings. Motors for most crane applications are never in continuous operation and need not have a continuous rating. To meet the need for motors to operate at less than continuous duty, motor manufacturers offer short-time-rated motors. Motor frame sizes are determined by the time rating, the insulation, and the allowable temperature rise of the motor in the prescribed service in which the motor is to be used.

(1) Time and temperature ratings for AC motors are as follows:

(a) Squirrel-cage and wound-rotor open, wound-rotor enclosed 30- and 60-minute: temperature ratings depend on insulation and type of enclosure.

(b) Mill-type, open--60-minute: 80 degrees C.

(c) Mill-type, totally enclosed, non-ventilated--60-minute: 85 degrees C.

(2) Time and temperature ratings for DC motors are as follows:

(a) Series, solid frame--30- and 60-minute: temperature ratings depend on insulation and type of enclosure.

(b) Series mill-type--30- and 60-minute: 75 degrees C.

(3) Motor insulation. Class B insulation is suitable for all but the hardest work motors. Motors for severe duty should be investigated in accordance with known or assumed duty cycles by the root-mean-square (RMS) method, to ensure a temperature rise no higher than is permissible for long life of the insulation. Refer to CMAA publication No. 70 for overhead traveling cranes. The assistance of motor manufacturers' engineering staffs should be enlisted in determining nominal horsepowers for application to intermittent duties. Typical recommended time ratings for each class of service involving moderate hoisting loads are as follows:

Recommended Motor Ratings

Service Class	Hoist	Bridge & Trolley	Motor AC	Insulation DC
A	Short lift, 15 min.	15 min.	B	B
	Long lift, 30 min.	15 min.	B	B
B	30 min.	30 min.	B	B
C	30 min.	30 min.	B	B
D	No cycle, 30 min.	30 min.	B	B
E*	With cycle, 60 min.	60 min.	B,F	B,H

*Consideration should be given to enclose motors since atmospheric conditions associated with severe service are often dusty, dirty, or otherwise unusual. Refer to Motor Classification.

g. Motor Classification by Duty.

(1) Mill-type.

(a) Mill-type motors are significantly more expensive than crane-and-hoist-type motors and are not justified for medium and light-duty cranes.

(b) Mill-type motors meet the AISE Standards and provide split, shock-resistant frames, heavy-duty mounting pads, oversized shafts, and heavy-duty, specially braced, Class F insulation.

(c) The breakdown torque of AC mill-type motors is not less than 325 percent of their 1-hour rating torques and their maximum allowable speed is 200 percent of rated rpm.

(2) Crane and hoist type.

(a) This is the type most commonly used on cranes. They should be used for light-duty gantry and overhead cranes, for all wall cranes and for all standby cranes, with the exception noted under (3) below.

(b) DC motors of this type should be provided with interpoles.

(3) General industrial type. Generally used on semi-mass produced unit hoists and commercial drive mechanisms. Motor is of light construction and does not have the characteristics desirable for weight-handling machines except for very small standby units.

7. MOTOR CONTROLS.

a. General. For crane service, motor controls perform their usual functions of starting, stopping, protecting, speed adjusting and control deceleration, limiting of acceleration during lowering of load or down-grade travel by means of dynamic and regenerative braking and by the application of eddy-current brakes and so-called "electric" brakes (spring-applied, electrically removed friction brakes). They also control the setting of holding brakes upon stopping. Mechanical (hydraulic) brakes, which are widely used in crane service, should always be backed up by automatically-applied holding brakes.

(1) Controllers, especially those for large motors, often provide protection beyond the usual overcurrent protection as follows: low-voltage; single-phasing; phase-reversal; plugging; over-speed; and field loss on shunt-wound and compound-wound DC motors.

(2) Crane service obviously requires reversing controllers for non-overhauling loads such as rotate, trolley, and travel motions. For hoists drive-down is usually desirable for lowering light loads when the termination of the hoisting system is a hook or other lightweight device.

b. Controls and Motors. Control systems for cranes cannot be considered apart from the motors being controlled. This fact applies entirely beyond such obvious considerations as: DC or AC motor? Squirrel-cage or wound-rotor AC motor?, etc. The combinations of motors and their controls represent indivisible systems which must respond to the needs of crane operation.

c. Needs and Affecting Considerations.

(1) Range and delivery of loads.

(2) Speeds required and duration of speeds (especially very slow speeds). Desirability of inverse speed-load relationship.

(3) Accuracy of spotting required.

(4) Skill of operator that can be expected.

(5) Frequency of use (prime or standby?).

(6) Travel around curves and on grades.

(7) Funds available.

d. Checklist for Hook and Luffing Service. The following should not be regarded as prescriptive but only as an aid in determining suitability of a motor-control system for a particular application.

(1) A wide range of speed, either stepless or in evenly spaced steps (three minimum, five preferable), for all hook loads, hoisting and lowering.

(2) A form of motor-braking for lowering and for slowdown during stopping (to minimize wear on external brakes).

(3) Constancy of speeds on any step or control point for all loads, or, depending on the application, the converse: speed varying inversely as the load.

(4) A slow minimum-speed step in both directions, particularly lowering.

(5) A fast maximum-speed step in both directions, particularly hoisting.

(6) Consistent, short-interval jogging for squirrel-cage-motor drives.

(7) Smooth, automatic acceleration and deceleration to limit current inrush and to provide shock-free operation.

(8) Plugging (with anti-reversal control) if slowdown not provided by other means.

(9) Freedom from runaway in either direction on any speed step.

(10) Inherent stall point to prevent hoisting excessive overloads.

(11) Off-point motor braking, and emergency dynamic braking on any point, upon loss of power.

(12) Master switch handle always indicating direction of motion and suggesting speed of hook by relative position.

(13) Minimizing of motor hot spots and hot resistor sections (over-size equipment?)

e. Checklist for Travel, Trolley, and Rotate Service. Same as d above, except for items (9), (10), and (11), which are not applicable, and except for hoist-oriented qualifications on remaining items.

f. Motor-Control Systems. As stated above, Navy policy is to replace unsatisfactory control systems with complete, commercially available systems (except resistors) wherever practicable. The following motor-control systems are most often used:

(1) Power source: constant-potential DC.

(a) Bridge, trolley, and rotate motors: Reversing, plugging, rheostatic, magnetic control (optionally with automatic dynamic braking) for stopping and emergency (power failure) service.

(b) Hoisting and luffing motors: Reversing, dynamic lowering, rheostatic, magnetic control with dynamic braking on all lowering points, for emergencies and in the "OFF" position.

(2) Power source: three-phase AC.

(a) Bridge, trolley, and rotate motors:

(i) Wound-rotor motor with reversing, plugging, magnetic control.

(ii) Wound-rotor motor with stepless, speed-regulated, reversing, plugging control (hydraulic brakes not needed).

(iii) DC motor with stepless, speed-regulated, reversing, regenerative, torque-limited, adjustable-voltage control and automatic setting of "electric" brake in "OFF" position (hydraulic brakes not needed).

(b) Hoisting and luffing motors: (as applicable for luffing)

(i) Wound-rotor motor with countertorque (modulated plugging) control having automatic speed-limitation, five manually-held speed points and one automatic speed point in each direction of motion. A mechanical load brake is not needed.

(ii) Wound-rotor motor with countertorque control as described under (i) except with stepless control.

(iii) Wound-rotor with reversing, magnetic control and a mechanical load brake.

(iv) Wound-rotor with reversing, magnetic control having at least two hoisting points and four lowering points (three if mechanical load brake is provided) and an eddy-current load brake. Eddy-current brake is excited with reduced voltage in the "OFF" position, (unless a mechanical load brake is provided). All lowering points have positive drive-down. Regeneration braking is provided on the last lowering point.

(v) Wound-rotor motor with stepless, speed-regulated, reversing control and an eddy-current load brake arranged for stalling at 200 percent of rated hook load with motor-temperature warning light. Eddy-current brakes are often equipped with alternators and rectifiers for automatic excitation connections with power "OFF" or failed. This provides a form of emergency dynamic braking for slowdown if the holding brake fails or is out of adjustment.

(vi) DC motor with stepless, speed-regulated, adjustable-voltage control, automatic setting of "electric" brake in "OFF" position, automatic regenerative or dynamic braking for stopping and emergencies, and a motor-temperature warning light.

(vii) Wound-rotor motor with a geared-down, single-speed, squirrel-cage motor clutched to a common shaft and controlled so that, with the clutch engaged, the squirrel-cage motor drives the hook at a constant slow speed (micro-drive).

(3) More detailed specifications for the motor-control systems described above can be found in military specification MIL-C-22137. It should be noted that the development of solid-state static components has steadily increased the availability of more sophisticated controls at a reasonable cost, thereby relegating some of the systems that were formerly popular to the category of "obsolete." It should also be realized that, prior to the advent of static controls, variations of basic control systems proliferated in manufacturers' attempts to circumvent the patents of others and to seem to offer an exclusive advantage for sales purposes. Many of these variants are no longer worthy of consideration. Refer to Appendix B.

g. Categories of Controls Equipment.

(1) Manual--Hand-operated, in-line, drum switch. Failure to operate in accordance with instructions results in high maintenance requirements and may burn out motor windings. This category is no longer used.

(2) Semi-Magnetic. A small drum switch in a pilot circuit controls magnetic contactors in the power circuits of multi-speed motors. Acceleration is under the control of the operator and, therefore, poor technique can cause motors to overheat. Push-buttons in pilot circuits perform similar functions for single-speed and two-speed motors. Cost is the only reason to select this category.

(3) Magnetic.

(a) Pilot circuit switches control magnetic contactors as described in (2) above, but the operator controls starting, speed-selective stopping, and reversing but not the rate of acceleration. Magnetic control, as a minimum, is preferable for all classes of cranes but is essential for heavy duty cranes with large motors.

(b) Each control panel has a master switch or push-button which usually provides five speed points for hoist and three to five points for trolley and bridge travel. Crane-duty resistors commonly provide 50 percent torque on the first point. Succeeding points cut out resistance in equal steps from the 50 percent torque to the maximum torque of the motor. For bridge and trolley travel motions, magnetic control of the reversing plugging type is commonly used. For hoisting, there are many circuits and combinations which can be used. Resistors for crane use are often provided with a permanent section of resistance to give better regulation during acceleration.

(4) Static-Magnetic. A combination of non-rotating control devices and magnetic contactors, with pilot devices as described above. Usually used in countertorque control systems for wound-rotor hoist motors. Control devices are commonly saturable-core reactors and fixed resistors. This equipment is available in stepless form.

(5) Static. Non-rotating control devices, with pilot devices as described above, effect speed changes without the use of contactors. Control devices include primary silicon-controlled rectifiers and secondary saturable-core reactors and fixed resistors or reactors for wound-rotor motors; silicon-controlled rectifiers for adjustable-voltage systems. This equipment is available in stepless form, is compact, and provides fine control.

(6) Adjustable-voltage. Although such equipment, in combination with the drive motor, constitutes a motor-control system and although some of its components are in categories described above, it nevertheless qualifies as a category of control equipment. Rectification of current from the AC power supply can be by motor-generator set or by static rectifiers, the trend being toward the latter. Also, the mode of controlling the voltage to the drive motor (generator field control or rectifier biasing) distinguishes this equipment. Adjustable-voltage motor-control systems are discussed below.

(7) Other. Refer to NEMA publication ICS.

h. Motor-Braking.

(1) Before motor-control systems are discussed, it is appropriate to examine motor-braking, which is usually an integral part of the control scheme and consists of permitting the load to overhaul the motor (regenerative braking), connecting a resistance or the series field of a DC-series-wound motor in place of the line (dynamic braking), or reversing the relationship of motor to line (plugging). Dynamic braking may be categorized as "service" dynamic braking (normal) and "emergency" dynamic braking (during a power outage).

(2) Motor-braking is used in a wide variety of applications, according to the control requirements, and may be generally divided into the categories of control for hoisting and control for other functions. The desirability of motor-braking in combination with the types of motors used, to satisfy varying requirements of the lowering function in different applications influences the choice of a control system. Special problems for which motor-braking is often used are a requirement for accurate spotting or extreme precision (and therefore an accurately controlled slow speed) in the hoist operation. The implementation of such requirements is illustrated in the figures accompanying the descriptions of motor-control systems and in those of Appendix C.

(3) It should be noted that, with some forms of motor-braking, external mechanical brakes are used for holding only whereas, with other forms of motor-braking, they are integrated into the control scheme. Eddy-current brakes are always integrated and are backed up by holding brakes. Some forms of AC motor-braking require DC current from motor-generator sets or rectifiers.

i. <u>Functioning of Motor-Control Systems</u> (refer to Appendix B).

(1) DC Power Source.

(a) Rheostatic or Constant Potential.

(i) Hoists. The most generally used DC control is rheostatic. In this control system, the motor is supplied with a constant-potential feed. Resistance is switched in or out of the armature circuit, thus altering the voltage across it and the series field, with resulting change of speed. All points of control are not available over the load range as the heavy loads may not move on the first steps of control. In general, for DC motors it may be considered that voltage means speed and current means torque. Dynamic braking should be included in hoist controls for lowering (series-wound motors only). It should operate in the "OFF" position and on loss of power. In dynamic braking circuits for lowering or slowdown, the series field is connected across the line in parallel with the armature, causing the motor to function as a shunt-wound machine, or as a self-excited generator pumping power back into the line or wasting it as heat in the resistors or both. It cannot stop a load, but it can reduce the speed to a very low rate. Besides dynamic braking, all DC cranes should also be equipped with one or more "electric" brakes (two for hoist motion). These "electric" brakes, however, would not be used to control lowering speed, but only to stop the motor and hold the load when current to the motor is cut. Plugging is seldom used for the hoist motion.

(ii) Luffing. In designing controls for luffing service, complete torque-speed-time curves, based on the motor, gear ratio, and reeving are required. For floating cranes, curves may be made neglecting the effect of list or trim. In luffing, with the motor operating for short periods much above its 30-minute rating, the control circuit characteristics and motor breakdown torque should be investigated to assure that possible overloads will stall the motor.

(iii) Travel, trolley, and rotate. Travel controls are similar in both directions to a series-resistance hoist control in the hoisting quadrant. The heaviest load occurs during starting and accelerating and reduces greatly as steady-state running is reached. This simple control is excellent unless overhauling loads occur (i.e., travel drive down a grade). Even with armature shunt resistors and motor shunt resistors (rarely) the automatic braking torque is so small that if the overhauling becomes large, a runaway condition exists. Slowdown for these drives may be accomplished by: dynamic braking (series-wound motors only); plugging (deliberately throwing motor into reverse--series-wound or compound-wound motors). Do not use dynamic braking for travel speeds less than 350 fpm. Plugging may be employed for fast slowdown and stop from slow speeds, and as an emergency action from high speeds, provided the control is equipped with reverse torque-limitation to protect the mechanism and the load. Torque-limitation is obtained by a current relay that holds the control on a low speed point, no matter whether the control handle is thrown to a high speed point or not, until the machine is shut off or is actually traveling in the reversed direction.

(iv) Controls for multiple-motor drives, except where motors are in series, should always be of multiplex type, duplex for two pairs, and quadruplex for four pairs of motors. For 230-volt motors operating in parallel, a duplex control should be used, with separate circuit elements and switching elements for each motor, but with common initiating devices such as relays reversing contactors, and master switch. The multiplex control is necessary to eliminate sneak currents, which may circulate harmfully through the motors and control devices, and to ensure equal division of load and current between the motors under plugging and dynamic-braking conditions. For motors in series, use a simplex (single) control, which functions as if only one motor of twice the voltage rating but of the same total horsepower were connected to it. The simplex control results in lower first and maintenance costs and occupies minimum space. The simplex control with motors in series is preferred over the duplex paralleled control with motors of twice the voltage rating and is required for curved-track applications with DC motors. See Motors, Section 6, Part 4, Paragraph 6.

(b) Control diagrams for rheostatic control are obtainable from any control manufacturer.

(2) AC Power Source.

(a) AC Motor Controls--General. Alternating current motors, basically constant-speed-devices, require careful selection of controls for application to weight-handling equipment, with its demand for speed control at all loads and where an inverse speed-load ratio is often desirable, a characteristic that is not inherent in these motors. For many applications, there are control systems that satisfactorily adapt AC motors to hoist, luffing, and rotate service and travel service on straight track. Do not use AC motors for travel drives on curved tracks as differential speed is required. Caution: Careful consideration should be given to secondary effects of the control, such as abnormal heating of the motor or sections of resistors. Depending on the type of control, there may be no inherent drive-down; the load may hoist on certain lowering points; speed control may be out of normal control-handle sequence; excessive jogging may be necessary on slowdown; and there may be large variation in speed with only small variation in load.

(b) Hoisting controls. Wound-rotor motor, reversing:

(i) This is the least expensive of the many magnetic controls for the hoist motion. It is used for cranes in powerhouses, pumping stations, substations, transfer points, machine shops, and similar applications where service is not too severe or is standby.

(ii) An automatic, mechanical, load-lowering brake must be used in conjunction with this control. The hoisting points provide good speed control for normal loads. In lowering, the motor must drive against the mechanical brake in order to lower the load. The speed of lowering depends on both the hook load and the torque-speed characteristic of the motor on its control point setting.

(iii) Good inching or jogging performance is obtained with this control, although lowering jogging is seldom consistent. The low torque on the first hoisting point makes provision for taking up slack cable and raising light loads. In the hoisting direction, the speed-torque curves are the same as for a travel control, but in the lowering direction the effect of the brake is evident. The desirable feature of "the heavier the load, the slower the speed" is achieved, but it is effective only on the slower speed points. A light load or empty hook may be lowered only slightly faster than a very heavy load. Figure 47 indicates the characteristics of this control.

(iv) Positioning and landing speeds are inherently available for only a fraction of the loads, and jogging, with its numerous starts and stops, must be relied on. In practice, the widely varying characteristics of the brake, resulting from lubrication, heat, adjustment, and contact-surface differences, make the speed-torque curves unreliable. Speeds tend to drift generally toward the higher speeds as the brake wears.

(v) Use. Select this type of control for relatively rough-handling situations.

(c) Hoist controls. Wound-rotor motor, countertorque:

(i) This simple system is used for rapid handling of bulk material by buckets and scrap material by magnets. It is small in size and provides for very low motor heating. This control eliminates the need for a mechanical load brake by providing a countertorque braking (modulated plugging) for retardation. An "electrical" holding brake is required.

(ii) The hoisting speed regulation is obtained by varying the resistance in the secondary of the motor, usually in five manually-held and one automatic step with magnetic and semi-magnetic equipment. With static-magnetic equipment, the regulation can be stepless.

(iii) To lower using magnetic or semi-magnetic equipment, the motor is not energized and the brake is not released until the master handle is moved to the last lowering point (regenerative braking), at which time the motor accelerates to rated lowering speed. To retard the load, the master handle is moved toward the "OFF" position. At this point the line contactors are reversed with all the secondary resistance inserted, thus causing the motor to produce a reverse or countertorque. Further movement of the handle toward the "OFF" position increases the value of the countertorque at each point until the maximum value is reached on the first point lowering. Best results are obtained in lowering of loads between 50 and 100 percent capacity. Figure 48 indicates the characteristics of this control.

(iv) High-speed lowering with such equipment is safe with certainty only on the regenerative point, or in this case point five. Lowering on the other points may be either very slow or very fast, depending on only small differences in the amount of load. With a control as illustrated, a load that may be lowered safely on point three, may be run-away on point four, but be safely controlled on point five. The control-handle positions are then unnatural. On point one or two lowering, a light load may hoist; on points three and four lowering, the operator may not be able to foresee whether the speed will be slow or fast.

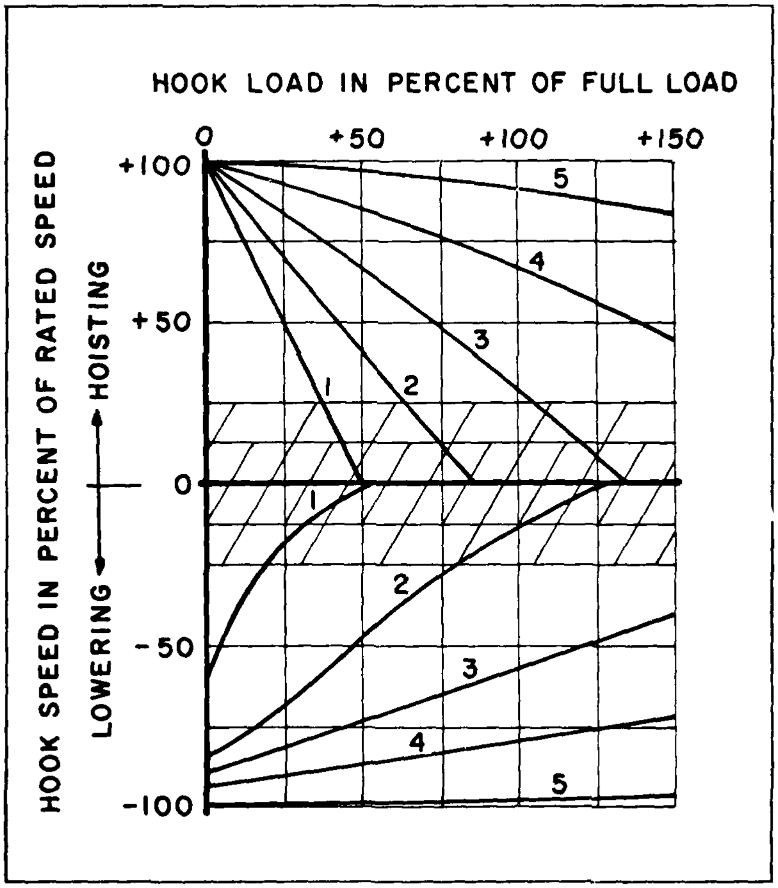

FIGURE 47
Hook-Speed/Hook-Load Curves of Wound-Rotor Motor:
Reversing Control with Mechanical Load Brake

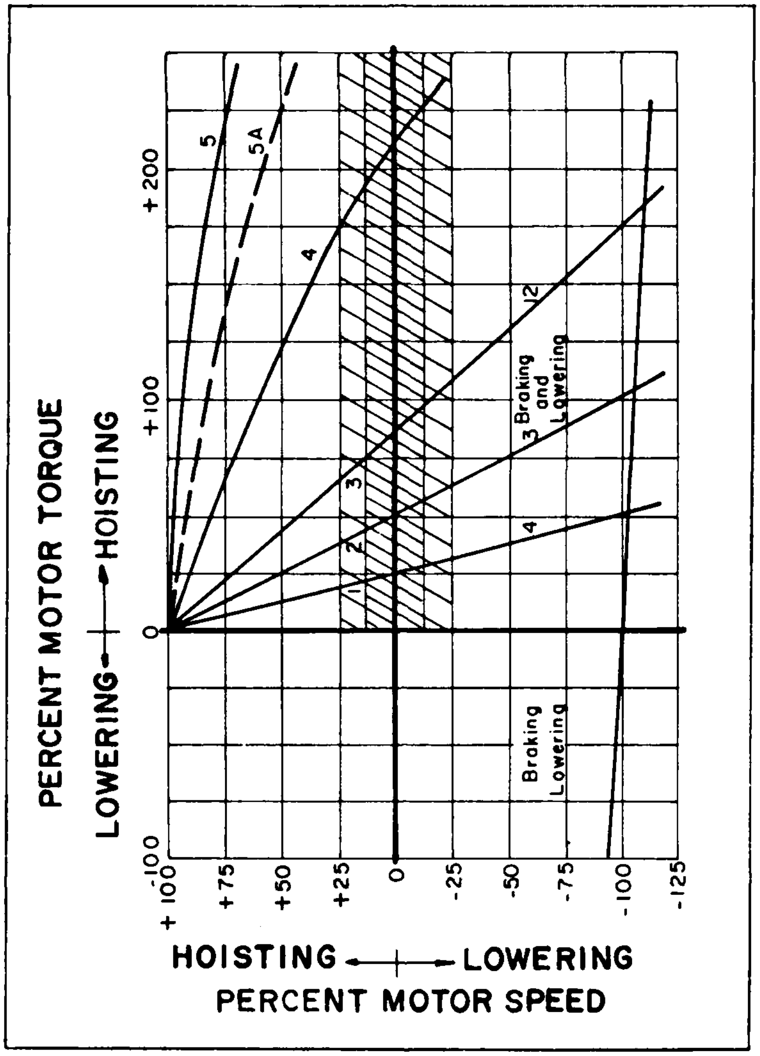

FIGURE 48
Torque-Speed Curves for Wound-Rotor Motor with Countertorque Control

(v) Care must therefore be taken that the hook or line is always loaded with fairly constant minimum and maximum loads, such as an empty bucket and a full bucket, and that only operators experienced with the particular crane are used. An overspeed device should be provided to limit the lowering speed to 150 percent of synchronous speed in any case. Under these conditions, the risk of damage to load or adjacent property may be inconsequential.

(vi) With static or static-magnetic control equipment, additional safeguards can be built into the circuitry; e.g., not more than 20 percent of full load hoisting speed on the first lowering point with any load; not more than 135 percent of full load hoisting speed on the regenerative lowering point with any load. Refer to the discussion of electronic controls below.

(vii) Use. Because of a certain amount of danger, very poor speed regulation, uncertain speeds, and unnatural control sequences, this control should be selected only where special circumstances dictate its use, such as bucket and magnet work on bulk materials.

(d) Hoist controls. Wound-rotor motor, magnetic control, eddy-current brake:

(i) This control is designed for applications requiring accurate speed control in both the hoisting and lowering directions for all conditions of loading. It is used in machine shops and similar applications.

(ii) The control system includes an automatically controlled eddy-current brake which provides a load on the motor at all times, permitting the excellent speed regulating properties of a loaded wound-rotor motor to be utilized. The DC-excited eddy-current brake is used as an element of the control to provide an adjustably varying artificial load on certain hoisting points (usually at least two) and on four lowering points (three if a mechanical load brake is used).

(iii) The effect in hoisting is to load the motor beyond that of the hook load, thus slowing the speed below normal for that load. The result is good speed regulation in hoisting light loads and very slow speed for pickup. For light loads on the hook, the eddy-current brake provides the additional motor load so that the speeds on each point are fairly constant regardless of hook load.

(iv) The effect in lowering is to force the motor to work against the brake in a drivedown manner, the eddy-current brake braking both the hook load and the motor. The motor itself works under the conditions of "reverse," as shown in Figure 49. Heating under these conditions occurs mainly in the brake and secondary resistors rather than in the motor itself.

(v) The speed-load curves, Figure 49, show the excellent control produced by this system. Hook-speed/hook-load characteristics are not readily seen from the torque-speed curves because of the artificial loading provided by the eddy-current brake. Figure 49, therefore, shows the hook-speed as a percent of synchronous speed and rated load as being 100 percent of hook-load. The flattening of the curves, with resulting excellence of speed regulation, is evident. Because the motor is actually working in reverse, there is an inherent drivedown. At the fifth point, eddy-current braking is removed and the load held to speed by regeneration. "OFF" position dynamic braking may be applied by energizing the eddy-current brake in the "OFF" position and emergency dynamic braking may be obtained by equipping the eddy-current brake with an alternator and rectifier.

(vi) Use. This control is suitable for heavy-duty, intermediate-speed, and precision work.

(e) Hoist controls. Wound-rotor motor, stepless, eddy-current brake: This control is similar to the control previously described except with the refinements of static, stepless control.

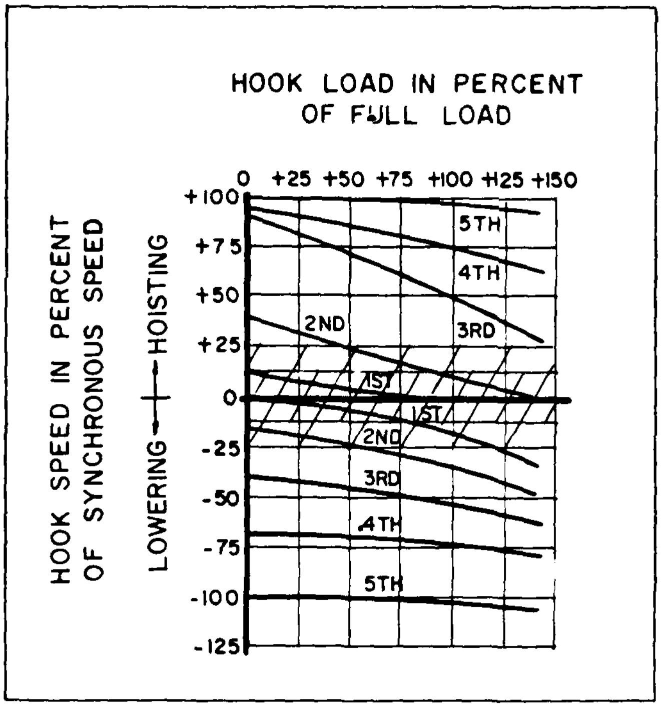

FIGURE 49
Load-Speed Curves of an Eddy-Current Brake Control for Wound-Rotor Motors

(f) Hoist controls. Wound-rotor motor plus microdrive:

(i) Where a very slow speed is required for extreme precision, a wound-rotor motor, with a mechanical load brake, in combination with a squirrel-cage reducer motor, an electric clutch, and a holding brake may suit the purpose.

(ii) The machinery is arranged so that, with the electric clutch in engagement, the wound-rotor motor is disconnected from the line, the single-speed squirrel-cage motor drives the hook at a constant slow speed. With the clutch disengaged, the wound-rotor motor drives the hook at the selected variable speeds as determined by the position of the master switch handle.

(iii) This control should be used where the intended loads can be handled at intermediate speeds with a simple form of control and where the requirement for precision justifies the expense of the additional slow-speed equipment.

(g) Hoisting controls. Wound-rotor motor, electronic (solid state) controls:

(i) Such controls are generally referred to as "static" controls. Most static control systems have primary contactor reversing means. A few systems perform the reversing function with silicon-controlled rectifiers. Torque control is obtained by saturable-core reactors in the primary or secondary circuit or by power amplifiers which apply driving power or countertorque as required by load on the motor.

(ii) Speed control may be conventional stepped or stepless, regulated (in which the hoist handles the load at a speed within 15 percent of the speed called for by the master switch regardless of load weight) or non-regulated (in which the load influences the speed irrespective of position of master switch by means of a feedback-signal from a pilot generator or other load-measuring device). Control may also involve load float (zero speed with brakes released).

(iii) Braking is accomplished by one of the following methods, either alone or in combination: Countertorque, regenerative, eddy-current load brake, mechanical load brake, electric holding brake.

(iv) Performance diagrams for these controls may vary slightly for the different manufacturers but all will approximate the stepped performance, Figure 50, and the stepless as shown in Figure 51. This latter type of control is compact, efficient, requires little maintenance, and provides exceptionally fine control with low maintenance and downtime.

(v) Static controls present a maintenance problem which requires the learning of new techniques. The ability to spot trouble by looking at the control board to find a malfunction of contactors does nothing to help where all units except the circuit breaker for main power are static. Static controls are put up in modules and plugged into the circuit. A meter across the various terminals will reveal the malfunctioning unit, which is replaced with a new unit. The old unit may be repaired at a later time.

(vi) Use. The use of static controls--and stepless static controls in particular--should be considered where fineness of control justifies its cost, which is now not unreasonable.

(h) Hoisting controls. Squirrel-cage motor:

(i) For cranes of light capacity, single-speed control is used where speed regulation is not essential, especially for standby cranes. This control provides one speed in each direction. Dual speed, in the case of a two-speed hoist motor, is available. The hoist is equipped with an automatic mechanical load brake and an "electric" holding brake. No resistors are required as motors are started across the line. Jogging is required and a micro-drive can be used if accuracy is essential.

(ii) Because the characteristics of squirrel-cage motors are basically not suitable for weight-lifting applications, their use should be limited to 10 hp maximum. Refer to Squirrel-Cage Motors.

(i) Adjustable voltage. Adjustable voltage control is applicable to hoist, travel, or trolley and is characterized by smoothness of operation, simplicity of control, low power losses, and extreme flexibility. It is ideal for handling delicate loads. It is the type of control used for high-speed elevators and can provide stepless speed control with smooth acceleration and deceleration, fast empty hook speed, dynamic and regenerative braking (or combination of both). Since empty hook speed can be fast, one hoist can often be used in place of separate main and auxiliary hoists. This control is accomplished through the use of motor-generator set or static converter (AC-to-DC) for main power, a shunt-wound or compound-wound motor, a constant-potential exciter for the fields of the generator and the motor, and voltage-changing devices for the fields, as illustrated in Figure 51.

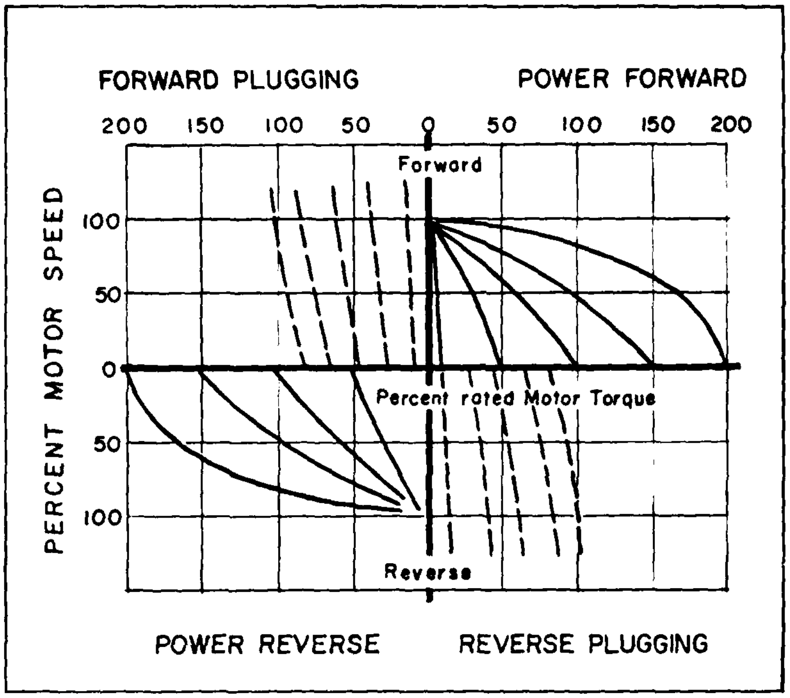

FIGURE 50
Torque-Speed Curves for Wound-Rotor Motor with Stepped Static Control

(i) Under this form of control, the motor changes speed in response to changes in the armature voltage from the main generator or static convertor, changes in the field voltage from the exciter, or simultaneous changes from both sources. With relatively simple modifications the following conditions may be obtained: Speeds may be constant within a slight percentage under any load; speeds on any point may reduce with increase in load, in both hoisting and lowering directions; speeds may gradually reduce, or be made to sharply reduce, to a safe sharp stall point just beyond the heaviest rated hoisting load; acceleration and deceleration, even with the practical small number of speed points, may be made smoothly; light hooks may be moved rapidly, and either light or heavy loads will hoist or lower very slowly for pick-up or landing of loads.

(ii) Primary control by the operator is by switching resistors in and out of the field circuits (usually for higher ranges of speed), by shunting the armature with a variable resistor (usually for low speeds). Pilot generators (for feedback signal), with amplidyne or rototrol comparison circuitry or electronic speed control are used where a wide range of speed is required. The latter have become increasingly popular with improvement in their relative cost. Reversing is by changing the polarity of the driving motor armature. The characteristics of speed control obtained depend on the listed modifications.

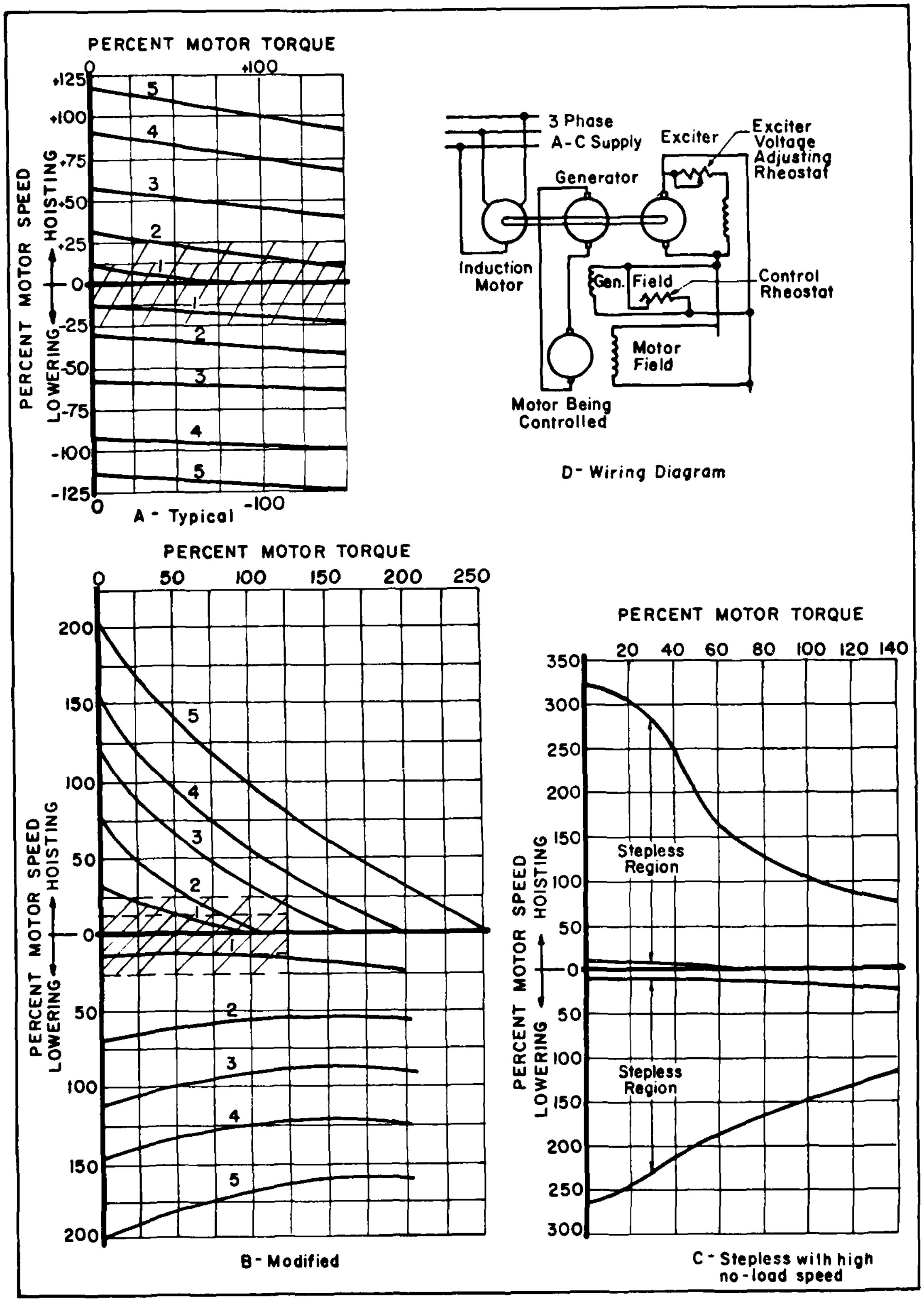

FIGURE 51
Torque-Speed Curves of Adjustable-Voltage Control with Shunt Motor

(iii) Caution: With adjustable-voltage control, control of the hook load can be maintained only as long as certain circuits are intact, particularly the loop circuit, which connects the armature or the static convertor of the generator and the armature of the hoist motor. Wherever practicable, the units of the hoist drive should be located so that connections of vital circuits cannot fail. If it is not practicable to do so, the circuits should be paralleled at possible failure points and other practical anti-failure measures also must be taken. At sliding contacts, for example, two independent collectors should be used, and the conductors should be of such material that corrosion will not interrupt the circuit.

(j) Travel, trolley, and rotate controls. Wound-rotor motor, reversing:

(i) Travel and trolley motors that are properly selected for size always have considerable load on them. Under those conditions, secondary resistors may be chosen so that good speed regulation may be obtained. Plugging is simple and usually applied with magnetic controls. When the master switch handle is quickly reversed, the directional contactors immediately reverse, holding the electric brake released, but the accelerating contactors are held open by the plugging relay until the motor has driven through zero speed and is accelerating in the reversed direction. On cab-controlled cranes, a drift point may be provided so the brake relay will keep the electric brake released until the control handle is returned to the "OFF" position, thereby allowing the motion to coast or the operator to stop with a foot brake. As indicated, braking is often accomplished by the plugging of the motor. Do not use dynamic braking.

(ii) See Figure 52 for typical characteristic curves for AC motors in travel service. Point two should be set to barely start the crane, so that on start-up there will be a slow creeping speed and on slowdown, point one will provide a corresponding slow speed. Acceleration and cutoff arrows are shown and should be compared with Figure 49 which has similar curves for DC cranes. In like manner, plugging from equivalent speeds is shown. Note that high-speed plugging is not as severe as with DC but still may be rather strong.

(iii) For overhauling loads, the slow-speed curves pass into the overhauling quadrant at a very steep angle, indicating that slow-speed points have little braking effect without great increase in speed; the high-speed-point curve is very flat, so that there may be great braking effect with little increase in speed, but the braking speed is always above the synchronous speed; the slowing down of an overhauling load can only be such as to prevent a runaway condition.

(iv) The high-speed running point is frequently used in the lowering direction on hoists, the motor connected to drive down the load for the highest (usually fifth) point. The highest fast speed lowering is then slightly over the motor synchronous speed and the motor is regenerating, pumping current into the line. The point is therefore commonly known as the regenerative point.

(v) The desirable qualities of control are only partially met.

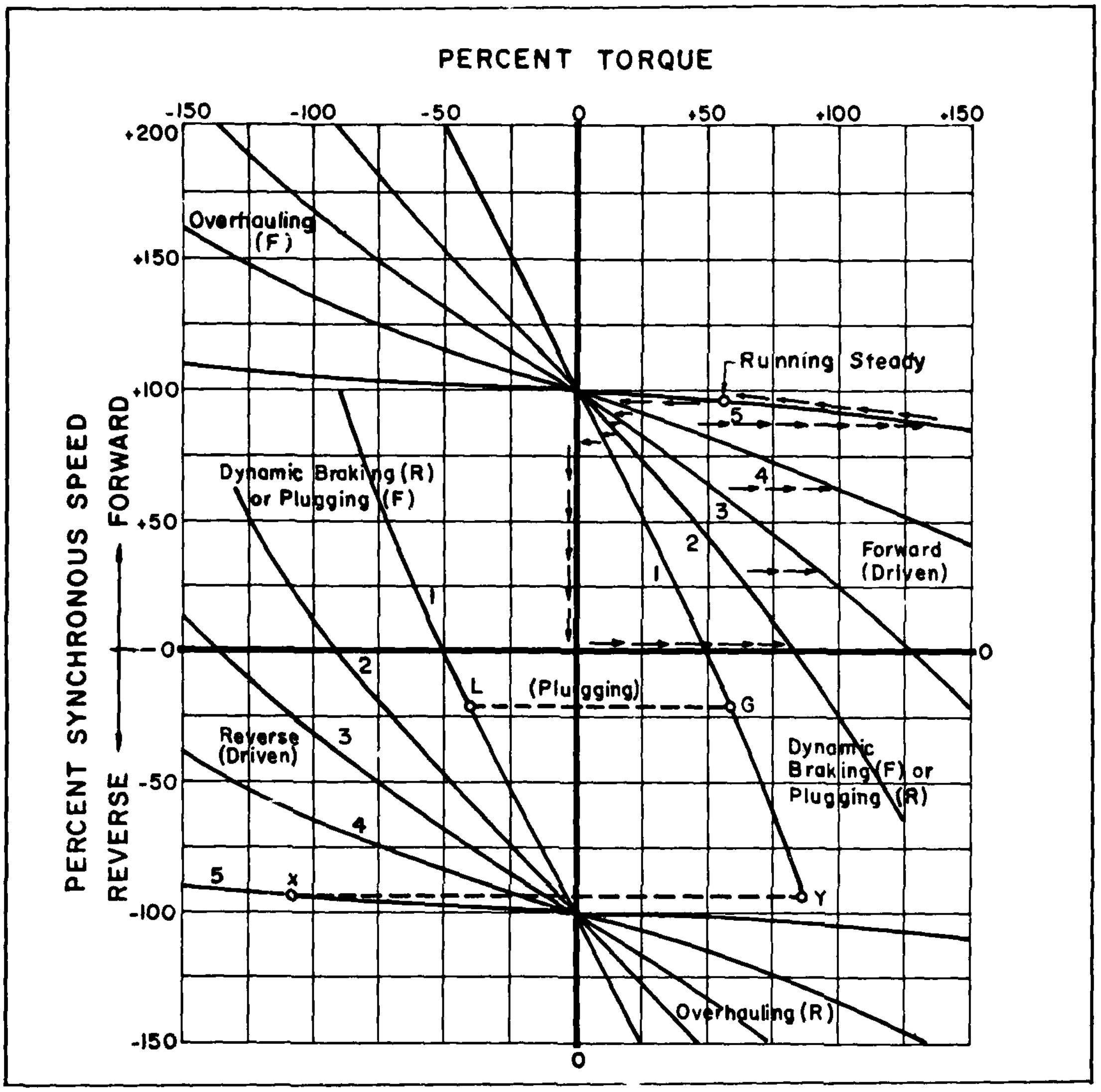

FIGURE 52
Torque-Speed Curves for Wound-Rotor Motors in Trolley and Travel Service

(k) Travel, trolley, and rotate controls. Squirrel-cage motor: Even with two-speed motors, the torque peak on squirrel-cage motors is so high that the acceleration is rough in travel service, unless the designed travel speed is very low, static control or reduced-voltage starting is used, or both. Reduced-voltage starting is essentially a single-speed device and therefore is not too satisfactory. Also, the additional equipment is such that it is preferable to use static controls or wound-rotor motors. Fluid-drive squirrel-cage motors permit gradual acceleration to operating speed. When torque-converters are used, the fluid level in the converter must be lowered to provide moderate acceleration rates. Efficiency is thereby lowered and creeping speeds cannot be maintained. Refer to Squirrel-Cage Motors.

(1) Other descriptions of control functioning are contained in Appendix C. Wiring diagrams of AC control systems can be obtained from any control manufacturer.

j. Characteristics of AC Controls. The following table indicates the characteristics of AC controls systems, including motor braking:

Type of Control	Relative Cost	Safety	Hoisting	Lowering
Drum with automatic mechanical load brake	lowest	Good	L.L. = Good R.L. = Good	Fair Good
Reversing magnetic with automatic mechanical load brake	low	Excell.	L.L. = Good R.L. = Good	Fair Good
Reversing--counter-torque lowering	low	Fair	L.L. = Fair R.L. = Fair	Poor Good
Reversing--DC dynamic lowering	average	Fair	L.L. = Good R.L. = Good	Fair Good
Reversing--AC dynamic lowering	average	Fair	L.L. = Good R.L. = Good	Fair Poor
Reversing--Eddy-Current load brake	low	Good	L.L. = Good R.L. = Good	Excell. Excell.
Eddy-Current with mech. load brake	low	Excell.	L.L. = Good R.L. = Good	Excell. Excell.
Static and adjustable voltage DC	high	Excell.	L.L. = Excell. R.L. = Excell.	Excell. Excell.

NOTES: L.L. = Light load
R.L. = Rated or near rated load

k. Ratings.

(1) Controls. Controllers for crane and hoist service should be rated in horsepower at 1-1/4 to 1-1/2 times the rating for 8-hour continuous operation in accordance with the applicable NEMA standards.

(2) Control resistors.

(a) Resistors should be rated in ohms, amperes, and class of service. NEMA classes are based on time-on during a given period and the percent of full load current on the first point of the control. To select resistors properly, the motor horsepower, motor characteristics, and duty cycle of the crane should be known, due weight being given to protracted operation at slow speed. With these factors, resistors of the proper size, NEMA class, and resistance value can be selected, as indicated in the following table.

Typical Starting Torques for Motors Used With
NEMA Resistor Class Series 90 and 170

Approx. % Full Load Current on 1st Point	Starting Torque in % of Full Load Torque					Class No. According to Duty Cycle	
	DC MOTORS			AC MOTORS			
	Series	Compound	Shunt	1 Phase Starting	3 Phase Starting	15 Sec. Out of 30 Sec.	Continuous Duty
25	8	12	25	15	25	171	91
50	30	40	50	30	50	172	92
70	50	60	70	40	70	173	93
100	100	100	100	55	100	174	94

(b) Typical selections are Class 172 resistors for cranes in intermittent service and Class 92 for cranes in heavy duty cycles. Class 174 resistors are recommended for three-point hoist control. The use of other classes of resistors is indicated if more or less than 50 percent of full load current or torque must be supplied on first point or if duty cycle is more or less than indicated in table. However, experience indicates that cranes are ordered for higher speeds than are actually used. This results in extended operation at slow speeds. For this reason, "continuous" ratings are indicated for heavy duty applications. For intermittent operations, the requirement for prolonged operation at the lowest speed should be carefully evaluated before a "less-than-continuous" class of resistor is selected.

(c) The effect of operating for significant periods of time at full load but at lower speeds than those contemplated in the crane specifications result in overtaxing the resistors, as can be seen from the following extract from a NEMA Standard table:

Class Number of Resistors for Continuous-duty Speed-regulating Service with Direct-current Shunt Motors and Alternating-current Wound-rotor Motors

	Percent Speed Reduction	Class Number (Percent of Rated Motor Torque at Reduced Speed = 100)
	5	1005
	10	1010
	15	1015
	20	1020
	25	1025
Example:	30	1030
	35	1035
	40	1040
	45	1045
	50	1050

Thus, full-load operation at 70 percent of rated speed instead of at rated speed (as contemplated) requires Class 1030 resistors but Class 1000 resistors are provided because of improper specification.

(d) Refer to National Electrical Manufacturers Association (NEMA) Standards ICS for additional information.

l. Rotating Equipment Control. Primary power and control is often provided by rotating equipment consisting of a continuous-duty rated squirrel-cage motor directly connected to a DC generator; a constant-potential exciter with field rheostat and voltmeter or an adjustable static exciter and voltmeter; reduced-voltage type squirrel-cage motor starter with thermal overload protection; a generator-field quenching circuit; and ribbon-type generator field resistors. The crane protective circuits should also control and protect the M-G set.

m. Rectifiers. Primary power and/or control is increasingly being provided by rectifiers of the 3-phase, full-wave, bridge connected silicon type, except that units rated at less than 15 hp may be 3-phase, half-wave or single-phase, full-wave. Where there is more than one phase power source, the phase loads should be balanced as closely as possible. Rectifying elements are hermetically-sealed and mounted on heat sinks cooled by natural convection. Rectifiers should be built, installed, and enclosed in accordance with NEMA Standard PV3.

(1) Straight rectifiers (non-controlled). Protection for the power diodes consists of a line isolation transformer, transient-surge suppressors, and either current-limiting rectifier-type fuses or static instantaneous overcurrent tripping of the line circuit breaker.

(a) Ratings. The rectifier bridge (including overload protection) should be rated for continuous-duty at a minimum of 150 percent of the load rating and for 1-minute at a minimum of 300 percent of the load rating. The peak inverse voltage rating relative to the actual working peak inverse voltage should be not less than 200 percent for avalanche type diodes and not less than 250 percent for other types.

(b) Current-equalizing devices should be provided to force diodes to share current. The DC average output voltage should not exceed 300 volts. Regenerated power is automatically absorbed by resistors and/or devices.

(2) Silicon-controlled rectifiers (thyristors). Protection shall be as described in (1) above. The control includes an adjustable circuit capable of limiting maximum current to not more than 25 percent overcurrent into shorted conductors.

(a) Ratings. The rectifier bridge should be rated for continuous-duty at a minimum of 150 percent of the highest motor current rating that will provide full-load torque at all speed points, and for 300 percent of this rating for 1 minute. The peak inverse voltage rating should be not less than 200 percent of the actual working peak inverse voltage.

(b) Parallel operation of rectifiers should not be permitted. The maximum DC average voltage should not exceed 500 volts.

(c) Controlled electric braking is provided by feeding regenerated power back into the power source.

n. Accessories and Installation.

(1) Control switches should conform to Military Specification MIL-C-22137 (YD). Remote switches should be provided as described under Protective Equipment.

(2) To obtain good service and long life from the resistors, it is important that adequate ventilation be provided. If enclosures are used, they should be designed so that an adequate natural flow of air will effectively remove the heat from the resistors. A wire mesh or expanded metal guard should be provided where required to prevent accidental contact with the resistors. Resistor units should be supported so as to be as free as possible from vibration.

8. PROTECTIVE EQUIPMENT.

a. Requirements.

(1) Protection should be provided in accordance with NEMA Standard ICS. The main line power circuit breaker should be automatic, instantaneous, electrically trip-free, and air type, in accordance with NEMA Standard SG-3.1. An emergency "STOP" button with mushroom head, furnished in red plastic, and a "RESET" button should be provided on or near the operator's control station. Protection against undervoltage on the system and overload protection for each motor should be arranged so that upon operation of either, or when the "STOP" push-button is depressed, all crane motions will stop, and will remain stopped until all master switches or push-buttons have been returned to the "OFF" positions. An exception is floor-controlled cranes, which should have "RESET" buttons in their control stations. All protective equipment should be full magnetic, except for isolating knife switches, and control circuit fuses. Fuses should be of the cartridge type conforming to W-F-791. Except on package hoists a manual, main line, lockable circuit breaker should be located on the crane structure adjacent to the access point. Refer to Engine-Generator Sets, Section 6, Part 4, Paragraph 5.

(2) Limit switches should be provided in accordance with Military Specification MIL-C-22137 (YD) and should not be adjustable except on portal cranes; upper limit switches for hoists should be power line switches without by-passing. If by-passing is considered essential, a key-operated switch should be used, with the key directly available to the operator.

(3) On portal, gantry, semi-gantry, and similar cranes with cabs, a remote emergency button, operable from ground level, should be provided to signal the operator. On floor-controlled, overhead traveling cranes, the disconnect means should be mounted on the bridge or footwalk near the runway collectors and should be one of the following types:

(a) Non-conductive rope attached to the main disconnect switch handle;

(b) A push-button for the main line contactor operated by an emergency stop button in the pendant push-button station.

(4) Automatic cranes shall be so designed that all motions shall stop if any malfunction of operation occurs.

b. Ratings. Protective equipment for all cranes and hoists should be rated in accordance with NEMA Standard for Industrial Control ICS (Classes I, III, IV, and V, Part 43, Magnetic Control for Cab-Operated Cranes).

9. ELECTRIC BRAKES.

a. Electric Brakes. The term is sometimes a misnomer and refers to friction brakes, spring-applied and released by solenoid, electric magnet, or to thrustor brakes (electrically driven hydraulic system). It also embraces eddy-current brakes. It is used to distinguish the foregoing types from mechanically applied brakes.

b. Types of Brakes (proper).

(1) Disc brakes are quite satisfactory, but their use is usually limited to brake motors, those installations where the brake is designed as a component or accessory part of the motor, with a 15 hp maximum.

(2) Shoe brakes are the most generally used friction brakes.

(3) Eddy-current brakes are speed-controlling devices used in place of mechanical load brakes or other electrical means of braking on cranes using wound-rotor motors. The brake holds the speed and load without friction, and at selected speeds, in accordance with the controller position. This brake stabilizes and loads the wound-rotor motor to such an extent that smooth lowering and hoisting speeds can be maintained regardless of load on the hook. The brake may be biased by reduced voltage when the control is in the "OFF" position. These brakes should always be backed up by holding brakes.

c. Operational Modes for Spring-Applied Friction Brakes.

(1) Solenoid-released. By means of a linkage arrangement, the spring pressure is overcome by the solenoid and the brake shoes are pulled back from contact with the brake wheel. These brakes are for holding only and are applied when the motor current is cut off. Variations of this type are:

(a) A design in which the solenoid is encapsulated in an oil bath which minimizes the pounding action of the solenoid, thus contributing to longer life of the solenoid and reduced wear on the brake linkage.

(b) A design which minimizes maintenance by the use of a self-adjusting mechanism which automatically compensates for lining wear and retains the gap between lining and face of brake wheel at the desired operating range.

(2) Magnet-released. The brake is spring-set and held in released position by magnetic action. With DC current supply, this brake is series-wound; the brake is released at 40 percent of full load motor current and remains released on 10 percent of full load motor current. With AC current supply, this brake is shunt-wound and requires a rectifier for its operation; it is released at 80 percent of full load motor current or torque (current check or torque proving circuit).

(3) Thrustor-released. This brake is spring-set and is held in released position by hydraulic pressure opposing the spring. This hydraulic pressure is developed by a small electric motor driving a centrifugal impeller forcing oil in a hydraulic cylinder against a piston. In some thrustor brakes, a delay action in the setting of the brake is provided by means of a valve in the hydraulic circuit. This brake is primarily used on AC current.

(4) The adjustable torque brake is a fail-safe, spring-set brake used as a parking brake for bridge or trolley motions and as a controlling brake for applying braking torque to the bridge or trolley motions by controlling the spring tension through a foot-switch-operated or push-button-operated coil in three steps of intensity. This brake is well adapted to the bridge motion of floor-operated and remote-operated cranes and for controlling the bridge braking when the cab is mounted on the trolley.

d. Speeds and Torque Values. The following tables give typical operating speeds and torque values for the different types of brakes in the available sizes:

Eddy-Current Brake Ratings

Model Brake	Operating Speeds		Max. Torque in Lb. Ft.	
	Normal	Maximum	1200 RPM	900 RPM
AB-701	3600 RPM	6000 RPM	5.5	5.0
AB-702	3600 RPM	6000 RPM	27	24
AB-703	1800 RPM	4400 RPM	49	43
AB-704	1800 RPM	4400 RPM	99	90
AB-705	1200 RPM	2000 RPM	204	195
AB-706	1200 RPM	2000 RPM	410	388
AB-707	900 RPM	2000 RPM	870	870
AB-708	900 RPM	2000 RPM	1740	1740
AB-709	720 RPM	1500 RPM	2100	2100

Magnetic Brake Ratings--Series or Shunt in Lb. Ft.

Size	Max. Torque Intermittent	Face	Size	Max. Torque Intermittent	Face
4-1/2	25	3-1/8"	16	1000	6-3/4"
6	50	3-1/8"	19	2000	8-3/4"
8	100	3-1/4"	23	4000	11-1/4"
10	200	3-3/4"	30	9000	14-1/2"
13	550	5-3/4"			

Adjustable Torque Brake Ratings Lb. Ft.

Size	Max. Parking Torque	Normal Adj. Torque	Maximum Adj. Torque
10"	200	200	400
13"	550	550	1100
16"	1000	1000	1500

e. Ratings.

(1) Electrical release mechanisms.

(a) Series-wound DC magnetic brakes shall have a rating of 1/2 or 1-hour intermittent service.

(b) Shunt-wound DC magnetic brakes shall have a rating of both continuous and intermittent service (the latter generally meaning continuous cycles of about 1 minute on and 1 minute off, or 1 hour on continuously from a cold start).

(c) Magnetic AC thrustor and torque-motor brakes shall have a continuous or intermittent rating, usually higher for the latter.

(2) Eddy-current brakes should have electrical rating as described for electrical release mechanisms and torque capabilities to produce 75 percent of the rated hoist motor torque at 1/8 of full speed and 112.5 percent at 1/4 of full speed.

(3) Mechanical ratings of friction brakes should be computed in terms of required torque as outlined in Section 9.

10. WIRING AND BUSWAYS.

a. Wiring.

(1) Wiring (including switches, enclosures, and raceways) should be in accordance with the National Electrical Code, Military Specification MIL-C-22137 (YD) and Design Manuals in the series DM-4 and in the series DM-8.

(2) Special attention should be given to installations out of doors and in hazardous areas. Heat shields should be provided under the control panels, wiring races, and the crane cab floor when the crane is operated in areas of high ambient temperatures.

(3) Wire on moving components should be stranded.

(4) Wire size should be checked for voltage drop from all sources, including self-inductance in the case of larger AC conductors, as affecting starting torque. The effect of power factor (after determination of amperes) on the voltage drop of AC conductors in the large sizes should be noted. The curves published by the IEEE provide a graphic indication of such effect.

b. Busways. Crane busways shall comply with the standards listed for wiring and should be selected for maximum safety to personnel. Enclosed conductors, available in a wide range of ampere capacities, provide a safe, low-cost, flexible system for cranes or monorails. In the horizontal arrangement (see Figure 53) they may be as close as 1-1/8 inch apart, thus saving much space in a multiple conductor system. There is little warrant for using exposed conductors if any hazard would be presented by them.

11. DESIGN SPECIFICATIONS AND CLASSIFICATION OF CONTROLS. See Military Specification MIL-C-22137 and NEMA Standard ICS.

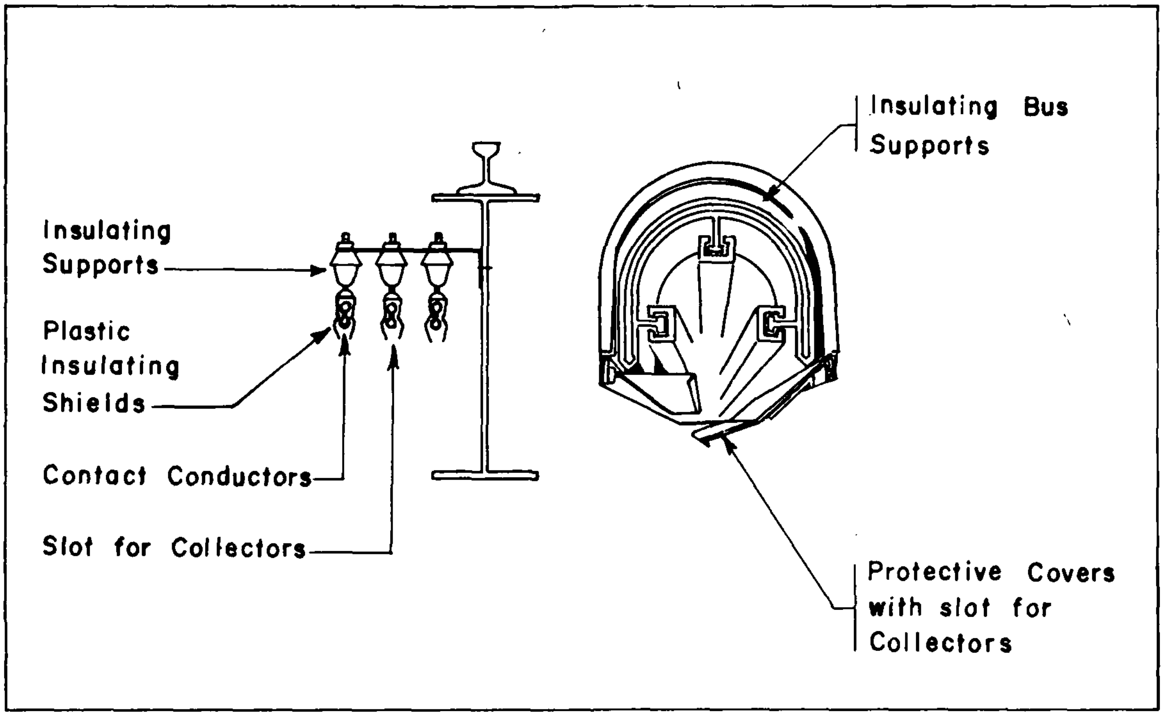

FIGURE 53
Enclosed Contact Rails

Section 7. MAINTENANCE, OPERATION, AND TESTING

Part 1. MAINTENANCE AND OPERATION

1. STANDARD. Maintenance and operation of weight-handling equipment shall conform to the requirements of NAVFAC P-300.

2. PREVENTIVE MAINTENANCE SERVICE AND INSPECTION GUIDE. See Part III of NAVFAC P-300.

3. SAFETY INSPECTION AND LOAD TESTING. See Part III, Section 3 of P-300.

Part 2. ACCEPTANCE TESTING

1. PURPOSE. The purposes of acceptance testing are:

(1) To insure that performance specifications have been met.

(2) To obtain data useful for improvement of design, for later utilization of machine capabilities, and for superior maintenance performance.

(3) To provide running time for allowance of possible malfunctioning of machine before the contractor leaves the premises.

2. PERFORMANCE OF TESTS.

a. Test Schedules and Data Forms.

(1) Before testing, test schedules shall be prepared, indicating all performance tests to be made (in a convenient, but flexible order), the methods, devices, and equipment to be used, and the data to be collected with space reserved for the comments and recommendations of the Resident Officer in Charge of Construction, or other official in charge of the test. File copies of the completed schedules and forms with the Command and the appropriate using activities. Machines that may be transferred, such as floating cranes, should have these data filed aboard with the otherwise specified data.

(2) Forms should be prepared and properly filed, showing items for storage or for use off the cranes, including specified cloth or microfilm reproducibles of plans, docking plans, towing and stowing equipment, equipment lists, and attachments. These forms should also include wiring diagrams, manuals, operating instruction books, spare parts lists, labels, and special tools.

b. Site.

(1) Sites suitable for erection are satisfactory for testing, except for crawler, motor-truck, and locomotive crane testing; the pavement and/or rails supporting the equipment shall be level and shall have minimum deflection under load.

(2) The site for any specified tests for radio interference suppression on mobile cranes shall be selected on the basis of minimum ambient interference.

c. General Requirements. Performance tests, generally, shall follow the Crane Test Procedure set forth in Appendix K to NAVFAC/P-300 (latest issue), with the following amplifications and modifications:

(1) All test loads shall be applied in increments of 0, 1/4, 1/2, 3/4, and full-capacity hook loads; followed by overload tests. The operation under these loadings shall be done in a normal operating manner, with the normal number of simultaneous motions, at normal speeds.

(a) In general, for portal, tower, hammerhead, floating, overhead traveling, monorail, wall, gantry, pillar, jib, and pillar-jib cranes, and simple hoists this means up to full load (on any one hook only), full speed, and all usual motions simultaneously.

(b) For locomotive, crawler, and motor-truck cranes, at high speed, only one motion should be operated at a time. The high-speed swing motion and the luffing motion may be too fast to test with any but a very light hook load. In all cases of high-speed tests and simultaneous-motion tests, the judgment of a competent, experienced operator should govern the speed to be used with the given hook load and the number of simultaneous operations to be performed. Extended, but not fully blocked, outriggers for all speed tests, except travel tests, are useful as a safety precaution for free rate capacity test.

(c) For derricks, test for high-speed and simultaneous motions in the same manner as for locomotive, crawler, and motor-truck cranes, but (1) with even greater caution and (2) boom rotation with vangs should never be performed hurriedly, or simultaneously with any other motion.

(2) Overload tests.

(a) Locomotive, crawler, and motor-truck cranes never should be tested beyond the rated outrigger capacities, with outriggers extended and blocked, except as may be required for tipping tests.

(b) Normal operating speeds and number of simultaneous motions should be employed. Rated speeds need not, and in some cases cannot, be attained.

(c) Full rotating and luffing circles in each direction should be performed.

(d) Hoist and travel motions need be carried out only until steady speeds each way are reached.

3. STABILITY TESTS.

In addition to performance testing, locomotive, crawler, motor-truck cranes; and floating-crane and derricks require stability testing.

(1) Floating-cranes and derricks. Test to prove conformance to contract limitations on list and trim and record as a baseline reading.

(2) Locomotive, crawler, and motor-truck cranes.

(a) These cranes are procured to commercial requirements and as such shall have as a minimum the margin of stability specified in ANSI B30.5 when tested in accordance with Society of Automotive Engineers (SAE) J7650.

(b) When locomotive, crawler and motor-truck cranes are assigned to hazardous or critical service, consideration should be given to rating the cranes in accordance with proposed SAE J1289. That is, when stability governs design, the allowable rated load shall be determined as follows:

$$\text{Rated Load} = \frac{\text{Tipping Load} - 0.1F}{1.25}$$

Where:

F = The factor of tipping as caused by the boom weight. F is the weight that if hung from the boom point would cause the same tipping moment as the actual boom weight.

Example:*

Consider a wheeled, hydraulic crane operating on outriggers with the following specifications:

Operating Configuration	=	Off The Side
Weight of Carrier, Upper and Counterweight	=	35,000 lbs (155.7 kN)
C.G. of Carrier, Upper and Counterweight	=	Center of Rotation
Boom Assy. Weight	=	8,000 lbs (35.6 kN)
C.G. of Boom Assy.	=	@ 42 ft Radius (12.8 meters)
Hook Position	=	@ 90 ft Radius (27.4 meters)
Outrigger Spread	=	10 ft Each Side (3 meters)

With no load, the moment applied to keep the crane stable (restoring moment) is:

35,000 lbs x 10 ft = 350,000 lb-ft (475 kN·m)

*Example, courtesy of the Society of Automotive Engineers, Inc.

The moment due to boom weight that is trying to tip the crane is:

$$8{,}000 \text{ lbs} \times (42-10) \text{ ft} = 256{,}000 \text{ lb-ft } (347 \text{ N·m})$$

Therefore, the live load moment that will cause tipping is:

$$\begin{aligned} \text{Tipping Load Moment} &= 350{,}000-256{,}000 \\ &= 94{,}000 \text{ lb-ft } (128 \text{ N·m}) \end{aligned}$$

Therefore, by calculation (or experiment) per J765, the tipping load will be:

$$\begin{aligned} \text{Tipping Load} &= \frac{94{,}000}{(90-10)} \\ &= 1{,}175 \text{ lbs } (5.2 \text{ kN}) \end{aligned}$$

The Rated Load for this configuration per B30.5 and Power Crane Shovel Association (PCSA) is:

$$\begin{aligned} \text{Rated Load} &= 85\% \text{ of Tipping Load} \\ &= 0.85 \times 1{,}175 \\ &= 999 \text{ lbs } (4.4 \text{ kN}) \end{aligned}$$

If 999 lbs is put on the hook, the moments tending to tip the crane are:

$$8{,}000 \text{ lb} \times 32 \text{ ft} + 999 \text{ lbs} \times 80 \text{ ft} = 335{,}920 \text{ lb-ft } (455 \text{ N·m})$$

but the total moment to tip the crane is 350,000 lb-ft (475 kN·m) so that the margin of stability is:

$$350{,}000 - 335{,}920 = 14{,}080 \text{ lb-ft } (19 \text{ kN·m})$$

or a safety factor of:

$$\frac{14{,}080}{350{,}000} \times 100 = \underline{\underline{4\%}}$$

The method recommended in J1289 makes an allowance for the overhung weight of the empty boom. Using the example cited above, the manufacturer would determine the tipping load as 1,175 lbs (5.2 kN) the same as above. The total tipping moment is as before - 350,000 lb-ft (475 kN·m). The rated load would be determined as:

$$\begin{aligned} F \times (90-10) \text{ ft} &= 8{,}000 \text{ lbs} \times 32 \text{ ft} \\ F &= 3{,}200 \text{ lbs } (14.2 \text{ kN}) \end{aligned}$$

Therefore,

$$\begin{aligned} \text{Rated Load} &= \frac{1{,}175 - 320}{1.25} \\ &= 684 \text{ lbs } (3 \text{ kN}) \end{aligned}$$

Now the total moment trying to tip the crane at rated load is:

$$8{,}000 \text{ lbs} \times 32 \text{ ft} + 684 \text{ lbs} \times 80 \text{ ft} = 310{,}720 \text{ lb-ft } (421 \text{ kN·m})$$

The margin of stability is:

$$350{,}000 - 310{,}720 = 39{,}280 \text{ lb-ft } (53.3 \text{ kN}\cdot\text{m})$$

or a safety factor of:

$$\frac{39{,}280}{350{,}000} \times 100 = \underline{\underline{11.2\%}}$$

4. MECHANICAL COMPONENT TESTING.

a. General. Each operating part or major component shall be tested or checked in some way. It may not be feasible to test many parts under individual load, but checks and tests shall be made so that it is reasonable to assume that the parts will function properly when under the general loading of the machine. Individual tests that are practicable are those for noise, overheating, vibration, sequencing, timing, fit, ease of movement, and adjustment. Check for the physical presence of contracted parts, equipment, and data.

b. Engines.

(1) It may be assumed that the block test required by industry standards has been made.

(2) Engines with pyrometers shall be tested for proper exhaust temperatures and uniformity of temperatures.

(3) Those without pyrometers shall be checked audibly for uniformity of firing and fuel delivery.

(4) Important tests after installation are ignition timing of spark-ignition engines, fuel and lubricating oil pressures, outlet temperatures of lubricating oil and cooling water, carburetor adjustments, valve lash, governor setting, and regulation for idle, run, and intermediate speeds.

c. Generators and Motors. For mechanical correctness, manufacturer tests shall be all that are required as individual tests for generators and motors.

d. General Mechanisms. Hoists, rotate mechanisms, travel mechanisms, and such need be tested in the field only as part of the performance test.

e. Clutches and Brakes. Clutches and brakes of whatever form shall be tested, if practicable, before performance tests. Checks are required for air-gap, clearances, spring settings, allowed toggle overrun for heating and wear, control-rod settings, and hydraulic system conditions.

f. Ratchets, Pawls, Spuds, Chocks, and Similar Locks. Devices such as ratchets, pawls, spuds, and chocks shall all be tested to ensure ease and certainty of intended operation and impossibility of inadvertent operation. They shall also be tested for full engagement. Tests shall be made for correct fit over the full surfaces of engagement.

g. Rope Reeving. Reeving tests shall consist of running tests to determine the freedom of sheaves; the free and true fleeting of fleeting sheaves; the rolling under rope motion of deflectors and guide rollers and sheaves; jumpout points (from guides); rubbing points; freedom and trueness of equalization; drum winding for closeness, overwind, pileups, and pinching; rotation and twisting of falls; spinning of lines; fouling of lines or blocks with the structure in any operation position; and the effectiveness of pre-acceptance lubrication of the ropes.

h. Levers and Control Rods. Operating levers and control rods shall be tested to ensure that the feel of the operated part is transmitted and that all lockins or lockouts are freely operable and positive.

i. Interlocks. Interlocks shall be tested before general testing to ensure their functioning at the proper time and sequence.

j. Radius Indicators.

(1) Radius indicators shall be tested for freedom from jamming or interference, and calibrated with a loaded hook.

(2) The radius to be marked on the indicator shall be the actual radius of the hook with a freely suspended full-capacity load.

(3) The radii shall be marked in 5-foot intervals.

(4) Cranes with variable-capacity ratings shall have the allowable load in pounds marked on the radius indicator at each 5-foot radius mark.

(5) Markings should be checked for clearness and for permanence of the clear markings.

(6) Floating crane and derrick indicators shall be calibrated with the boom directly athwartship. It should be noted that unless the indicator is truly compensating for list and trim, the readings at any other position may be slightly inaccurate, but usually will be on the safe side.

k. Load Indicators. All load indicators shall be tested for freedom of movement, freedom from interference, and calibrated in the field.

(1) Ammeter type. Hoists with series-wound DC motors usually are equipped with ammeters conveniently located in the operator cab. The shunts are placed in that part of the hoisting circuit that governs the hoisting torque, and the ammeter reading under steady load is consequently proportional to the load. The dial shall be calibrated and marked in pounds hoisting, on the hook. The indicator shall have a note that the calibration is for a hoisting load only.

(2) Spring, hydraulic, and strain-gage types.

(a) Whenever load indicators of spring, hydraulic, and strain-gage types are permitted and installed, they shall be tested and checked for freedom from exposure to abuse and accident.

(b) These components must be tested for field calibration under capacity hook loads and under as many conditions of temperature, lubrication of associated equipment, inclination of the crane, or waviness of tracks, ground, or pavement, as is practicable.

(c) Many of these indicators have complicating devices, such as audible or visual signals and automatic shut-offs, and are operated by sensitive hydraulic or electronic means. Their certainty and accuracy must be carefully tested.

l. Hydraulic Systems.

(1) Where applicable, hydraulic systems shall be tested for completeness of filling and bleeding, cleanliness of filters, leakage, proper buildup and maintenance of pressure (or, if so designed, drop of pressure), accuracy and proper setting of compensating valves, and timing and sequencing of all valves and components of the control apparatus.

(2) Test the proper functioning and control of hydraulic motors and generators, including the heat dissipation of all powerloss equipment.

(3) Unusual or unexpected heat shall be investigated immediately.

m. Air Systems.

(1) Air starting and air control systems require testing for buildup and maintenance of pressure where maintenance is required, and for speed and amount of pressure buildup or drop. The accuracy and adjustment of compensating valves and the speed and completeness of action of relay valves are especially important phases of this test procedure.

(2) Moisture traps, water reliefs, pressure reliefs, pressure gates, unloaders, loadless starting devices, pressure reducers, and the final air-operated devices must be tested for proper functioning and adjustment.

5. ELECTRICAL COMPONENT TESTING.

a. General. Electrical testing in units or components is aimed at the certainty of operation; direction of rotation or indication of proper sequencing; initial timing or other adjustment; excessive noise; vibration, or arcing; the presence of undesired grounds; the adequacy of insulation (old machines only); and for the presence of contracted parts, equipment, and data. Make sure that all wiring diagrams, manuals, operating, and maintenance instructions, parts lists, spare parts, labels, and special tools have been delivered and preserved.

b. Generators and Motors.

(1) Test for voltage regulation and polarity of the generators and direction of rotation of the motors.

(2) If the fields are connected externally, check for proper connections.

c. Panel Equipment (Generator and Protective). Test panel equipment for sequencing, timing, and indication, before the machine is tested as a whole.

d. Motor Controls.

(1) Motor controls usually have isolating switches, so that relays, contactors, and other panel equipment may be checked without applying power to the motors.

(2) The proper functioning of all equipment shall be tested individually for sequencing, initial timing, and indication, in addition to all tests required by the manufacturer's instructions.

(3) Checks on resistances in the circuit for each speed point shall be made.

e. Limit Switches and Interlocks.

(1) Test all switches for proper setting and for secure locking in place at the proper setting. The part affected after the switch operates shall be taken into account.

(2) Check to make sure that all associated functions, such as consequent dynamic braking, occur.

(3) Test to determine how abuse of operation might cause malfunctioning, such as severe swing of ropes in any direction, overspeed operation, and skew of crane or trolley.

(4) Retest hoist limit switches after ropes have stretched, if the setting depends on rope length.

f. Indicators.

(1) On-off indicators are easily tested for functioning, but indicators of measurement, such as voltmeters and ammeters, shall be tested for accuracy only if they are believed to be in error.

(2) Indicators of all types shall be checked for accuracy.

g. Wiring.

(1) Test new wiring for correctness of connections, and old wiring for adequacy of insulation.

(2) All wiring shall be tested for grounds, because weight-handling equipment is almost universally equipped with nongrounded electrical circuits.

(3) A ground that does not cause a circuit interruption is a shock hazard and should be removed at the first opportunity.

h. Conductors and Collectors. Tests of these devices shall be made to ensure low resistance contact and freedom from sparking. Proper pressure, uniform and complete contact, freedom from corrosion, alignment, and sufficient margin for misalignment are items for test.

6. MISCELLANEOUS.

a. Tests on Inclines. Crawler and motor-truck cranes specified to negotiate inclines shall be tested on the specified inclines with the specified load. These tests should be made at slow speed. If a capacity or near-capacity hook load is suspended, the hook should be maintained downhill. If a small hook load is suspended or if there is no hook load, the counterweight should be maintained downhill. In no case should the crane be rotated.

b. Floating Cranes and Derricks. Each compartment shall be subjected to a hydrostatic or air test, except that occupied compartments shall be subjected to air test only.

(1) Hydrostatic test. All seams including bulkhead boundaries shall be hose tested with water at a pressure of not less than 30 psi. Any leakage shall be repaired.

(2) Air test. Each compartment shall be subjected to an air test of 2-1/2 psi. There shall be no drop in pressure in 10 minutes except that occupied compartments may have a maximum pressure drop of 2 ounces in 10 minutes.

c. Adjustment. As necessary during performance tests and before completion of all testing, all mechanical and electrical mechanisms shall be checked for adjustment and placed in proper adjustment. Following acceptance, when the mechanisms have been broken in, these adjustments should be rechecked and all indicators recalibrated. Electrical-control checks should be made by a representative of the control manufacturer.

d. Useful Test Equipment. Wherever applicable, the use of recording instruments will speed up the tests, give increased accuracy, eliminate inconsistent readings, expose maladjustments, and clearly show operating characteristics. In particular, peaks of loading, timing, sequences, accelerations, and simultaneous quantities cannot be obtained in any other practical manner. Recording voltmeters, ammeters, and tachometers are the minimum required for good results. A hand tachometer, applied to a shaft, is useful for indicating the advent of steady speed conditions and, by means of a multiplier computed from gear ratios, wheel diameters, or reeving, for indicating the actual speed of the particular machine motion.

e. Hook Throat Spread. Required to be made and recorded before and after the 125 percent rated load tests. The throat dimension base will be established before test by installing two tram points and measuring the distance between these tram points before and after tests. Any measurable increase in the hook throat opening shall constitute failure.

f. Hook Disassembly and Non-Destructive Test. The hook and all its components shall be magnetic particle inspected in conformance with ASTM A275. Acceptance standard shall be no defects. A defect is defined as a linear indication revealed by magnetic-particle inspection that is greater than 1/8 inch long whose length is equal to or greater than three times its width. Weld repairs of the hook or any of its components will not be permitted.

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A-Frame. (1) On cranes equipped with booms, the structural portion, exclusive of the boom, above the rotate platform; (2) on derricks, the stationary portion of the structural framing above the foundation or sills.

A-Frame Block. The lower block of luffing tackle, usually integral with the apex of the A-frame. The term lower luffing block is preferred.

Automatic Mechanical Load-Lowering Brake. A completely mechanical brake placed in the gear train of a hoist, which functions only on lowering in conjunction with the electrical control of the motor, to control the speed of lowering and with no power applied to the motor to stop and hold the load.

Ballast. A weight, usually fixed, added to the non-rotating portion of a crane or derrick to provide the required stability of the crane or derrick as a whole.

Beam. Maximum width of vessel hull.

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

Bilge Keel. A fin fitted to the hull on each side of a vessel at the turn of the bilge to reduce rolling.

Billboard. A flat, usually inclined, platform on which to stow spare or emergency anchors.

Bitt. Double post fitting to which mooring lines from vessels are attached.

Bolster. See Equalizer.

Boom. In crane and derrick usage, an inclined spar, strut, or other long member supporting the hoisting tackle.

Boom Hinge. The combination of the immediate parts of the rotate structure, boom, and (as most frequently used) the pin about which the boom turns when luffed.

Bridge. The main structural and mechanical portion of an overhead traveling crane, spanning from one runway rail to the other, consisting of the girders supporting the trolley, the end trucks, the travel drive mechanism, and related parts.

Bridle. A two-legged device, usually chain, wire rope, etc., which is used to transfer the pull of a single towline or anchor line to two fittings on a vessel.

Bull Gear-Pinion. The large gear, usually attached to the nonrotating part of a crane, and the mating pinion, usually attached to the rotating superstructure, by which the superstructure is caused to rotate.

Bull Wheel. A relatively large wheel attached to the base of mast and boom of a derrick, with a rim shaped to accommodate two cables. By pulling on the cable, the boom is rotated by the bull wheel.

Bumper. A device fastened to a traveling crane or traveling portion of a crane to cushion the impact of striking another crane or portion thereof or a runway stop.

Cab. The compartment containing the controls for cranes or derricks and a seat and shelter for the operator.

Cage. (1) A partially open circular ring that retains, spaces, and aligns the balls or rollers of an anti-friction bearing, or the rollers or wheels of a live roller path; (2) Also see cab.

Camber. The convexity of deck line in the thwartship direction.

Capstan. A vertical drum or spindle on which a line is wound.

Center Steadiment. A pair of male and female castings or weldments, one connected to the fixed portion and the other to the revolving superstructure of a crane, for the purpose of maintaining the position of the center of rotation of the superstructure and of spider and cage of the roller path when used. When a center steadiment is used, the kingpin threads through it.

Chafing Block. Wood or brass wear plate to prevent excessive wear or damage to cable.

Chock. A mooring fitting having faired inner surfaces for guiding lines.

Classes of Overhead Traveling Cranes.

Class A - Standby Service
Class B - Light Service
Class C - Moderate Service
Class D - Heavy Duty Service
Class E - Severe Duty Cycle Service (continuous material handling)

Cleat. A mooring fitting having two horizontal arms to which mooring lines are secured.

Coaming. The vertical plate frame around the periphery of a vessel's deck or opening in deck.

Collector. A device maintaining contact between the moving and stationary parts of an electric circuit.

Complex (Crane). A group of docks or piers so arranged, or interconnected, that the cranes can be transferred among the several docks, or piers, at will.

Conductor. A metal bar, shape, or wire used to conduct electric current.

AD-A123 624 WEIGHT-HANDLING EQUIPMENT DESIGN MANUAL 381(U) NAVAL FACILITIES ENGINEERING COMMAND ALEXANDRIA VA JUN 82 NAVFAC-DM-38.1

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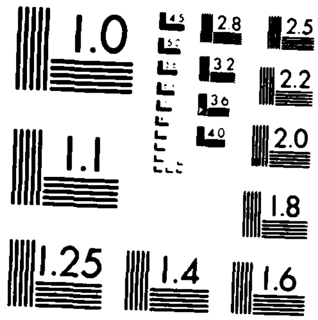

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NATIONAL BUREAU OF STANDARDS 1963 A

Contactor. A device, operated other than by hand, for repeatedly establishing and interrupting an electric power circuit.

Counter. That part of a ship's stern which extends beyond the rudder post, forming a continuation of the lines of the hull.

Counterweight. Weight, usually attached to the rotating part of a crane, to provide stability to the rotating superstructure.

Crane Base. The portion of the supporting structure immediately below the roller path of a crane. In land cranes, it is a portion of the portal, underbody, carrier, or carbody. In floating cranes, it is that portion of the framing extending down to the deck of the pontoon.

Crane Jib. A boom or arm supporting a trolley or fall block, fitted to swing in sockets attached to a wall or column. The arm is generally fixed in a vertical direction but free to rotate horizontally.

Cruiser Crane. See Wagon Crane.

Dead End. The fixed end of a rope or cable on a crane, derrick, or hoist.

Draft. Depth of vessel hull below the water line.

Drift. (1) Motion after the power is cut off; (2) Change of hook radius due to load; (3) Amount of available vertical travel of hook (from maximum hook height to low point defined by amount of cable on drum).

Drift Point. A motor control circuit in which all power is cut off from the motor but the electric brake remains energized, allowing the driven load to "drift" or "coast."

Duty. A requirement of service that defines the degree of regularity of the load. It is determined by the kind of loads to be handled and the facility to be served.

Duty Cycle. (1) A complete operation from preparation for lifting a load to its final deposition, or a series of such movements--the kind, amount, sequence, frequency, duration, and period of work performed; (2) A factor in determining mechanical, control, and electrical duty classifications and the design ratings of engines, generators, motors, gearing, clutches, brakes, bearings, and other parts.

Dynamic Braking. Braking a driven load by connecting an electrical control and motor circuit so that the motor becomes a generator under an overhauling load, absorbing energy from the load and returning it to the power-input line or wasting it as heat in special resistances, or both.

Eddy-Current Brake. A brake consisting of a stationary magnetic field, usually variable, and a metallic rotor through which braking forces are exerted electromagnetically by the induced eddy currents in the rotor, the rotor absorbing the energy of motion and dissipating it as heat. An eddy-current brake can slow down but cannot stop a moving load.

Electric Control or Controller. A device or group of devices that serve to govern, in a predetermined manner, the electric power delivered to the apparatus to which it is connected. Some of the basic functions are the control of acceleration, retardation, line closing, and reversing.

Endurance Limit. The limiting stress below which the material will withstand, without fracture, an indefinitely large number of cycles of completely reversed stress.

Equalizer. A pivoted bar or frame upon which two loads may be maintained in constant relationship (most often equal) regardless of differences in elevation or horizontal attachment of the loads; usually used between trucks or undulating rails or surfaces, and between two lines whose length may be unequal. Example: A single sheave serves as an equalizer between two parts of line.

Equalizer Beam (Strongback). Most frequently applies to a beam with a hook at or near its center and arranged to be hoisted at the ends by two cranes, thereby simplifying the hoisting of a single load with two cranes. (See Fig. 46.)

Fairlead. A small fitting through which a line may be led so as to preserve or change its direction without inducing excessive friction.

Fender. A protective system installed around the hull of a floating vessel.

Fleet. The winding of a rope across the face of a drum.

Fleet Angle. The angle formed by the lead of a rope at the extreme end of a drum, with a line drawn perpendicular to the axis of the drum through the center of the nearest fixed sheave, expressed in degrees.

Fleeting Sheave. A sheave that moves along its supporting shaft or pin.

Float. In connection with traveling crane trucks, float is the total amount of lateral movement of the pairs of trucks on both sides of a crane that is permitted by their construction.

Freeboard. Distance from the main or weather deck of a floating vessel to the water line.

Full Magnetic Control or Controller. An electric control having all of its basic functions performed by electromagnets.

Gage. For wide gage track, distance center to center of rails. For railroad track, clear distance between rail heads.

Gantry. A framework supported at each end so that it spans a distance, used for carrying a traveling crane.

Gudgeon. In crane usage, a vertical pin about which a travel truck (or its associated equalizers or bolsters) pivots in a horizontal-plane, and on which the weight of the truck usually bears.

Gudgeon Pin. In crane usage, a horizontal pin connected to a gudgeon that carries the weight of a crane to the trucks or equalizers, and on which the latter pivots in a vertical plane and frequently floats.

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

Headache Ball. A heavy weight attached above the hook on a single line or whip hoist to provide sufficient weight to lower the hook when unloaded.

Headlog. Vertical transverse portion of the bow of a barge.

Heel. The transverse inclination of a vessel due to the action of the waves, the wind, or greater weight on one side, etc.; usually transitory.

Hogging. A term applied to the distortion of a vessel's hull when her ends drop below their normal position relative to her midship portion.

Hogline. Boom stay cable attached to the equalizer bar.

Hook, Double-Barbed. A hook with two symmetrical barbs from a common shank. Also known as a sister hook or a duplex hook.

Hook Roller. A roller attached to the underside of the rotate platform, rolling under a projecting flange usually attached to the lower roller path, to prevent the rotate platform from overturning.

Hook, Sister. See Hook, Double-Barbed.

Jogging (Notching, Inching). The rapidly repeated closure of an electrical circuit to start a motor from rest for the purpose of accomplishing small movements of the driven machine.

Kingpin (Centerpin). A vertical steel pin or hollow tube located at the center of rotation of a crane for the purpose of aiding in preventing overturning of the superstructure, also for maintaining the center of rotation in position, and for passing the electrical wiring to motors, signals, etc., below the rotating frame.

Knuckle. Intersection formed by bilge side and stern plates just below the deck.

Lift. (1) Height of lift, or distance of hook travel, in a vertical direction; (2) The load being lifted.

Live Boom. A boom that is lowered by gravity solely under the control of the boom hoist drum brake.

Load Brake. A brake which provides retarding force without external control.

Luffing. A radial in and out movement of the load by raising or lowering of a crane or derrick boom.

Manual Control or Controller. An electric control having all of its functions performed by hand.

Master Switch. A switch, usually in low-current and low-voltage circuits and operated by a crane or hoist operator, that dominates the operation of other control devices most often of greater current and voltage, such as contactors, relays, and other magnetically operated devices.

Notch. Movement across or to mechanical notches that indicates by feel of the master switch handle the various speed points, and which automatically centers the handle at the contact points.

Pawl. A gear locking device.

Plugging. Braking the motion of an electric motor by throwing it into reverse.

Pontoon. That portion of a floating crane, pile driver, dredge, or derrick that provides the necessary buoyancy for its support and stability as a whole.

Rack. A bar, straight or curved, with teeth or one face for gearing to a pinion, worm, or other mechanism.

Rating. Designated limit of operating characteristics based on specific conditions.

Reach. The horizontal distance from the hook to the center of rotation of a crane or derrick (radius and reach as used for crane are synonymous).

Reactor. A device that introduces reactance into an AC circuit for such purposes as motor starting, paralleling transformers, and control of current.

Reeving Arrangements. A plan showing the path that a rope takes in adapting itself to all sheaves and drums of a piece of equipment.

Regenerative Braking. In crane and hoist usage; braking a driven load that becomes overhauling by virtue of over-speed beyond the synchronous speed of an AC motor, the motor then becoming a generator, which absorbs energy from the over-speeding load and returns it to the power-input line.

Relay. A device that is operative by a variation in the conditions of one electric circuit to effect the operation of other devices in the same or another electric circuit.

Roller Path. The circular rails, or flat tracks or conical surface tracks on which rollers or wheels travel.

Rotate Platform (Turntable). That part of a rotating crane immediately above the roller path, supporting the machinery, the machinery house, and cab.

Sagging. The deformation or yielding caused when the midportion of a vessel settles or sinks below its designed position. The reverse of hogging.

Semimagnetic Control or Controller. An electric control having only a part of its basic functions performed by electromagnets.

Service Factors. Multipliers applied to ratings to adapt them to conditions of service other than those for which the ratings were established.

Shackle. A U-shaped fitting with a pin across the throat used as a connection between lengths of a chain or to attach other fittings.

Sheer Strakes. The upper strake of the main shell plating just below the bulwarks.

Shunt. A conductor of one of many forms joining two points in a circuit to form a parallel or by-pass circuit through which a portion of the current may pass for the purpose of regulating the relative electrical characteristics of various portions of the circuit.

Skeg. Vertical appendage extending below the hull of a barge to reduce yawing.

Slewing. Rotation of a rotating crane.

Speed Point. One of a series of circuits and associated electrical control devices that control the various speeds and directions of a motor.

Speltered Socket. A type of connection for rope in which molten zinc is used.

Spider. The radial members connecting the roller cage with the center steadiment to maintain the true circular path of the rollers and to resist the outward thrust of the rollers.

Spud. A long member of any cross-sectional shape, attached to a part that has relative motion with another part, which may be inserted into a socket attached to the other part for the purpose of locking the two together (i.e., in dredging, the vertical anchor piles that fix a vessel during dredging).

Spud Lock. A device consisting of a spud and socket used for the purpose of preventing motion of the rotating structure of a crane while idle.

Stop. A fixed obstruction designed to contact the bumper of a traveling crane or trolley.

Topping Block. The upper block of luffing tackle. The term upper luffing block is preferred.

Transom. The flat portion at the stern of a floating vessel.

Travel. The horizontal, usually straight-line motion, of a crane or its parts (such as a trolley).

Trim. The difference in draft at the bow of a vessel from that at the stern.

Trochoidal Wave. Form of wave used for the design of floating vessels in which the profile is a curve described by a point within a circle that rolls along a straight line.

Trolley. A wheeled carriage designed to support and transport a suspended load--the term includes all integral associated equipment for hoisting, suspending, and propelling the load.

Truck. The complete unit of frame, wheels, integral driving, and associated equipment that supports a traveling crane or a traveling portion of a crane, such as a trolley.

Tumbler. Pivot wheel at either upper or lower end of a bucket dredge ladder.

Two-Block. The overhoisting of a set of tackle by direct hoisting or indirectly by lowering the boom so that the two blocks come together and further hoisting is thereby prevented.

Vangs (Vang Lines). Lines attached to each side of a derrick boom near the outer end and to tackle on the base, ground, or pontoon, by means of which the boom is rotated from one side to the other.

Wagon Crane. Single engine motor truck crane.

Wheelbase. The distance between the centers of the most forward and most aft wheels on a traveling crane. On overhead traveling cranes with more than a total of four bridge wheels, the distance between the centers of the forward group of wheels and the aft group of wheels.

Whip Hoist. A hoist utilizing a single line only to the hook without other intervening tackle.

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

Windlass. A winch used to haul chain and hoist an anchor.

Wind Lock. A means, usually a spud lock, for preventing the motion of a crane that might be caused by the action of the wind.

Yaw. Rotary oscillation of a vessel about a vertical axis approximately through its center of gravity.

APPENDIX A

Sample Information Forms
for
Procurement of *Cranes*

APPENDIX A

Sample Information Forms for
Procurement of Overrunning Overhead Traveling Crane and of
Traveling, Rotating Portal Crane with Boom

INFORMATION FORM FOR OVERRUNNING OVERHEAD TRAVELING CRANES

Date ______________________

1. ORIGINATED BY - - - - - ______________________ Division, ______________

Naval Facilities Engineering Command

2. USING ACTIVITY - - - - ______________________________________

____

____

3. BUILDING INFORMATION:

(a) Building name (and number) ______________________

(b) Room or area for crane ______________________

(c) Building contract number ______________________

(d) Anticipated date for EFD receipt of 100% completed building drawings from A-E ______________________

(e) Anticipated date for completion of building construction ______________________

(f) Desired date for crane operation ______________________

(g) Priority rating for building contract ______________________

4. QUANTITY:

(a) Number of cranes required ______________________

(b) If more than one crane is required, and cranes are not similar, prepare a separate form for each crane.

5. CAPACITY:

(a) Nominal rating - - - - - - - - - - - - - - ______________ TONS

(b) Maximum load - - - - - - - - - - - - - - - - ______________ pounds

(c) Average load - - - - - - - - - - - - - - - ______________________ pounds

(d) Auxiliary hoist max. load - - - - - - - - ______________________ pounds

(e) If two trolleys are required:
Maximum load of North/East trolley - - - ______________________ pounds
Maximum load of South/West trolley - - - ______________________ pounds
Will trolleys be required to handle their maximum rated loads simultaneously?______________________

6. CRANE SERVICE:

(The answers to Questions 6a through 6d should be as accurate and complete as possible. These answers will be used to determine the duty classification of the crane.)

(a) Type of work handled______________________

(b) Main hoist lifts per 8 hour shift:

Number of full load lifts______________________
Number of 75% of full load lifts______________________
Number of 50% of full load lifts______________________
Number of 25% of full load lifts______________________

(c) Total number of main hoist lifts per 24 hour day______________________

(d) Detailed explanation of operating procedure:______________________
____
____

(e) Desired speed ranges:

Bridge high speed - - - - - - - - - - - - ______________________
Bridge low speed - - - - - - - - - - - - ______________________
Trolley high speed - - - - - - - - - - - ______________________
Trolley low speed - - - - - - - - - - - - ______________________
Main hoist high speed - - - - - - - - - - ______________________
Main hoist low speed - - - - - - - - - - ______________________
Aux. hoist high speed - - - - - - - - - - ______________________
Aux. hoist low speed - - - - - - - - - - ______________________

7. IS CRANE TO BE USED FOR:

(a) Very expensive loads?__________ (b) Loads that are sensitive to shock or rough handling?__________ (c) Loads that are difficult or time-consuming to replace?__________ (d) Precision assembly purposes at any time?__________ (e) Hot metal, magnet, or bucket purposes? __________ Which?__________ (f) If hot metal crane, shall safety closet be provided in cab?__________

8. ENVIRONMENT:

(a) Classification:
(1) Non-hazardous__________ (2) Hazardous__________
(3) Corrosive__________ (4) Dusty__________
(5) Other__________

(b) If area is hazardous, what is the National Electric Code:

Class______ Group______ Division__________

If hazardous condition exists, explain:__________

(c) To what height above floor does hazardous condition exist?__________

(d) Are a cable reel and flexible conductors required?__________
If so, what is the location of the electrical junction box?__________

(e) Is spark resistant construction required?__________

(f) What is the highest ambient temperature expected?__________

(g) Will crane operate indoors, outdoors, or both?__________

9. CRANE CONTROL:

(a) Cab______ Floor (Pendant)______ Remote______ Other (specify)______

(b) Location: At end of bridge______; At middle of bridge______; Attached to trolley______; Remote room (specify)______; Other (specify)__________

(c) Shall cab be open or enclosed, heated or air conditioned?__________

(d) Shall a "power on" indicating light be provided on the push-button station?__________

(e) Shall a lock be provided in push-button station to prevent unauthorized personnel from operating crane?__________

10. Are there other cranes on the runway?______ What are they:

(a) Wheel leads (excluding impact) and wheel spacing?__________

(b) Out to out dimensions between bumpers?__________

(c) Height above runway rail of the center of the striking area of the bumpers?__________

(d) Distance from centerline of crane (hook) to extremity (such as foot-walk if bumpers are not beyond other parts of crane), each side?__________

11. RUNWAY CONDUCTORS:

(a) What is the kind, voltage, frequency, and phase of the electric current supply?__________

(b) What is the location of the electrical junction box?__________

(c) Are runway conductors to be provided by crane contractor, building contractors, or are they existing?__________

If provided by building contractor, or existing,
(1) What is their type, size, and manufacturer's model number?__________

(2) On which end of the crane are they located?__________

12. What is the height above top of rail and the distance along the runway of the striking area of the runway bumper stops?__________

13. Will crane be required to pass through any doors?__________
If so:

(a) What provision has been made for interlocking to prevent collisions?__________

(b) Are there crane height and width limitations at the doors?__________

(c) Door locations?__________

14. What is the location and the outside dimensions of the access platform with respect to top and centerline of runway rail?__________

15. Are bridge or cab floodlights required?__________

16. Are lower limit switches necessary for the hoists?__________

17. Will occasional oil or grease drips be objectionable to the point of requiring oil or grease tight gear cases for trolley and bridge drive wheel gears?__________

18. Is radio interference suppression required?__________

19. Is fungus resistance treatment of electrical components required?__________

20. Is any special painting required?__________

21. Will the crane be erected by the Government under the supervision of a supervising erector furnished by the crane manufacturer or will it be erected by the crane manufacturer?______________________________

22. What is the place of delivery or location of the field work?____________

_____ ____

23. Provide a floor plan of the building in the area of crane operation showing:

(a) Location of access platform
(b) Hook approaches at each end of crane runway, if critical
(c) Runway support columns and spacing
(d) Length of runway rail
(e) North arrow
(f) Location of electrical junction box.

24. Are there any special requirements or circumstances not covered by the preceding questions or the clearance sketches?________________________

____
____
____
____
____

25. FOR NEW BUILDINGS, PLEASE FORWARD A COMPLETE SET OF 100% BUILDING PLANS AND SPECIFICATIONS WHEN RETURNING COMPLETED INFORMATION FORM.

READ THE FOLLOWING NOTES BEFORE COMPLETING CLEARANCE SKETCHES:

(a) The "B" dimension should be to the floor line unless there are requirements for lowering loads in a pit.

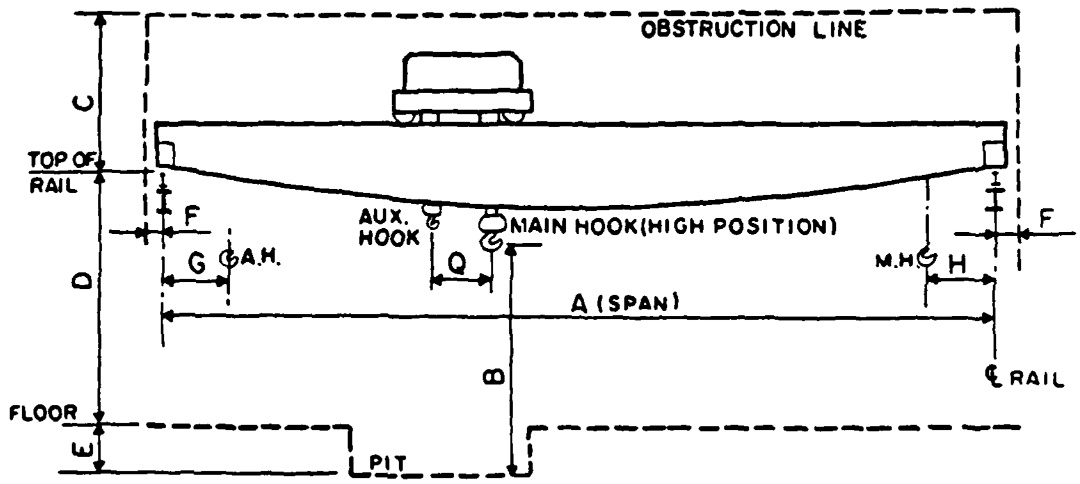
(b) The "C" dimension should be measured from the top of the runway rail to the lowest overhead obstruction (bottom chord of truss, light fixtures, beams, knee braces, ducts, pipe, conduit, etc.).

(c) Wheel loads "K" and "L" are the wheel loads used for the design of the crane runway girders, excluding the impact load.

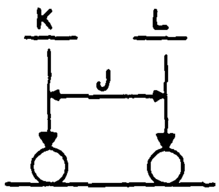
(d) If runway girder is not similar to that indicated on clearance sketch, prepare a sketch giving details of girder.

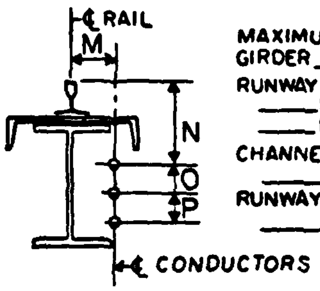
CLEARANCE SKETCH

CLEARANCE SKETCH ______________ TON OET CRANE



A ____ FT. ____ IN.	F ____ FT. ____ IN.	L ________ KIPS
B ____ FT. ____ IN.	G ____ FT. ____ IN.	M ________ INCHES
C ____ FT. ____ IN.	H ____ FT. ____ IN.	N ________ INCHES
D ____ FT. ____ IN.	J ____ FT. ____ IN.	O ________ INCHES
E ____ FT. ____ IN.	K ________ KIPS	P ________ INCHES
		Q ____ FT. ____ IN.





MAXIMUM SPAN OF RUNWAY GIRDER _____ FT. _____ IN.

RUNWAY RAIL
_____ POUND A.S.C.E.
_____ POUND A.R.E.A.

CHANNEL CAP
____

RUNWAY GIRDER
____

"K" AND "L" ARE WHEEL LOADS USED FOR DESIGN OF RUNWAY GIRDERS EXCLUDING IMPACT.

INFORMATION FORM FOR
TRAVELING, ROTATING PORTAL CRANE WITH BOOM

Date ____________________

1. ORIGINATED BY - - - - - ______________________________ Division, __________

Naval Facilities Engineering Command

2. USING ACTIVITY - - - - ________________________ ______________________

____

____

3. SITE INFORMATION:

(a) Location ____

____
(provide location plan)

(b) Clearances (provide site plan and sections showing vertical and horizontal clearances to all obstructions and/or nearby equipment, railroad or crane tracks, or roadways). Indicate clearances for portal.

(c) Locations of any anticipated future obstructions, equipment, track, or roadways ____

____

____

(d) Desired date for crane operation ______________________________

4. QUANTITY:

(a) Number of cranes required ______________________________

(b) If more than one crane is required, and cranes are not similar, prepare a separate form for each crane.

5. CAPACITY AND REACH:

(a) Main Hoist:

Maximum reach required ______________________________ ft.[1]
Required capacity at maximum reach ______________________ pounds[2]

---

[1]Indicate point from which distances are measured and relation of this point to facility being served.
[2]If available, a hologram showing weight of lifts as a percentage of total lifts should be submitted.

Required capacity at less than maximum reach:

__________ pounds[2] @ __________ ft.[3]
__________ pounds[2] @ __________ ft.[3]
__________ pounds[2] @ __________ ft.[3]

(b) Auxiliary Hoist:

Maximum reach required __________ ft.[3]
Required capacity at maximum reach __________ pounds[2]

(c) Whip Hoist:

Maximum reach required __________ ft.[3]
Required capacity at maximum reach __________ pounds[2]

(d) Indicate any requirements (capacity, reach, and nature of lift) for handling of lifts, simultaneously, with two, or more, hooks. __________

6. CRANE SERVICE:

(The answers to Questions 6a through 6d should be as accurate and complete as possible. These answers will be used to determine the duty classification of the crane.)

(a) Type of work handled __________

(b) Main hoist lifts per 8 hour shift:

Number of full load lifts __________
Number of 75% of full load lifts __________
Number of 50% of full load lifts __________
Number of 25% of full load lifts __________
Total number of lifts per 8 hour shift __________

(c) Total number of main hoist lifts per 24 hour day __________

(d) Detailed explanation of operating procedure: __________

---

[2] If available, a hologram showing weight of lifts as a percentage of total lifts should be submitted.
[3] Indicate point from which distances are measured and relation of this point to facility being served.

7. SPEEDS:

(a) Travel speed (max.)__________ fpm

(b) Main Hoist:
High Speed__________ fpm
Low Speed __________ fpm

(c) Auxiliary Hoist:
High Speed__________ fpm
Low Speed __________ fpm

(d) Whip Hoist:
High Speed__________ fpm

8. IS CRANE TO BE USED FOR:

(a) Very expensive loads?__________ (b) Loads that are sensitive to shock or rough handling?__________ (c) Loads that are difficult or time-consuming to replace?__________ (d) Precision assembly purposes at any time?__________ (e) Magnet, or bucket purposes?__________ Which?__________ (f) Nuclear work?__________ Describe__________
____
____

9. ENVIRONMENT:

(a) Classification:
(1) Non-hazardous__________ (2) Hazardous__________
(3) Corrosive__________ (4) Dusty__________
(5) Other__________

(b) Explain conditions of "corrosive," "dusty," or "other" classifications.__________
____
____
____

(c) If area is hazardous, what is the National Electric Code:

Class__________ Group__________ Division__________

If hazardous condition exists, explain:__________
____
____

(d) To what height does hazardous condition exist?__________
____

(e) Is spark resistant construction required?__________

(f) What is the highest ambient temperature expected?__________

(g) Will crane operate indoors, outdoors, or both?__________

10.

(a) Existing track:

(1) Gauge__________ (ft.) (2) Type and weight of rail______________
(3) Curves (show sketch)
(4) Track foundations (show sketch of wheel train for which existing track foundations were designed).
(5) Remarks:____

(b) New installation of track:

(1) Indicate any pertinent limitations imposed by foundation conditions or subsurface obstructions.________________________

(2) Is any connection to existing track required?______________ Gauge of existing track________________ft. Type and weight of rail____

(3) Any curves required?__________________ Curve data______________

(show plan)

11. LOADS:

(a) Describe any local conditions which might influence selection of design wind pressures.____

(b) Describe any other special conditions.___________________________

12. POWER:

(a) Is there a preference or need for shore power or independent power supply?_____________ Explain basis of preference or need.__________

(b) What is the kind, voltage, frequency, and phase of the available electric current supply?____

(c) What are the locations nearby of the connections for electrical current supply?____

13. FEATURES:

(a) Type of hook capacity rating desired.
Straight Line__________ Variable__________

(b) Features of operator's cab.

(1) Desired interior temperature__________________________ °F.
(2) Is sunshade desired?__________________________
(3) Is elevator desired?__________________________
(4) Is a chemical toilet required?__________________________
(5) Describe any special features required__________________________
____

(c) Motor controls:

(1) Cab?__________ Pendant?__________ Remote?__________ Other? (specify)__________________________
(2) If pendant or remote; where located?__________________________
Shall provision be made to prevent operation by unauthorized personnel?__________ Shall a "power on" indicating light be provided?__________________________

(d) Is level luffing feature desired?__________________________

(e) Other desired features (specify)__________________________

14. MISCELLANEOUS:

(a) Are there any other cranes on same track?__________ If so, what provisions are proposed to prevent their collision?__________________________
____

(b) Are cab, under portal, or boom floodlights required?__________________________

(c) Will occasional oil or grease drips be objectionable to the point of requiring oil or grease tight gear cases for truck drive wheel gears?
____

(d) Is radio interference suppression required?__________________________

(e) Is fungus resistance treatment of electrical components required?_____

(f) Is any special painting required?__________________________

(g) Will the crane be erected by the Government under the supervision of a supervising erector furnished by the crane manufacturer or will it be erected by the crane manufacturer?__________________________

(h) What is the place of delivery or location of the field work?__________
____

(i) Are there any special requirements or circumstances not covered by the preceding questions or the clearance sketches?

APPENDIX B

Other Motor-Control Systems

APPENDIX B

Other Motor-Control Systems
(Refer to paragraph 7.f.(3) on page 38.1-132.)

1. Hoist Controls--Wound-Rotor Motor, Single-Phase AC Dynamic Braking.

a. This control is suitable for installation where operation is so frequent that a mechanical load brake would develop excessive wear and cause high maintenance, where slow lowering speeds are not required, and where accurate spotting is required only for light loads.

b. The hoisting speed regulation is the same as with countertorque braking.

c. Slow lowering speeds for light loads are obtained by applying a single-phase AC braking voltage to the stator (braking lowering). Only two power-lowering speeds are available. The first power-lowering step (high speed) is regenerative and, therefore, foreseeable by the operator. The second power-lowering step (intermediate speed) reduces acceleration to the intermediate speed, which aids materially in positioning and landing loads by jogging. This step is a drivedown point (drivedown is not inherent) and an intermediate-speed lowering point safe to use with normal loads. Note that, at 100 percent motor torque, the speed on this step is slightly lower than on the dynamic-braking step. It is a regenerative point with external resistance added to the motor rotor, or secondary.

d. Dynamic-braking, intermediate-speed lowering is obtained by applying single-phase current to the motor, which then has only a pulsating stationary field, instead of a rotating field. The motor cannot start as a motor with this field, but rotation of the rotor caused by an overhauling load produces current in the rotor windings and resistors and it acts as a brake, dynamically braking the lowering hook load. The intermediate speeds on this step vary greatly with load, so that light loads may have a low speed, medium loads a medium speed, and heavy loads a fairly high intermediate speed. Note that, for loads above 100 percent motor torque, the second power-lowering step produces slower speeds and produces them in inverse ratio to the load.

e. The light hook will not run in the hoisting direction when the master handle is set for 1 step lowering, as in the countertorque system. On this curve zero torque and zero speed coincide. Figure B-1 indicates the characteristics of this control.

f. With single-phase braking applied, the motor draws more than rated current through primary windings and produces more in the secondary. The resulting heating is similar to that from an overload. Intermediate-speed lowering should not be continued for long periods or used too frequently.

g. Use. This control should only be used for relatively lightly loaded cranes requiring little precision and little (short duration) intermediate-speed work where slow lowering speeds are not required for loads above 25 percent of rated load and where skilled operators are available. This control is not appropriate for delicate loads of intermediate weights.

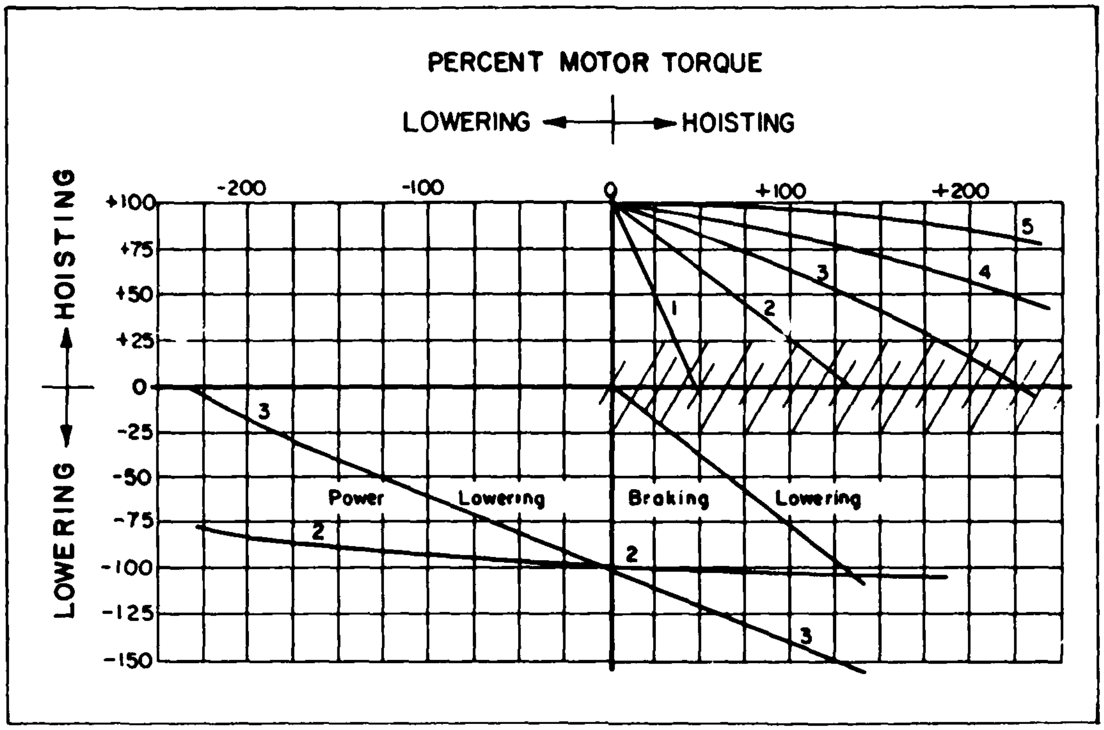


FIGURE B-1
Torque-Speed Curves of Wound-Rotor Motor with
Single-Phase Dynamic Braking Control

2. Hoist Controls--Wound-Rotor Motor, DC Dynamic Braking.

a. This type of control is used for Class D and E service in shipyards, machine shops, and cargo-handling applications where high lifts are necessary. It uses AC for hoisting and DC for lowering except that, to ensure a stable high speed under all loads, the last point lowering is usually regenerative. No mechanical load brake is used. A rectifier or motor-generator set is the usual source of DC power necessary to this control system. An electrical holding brake is necessary.

b. The hoisting speed regulation is the same as with countertorque braking. With this control the slowest hoisting speed is 50 percent for a 25 percent load and loads over 50 percent will tend to lower on the first point of hoisting.

c. Characteristics during lowering resemble those of countertorque braking, except that the curves are flatter and converge at or near the zero-torque/zero-speed point. The operation for lowering is similar to that for countertorque braking on the first step. Then as the handle is moved to the "OFF" position, the speeds are controlled by applying low-voltage DC power to the stator winding of the motor to produce a steady but adjustable field while regulating the secondary resistance for the desired speed. Any desired number of intermediate points may be obtained.

d. This control provides a reasonably slow point for landing, good speed regulation for medium and heavy loads, but indifferent regulation for light loads. Since the field is stationary, there is no inherent drivedown for slow or intermediate speed points, all curves coming to zero speed at zero torque.. Note from the speed-load curves, Figure B-2, that there is a large step in lowering speed for light loads between steps 4 and 5.

e. To ensure that an empty hook or very light load will lower on these points, a push-button point, represented by the curve in quadrant III, is provided for a light torque to start the load down. This is hoisting point 1 connected in reverse. During acceleration down it is functioning as a drivedown, and after acceleration, the push-button should be released and the control set on the desired point. If an attempt is made to lower a heavy load rapidly on the push-button, a runaway will occur before stable regenerative speed is reached. "OFF" position and emergency dynamic braking may be provided.

f. Due to the way the motor is used in controlling lowering speeds, additional heating takes place within it. While heating is not severe, a duty-cycle analysis for the hoist motor should be made for heavier-duty applications to make sure that overheating will not interfere with performance.

g. Use. Select this control as suitable for heavy-load, medium-precision, medium-duty service.

3. Hoist Controls--Wound-Rotor Motor, Adjustable-Varying Unbalanced Voltage Braking (Reactor Type).

a. This control uses some of the features of countertorque, single-phase, and unbalanced-voltage braking. Note the resemblance of its characteristics to those of DC dynamic braking (with steeper curves).

b. Secondary current is rectified and fed into a saturable-core reactor, modifying the primary current characteristics so that torque, in lowering, increases with speed. This inherently varying characteristic changes the primary current from nearly single phase to nearly balanced three-phase operation, depending on the control-handle setting, the load, and the speed. The primary currents do not rise excessively over the rated full-load current on any speed point or load within the rated load. The reactor is like a dry-type transformer with an iron core, AC power windings, and DC core bias windings. The more DC bias on the core, the more AC flows to the motor until, at complete magnetic saturation, the motor gets nearly full AC power.

c. Speed regulation for heavy loads is superior to that for light loads. One drivedown point for very light loads, in a rather unnatural position, is provided. Compare this to the push-button-controlled drivedown point in the DC dynamic-braking control. Figure B-3 indicates the characteristics of this control.

d. Use. This control may be used for intermediate-speed work and on heavy-duty service. See comment below regarding static controls.

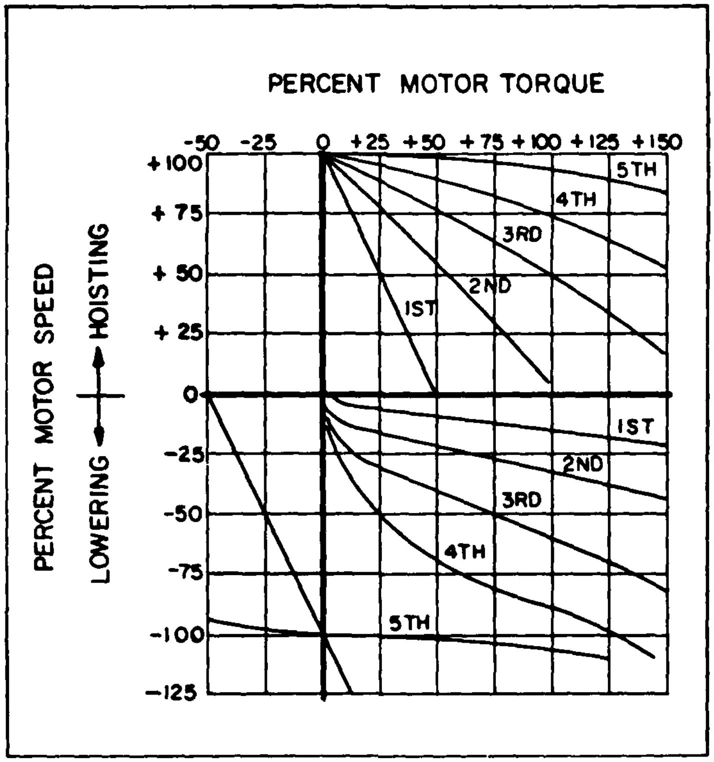


FIGURE B-2
Torque-Speed Curves for Wound-Rotor Motor with
DC Dynamic-Braking Lowering Control

4. Hoist Controls--Wound-Rotor Motor, Load-Sensitive Reactor.

a. The load-sensitive reactor control is adjustable by the operator and is inherently variable in accordance with the hook load and the speed in both hoisting and lowering operations. Variations are produced by special hook-load sensors, which are dominant, and by speed sensors, which serve to apply unbalanced voltage to the stator. Special safety measures, such as torque-limitation, "OFF" position, and power-failure dynamic braking are usually provided.

b. In the lowering direction, the slow speed points provide slower speed for the heavier loads and a very good (minimum) slow speed for landing all loads. By means of additional equipment, the slow landing speed may be made much slower than shown, from 0 to 7 percent of rated speed.

c. Speed regulation is good to excellent at all loadings. The obvious shortcoming is the lack of materially higher full speeds for light loads or empty hook than for heavy loads.

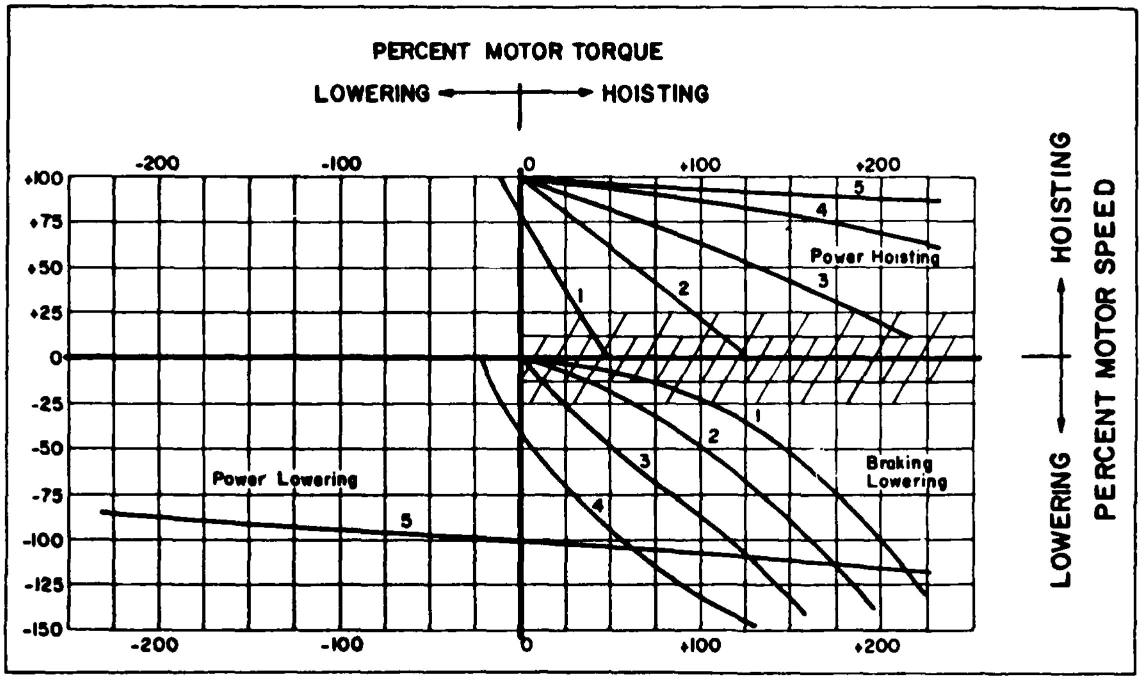


FIGURE B-3
Torque-Speed Curves for Wound-Rotor Motor with
Adjustable-Varying Unbalanced-Voltage (Reactor-Type) Control

d. Use. This control is suitable for heavy-duty, intermediate-speed, and precision service and does not require exceptional skill in operation. It possesses, to some degree, most of the desirable qualities of a hoist control. See comment below regarding static controls.

5. Hoist Controls--Wound-Rotor Motor, Secondary DC Feedback.

a. For a secondary DC feedback control, a small amount of DC is applied to the stator from a rectifier taking current from the line to ensure initial excitation of the motor, because in lowering on intermediate points the motor is not connected to the line. An overhauling load generates secondary AC, a portion of which is rectified to DC and also fed into the stator. This feedback current produces a braking effect, increasing with load increase and decreasing with load decrease. Stator currents are not excessive and, therefore, heating is not aggravated. On the intermediate speed points, there is no inherent drivedown. If desired (usually for hook service) it may be provided similar to that for the externally excited AC-DC control. The last lowering step is on a regenerative point which inhibits higher empty-hook speeds than loaded-hook speeds. Intermediate points show a good low speed, within the positioning range, and good speed regulation for medium to heavy loads. Figure B-5 indicates the characteristics of this control.

b. Use. Secondary DC feedback controls are suitable for heavy-duty, intermediate service, and medium-precision work.

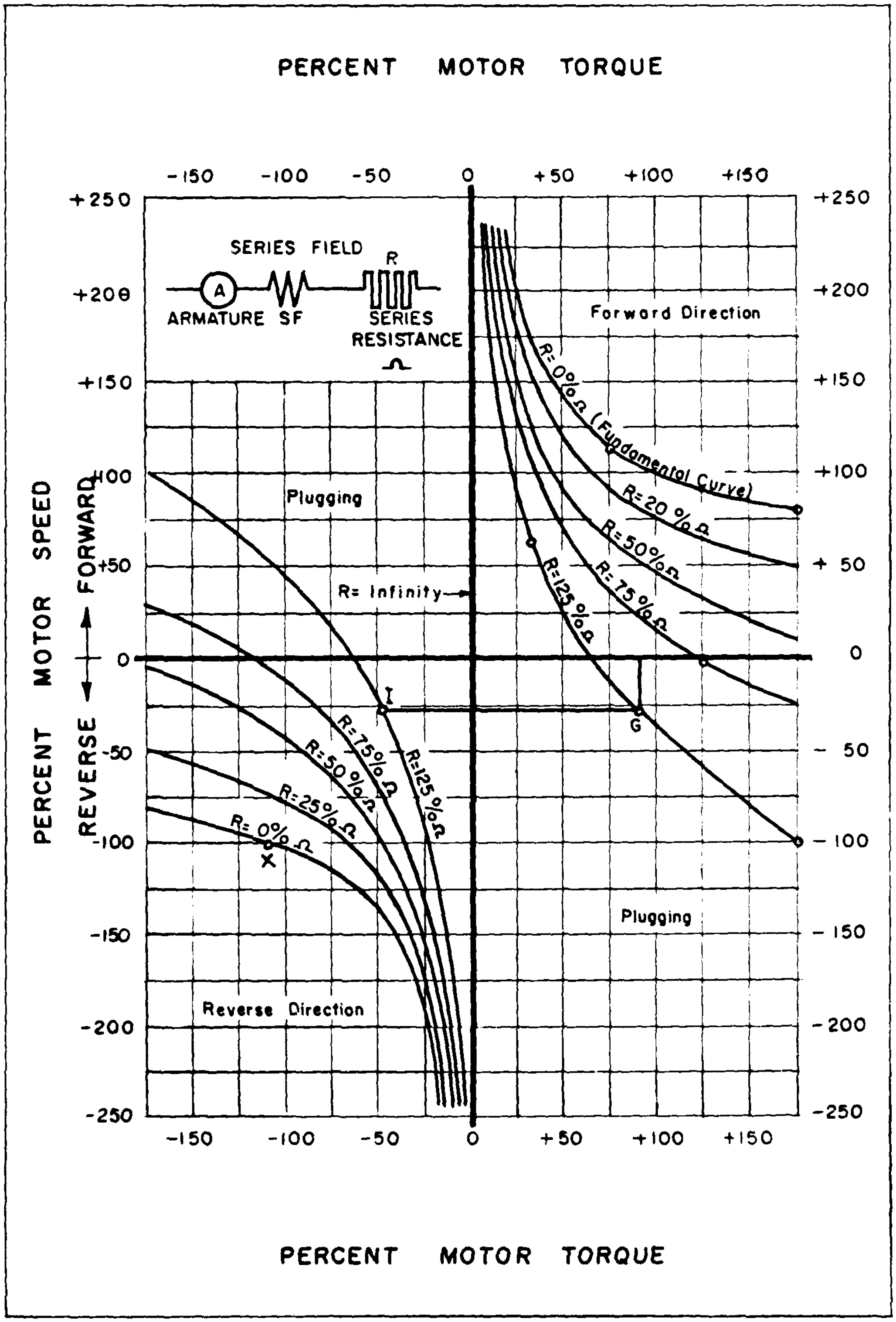


FIGURE B-4
Series-Wound Motor: Torque-Speed Curves, Series-Resistance Condition

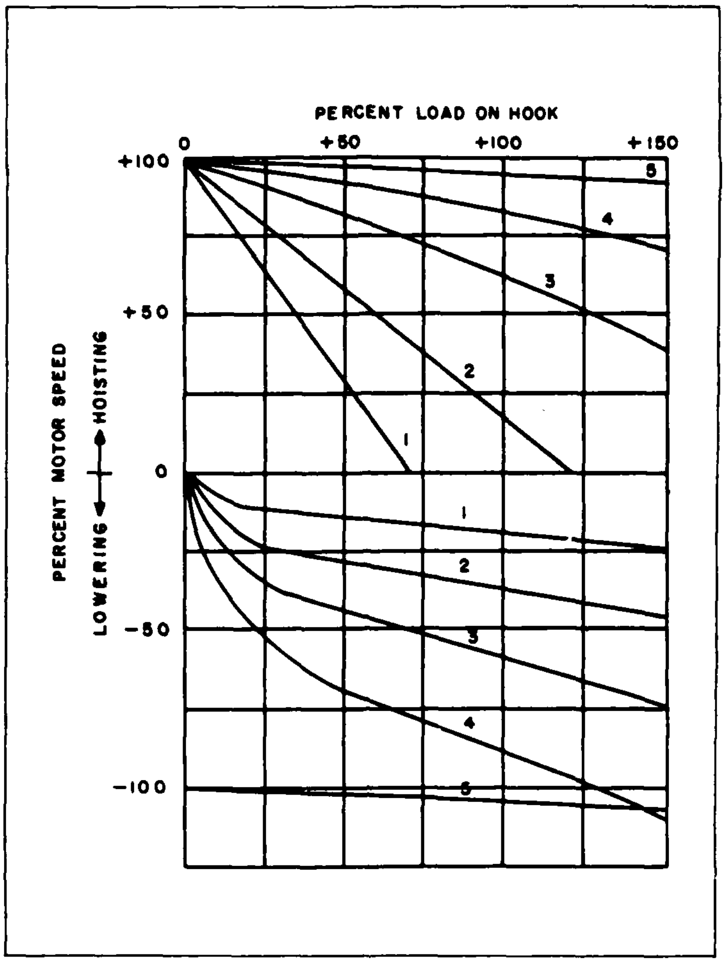


FIGURE B-5
Torque-Speed Curves of A.C. Secondary D.C. Feedback Control

6. Comment.

The systems described in this Appendix are going out of favor for two reasons:

a. For light-duty, limited-duty, and economical installations, countertorque control and simpler package forms are less costly.

b. For heavy-duty and more precise controls, adjustable-voltage equipment has become reasonable in price and offers superior control characteristics.

APPENDIX C

Interpretation of Control Curves

APPENDIX C
Interpretation of Control Curves

1. General. Motor speed-torque curves for crane applications involve the characteristics of reverse motion and electric braking of the dynamic and regenerative type. Because of their inherent characteristics, these braking modes plot in certain areas of the coordinate system. See Figure C-1 for the coordinate system and the areas in which curves should fall for certain definite operations. This figure is a skeletonized representation of the coordinate system annotated to present in clear terms the functions plotting in each quadrant.

2. If the motor is rotating in the forward direction, the upper half of the chart is used; if rotating in the reverse direction, the lower half is used. If the motor is exerting a torque that attempts to rotate the armature in the forward direction, the right-hand half of the chart is used; if in the reverse direction, the left-hand is used.

3. The four quadrants represent four distinct conditions of operation. In the upper right-hand (I) and lower left-hand (III) quadrants, the motor is driving the load in the hoisting and lowering, or forward and reverse directions, respectively. See Figure B-4 for the forward/reverse relationship. In the upper left-hand (II) and lower right-hand (IV) quadrants, the motor torque is acting to retard the load with a braking action (dynamic braking, regenerative braking, or plugging).

4. Although Figure C-1 applies to hoists, it is equally applicable for travel, trolley, and rotate drives, the upper two quadrants for one direction and the lower quadrants for the other.

5. Quadrant I considers the motor when it is hoisting or normally driving. During deceleration or on travel drives with wind or downgrade, the load may drive the motor, which then acts as a brake, and the curves from Quadrant I pass into the braking curves, Quadrant II (see Figures B-4 and 52). Consider only Quadrants I and II for travel, trolley, and rotate motions unless motor braking is used.

6. Quadrant III indicates the motor performance when an empty hook or light load is insufficient to overhaul the mechanism and accelerate it, or when rapid downward acceleration is required. It is the drivedown (power-lowering) quadrant.

7. Quadrant IV represents the motor performance when lowering (or traveling) with motor-braking (see Figure 57).

8. Points 1, 2, etc., in the figures for characteristic curves accompanying control schemes are the points, or positions, on which the master switch or control handle is set by the operator.

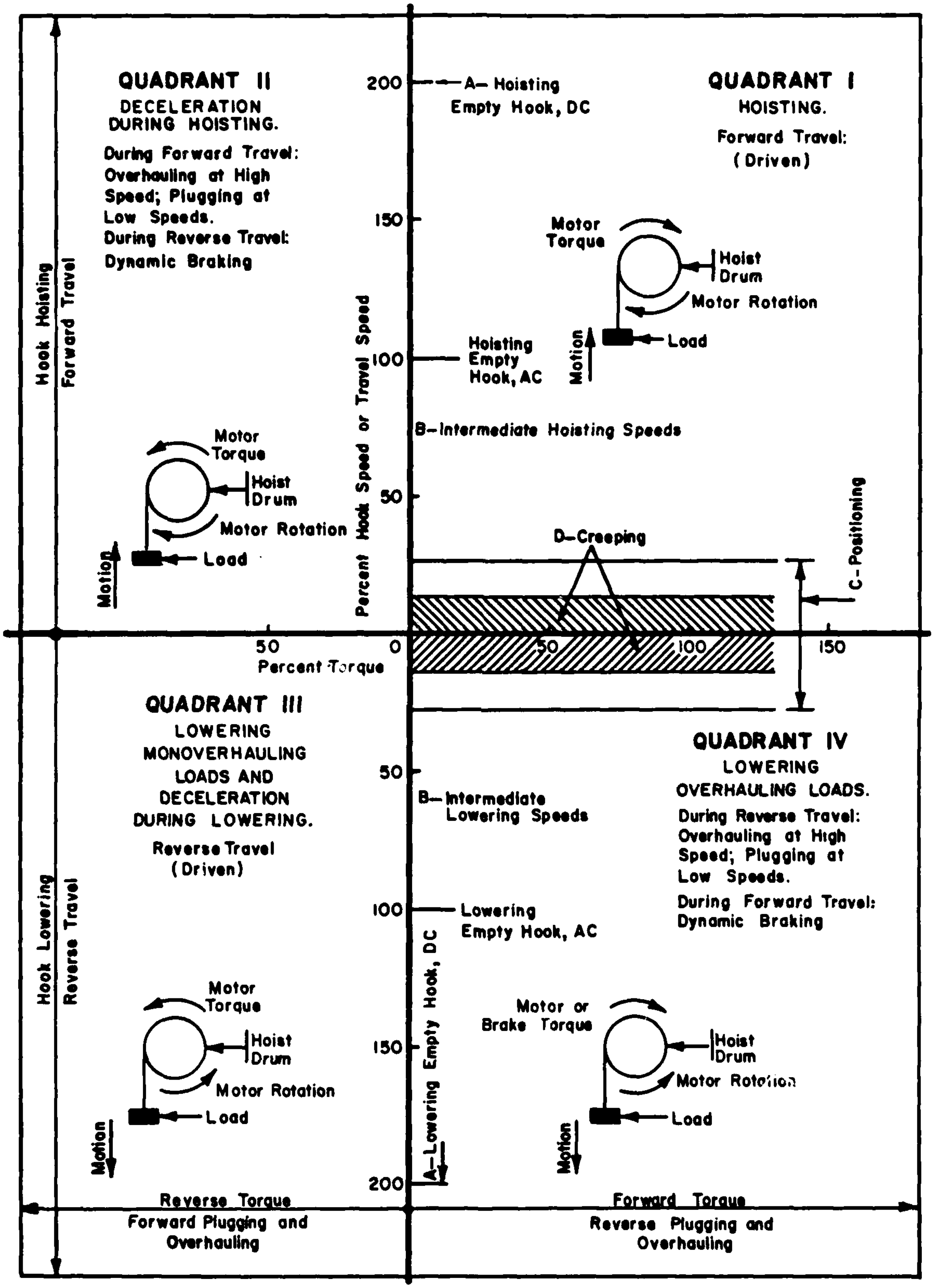


FIGURE C-1
Basic Coordinate Form of Speed-Torque Diagram

9. For purposes of describing control functions, speeds of 10 percent of rated or less are creeping speeds; those between 10 and 20 percent are positioning speeds; and those between 20 percent and rated are intermediate speeds. Extremely slow speeds are usually referred to as "microdrive."

10. See Figure C-2 for the use of control characteristic curves. This figure consists of the torque-speed curves produced by each of the control-handle positions in the hoisting direction of a manual, series-wound DC motor rheostatic hoist control without modifications such as armature shunts. Each curve is marked by its respective switch-point position. For example, the first position in hoisting is H1, the first in the lowering direction is L1, etc.

11. The hoisting curves are obtained by the use of resistors connected in series with the motor. The lowering curves are produced by shunting the field across the armature, making the motor a shunt generator (or on failure of power, a series generator, whose curves are not shown here).

12. A typical hoisting and lowering cycle may be followed by means of the arrows. For illustrative purposes, the hoisting load at the motor is assumed to be 100 percent rated torque, and the mechanical efficiency of the hoist to be 80 percent. The load on the hook is then 0.80 x 1.00 = 80 percent torque. In the lowering direction, efficiency is reversed and the load at the motor becomes 0.80 x 0.80 = 64 percent torque, which corresponds to a vertical line passing through points AH and W. The sequence of operation is then as follows:

13. Accelerate hoist. The controller is notched gradually from the off position to the final hoist position (H5). Speed and torque follow arrows through points A, B, C, D, E, F, G, H, to I. The motor does not start to accelerate until the third position (H3) is reached, at point D, when the motor torque exceeds the load torque and the excess torque is available for acceleration. The first two positions, B and C, would support this load but not accelerate it, because of the reserved efficiency referred to previously. It is assumed that the motor does not have time to change speed between controller points, so that the transfer between curves is made at constant speed or with horizontal lines.

14. Full-speed hoist. The controller remains on position (H5); speed and torque remain at point I.

15. Decelerate hoist. The controller is notched rapidly back to off position, where the holding brake is set. Arrows are followed through points I, J, K, L, M, N, O, P, Q, R, and back to A.

16. Accelerate and lower. The controller is notched rapidly to position (L5) and then, after a short time, to (L6). Arrows are followed through A, S, T, U, V, to W. At point V, the motor torque reverses and starts to pull back on the load. At point W, this braking torque is balanced by the load on the hook and equilibrium is obtained.

17. Full-speed lower. The controller remains on position (L6); speed and torque remain at point W.

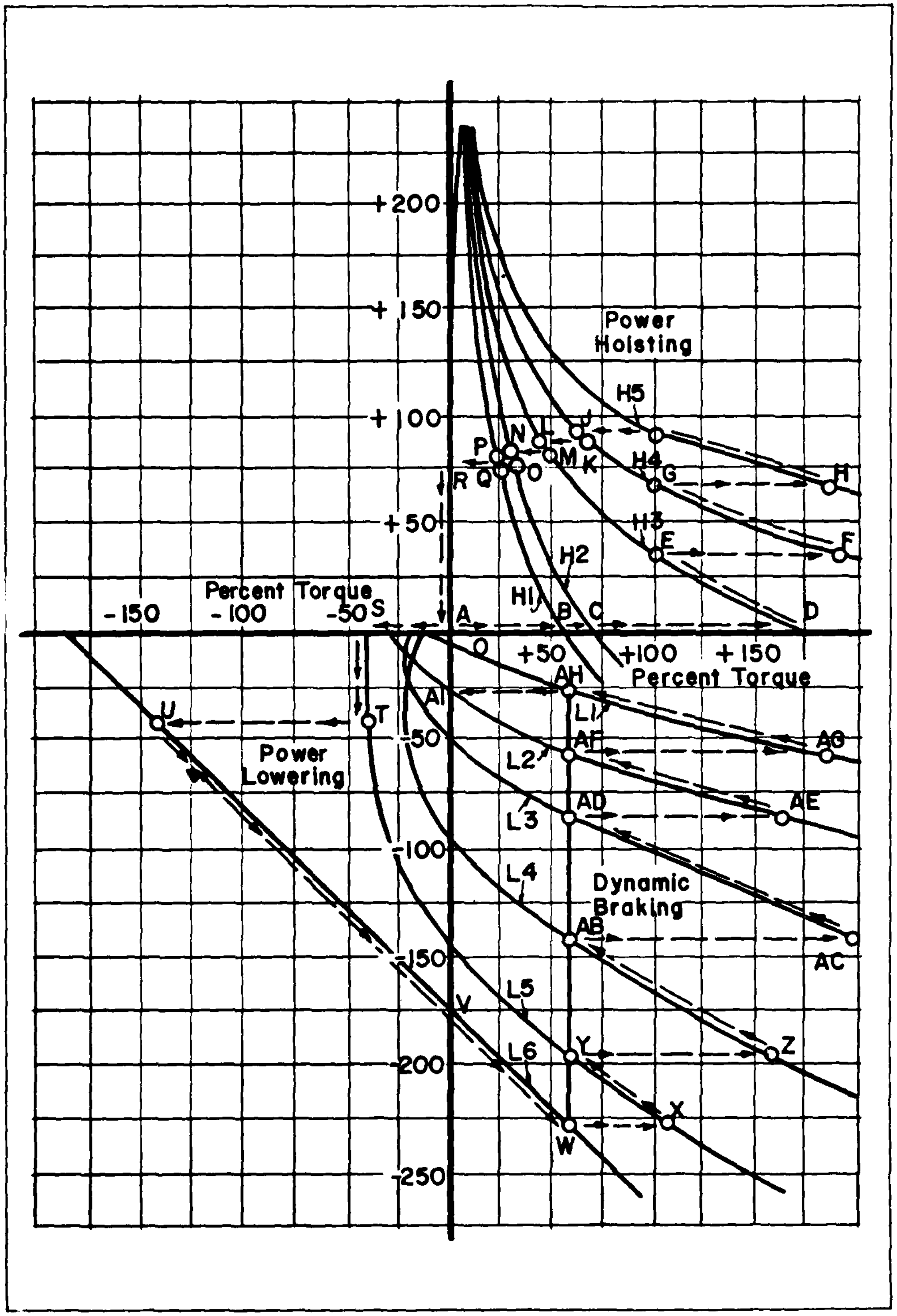


FIGURE C-2
Use of Control Characteristic Curves

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A. Department of Defense activities may obtain copies of Design Manuals and P-Publications from the: Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

Department of Defense activities must use the Military Standard Requisitioning and Issue Procedure (MILSTRIP) using the stock control number obtained from NAVSUP Publication 2002.

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