ASME P30.1-2024

(Revision of ASME P30.1-2019)

# Planning for Load Handling Activities

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AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers

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# FOREWORD

As load handling activities grow in complexity, there is an increased need to develop a set of recognized planning guidelines. While some guidance for planning of load handling activities, also referred to as lift planning, has been available in publications, literature from equipment manufacturers, and in-house procedures of various organizations and companies, there has not been any published comprehensive, broadly authoritative guidance available. The absence of uniform considerations or comprehensive practices has created an uneven range of planning activities.

In 2008, the B30 Standard Committee created a Task Group to consider the feasibility of developing a standard for lift planning. Based upon the report of the Task Group, the B30 Standard Committee favored the creation of a standard but recognized that such a standard would not fit the equipment-based orientation of B30. The American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI) were petitioned to form a committee to develop a lift planning standard.

The formation of the ASME P30 Standards Committee, Planning for the Use of Cranes, Derricks, Hoists, Cableways, Aerial Devices, and Lifting Accessories, was approved by ASME on June 8, 2010, and a Project Initiation Notification System (PINS) was posted in ANSI Standards Action on July 2, 2010. The Committee held its inaugural meeting on September 20, 2010, with the intent to develop a standard that provides guidance on general planning considerations and practices for load handling operations occurring in all industries, so that users could apply the Standard as a template and adapt it to the needs of their specific industry or situation.

The first edition of ASME P30.1 was approved by ANSI on January 14, 2014. The 2019 edition contained changes to Nonmandatory Appendix A, additional guidance on rigging planning and how to establish a limiting wind speed for a load handling activity as part of the lift-planning process. The 2024 edition revises section C-7, including adding para. C-7.1, and adds a new Nonmandatory Appendix D.

ASME P30.1-2024 was approved by the P30 Committee and by ASME, and was approved by ANSI and designated as an American National Standard on November 15, 2024.

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# Planning for the Use of Cranes, Derricks, Hoists, Cableways, Aerial Devices, and Lifting Accessories

(The following is the roster of the committee at the time of approval of this Standard.)

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**Revisions and Errata.** The committee processes revisions to this Standard on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published in the next edition of the Standard.

In addition, the committee may post errata on the committee web page. Errata become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata.

This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

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# P30 STANDARD INTRODUCTION

## SECTION I: CHARTER FOR P30 — PLANNING FOR THE USE OF CRANES, DERRICKS, HOISTS, CABLEWAYS, AERIAL DEVICES, AND LIFTING ACCESSORIES COMMITTEE

The development and maintenance of standards that support load handling activities where mechanical equipment including, but not limited to, cranes, derricks, hoists, cableways, aerial devices, material lifting accessories, and combinations thereof are used.

## SECTION II: PURPOSE

The P30 Standard is intended to

*(a)* prevent or minimize injury, and provide for the protection of life, limb, and property by offering guidance for planning efforts that enhance the safety of load handling activities

*(b)* provide guidance to work site personnel, equipment owners, employers, users, and others concerned with or responsible for the safety of load handling activities

*(c)* guide governments and other regulatory bodies in the development, promulgation, and enforcement of appropriate safety directives

## SECTION III: USE BY REGULATORY AGENCIES

This Standard may be adopted in whole or in part for governmental or regulatory use. If adopted for governmental use, the references to other codes and standards in this Standard may be changed to refer to the corresponding regulations of the regulatory agency or governmental authorities.

## SECTION IV: EFFECTIVE DATE

*(a) Effective Date.* The effective date of this Standard shall be 1 yr after its date of issuance.

*(b)* The need to meet the guidelines established in the current edition of this Standard shall be evaluated by a qualified person, and any recommended changes to the user's planning activities shall be made within 1 yr.

## SECTION V: REQUIREMENTS AND RECOMMENDATIONS

Requirements of this Standard are characterized by use of the word *shall*. Recommendations of this Standard are characterized by the word *should*.

## SECTION VI: ADDITIONAL GUIDANCE

Load handling activities addressed by the P30 Standard are subject to hazards that cannot be abated solely through planning. Only by the application of knowledge, care, common sense, and experience can safe load handling activities be anticipated. It is therefore essential that personnel responsible for the planning and implementation of load handling activities are competent, qualified, and trained with the skills to satisfactorily accomplish their assigned tasks.

The P30 Standards Committee recognizes the importance of proper design factors, minimum or maximum dimensions, and other limiting criteria of equipment used in load handling activities. The P30 Committee expects that the equipment used to execute load handling activities meets the requirements of applicable equipment safety standards. The P30 Committee also expects that any recommendations or requirements provided in those standards are interpreted and applied correctly.

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# ASME P30.1-2024
# SUMMARY OF CHANGES

Following approval by the ASME P30 Standards Committee and ASME, and after public review, ASME P30.1-2024 was approved by the American National Standards Institute on November 15, 2024.

ASME P30.1-2024 includes the following changes identified by a margin note, **(24)**.

| *Page* | *Location* | *Change* |
|---|---|---|
| vii | Correspondence With the P30 Committee | Added |
| viii | P30 Standard Introduction | Updated |
| 1 | 1-2 | Definitions of *crane mat*, *float*, *ground mat*, and *outrigger pad* added |
| 23 | C-7 | Revised in its entirety |
| 35 | Nonmandatory Appendix D | Added |
| 63 | Nonmandatory Appendix E | Former Nonmandatory Appendix D redesignated and updated |

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# Chapter 1
# Scope and Definitions

## 1-1 SCOPE

This Standard establishes planning considerations and practices that apply to load handling equipment (LHE), other associated equipment, and activities when moving loads vertically or horizontally. The planning guidance contained in this Standard is divided into two categories dependent upon the nature of the load handling activity and the degree of exposure to the issues that impact safety. The categories are designated as standard lift plan and critical lift plan. This Standard does not preclude the user of this Standard from creating subcategories based on their specific load handling activity considerations.

The P30.1 Standard does not exclude any particular equipment or industry. This Standard may not address all of the hazards that could be encountered during a load handling activity. It is the responsibility of the user of this Standard to assess and address the hazards associated with a particular load handling activity.

## (24) 1-2 DEFINITIONS

*crane mat:* a structural element or assembly placed under the load handling equipment capable of distributing the load primarily along its length.

*D/d ratio:* the ratio between the diameter of curvature, *D*, taken by the sling when in contact with an object and the diameter of the wire rope, synthetic rope, or chain, *d*.

*dynamic load:* forces introduced into the load handling equipment as a result of change in motion.

*float:* a rigid footing component that attaches to the bottom of an outrigger or stabilizer.

*ground mat:* a protective cover used to limit tires or tracks from damaging the support surface. Also known as *access mat*, *mud mat*, *swamp mat*, or *ground protection mat*.

*lift:* to move a load vertically or horizontally with the load handling equipment.

*lift director (load handling director):* the person designated to direct the load handling activity.

*lift plan:* information and/or instruction, written or verbal, used in support of a load handling activity.

*load handling equipment (LHE):* equipment used to move a load vertically or horizontally.

*outrigger pad:* a structural element or assembly placed under a float of the load handling equipment capable of distributing the load in all directions.

*qualified person:* a person who, by possession of a recognized degree or certificate of professional standing in an applicable field, or by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

*rigging (noun):* the components, hardware, and devices used to attach a load to the load handling equipment.

*rigging (verb):* the process of attaching a load to the load handling equipment by means of components, hardware or devices.

*shall:* the term used to indicate that a rule is mandatory and must be followed.

*should:* the term used to indicate that a rule is a recommendation, the advisability of which depends on the facts in each situation.

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# Chapter 2
# Load Handling Activity Considerations and Plan Categories

## 2-1 LOAD HANDLING ACTIVITY CONSIDERATIONS

An evaluation of a proposed load handling activity shall be performed (see Figure 2-1-1). Documentation of the evaluation is not required. It is recommended that the evaluation includes a risk analysis. Useful resources include ISO 31000:2009 and ISO 31010:2009. At a minimum, the load handling category should be determined based on review of the following considerations:

*(a) Potential Hazards to Persons*

*(1)* if the load handling activity will involve personnel lifting.

*(2)* if the load will be moved or suspended over areas accessible to the general public.

*(3)* if the load contains materials immediately dangerous to life and health.

*(4)* if load handling personnel will be in locations that may be hazardous during the load handling activity (e.g., pinch points, crush points).

*(5)* if site personnel other than load handling personnel will be in locations that are hazardous due to the load handling activity. This should include consideration of protection provided by existing structures.

*(b) Hazards in Proximity to the Work Area*

*(1)* if the load and/or the LHE can encroach the prohibited zone of power lines

*(2)* if there is potential for electromagnetic radiation/radio frequency hazard (e.g., loss of communication, electrical discharge, and shock)

*(3)* if the load handling activity can cause damage to pipes, lines, tanks, equipment, or products that could create an adverse environmental impact

*(c) Complexity of Load Handling Activity*

*(1)* if the load has potential for instability during the load handling activity due to the

*(-a)* design or configuration of the load (e.g., shape, load integrity, and sail area)

*(-b)* center-of-gravity of the load relative to the established connection points

*(-c)* load weight shift (e.g., liquid filled, swing arms, and moveable parts)

*(2)* if the load handling activity uses complex load handling methods

*(3)* if the load handling activity will be performed in proximity to obstructions or in limited clearance areas, including consideration of clearance between the LHE and the load

*(4)* if the load is to be manipulated (e.g., turned, rotated, and tilted)

*(5)* if the LHE travels during the lift

*(6)* if the load handling activity uses multiple LHE

*(7)* if the load handling activity is unique to or infrequently performed by the personnel involved

*(8)* if special means or access for attaching and removing rigging is required

*(d) Adverse Impact From Environmental Conditions.* If the load handling activity could be adversely impacted by conditions such as

*(1)* effects of wind on the load and/or LHE (e.g., speed, direction, sustained, and/or gusts)

*(2)* support for the load, the LHE, or both (e.g., ground, rail, girder, structure, foundation, vessel list, and trim)

*(3)* ambient temperature (e.g., high, low, and range)

*(4)* surfaces moving relative to one another (e.g., from land to water, or water to land, or water to water)

*(5)* visibility (e.g., fog, sun glare, lighting, and obstructions)

*(6)* precipitation

*(7)* lightning

*(e) LHE Capacity and/or Performance*

*(1)* if the load weight is significant compared to the LHE capacity as configured

*(2)* if factors, such as the following, have the potential to encroach upon maximum capacity of the LHE, as configured, and/or diminish its performance:

*(-a)* increased loading due to extraction or removal of a load (e.g., demolition, suction, and friction)

*(-b)* dynamic loading (e.g., abrupt starting, stopping, acceleration, deceleration, and abrupt load transfer)

*(-c)* line pull

*(-d)* brake/clutch/pump settings and/or conditions

*(-e)* accuracy of load weight information/determination

*(-f)* site conditions as outlined in para. 5-2.6

*(-g)* potential load shift during load handling activity

*(-h)* weight distribution or transfer between multiple LHEs

*(-i)* effects of moving to/from liquids (current, buoyancy)

*(-j)* out-of-plane loading

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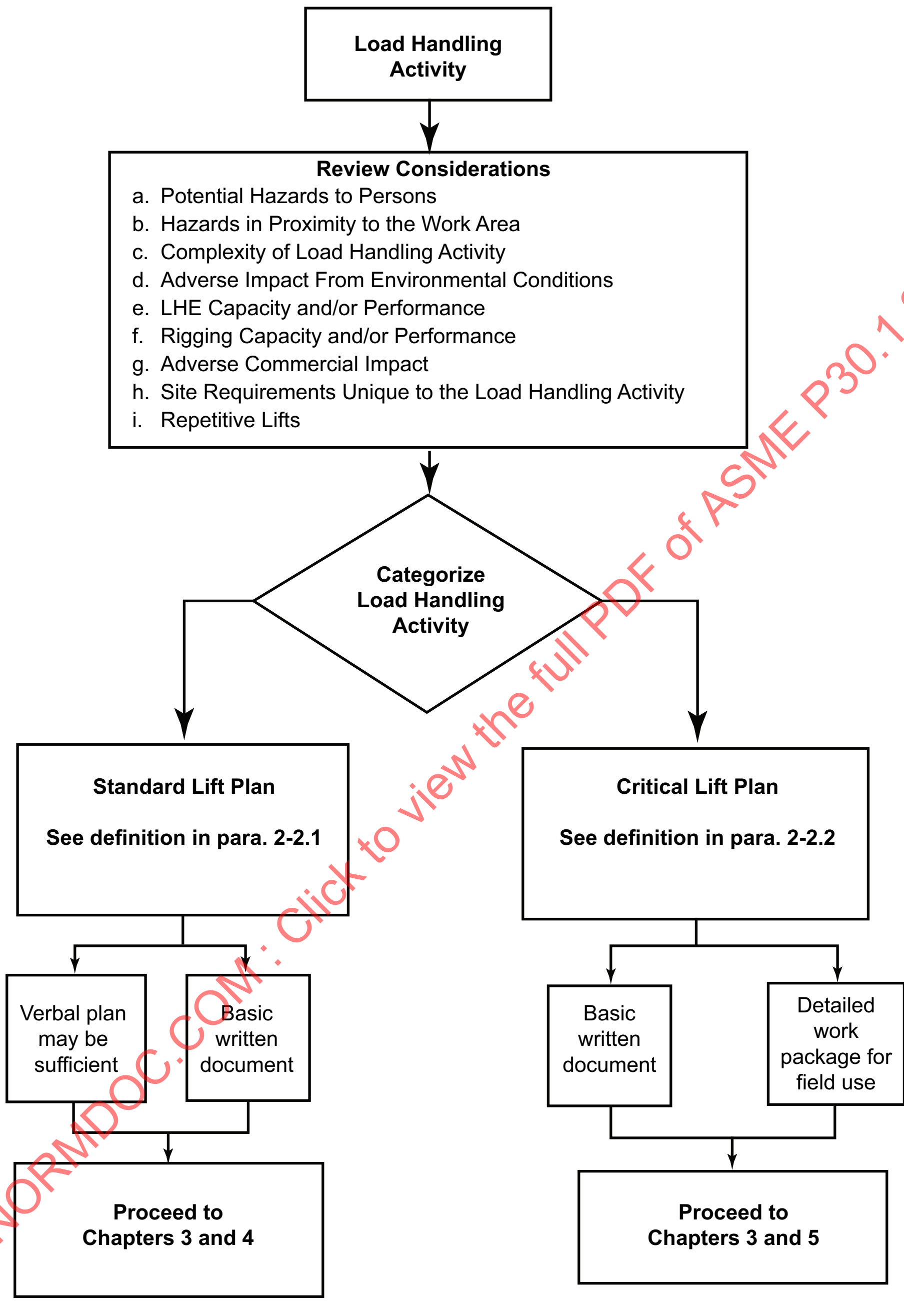
**Figure 2-1-1**
**Load Handling Activity Categorization**

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*(-k)* equipment history or condition

*(f)* *Rigging Capacity and/or Performance.* If factors, such as those listed in (e)(2)(-c) and (e)(2)(-e) above, and/or the following, have the potential to encroach upon maximum capacity of the rigging, as configured, and/or affect its performance:

*(1)* rigging attachment points of the load (e.g., lifting lugs, precast inserts)

*(2)* side loading of the rigging hardware and attachments

*(3)* complexity of rigging

*(4)* weight distribution or transfer of load within the rigging arrangement

*(5)* environmental conditions (e.g., temperature or chemically active environment)

*(g)* *Adverse Commercial Impact*

*(1)* if the load has a significant replacement time

*(2)* if the cost of replacing the load is considered significant or the load is irreplaceable

*(3)* if failure to complete the load handling activity could create a project delay, work shutdown, or disruption to the general public

*(4)* if the load handling activity can cause damage to pipes, lines, tanks, equipment, or products that could create an adverse commercial impact

*(h)* *Site Requirements Unique to the Load Handling Activity*

*(1)* corporate considerations/policies

*(2)* regulatory considerations [e.g., local, state, federal, DOT, railroad (FRA), FAA, and military]

*(3)* potential impact to vital infrastructure (e.g., public utilities, roadways, seaports, pipelines, and railroads)

*(i)* *Repetitive Lifts*

*(1)* distractions, fatigue, inattention, or lack of concentration of the load handling personnel

*(2)* the LHE and rigging equipment manufacturer's recommendations for duty cycle or repetitive operations

## 2-2 PLAN CATEGORIES

### 2-2.1 Standard Lift Plan

A standard lift plan is a proposed load handling activity plan in which considerations in section 2-1 have been evaluated and it has been determined that the load handling activity can be accomplished through standard procedures, and that the load handling activity personnel can execute using common methods, materials, and equipment.

### 2-2.2 Critical Lift Plan

A critical lift plan is a proposed load handling activity plan in which considerations in section 2-1 have been evaluated and it has been determined that the load handling activity exceeds standard lift plan criteria and requires additional planning, procedures, or methods to mitigate the greater risk.

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# Chapter 3
# Personnel and Responsibilities

## 3-1 PERSONNEL QUALIFICATION/COMPETENCE

Persons performing the lift planning and load handling activities shall be qualified and competent, as determined by the employer or employer's representative, to perform the assigned tasks.

All personnel involved in the load handling activities shall meet the qualifying criteria established in applicable consensus standards, site-specific requirements, or regulations.

## 3-2 ROLES AND RESPONSIBILITIES

It is essential that roles and responsibilities identified in the lift plan are defined and understood by all personnel involved. The roles and responsibilities may include, but are not limited to, those outlined below. Not all of the roles below may be identified in or required by the lift plan. In some cases an individual or entity may perform multiple, nonconflicting roles.

*(a)* Assembly/disassembly director — responsible for directing the assembly/disassembly (erect/dismantle) of the LHE

*(b)* Engineer — responsible for providing any required engineering support and documentation for the load handling activity

*(c)* General contractor/construction manager — responsible for contractual requirements including deliverables, and ensuring performance and safety requirements are established and implemented

*(d)* Lift director — responsible for verifying the category of the load handling activity and reviewing and implementing the lift plan

*(e)* LHE operator — responsible for directly controlling the LHE's functions

*(f)* LHE owner — responsible for custodial control of the LHE by virtue of a lease or ownership

*(g)* LHE user — responsible for arranging the LHE's presence on a work site and controlling its use

*(h)* Lift planner — responsible for developing the lift plan

*(i)* Rigger — responsible for performing rigging tasks associated with the load handling activity

*(j)* Signalperson — responsible for directing the movements of the LHE by providing signal commands to the LHE operator

*(k)* Site safety officer — responsible for enforcing work site safety policies

*(l)* Site supervisor — responsible for overseeing the work site on which the LHE is used and the work that is performed on the site

*(m)* Spotter — responsible for observing and reporting as directed on the movement of the LHE and load

*(n)* Transport operator — responsible for operation of transport equipment used in support of the load handling activity

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# Chapter 4
# Standard Lift Plan

## 4-1 INTRODUCTION

The decision to use a standard lift plan should be based on the considerations outlined in Chapter 2. The lift director should determine that none of these considerations would cause the load handling activity to be recategorized.

Prior to the load handling activity, the lift director should verify that the standard lift plan has been developed. The standard lift plan can be written or verbal. See Nonmandatory Appendix A for an example of lift plan template, Nonmandatory Appendix B for an example of rigging data sheet, and Nonmandatory Appendix C for guidance on establishing a limiting wind speed.

## 4-2 STANDARD LIFT PLAN DEVELOPMENT

*(a)* The standard lift plan should identify, evaluate, and address the following for all phases of the load handling activity:

*(1)* the load, its weight, center of gravity, and attachment points

*(2)* the gross load is within the LHE's rated capacity as configured

*(3)* the rigging

*(-a)* is selected to have sufficient rated capacity for the intended configuration

*(-b)* is configured to secure and stabilize the load

*(-c)* and the loads are protected from damage

*(4)* movement of the LHE and load

*(5)* the personnel required to execute the load handling activity

*(6)* site conditions, weather, work area, LHE foundation and support, utilities, support services, and ancillary equipment

*(7)* communication method or system

*(8)* site control for vehicular and pedestrian access and potential interferences

*(9)* contingency considerations

*(10)* emergency action plan

*(11)* for repetitive lifts, additional LHE and rigging inspection and maintenance

*(b)* Standard lift plans do not require documentation unless required by site policies or as otherwise warranted.

## 4-3 PRE-LIFT REVIEW

*(a)* Prior to executing the load handling activity, the participants should communicate and agree upon the details of the plan and their assignments.

*(b)* For repetitive lifts, the lift director should decide the frequency of pre-lift reviews. Pre-lift reviews may not be required prior to each repetition of the lift.

*(c)* Concerns raised during the pre-lift review should be addressed prior to proceeding with the load handling activity.

## 4-4 EXECUTING THE STANDARD LIFT PLAN

*(a)* The load handling activity should only commence after

*(1)* all setup and preparation requirements of the plan are in place

*(2)* all required inspections and tests of the LHE and rigging equipment have been completed

*(3)* all requirements of the plan continue to be met and no conditions exist that would preclude implementation of the plan

*(b)* If the operation deviates from the plan, the load handling activity should be stopped and evaluated. The deviation should be resolved before resuming the load handling activity. Changes or modifications to the plan should be communicated to all affected load handling personnel.

## 4-5 POST-LIFT REVIEW

*(a)* After completion of the load handling activity, any measures identified by the participants to improve future load handling activities should be communicated to the appropriate personnel.

*(b)* For repetitive lifts, the lift director should decide the frequency of post-lift reviews and evaluation of the lift plan. Post-lift reviews may not be required after each repetition of the load handling activity.

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# Chapter 5
# Critical Lift Plan

## 5-1 INTRODUCTION

The decision to use a critical lift plan should be based on the considerations outlined in Chapter 2.

The critical lift plan shall be written prior to executing the load handling activity. See Nonmandatory Appendix A for an example lift plan template, Nonmandatory Appendix B for an example of rigging data sheet, and Nonmandatory Appendix C for guidance on establishing a limiting wind speed.

## 5-2 CRITICAL LIFT PLAN DEVELOPMENT

The critical lift plan should address the applicable items identified in paras. 5-2.1 through 5-2.10 and any additional considerations identified during the planning process.

### 5-2.1 The Load

*(a)* Identify the load's weight, center of gravity, and dimensions, and the sources of that information.

*(b)* Identify components that could shift during the load handling activity and develop a method for securing, if required.

*(c)* Identify the load attachment or contact points and ensure that they are suitable for the load to be handled, while maintaining load integrity.

*(d)* Identify the requirements to be met for the load's orientation and securement prior to the release of the LHE and rigging.

### 5-2.2 Load Handling Equipment

*(a)* Identify the LHE and the anticipated configurations.

*(b)* Ensure that the LHE is capable of handling the total anticipated load, including the rigging, accessories, and attachments in the intended configurations, giving consideration to the factors listed in (e).

*(c)* Ensure that the LHE is in compliance with the requirements of the site, the manufacturer or qualified person, industry-recognized standards (e.g., applicable ASME B30 volume), and federal, state, or local regulations.

*(d)* Establish the process to set up, erect, install, and dismantle the LHE using the information provided by

*(1)* the manufacturer

*(2)* a qualified person

*(3)* site-specific recommendations

*(4)* applicable regulatory requirements

*(e)* Identify all required inspections and tests on the LHE that need to be performed using the information provided by the manufacturer, a qualified person, site-specific recommendations, or applicable regulatory requirements. For repetitive lifts, additional LHE inspection and maintenance should be considered.

### 5-2.3 Rigging Plan

*(a)* Establish the rigging method that will support and secure the load and is suitable for the load handling activity.

*(b)* Ensure that the rigging method and the equipment have the capacity to support the load, in the configuration or geometry required, giving consideration to the factors addressed in para. 5-2.1 and the following:

*(1)* dynamic effects (beyond that considered in the design of the equipment)

*(2)* adverse environmental conditions (temperature, wind, and water/ice)

*(3)* position of the center of gravity relative to rigging support points

*(4)* $D/d$ ratio

*(c)* Identify the weight of the rigging, accessories, and attachments, and the sources of that information.

*(d)* Establish the process to ensure that the rigging equipment meets the manufacturer's specifications, regulations, industry-recognized standards (e.g., ASME B30.9, ASME B30.20, and ASME B30.26), and site-specific requirements for the methods and equipment selected.

*(e)* Identify all necessary inspections and tests for the rigging equipment.

*(f)* For repetitive lifts, establish any additional rigging inspection and maintenance requirements that may be necessary.

*(g)* Establish the process to assemble, install, remove, and disassemble the rigging equipment using the information provided by

*(1)* the manufacturer

*(2)* a qualified person

*(3)* site-specific recommendations

*(4)* applicable regulatory requirements

*(h)* Ensure that the rigging will be protected from damage during the load handling activity from conditions such as the following:

*(1)* temperature (e.g., shielding from heat, cold)

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*(2)* degradation (e.g., chemically active environment)

*(3)* cutting, abrasion, and friction damage (e.g., turning, shifting, and contact with edges)

### 5-2.4 LHE and Load Travel Path

*(a)* Identify the travel path of the load and LHE.

*(b)* Ensure that the load and LHE have adequate clearance to prevent contact with site-specific hazards or obstructions during the load handling activity (e.g., LHE to LHE, load to LHE, tail swing, boom/attachment clearance, and headroom).

*(c)* Consider the factors addressed in paras. 5-2.6 and 5-2.8 and the following:

*(1)* dynamic movement

*(2)* environmental (e.g., temperature, wind, and water/ice)

*(3)* load eccentricities during operation

*(d)* Identify the need for load control (e.g., tag line, push/pull poles).

*(e)* Identify positioning and movement of personnel required to support the load handling activity.

*(f)* Identify effects of slope or grade on the LHE.

### 5-2.5 Personnel

*(a)* Identify tasks to be completed prior to, during, and after the load handling activity, and the personnel required to complete each task (see Chapter 3).

*(b)* Identify specialized training of personnel necessary to accomplish the load handling activity, if required.

### 5-2.6 Site, Services, and Ancillary Equipment

*(a)* The following site parameters/conditions/services required to perform the load handling activity should be identified:

*(1)* the work area required (e.g., equipment setup, laydown, load, and LHE path).

*(2)* support services/utilities (e.g., fuel, air, electrical, and water).

*(3)* ancillary equipment required (e.g., high reach equipment, assist LHE).

*(4)* unobstructed access, travel path, and egress for the LHE and the load.

*(5)* suitable LHE foundation and support requirements during all phases of the load handling activity. Considerations should include, but not be limited to

*(-a)* soils analysis (e.g., allowable ground bearing pressure)

*(-b)* potential for change to support due to environmental conditions (e.g., erosion, frost heave, water saturation, and flooding)

*(-c)* supporting structure integrity (e.g., barges, piers, slabs, bridge decks, foundations, pavements, buildings, crane mats, and cribbing)

*(-d)* site-specific hazards such as vaults, pipelines, tunnels, previous excavations, or voids

*(-e)* presence of additional loads imposed by surrounding structures on the LHE foundation

*(-f)* presence of additional loads imposed by LHE on surrounding structures, excavations, or backfill

*(6)* requirements that ensure sufficient capacity, stability, and orientation to support the load at the point of origin and landing point.

*(b)* Ensure that all adjustments, soil mitigation, and reinforcements are completed prior to performing the load handling activity.

### 5-2.7 Communication System

*(a)* Identify suitable communication systems for use during the load handling activity, such as the following:

*(1)* hand signals

*(2)* voice signals (e.g., direct, radio, and hardwired audio)

*(3)* video

*(4)* horns or other audible signals

*(5)* signal or warning lights

*(b)* Identify a backup communication system and plan in case the primary communication system becomes ineffective.

### 5-2.8 Site Control

*(a)* Identify the vehicular and pedestrian access and the traffic controls to be used.

*(b)* Ensure that the plan addresses the following:

*(1)* vehicular and pedestrian traffic in and around the site that could be affected by or will affect the load handling activity

*(2)* potential interference from other site activities and the controls to be in place

*(c)* Identify location of barricades or other measures to be put in place to restrict traffic or prohibit interference during the load handling activity.

### 5-2.9 Contingency Considerations

The plan should address, at a minimum, the following potential events that could cause a deviation from the lift plan:

*(a)* equipment malfunction (e.g., LHE power failure, fouled rigging, and radio communication failure)

*(b)* adverse changes to environmental conditions (e.g., weather, visibility)

*(c)* deviation from the planned load characteristics as identified in para. 5-2.1

*(d)* adverse changes to site conditions (e.g., surrounding activities, change in ground conditions, and unauthorized entry into the work site as identified in para. 5-2.8)

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### 5-2.10 Emergency Action Plan

*(a)* Review any existing site-specific emergency action plans and coordinate any required modifications.

*(b)* Identify the need for an emergency action plan directly related to the load handling activity.

## 5-3 PRE-LIFT MEETING

The lift director should hold a pre-lift meeting to discuss the plan and the roles of the personnel involved.

*(a)* At a minimum, the following elements should be reviewed with all load handling activity personnel:

*(1)* overview of the load handling activity

*(2)* LHE, rigging, and other equipment involved in the load handling activity

*(3)* the sequence of events and step-by-step procedures for the entire load handling activity

*(4)* safety measures, as required (e.g., Job Safety Analysis action items)

*(5)* load handling activity personnel assignments, addressing

*(-a)* individual responsibilities (e.g., location, time, and task)

*(-b)* work location hazards (e.g., pinch points)

*(-c)* communication methods

*(-d)* personal protective equipment requirements

*(-e)* qualifications of assigned personnel

*(6)* any contingency measures as determined in para. 5-2.9

*(7)* any emergency action plan as determined in para. 5-2.10

*(b)* Concerns raised during this meeting shall be addressed prior to proceeding with the load handling activity.

*(c)* At the completion of the pre-lift meeting, the lift director should confirm that the attendees understand the plan and their roles and responsibilities during the load handling activity.

*(d)* For repetitive lifts, the lift director should decide the frequency of pre-lift meetings. Pre-lift meetings may not be required prior to each repetition of the load handling activity.

## 5-4 EXECUTING THE CRITICAL LIFT PLAN

### 5-4.1 Preparation for the Load Handling Activity

The lift director should confirm that all setup and preparation requirements of the plan (see sections 5-2 through 5-3) are in place and all required inspections and tests on the LHEs and rigging equipment have been completed.

### 5-4.2 Initiating the Load Handling Activity

Immediately prior to performing the load handling activity, the lift director should ensure that either

*(a)* all requirements of the plan continue to be met and no conditions exist that would preclude implementation of the plan, or

*(b)* a deviation exists, in which case the load handling activity is not initiated until the deviation is addressed by a qualified person or the lift director determines that conditions are acceptable to allow the activity to begin.

### 5-4.3 During the Load Handling Activity

The lift director should ensure that the load handling activity continues to comply with the plan.

*(a)* If the operation deviates from the plan, the load handling activity should be stopped and evaluated to determine if

*(1)* the load handling activity can resume according to plan.

*(2)* the contingency measures can be implemented per para. 5-2.9.

*(3)* the plan can be readily modified at the site to accommodate an unexpected condition or event.

*(4)* the load handling activity can no longer be implemented as planned, requiring a modified plan to be prepared. In such cases, the load and the LHE shall be secured, if possible, until a new plan can be developed.

*(b)* Changes or modifications to the plan should be communicated to all affected load handling personnel prior to initiating the change.

*(c)* If the load handling activity is stopped for any reason, only the lift director may initiate a restart.

## 5-5 POST-LIFT REVIEW

After the completion of the load handling activity, the lift director should

*(a)* review the development, planning, and execution of the load handling activity with the load handling personnel. Items for review should include, but not be limited to, the requirements of sections 5-2 through 5-4.

*(b)* identify potential measures to improve future load handling activity.

*(c)* communicate any recommendations identified in (b) to the appropriate personnel for future consideration.

*(d)* for repetitive lifts, decide the frequency of post-lift reviews and evaluation of the lift plan. Post-lift reviews may not be required after each repetition of the load handling activity.

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# NONMANDATORY APPENDIX A
# LIFT DATA SHEET (LDS)

## A-1 INTRODUCTION

A documented lift plan may be one or more pages comprised of applicable data files, charts, schematics, and procedural instructions. Figure A-1-1 is offered as an example of a blank planning document for a single mobile crane load handling activity and may be modified by the user as required.

Similar documents can be developed for LHE performing a variety of vertical and horizontal load handling.

## A-2 LIFT DATA SHEET INSTRUCTIONS AND COMMENTARY (FIGURE A-1-1)

### A-2.1 General

A lift data sheet (LDS) summarizes the essential details of a lifting operation in a standardized, easy-to-read form. It should include

*(a)* a brief description of the operation to be undertaken

*(b)* load characteristics including weight and center of gravity

*(c)* details of the crane or other LHE to be used, including specific configuration

*(d)* a summation of the total load to the LHE

*(e)* LHE rated capacities during the relevant phases of the operation

*(f)* a comparison of total load to the LHE versus LHE capacity throughout the operation (as a percentage)

*(g)* a comparison of total load supported by the LHE's reeved load line versus the rated capacity of the reeved load line (as a percentage)

*(h)* notes outlining key operational requirements on which the validity of the data sheet is based

*(i)* a list of relevant attachments included (e.g., LHE chart extract, layout, and rigging sketches)

*(j)* any required review and approval signatures and applicable statutory requirements such as a Professional Engineer's stamp

The LDS should be designed to suit the type of operation to be undertaken (e.g., mobile crane — single lift, mobile crane — tandem/multiple crane lift, tower crane lift, overhead traveling crane lift, jacking and rolling activity, lift system, or gantry lift). It is unlikely that a single format sheet will suffice for every eventuality.

### A-2.2 Example Data Sheet

For guidance, an example of a blank lift data sheet for a lifting operation using a single mobile crane is included (see Figure A-1-1).

Crane chart capacities for mobile cranes are the load the crane is rated to support at the boom or jib head as applicable. To evaluate what percentage of that capacity it is planned to use, it is first necessary to sum the total load applied to the crane at the boom or jib head.

Note that in the case of LHE such as tower cranes or overhead traveling cranes, the situation is slightly different, as the capacity is likely to be quoted at the hook block. In all cases, follow the instructions and warnings of the manufacturer concerning the LHE's capacity and limitations and adjust your data sheet accordingly.

### A-2.3 Completing the Example LDS

**A-2.3.1 Payload and Crane Details Sections.** The first two sections, "Payload" and "Crane Details," are self-explanatory. Mark nonapplicable fields as "N/A" rather than leaving them blank (which could be construed as an omission).

The "single hoist line pull" is the rated winch line pull. "Parts line used" are the actual parts of line with which the crane is reeved for the lift (not necessarily the maximum for which it is equipped). "Reeved capacity" is the hoisting capacity as reeved, typically the parts of line times the rated single line pull. This figure is carried below.

**A-2.3.2 Load Details.** The next three subsections relate to load applied to the crane.

*(a)* Load details — the weight of the payload, any attachments to it (e.g., ladders and platforms, insulation), or contents (e.g., oil, catalyst) can be summed here to yield a total weight of the item to be lifted.

*(b)* Rigging data — the weight of rigging materials to attach the load to the crane hook is weight on the crane and has to be considered. This section allows the rigging items to be described, quantified, and summed to give a total rigging weight. If the rigging is simple, it can be placed on the Lift Data Sheet. For more complex rigging arrangements, Nonmandatory Appendix B can be used.

*(c)* Additional weight items — as applicable, allowance should be made for

*(1)* the weight of the main hook (block) being used to suspend the payload.

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*(2)* the weight of the parts of hoist line below the boom or jib head (whichever is being used), i.e., the number of parts of line being used times the longest anticipated drop from boom or jib tip to the hook block (ft) times the weight per foot of the hoist line. Check the manufacturer's manual to determine if the weight of the wire rope necessary to lift the suspended load has been accounted for in the load chart and the weight of any extra reeved parts of line need to be added as additional weight, or if all parts of line need to be accounted for as additional weight.

*(3)* jibs where fitted when using the main boom; the weight allowances to be considered vary according to whether the jib is erected, stowed, extended, or retracted — consult the manufacturer's manual.

*(4)* the weight of other suspended hooks/overhaul balls fitted and the weight of the associated suspended hoist lines.

*(5)* boom extensions/runners/auxiliary boom sheaves and other similar attachments fitted to the boom or jib (when the chart being used does not relate to their use).

Totaling the above three subtotals (payload plus rigging plus additional weight items) gives the total weight to the crane for comparison with the rated capacity.

**A-2.3.3 Crane Capacities.** The next section relates to the crane capacities. Capacity varies according not only to configuration but also to operating radius. Three columns are provided on this particular sheet allowing the user to calculate the loads at up to three different radii as applicable (e.g., hoist, swing, and place). It may however be sufficient to consider only the worst radius. For each column to be used, enter first the actual radius of operation then, unless capacity interpolation for that specific radius is allowed, the next greatest radius for which a chart capacity is quoted. The next line, "Chart Capacity," is for entering the rated capacity of the crane at the aforementioned chart radius. Ensure use of the correct chart specific to that particular crane in the particular configuration in which it is being used.

The "Total Load to Crane" divided by "Crane Capacity" yields the percentage of chart capacity being used for each radius for which the calculation is performed. Knowing this figure at up to three operating radii, the "Maximum Percentage of Chart Capacity Used" can be noted.

The total suspended load is the load supported by the main hoist lines equal to the total of "Total Weight of Item to be Lifted" plus "Total Rigging Weight" plus the weight of the hook block being used plus the self weight of the reeved hoist lines being used.

**A-2.3.4 Reeved Capacities.** The ability of the crane to hoist the load within capacity is a function of the rated line pull and the number of reeved parts of line. The load suspended on the parts of the line is the total weight of item to be lifted plus the rigging weight plus the weight of the load block, if applicable. The manufacturer's recommendations for reeved capacity should always be followed.

NOTES:
(1) The weight of a jib or boom attachments is not part of the load suspended on the reeved hoist line.
(2) In the case of cranes such as tower cranes or overhead cranes, the manufacturer may have already considered the weight of the load block when specifying a part of line capacity.
(3) Weight of the hoist line below the boom tip should be considered, where applicable.

The "Maximum Percentage of Reeved Capacity Planned to Be Used" is "Total Suspended Load (main)" divided by the reeved capacity (from above) — see the "Crane Details" section.

**A-2.3.5 Document Attachments.** This section lists documents commonly attached to an LDS (e.g., a crane layout, rigging arrangement, and crane chart extract). Not all will be relevant or required. The user should mark (check) those appended, adding to the list as required. Note the acronyms: GBP (ground bearing pressure), JHA (job hazard analysis), JSA (job safety analysis), AHA (activity hazard analysis). It is recommended that a risk analysis be undertaken. Resources such as ISO 31000 and other industry guides may be useful.

**A-2.3.6 Notes.** In this section, the user should include any further information (e.g., warnings, references, and instructions) essential to the safety of the operation. This section may also detail the crane operating mode if not adequately described elsewhere.

Included in this section are

*(a)* a line allowing the user to compare the planned imposed ground loading (typically derived from a ground bearing pressure estimator further distributed through any load-spreading mats or blocking/cribbing provided) with the permissible ground bearing pressure (as derived from geotechnical data, calculation, or other informed guidance).

*(b)* a line in which the limiting wind speed for the operation should be entered. For guidance see Nonmandatory Appendix C.

**A-2.3.7 Signatures and Approvals.** This section is to be completed by the preparer, then checked and approved by qualified and competent persons as required by governing policies (modify the sheet as required).

Where this document forms the official record of the operation, applicable legislation or contractual stipulations may require it to be stamped by a knowledgeable Professional Engineer, in which case it shall appear prominently in a relatively clear area of the sheet.

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## A-3 CRANE LAYOUT (SCHEMATIC)

The purpose of the crane layout schematic is to dimensionally locate the crane in the work area and indicate related crane information and site features so that the end user can understand how the crane is to be set up (see Figure A-3-1).

### A-3.1 Plan View

A Plan view could include the following, as applicable:

*(a)* geographic orientation (e.g., north)
*(b)* drawing scale/scale bar
*(c)* key site features (e.g., buildings and property lines)
*(d)* layout sections and detail references
*(e)* crane center and orientation including field verifiable dimensions
*(f)* front, rear and side quadrants, where relevant to capacity
*(g)* crane swing radius (tail and cab)
*(h)* load delivery and disposal locations
*(i)* weight/radii of loads
*(j)* support under the crane and load (e.g., matting, cribbing, and dunnage)
*(k)* crane description
*(l)* overhead/underground obstructions
*(m)* pedestrian and traffic control
*(n)* delivery and disposal call out
*(o)* column line, station, bent, pier, and call outs

### A-3.2 Elevation View

An elevation view could include the following, as applicable:

*(a)* drawing scale/scale bar
*(b)* locate centerline of crane with field measurable dimension
*(c)* indicate elevations
*(d)* dimension crane radius/radii
*(e)* boom lengths showing adequate lift height
*(f)* specify hook block weight and minimum parts of line
*(g)* tail swing radius
*(h)* clearances from existing structures and load set points
*(i)* cross sections showing vault, foundation wall, and influence line of load and underground structure affected by crane
*(j)* column line, station, bent, pier, and call outs
*(k)* two blocking distance
*(l)* boom and jib angles

## A-4 RIGGING DIAGRAM

The rigging diagram is used to describe the load or items to be lifted and show the configuration of the rigging equipment. The diagram should include enough detail to allow field personnel to install appropriately rated gear and reviewers to follow calculations (see Figure A-4-1).

### A-4.1 Diagram

The diagram could include the following:

*(a)* scale/scale bar
*(b)* dimensions of item to be lifted, lifting points and center of gravity
*(c)* sling size and hitch configuration
*(d)* rigging components/hardware used and key dimensions (i.e., pin diameter/hole diameter for lifting lugs)
*(e)* sling/hoist angles at critical stages of the lift
*(f)* rated capacity of rigging components and adjusted capacity as used (e.g., *D*/*d* ratio, temperature)
*(g)* loads within the rigging system and support reactions
*(h)* tension on slings/hoist, rigging hardware and BTH lifting devices
*(i)* dimensions of the overall height and length of the rigging arrangement
*(j)* accessories used (softeners, grillage, etc.)
*(k)* elevation section and detail references
*(l)* effects of friction, as applicable

**A-4.1.1** The diagram should also confirm that the centerline of the LHE lift point (i.e., boom tip or hook block) is located above the center of gravity of the load.

**A-4.1.2** The rigging planner should ensure the rigging components, geometry and lifting points are compatible.

**A-4.1.3** The rigging diagram should identify loads at the interface of the rigging system such as at load attachment points and at temporary or permanent suspension points. See para. 5-2.6(a)(5).

**A-4.1.4** The overall height and length of the rigging arrangement should also be shown on the elevation view of the LHE.

## A-5 PRE-LIFT SAFETY CHECKLIST

A pre-lift safety checklist summarizes the essential safety considerations of a load handling operation in a standardized, easy-to-read form. The checklist should include notes for outlining key safety requirements on which the validity of the checklist is based. The pre-lift safety checklist should be designed to suit the type of operation to be undertaken (e.g., mobile crane (LHE) — single lift, mobile crane (LHE) — tandem/multiple crane (LHE) lift, jacking and rolling activity, lift system, or gantry lift). It is unlikely that a single format sheet will suffice for every situation.

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### A-5.1 Example Pre-Lift Safety Checklist

For guidance, an example of a blank pre-lift safety checklist for a lifting operation using a single mobile crane (LHE) is included (see second page of Figure A-1-1). This example has been broken down into four main categories and key points per category as it applies to a single mobile crane (LHE) lift.

### A-5.2 Notes

This section allows the user to input notes that are important to the load handling activity that are not covered elsewhere.

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## Figure A-1-1
## Lift Data Sheet

### Single Mobile Crane Lift

| | | | |
|---|---|---|---|
| **Payload Name:** | | **Lift Description:** | |
| **Project:** | | **Units:** | U.S. (ft-lb) |

**Crane Details** **Manufacturer:** **Model No.**

| | | | | | |
|---|---|---|---|---|---|
| Configuration: | | Base mount type: | | Track/outrigger c/s: | ft |
| Boom type: | | Boom length used: | ft | Boom/jib angle: | deg |
| Jib type: | | Jib length used: | ft | Tail swing: | ft |
| Machine ballast: | lb | Aux. counterweight: | lb | | |
| Block capacity: | ton | Line size: | in. | | |
| Single hoist line pull: | lb | Parts line used: | | Reeved capacity: | lb |
| Heavy lift attachments: | | SL radius | ft | Superlift wt: | ton |

**Load Details** — Quantity | Wt./each | Weight | Totals

| | Quantity | Wt./each | Weight | Totals |
|---|---|---|---|---|
| Basic weight of item | | | lb | |
| | | | lb | |
| | | | lb | |
| | | | lb | |
| | | | lb | |
| **Total weight of item to be lifted** | | | | **lb** |

**Rigging Data (size, type, and capacity)**

| | | Weight | Totals |
|---|---|---|---|
| | | lb | |
| | | lb | |
| | | lb | |
| | | lb | |
| | | lb | |
| | | lb | |
| | | lb | |
| **Total rigging weight** | | | **lb** |

**Additional Weight Items**

| | | | Weight | Totals |
|---|---|---|---|---|
| Main hook | | | lb | |
| Wire rope | | | lb | |
| Other suspended hooks | | | lb | |
| Aux. boom sheaves | | | lb | |
| Jib | | | lb | |
| Other: | | | lb | |
| Other: | | | lb | |
| **Total additional weight** | | | | **lb** |
| **GROSS LOAD (sum of all items above)** | | | | **lb** |

**Crane capacities**

| | | | |
|---|---|---|---|
| | (Desc.) | (Desc.) | (Desc.) |
| **Total load to crane:** | lb | lb | lb |
| Planned Radius: | ft | ft | ft |
| Chart Radius Used: | ft | ft | ft |
| **Chart Capacity:** | lb | lb | lb |
| **% of chart capacity:** | | | |

**THE MAXIMUM PERCENTAGE OF CHART CAPACITY PLANNED TO BE USED IS %**

**Reeved Capacities:**

**Total suspended load (main):** lb **Reeved capacity:** lb

**THE MAXIMUM PERCENTAGE OF REEVED CAPACITY PLANNED TO BE USED IS %**

**Document Attachments**

| | | |
|---|---|---|
| ☐ Crane layout | ☐ Plan categorization | ☐ GBP source/calculations |
| ☐ Rigging hookup arrangement | ☐ JHA/JSA/AHA | ☐ Project scope |
| ☐ Crane chart extract | ☐ Risk evaluation | ☐ Load weight/CG source info |
| ☐ Foundation details/calculations | ☐ Wind/weather Forecast | ☐ Load/crane clearances |
| ☐ Crane cribbing arrangement | ☐ Drawing of load | ☐ |

**Notes**

**Ground Bearing Pressure:** Allowable: **Actual:**

**Max. allowable wind speed:** Allowable:

| | Name (Print) | Signature | Title | Date |
|---|---|---|---|---|
| Prepared by: | | | | |
| Checked by: | | | | |
| Approved by: | | | | |

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**Figure A-1-1**
**Lift Data Sheet (Cont'd)**

| **Pre-Lift Check** | **Yes** | **N/A** | **Personnel Check** | **Yes** | **N/A** | **LHE Setup Check** | **Yes** | **N/A** |
|---|---|---|---|---|---|---|---|---|
| Payload weight / CG verified? | | | Lift director in place? | | | Annual inspection? | | |
| Lift correctly categorized? | | | Qualified rigger in place? | | | Pre-use inspection? | | |
| Plan in place? | | | Qualified signalperson(s)? | | | Adequately supported? | | |
| Field conditions match plan? | | | Communication (hand/radio)? | | | Mats where required? | | |
| Required approvals / permits? | | | Operator certified/qualified? | | | Setup checked/level? | | |
| Weather / wind acceptable? | | | Nonessential persons out? | | | Adequate parts of line? | | |
| Power lines/undergrounds? | | | Rigger roles identified? | | | Obstructions/clearance? | | |
| Site control / area barricaded? | | | Other roles identified? | | | Configuration correct? | | |
| Contingency plan needed? | | | Qualified person present? | | | Controls / functions OK? | | |
| Emergency plan needed? | | | Pre-lift meeting held? | | | Services / ancillary eqpt.? | | |

| **Rigging Check** | **Yes** | **N/A** |
|---|---|---|
| Correct rigging? | | |
| Rigging inspections current? | | |
| Inspected before use? | | |
| Rigging correctly assembled? | | |
| Softeners used as needed? | | |
| Rigging properly tagged? | | |
| Sling angles acceptable? | | |
| Sling tension acceptable? | | |
| Length of rigging acceptable? | | |
| Obstruction/clearance? | | |
| *D*/*d* ratio adequate? | | |
| Lift points identified? | | |
| Lift points visually inspected? | | |
| Tag lines? | | |
| Height of rigging acceptable? | | |

**NOTES:**

**PRE-LIFT BRIEFING**

I confirm that the rigging design has been explained to me, that we have discussed it, and that I understand the operation and my role and responsibilities.

| **NAME (PRINT)** | **SIGNATURE** | **CRAFT/TRADE** |
|---|---|---|
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| **NAME (PRINT)** | **SIGNATURE** | **LIFT DIRECTOR** |
|---|---|---|
| | | |

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**Figure A-3-1**
**Crane Layout (Schematic)**

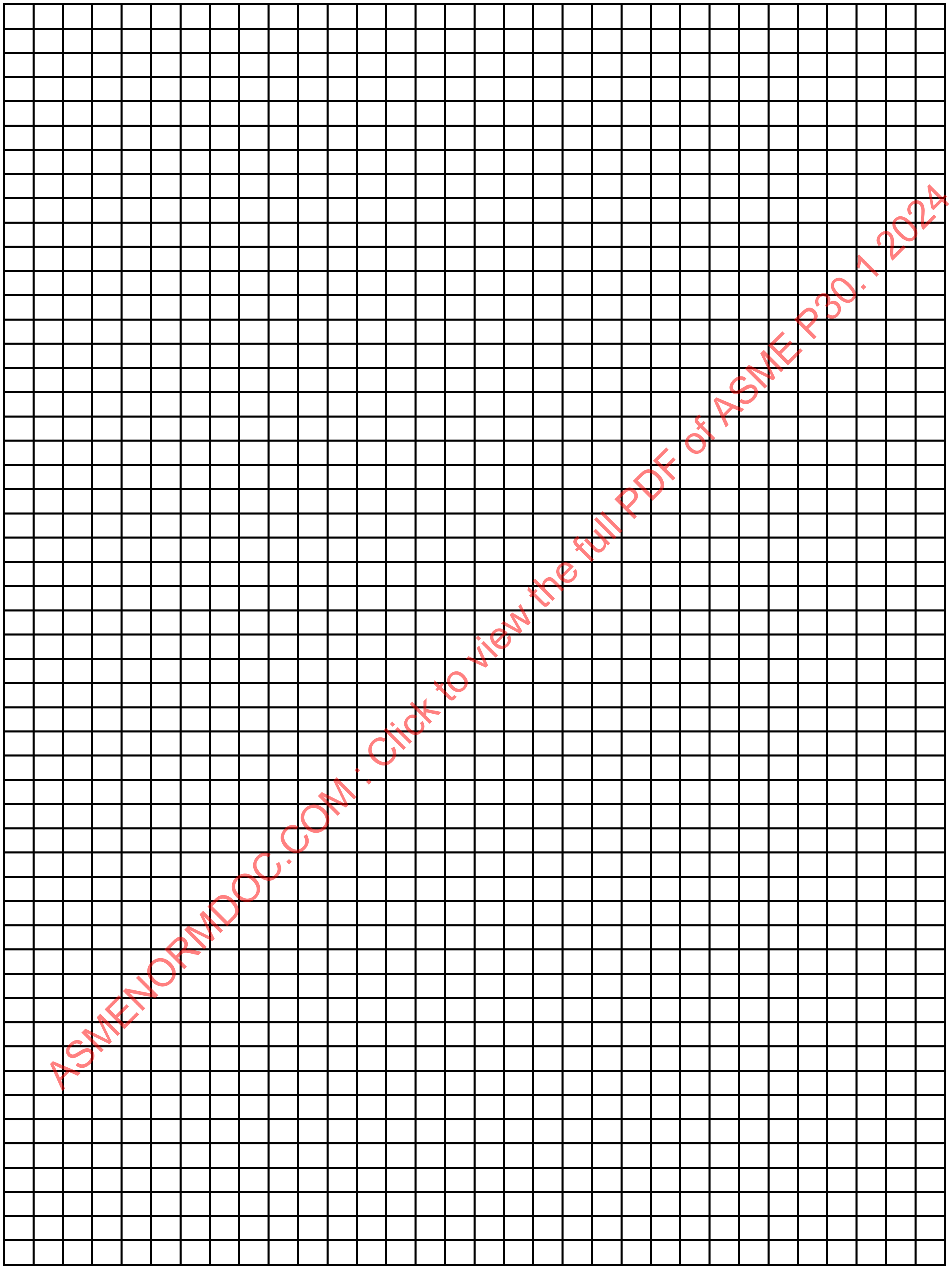

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**Figure A-4-1**
**Rigging Arrangement (Schematic)**

LIFT SEQUENCE

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# NONMANDATORY APPENDIX B RIGGING DATA SHEET (RDS)

## B-1 RIGGING DIAGRAM

The rigging diagram is used to describe the load or items to be lifted and configure the rigging equipment. The diagram should include enough detail to allow field personnel to install appropriately rated gear and reviewers to follow calculations.

Figure B-1-1 is offered as an example of a blank planning document for a single rigging activity and may be modified by the user as required. This document can be used in conjunction with Nonmandatory Appendix A or as a standalone planning document for when a crane or similar LHE is not incorporated in a lift plan (e.g., operations using chain hoists, jacks, and industrial rollers).

### B-1.1 Diagram

The diagram could include the following:

*(a)* scale/scale bar

*(b)* dimensions of item to be lifted, lifting points and center of gravity

*(c)* sling size and hitch configuration

*(d)* rigging components/hardware used and key dimensions (i.e., pin diameter/hole diameter for lifting lugs)

*(e)* sling/hoist angles at critical stages of the lift

*(f)* rated capacity of rigging components and adjusted capacity as used (e.g., *D*/*d* ratio, temperature)

*(g)* loads within the rigging system and support reactions

*(h)* tension on slings/hoist, rigging hardware and BTH lifting devices

*(i)* dimension the overall height and length of the rigging arrangement

*(j)* accessories used (softeners, grillage, etc.)

*(k)* elevation section and detail references

*(l)* effects of friction, as applicable

*(m)* revision date

**B-1.1.2** The diagram should also confirm that the centerline of LHE lift point (i.e., boom tip or hook block) is located above the center of gravity of the load.

**B-1.1.3** The rigging planner should ensure the rigging components, geometry, and lifting points are compatible.

**B-1.1.4** The rigging diagram should identify loads at the interface of the rigging system such as at load attachment points and at temporary or permanent suspension points. See para. 5-2.6(a)(5).

## B-2 RIGGING DATA SHEET INSTRUCTIONS AND COMMENTARY

### B-2.1 General

A rigging data sheet (RDS) summarizes the essential details of a rigging operation in a standardized, easy-to-read form and should be designed to suit. It should include the following:

*(a)* a brief description of the operation to be performed

*(b)* lift type (e.g., vertical, horizontal, or slope)

*(c)* load characteristics including weight, center of gravity, and lift point location

*(d)* details of the rigging/hardware to be used including specific configuration

*(e)* a summation of the total load to the rigging/hardware

*(f)* a comparison of total load to the rigging/hardware versus rigging/hardware capacity

*(g)* below-the-hook (BTH) lifting device details

*(h)* a list of relevant attachments included (e.g., load weight, center of gravity source, and LHE specs)

*(i)* any required review and approval signatures and applicable statutory requirements such as a Professional Engineer's stamp

*(j)* detail diagram

### B-2.2 Example RDS

For guidance, an example of a blank RDS for a lifting operation is included (see Figure B-2.2-1).

### B-2.3 Completing the Example RDS

**B-2.3.1 Type of Lift.** Indicate whether the load will be lifted vertically or will be moved horizontally. If moved horizontally, indicate the percentage of slope in degrees and the anticipated coefficient friction (drag). Mark nonapplicable fields as "N/A" rather than leaving them blank (which could be construed as an omission).

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**B-2.3.2 Load.** Enter the load dimensions. State whether the center of gravity is located in the center of the load (symmetrical) or is the center of gravity offset on the load. Report that center of gravity is above or below the lift points and that stability has been checked.

**B-2.3.3 Rigging Data.** The next four subsections relate to load applied to the external supports.

*(a) Load Details.* Enter the weight data for the load. Indicate whether the weight is actual or estimated. Enter a detailed description of the load and its components with individual weights and total weight.

*(b) Slings.* Indicate if slings are used and the type, size, rated capacity and actual load, quantity, and weight of each; provide a total weight of slings.

*(c) Hardware.* Indicate the type of rigging hardware (eye bolts, shackles, etc.) to be used. Provide rated capacity and actual load, quantity, weight of each item, and total weight of hardware.

*(d) Below-the-Hook Lifting Devices.* Indicate the below-the-hook (BTH) lifting devices (spreader bars, beam clamps, etc.) to be used. State the BTH category (A or B) of the devices as well as the rated capacity, actual load, quantity, and weight. Provide a total weight of all BTH lifting devices and report if a load test was certified by a qualified person. Totaling the above four subtotals gives the total weight to the external supports for comparison with the rated capacity.

**B-2.3.4 Document Attachments.** This section lists documents commonly attached to an RDS (e.g., rigging diagram, load information). Not all will be relevant or required. The user should mark (check) those appended, adding to the list as required. It is recommended that a risk analysis be undertaken. Resources such as ISO 31000 and other industry guides may be useful.

**B-2.3.5 Notes.** In this section, the user should include any further information (e.g., warnings, references, and instructions) essential to the safety of the operation.

**B-2.3.6 Signatures and Approvals.** This section is to be completed by the preparer, then checked and approved by qualified and competent persons as required by governing policies (modify the sheet as required).

Where this document forms the official record of the operation, applicable legislation or contractual stipulations may require it to be stamped by a knowledgeable Professional Engineer, in which case it shall appear prominently in a relatively clear area of the sheet.

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**Figure B-1-1**
**Rigging Arrangement (Schematic)**

LIFT SEQUENCE

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## Figure B-2.2-1
## Rigging Data Sheet

**Payload Name:** ______ **Lift Description:** ______

**Project:** ______

**Date:** ______ **Date planned:** ______

**Load Handling Equipment**

| | | | | | |
|---|---|---|---|---|---|
| ☐ | Mobile crane | ☐ | Tower crane | ☐ | Overhead crane |
| ☐ | Derrick | ☐ | Fork lift | ☐ | Chain fall |
| ☐ | Hoist | ☐ | Jack | ☐ | Other |

**Type of Lift**

☐ Vertical lift ☐ Horizontal lift

Slope (%, deg): ______

Coefficient of friction: ______

**Load**

Dimension: Length: ______ ft
Width: ______ ft
Height: ______ ft

Center of Gravity's Location:
☐ Symmetrical
☐ Offset ______
☐ Above the rigging lift point
☐ Below the rigging lift point
If below, has stability been checked? ______

☐ Actual (source): ______
☐ Estimated (source): ______

| Description | Quantity | Wt./each | Weight | Total |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

Total weight of item to be lifted ______

**Rigging Data**

Slings

| Type | Size | Rated load | Applied load | Quantity | Wt./each | Weight |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Total slings weight ______

Hardware

| Type | Size | Rated load | Applied load | Quantity | Wt./each | Weight |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Total hardware weight ______

Below-the-Hook Lifting Device (per ASME B30.20) if applicable

| Type | Rated load | Applied load | Quantity | Wt./each | Weight |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

Total below-the-hook weight ______

Below-the-Hook Lifting Device: ☐ Load tested (if applicable) ☐ Certified by qualified person
☐ Lifter specifications and drawings

RIGGING WEIGHT

**TOTAL WEIGHT:** ______ **lb**

**Document Attachments (As Needed)**

| | | | | | |
|---|---|---|---|---|---|
| ☐ | Rigging procedure | ☐ | Lift plan | ☐ | Rigging specifications |
| ☐ | Load weight/CG source info | ☐ | JHA/JSA/AHA | ☐ | Lifter specs and drawings |
| ☐ | Drawing of load/lift points | ☐ | Risk evaluation | ☐ | Rigging sketch |

**Notes** ______

| | Name (Print) | Signature | Title | Date |
|---|---|---|---|---|
| Prepared by: | | | | |
| Checked by: | | | | |
| Approved by: | | | | |

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# NONMANDATORY APPENDIX C
# ESTABLISHING A LIMITING WIND SPEED

## C-1 INTRODUCTION

The purpose of this Appendix is to provide guidance in establishing a limiting wind speed (LWS) for a load handling activity (LHA) as part of the lift-planning processes outlined in this Standard. The scope includes

*(a)* assessment of wind forces on loads being handled and the effects those forces have on the load handling equipment (LHE)

*(b)* securing the load after landing

*(c)* contingency planning

*(d)* preparing for out-of-service winds and the control of loads subject to wind forces

## C-2 RESPONSIBILITIES

*(a)* Planning for wind during an LHA requires knowledge of the LHE limitations, site conditions, load characteristics, and rigging method.

*(b)* Multiple parties may share planning responsibility, and one person may have more than one responsibility. Those involved in preplanning for wind may include the Engineer, Lift Planner, LHE User, and General Contractor/Construction Manager. Those involved in task planning may include the Lift Director, LHE Operator, Rigger, and Site Supervisor.

*(c)* Those involved in preplanning should remain available for future reference.

## C-3 GUIDANCE FOR LIFT PLANNERS

*(a)* When developing a plan for an LHA in an area subject to wind, the lift planner should establish an LWS for the activity. The LWS should be sufficiently low to ensure the safe operation of the LHE and the safe execution of the LHA, and to ensure that control and stability of the load are maintained throughout the activity. The planned LWS should not exceed the maximum wind speed specified by the LHE manufacturer for the LHE as configured and should not result in wind forces being imparted into the LHE, the load, or the supporting environment in excess of their design parameters.

*(b)* Wind forces act on both the LHE and the load being handled. The LHE manufacturer normally provides a maximum operating wind speed; however, dependent on the design, this may not consider the effects of forces transferred into the LHE by wind acting on the load being handled. These effects may be reason to reduce the LWS for the activity.

*(c)* Further considerations include the effect of wind forces acting on the load regarding control, stability, and strength; these may be reason to further reduce the LWS.

*(d)* The guidance of a qualified person should be followed when

*(1)* custom LHE is involved

*(2)* the LHE manufacturer wind guidance is not available

*(3)* assessing the wind forces on an object is complex

*(4)* wind effects on the LHE are difficult to assess

*(e)* The flowchart and associated narrative contained in section C-9 provide a logical process map to guide the user in establishing an LWS and thereby mitigate wind hazards.

## C-4 EFFECTS OF WIND FORCES ON THE LHE

*(a)* Regarding the LHE itself, in most cases the LHE manufacturers will provide maximum operating wind speeds for their equipment either in the operating manual or on the load charts. A general figure may be quoted or there may be a specific wind speed for each configuration. In the case of cranes with long booms, jibs, or both, the permissible wind speed will likely decrease with increasing length. The manufacturers may also recommend, or require, shutting down the LHE and making the LHE safe under specific conditions.

*(b)* The effect of the wind acting on the LHE varies with wind direction. Figure C-4-1 shows the different ways the wind affects a crane and a suspended load when it blows from the side, from behind, or from the front.

*(c)* Considerations for wind from the side of the boom. When the wind is from the side

*(1)* boom strength is a major factor.

*(2)* the wind creates lateral loading on the boom.

*(3)* the wind forces on the suspended load are transferred horizontally into the boom or jib head through the hoist ropes, independent of the elevation of the load.

*(4)* the wind acts to rotate the upper works of the crane. The LHE operator might need to compensate for this tendency to swing.

*(5)* wind forces on the load and LHE may increase LHE support loads.

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*(d)* Considerations for wind from rear of the boom. When the wind is from behind a crane

*(1)* the wind applies a force to the boom, jib, and load that adds to the overturning moment of the LHE and may affect the forward stability

*(2)* the wind effect on the load increases the load radius in the plane of the boom/jib, effectively reducing rated capacity

*(e)* Considerations for wind from front of the boom. When the wind is from the front of the boom

*(1)* it reduces backwards stability. For a crane operating with the boom/jib approaching the maximum boom angle, the force could cause the boom/jib or the entire crane to tip backwards.

*(2)* wind acting on a suspended load decreases the load radius and can reduce clearances to the boom/jib, potentially creating the risk of contact.

*(f)* Considerations for wind on wheel- or rail-mounted LHEs. Wind acting on the load or structure of the LHE may cause unexpected movement along the travel paths.

## C-5 EFFECTS OF WIND ON A LOAD

*(a)* When planning an LHA, it may be necessary to assess the wind forces acting on the load to determine whether they are of a magnitude that could affect the integrity of the load or make it difficult to control.

*(b)* The wind force acting on the load itself is a function of wind speed, surface area, and shape of the load. The weight of the load, the location of the center of gravity, and the location of the lift points are also very important to identify. The lighter the load and greater its surface area, the more difficult it may be to control.

*(c)* The wind pressure on a load may not be uniform (e.g., consider a modular electrical house; a closed recess in a flat wall may have an increased pressure while on an inclined roof the pressure may be reduced). This may alter with rotation of the load, LHE, or both. Section C-7 provides guidance on evaluating wind forces on a load.

*(d)* The center of wind pressure acting on a suspended load may not lie on the axis of suspension, e.g., if the center of area of panel is not coincident with its center of gravity as shown in Figure C-5-1.

The wind load acting to one side of the line of suspension will result in the load wanting to rotate until the center of area lies directly downwind of the suspension. This rotational effect can be considerable and the forces required to oppose it large. This possibility should be accounted for in planning for the LHA.

## C-6 EFFECTS THAT WIND FORCES ON HANDLED LOADS HAVE ON LHE

*(a)* Wind acting on the load creates forces that are passed into the LHE; these act in conjunction with the forces acting on the LHE itself. In the case of a load suspended from a crane, the forces are transmitted through the suspension at the boom/jib tip sheaves; in the case of heavy transport, the forces are transmitted through friction at the supporting surface and lashing or restraints. These combined forces have effects on the LHE and its support that must be assessed. Typically, the user assesses the forces and determines whether the LHE can safely withstand the forces or the LWS should be reduced. When in doubt, consult the manufacturer or a qualified person.

*(b)* When a freely suspended (unrestrained) load hanging from an LHE is subject to a steady lateral wind force, the load moves downwind and the suspension takes up an out-of-plumb angle. The load comes to a new static equilibrium when the horizontal component of the tension in the suspension equals the wind force.

*(c)* The greater the wind force and the lighter the load, the greater the resulting angle adopted. The distance the load moves to achieve this angle is determined by the suspension length (and the angle). Dependent on wind direction, this movement may increase or decrease the operating radius.

*(d)* The angle of the suspension transfers the wind load acting on the load up to the tip of the supporting structure where the horizontal force is resisted. The direction in which this force acts is determined by the wind direction relative to the LHE. Note that this force may be additive to inertial effects from swinging. As a result of the inclination, the suspension is less effective in supporting the vertical weight of the load and so the tension in the suspension is increased slightly. Note that an unrestrained load will tend to swing in the wind, particularly if it is gusting, creating dynamic forces.

*(e)* Possible adverse effects on an LHE of these forces include but are not limited to

*(1)* pendulation (swinging of the load).

*(2)* collision with the LHE structure (potentially causing damage or even failure).

*(3)* increase in load radius (which may take the LHE out of capacity).

*(4)* side loading on the LHE structure (which together with other operational forces may exceed permissible limits).

*(5)* increased loading in the plane of the LHE structure (which together with other operational forces may exceed permissible limits).

*(6)* load weather vaning in an uncontrolled fashion, i.e., turning at the load's attachment point to present its smallest area side to the wind; this can present a collision hazard. Please refer to Figure C-6-1.

## C-7 CALCULATING LIMITING WIND SPEED FOR LHE WITH SUSPENDED LOADS (24)

If a suspended load presents a large area to the prevailing wind it may be necessary to calculate or reevaluate the LWS for the LHA; this is particularly so when the area is large relative to the weight of the load.

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The following equations can be used to calculate reference values, such as wind pressure and wind force occurring during an LHA. Manufacturer's specific instructions for the LHE being used take precedence.

*(a)* The wind pressure, $q$, created by wind velocity, $V$, acting on an object can be calculated for a specific maximum wind speed (the proposed LWS at the load). The equation to determine wind pressure, $q$, is the following, with $V$ measured in mph:

$$q = 0.00256V^2\left[\mathrm{lb/ft^2}\right]$$

*(b)* The wind area, $A_s$ (sail area), of a load ($\mathrm{ft}^2$) is the surface area of the load presented to the wind. Wind forces are greatest when the wind acts normal (perpendicular) to that area.

*(c)* The drag area, $A_w$, is a function of the wind area and the shape of the object. The drag area is usually expressed as a product of the wind area, $A_s$, and the drag coefficient, $C$ (also referred to as the shape factor or force coefficient), appropriate to the shape of the object. ASCE 7, chapter 29 offers coefficients for several different structure types and geometries. The drag area of an object is given by the following equation:

$$A_w = A_sC\left[\mathrm{ft^2}\right]$$

*(d)* The wind force, $F$, is the external force acting on an object caused by wind during the LHA. Typically, it is suggested to start by calculating the wind forces using the wind velocity that the LHE manufacturer specifies as the LWS for the LHE itself. Check whether those forces are satisfactory for stability and control of the LHE and, if not, reduce the LWS and repeat until the wind forces are sufficiently low. The wind force acting on an object is given by the following equation:

$$F = qA_w\left[\mathrm{lb}\right]$$

*(e)* For some LHE, the LWS is defined based on an assumed drag area proportional to the lifted weight. The equations in this section are examples that may be used as supplementary tools for planning. They are not a substitute for the manufacturer's instructions. The user should confirm with the LHE manufacturer or a qualified person as to the applicability of the equations below.

For this LHE, there is an allowable area exposed to wind, $A_{\mathrm{allow}}$, which is the sail area accounted by the LHE manufacturer during the design process. $A_{\mathrm{allow}}$ can be calculated by multiplying the load chart capacity (LC) of the LHE at the specific configuration times the area exposed to wind per mass (weight) unit $A_{\mathrm{unit}}$. For LHE designed per EN 13000, $A_{\mathrm{unit}}$ is 1.2 $\mathrm{m^2/mton}$ (0.00586 $\mathrm{ft^2/lb}$). For mobile and locomotive cranes supporting objects with a drag area $A_w$ larger than the sail area accounted by the manufacturer $A_{\mathrm{allow}}$, the LWS can be expressed as follows:

$$\mathrm{LWS} = \mathrm{LWS_{CHART}}\sqrt{\frac{0.00586\frac{\mathrm{ft}^2}{\mathrm{lb}}\cdot M}{A_w}}\ [\mathrm{mph}]$$

$$\mathrm{LWS_{CHART}}\sqrt{\frac{1.2\frac{m^2}{mton}\cdot M}{A_w}}\ [\mathrm{m/s}]$$

$$\mathrm{LWS} \le \mathrm{LWS_{CAHRT}}$$

$\mathrm{LWS_{CHART}}$ is a general or configuration-specific maximum permissible wind speed per manufacturer specifications. The calculated LWS must always be less than or equal to $\mathrm{LWS_{CHART}}$. The last component of the equation is the load mass effect, $M$. This value depends on the manufacturer's approach. For some manufacturers, the value to be used is the load chart capacity (LC). For others, the value to be used is the hoisted gross weight suspended from the LHE. Consult with the LHE manufacturer or qualified person to determine the proper multiplier.

## C-7.1 Limiting Wind Speed Calculation Steps for Mobile and Locomotive Cranes

The following calculation steps can be used to evaluate the manufacturer's provided maximum permissible wind speed, $\mathrm{LWS_{CHART}}$, and determine whether a derate is required based on the payload's geometry, dimensions, (large sail area), and hoisted gross weight. The calculated wind speed will be the established LWS for the LHA. The calculation steps are valid for mobile and locomotive cranes designed per EN 13000 only. See Figure C-7-1.

*Step 1.* Establish the LC for the LHA based on the LHE configuration (see Figure C-7-2).

*Step 2.* Calculate the allowable area exposed to wind, $A_{\mathrm{allow}}$. Multiply LC by $A_{\mathrm{unit}}$.

*Step 3.* Calculate the drag area, $A_w$, for the suspended payload. The drag coefficient will vary based on the payload's geometry.

*Step 4.* Compare $A_w$ to $A_{\mathrm{allow}}$, and determine whether the LWS needs to be calculated.

*(a)* If $A_{\mathrm{allow}}$ is greater than the $A_w$, then the LHE maximum permissible wind per manufacturer's specification, $\mathrm{LWS_{CHART}}$, does not need to be reevaluated.

*(b)* When the allowable area exposed to wind, $A_{\mathrm{allow}}$, is less than the drag area, $A_w$, then a new LWS must be calculated. The derated wind speed will take into account the payload's sail area.

*Step 5.* Find the permissible wind speed per manufacturer specifications, $\mathrm{LWS_{CHART}}$. This value can be load chart specific or configuration/model specific. Consult with the LHE manufacturer for additional information.

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When the $LWS_{CHART}$ does not need to be reevaluated, then $LWS_{CHART}$ is established as the LWS for the LHA.

*Step 6.* The value to be used for the load mass effect multiplier, *M*, is specific to the manufacturer's approach to calculating limiting wind speed. Consult with the LHE manufacturer or qualified person to determine the proper multiplier.

*Step 7.* For payloads with $A_{allow}$ less than $A_w$, the established LWS equation provided in section C-7 can be used. The calculated LWS must always be less than or equal to the $LWS_{CHART}$.

*Step 8.* Calculate the wind pressure, *q*.

*Step 9.* Calculate the wind force, *F*, acting on the payload for additional lift-planning parameters.

## C-8 LOAD CONTROL

*(a) Suspended Loads and Taglines.* The lift planner should always consider how a freely suspended load, being acted on by the wind, is to be controlled to avoid uncontrolled movement and the associated hazards. Taglines shall be used where hazards exist to employees and should always be used where they would serve a useful purpose in controlling a suspended load.

*(1)* Taglines are used to

*(-a)* oppose uncontrolled rotation of a freely suspended load as it is lifted, maneuvered, or relocated under the influence of forces such as wind acting on it

*(-b)* alter the rotational attitude of a suspended load as it is guided along a path, or to position it in a particular attitude

*(-c)* avoid the need for persons to put their hands directly on a load to control it where that would pose a hazard, allowing distance between them and the load

*(2)* Taglines are not to be used to

*(-a)* pull a load out of its natural suspended line, thereby inducing in-haul or out-haul of the load lines

*(-b)* hold a load against wind forces trying to push it out of line

*(-c)* contribute to supporting the load

*(3)* Two opposing taglines may be required to adequately control a suspended load. They should be of adequate length to maintain an angle to the horizontal of approximately 45 deg or less and should be attached as far as possible from the *C* of *G* and as square as possible to the face for maximum effectiveness. Refer to Figure C-8-1 for an illustration of effective tagline use.

*(4)* The size and shape of the suspended load, the way its area is disposed relative to the line of suspension, and its weight together with the wind speed at the height of the load all determine the wind force on the suspended load and its tendency to rotate. A large flat-sided light object will, for instance, be more likely to swing and rotate, whereas a heavy cylindrical shape of a similar area will be much less likely to swing and weather vane. These factors should be taken into consideration when establishing an LWS for the activity.

*(b) Supported Loads*. The effect of wind loads on large structures on transport equipment should also be considered. Horizontal wind forces acting on the load will cause a rotational effect that can change the load distribution within the suspension arrangements of a trailer; inclination, overload, or instability may be induced as a result. Lashing and securing loads may be affected. Note also that potentially dangerous sway may be induced.

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## C-9 ESTABLISHING AN LWS FOR AN LHA

*(a)* Figure C-9-1 is a process flowchart providing guidance in establishing an LWS for an LHA. The required information includes the following:

*(1)* the shape and area of the load to be handled

*(2)* the LHE to be used and its configuration

*(3)* the environment in which the LHA is to be conducted

*(4)* historical wind data for the locale (where available)

*(5)* the intended travel path of the load and any obstructions

*(b)* If the LHE is a nonstandard engineered device or is a standard device used in a nonstandard configuration, it will be necessary to seek subject matter expertise from the manufacturer/designer of the LHE or from a qualified person to establish an LWS. The following paragraphs elaborate on the flowchart; the numbers below refer to the blocks in Figure C-9-1. If the LHE is configured within the manufacturer's specifications and guidelines for the required LHA, proceed as follows:

*(1) Box 1.* The LHE manufacturer should provide an LWS for the LHE as configured. This information is routinely found in machine manuals, posted operating data, or planning software, and may vary by machine configuration.

*(2) Box 2.* Depending on the LHE design, the manufacturer-defined LWS might include some allowance for wind forces on the suspended load and there should be stipulations regarding the maximum wind area included in the chart capacities. The manual for the LHE should state whether this is the case or not. The manufacturer may also define limitations on lateral forces from the wind acting on the LHE.

*(3) Box 3.* If a specific chart capacity is subject to the wind area of the load being below a stated maximum value, determine if the wind area of the load exceeds that value. If it does, find out if the manufacturer provides a formula by which a load of that area can be lifted at a reduced LWS. If a formula is provided, a qualified person should use it to recalculate a lower LWS then proceed to Box 7. If no formula is provided, it will be necessary for a qualified person to assess the wind force on the load at the planned operational wind speed and its effect on the LHE. See Box 4. If the manufacturer does not provide a

maximum wind area for the LWS, proceed directly to Box 7.

*(4) Box 4.* In some cases, the manufacturer might simply provide a general LWS for the LHE, which includes no specific provision for imposed forces resulting from the effects of wind on the load, leaving it to the user to assess the wind forces on the load at the planned operational wind speed and their effect on the LHE. In other cases, it might be necessary to determine an LWS for the operation that is less than the general LWS. If the manufacturer doesn't provide applicable general guidance, the user should seek specific technical advice from the LHE manufacturer or a qualified person.

*(5) Box 5.* Maximum wind speeds quoted by the LHE manufacturer are typically intended to be those indicated at the highest point of a lifting apparatus, e.g., a crane boom or jib head. The suspended load will be at a lesser elevation, and the wind speed acting on the suspended load may be different (usually lower) in which case applying the "crane" wind speed to the suspended load will be conservative. However, local effects such as wind funneling can raise the wind speed on the load, where such conditions exist; this must be considered.

*(6) Box 6.* If the steps followed so far do not allow the determination of an LWS, it may be necessary to calculate the wind force on the suspended load and make an engineering judgment as to whether the LHE can safely withstand its magnitude. Section C-7 provides guidance in calculating the wind forces on suspended loads.

*(7) Box 7.* Knowing the predicted wind speed acting on the load, the resulting wind forces on the load can be calculated and their effects when transferred into the LHE assessed to determine whether they are within LHE acceptable limits. If the site personnel cannot readily assess the effect of the wind speed on the LHE and determine that it is within acceptable limits, they should seek the advice of the manufacturer or qualified person. A determination should be made as to whether the LWS should be reduced. If it is necessary to reduce the LWS, go back to Box 4 and repeat. Once an acceptable LWS has been established for the LHE with suspended load, go to Box 8.

*(8) Box 8.* Once a safe LWS for the LHE is established, it is also necessary to ensure that the suspended load can be controlled at that wind speed. The following should be considered:

*(-a)* wind forces (including gusts) acting on the suspended load at the safe LWS

*(-b)* the size and shape of the load

*(-c)* maintaining control without causing harm to personnel

*(-d)* the environment

*(-e)* clearances to the load and its surroundings

These considerations might require that the LWS for the operation be lowered even further to ensure it is within acceptable levels. An established LWS that is satisfactory for the LHE and the load should be included in the plan for the LHA, together with necessary monitoring and other control measures.

*(c)* Following the steps in the process map should allow an LWS to be established for the operation at which the LHE can be operated within its design limits and the load can be safely controlled. That LWS is an essential element of the plan for the LHA.

*(d)* The LHA should only commence if the wind speed at the location of the activity (adjusted for height at the top of the LHE) is predicted not to exceed the established LWS for an adequately long window of time in which to complete the LHA safely.

The LWS is only one factor affecting the safety of an LHA. Calculation of a planned LWS, and confirmation that wind speed conditions at a work site are within the planned LWS, shall not supersede other concerns participants may have about the site conditions and the safety of the LHA.

## C-10 WIND VELOCITY — PLANNED AND MEASURED

This section provides guidance on forecasting wind speeds, and measuring the wind speed, and the effects of gusting, and wind funneling. The following effects should be considered:

*(a)* Local weather information provides the forecast for sustained wind velocity and wind gust at a standard elevation of 10 m (33 ft) above the ground surface, assuming an open environment.

*(b)* National Oceanic and Atmospheric Administration (NOAA) defines "wind" as the horizontal motion of the air past a given point. Wind describes the prevailing direction from which the wind is blowing with the speed given usually in miles per hour or knots. It may be a 2-min average speed (reported as wind speed) or an instantaneous speed (reported as a peak wind speed, wind gust, or squall). Sustained wind velocity is the average wind speed steadily maintained over a period of 10 sec. Wind gusts are defined as rapid fluctuations in the wind speed with a variation of 10 knots (11.5 mph) or more between peaks and lulls. The speed of the gust is the maximum instantaneous wind speed maintained up to 3 sec.

*(c)* Wind speed is reduced by the force of interaction with the ground surface, and generally increases as distance above the ground increases. Wind speed varies with height, local terrain, and ground surface roughness conditions (e.g., buildings, vegetation).

*(d)* The wind velocity that the LHE manufacturer is typically referencing is that measured at the highest point on the LHE, whereas as noted above wind forecasts obtained from official sources are typically referenced at 10 m (33 ft) above grade in an open environment and may therefore need to be adjusted for height and location to be a useful predictor. Historical data from the jobsite, measured at height, is very useful (where available).

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(e) Ideally, the wind velocity at the load is measured at the same height as the load is (or will be) above the ground. Supplemental anemometer devices can be used to measure wind velocities located at or about this height to verify that the wind is at, or below, the maximum velocity for which the LHA is planned. Anemometers are commonly used wind sensors that are mounted at the desired elevation of the load. They either wirelessly transmit the wind velocity to a device in the LHE or are monitored by the lift director, operator, or a designated person. The range, responsiveness, and accuracy of the wind sensor device should be capable of reporting the anticipated wind speed and wind gusts during the LHA in a timely manner.

(f) Wind speed is affected by localized conditions, which can affect the magnitude, direction, or both, depending on site conditions. Funneling effects, which increase the magnitude of wind velocity or change its direction, can result from the reflection or amplification of wind off adjacent buildings, vegetation, or other site conditions.

## C-11 LHE OUT-OF-SERVICE DISPOSITION

Out-of-service disposition refers both to the ordinary preparation of an LHE before it is to be left unattended at the end of a shift and to exceptional preparations that are infrequently necessary in advance of a severe wind. Commonly, an LHE manufacturer will specify both.

(a) Ordinary preparations might include measures to secure the LHE in an optimal configuration and orientation with its mechanisms in safe mode. A telescopic crane, for instance, would be scoped in, or a tower crane slew brake released, to allow for weather vaning. Operating personnel on duty in every shift should be familiar with these ordinary preparations and complete them daily.

(b) In anticipation of severe wind, some LHEs must be taken out of harm's way or preparations made to weather the storm (e.g., a lattice mobile crane boom might be lowered to the ground or a gantry crane tied down in a designated parking location). In these instances, planners must specify the wind threshold for action and the response necessary to secure the LHE. The fundamental requirements for the plan usually comes from the LHE manufacturer, but might also be from a qualified person. Site Supervisors should have the following responsibilities:

(1) be aware of the wind limitations and the necessary response

(2) monitor forecasts

(3) maintain site conditions compatible with the execution of the response

(4) ensure designated personnel are qualified and available to carry out the response

(5) coordinate with public authorities or other appropriate entities if notifications, clearing of space, or access is needed

## C-12 ASSESSING WIND FORCES ON LHE — SEMIPERMANENT INSTALLATIONS

(a) If an LHE is a semipermanent installation (e.g., strand jack tower system, tower cranes) and cannot be lowered in the event of high winds, the structure should be designed so that it can withstand

(1) out-of-service wind forces on the LHE

(2) in-service wind forces on the LHE and suspended load during the LHA at the defined LWS

(b) Determining the magnitude of design wind loads imposed on a structure should follow an established standard such as ASCE 7 or a similar standard.

(1) A design wind speed is determined on the basis of limiting the probability of it being exceeded during the design life of the structure.

(-a) The procedure requires that a basic wind speed be selected for the locale where the LHE is installed. ASCE 7 provides wind maps for this purpose. In some instances, the basic wind speed is dictated by the local authorities.

(-b) The wind speeds on the ASCE 7 wind maps are intended for permanent structures. When designing for shorter duration construction periods, wind speeds associated with the same probability of exceedance would be less. ASCE 37 takes this into consideration. ASCE 37 allows a reduction factor to be applied to the basic wind speed based on the duration of construction.

(2) Once a design wind speed for exceptional winds is determined, the equations in ASCE 7 may be used to determine the design wind pressure. Factors to be accounted for include the exposure category, height above ground, gust factor, wind directional factor, and the object geometry (force coefficient). The result is a design wind pressure to be applied in the analysis. This pressure can be used to assess whether the LHE installation has sufficient strength and stability for the local wind climate.

(c) Engineered lift systems may require analysis of the out-of-service condition and the establishment of an LWS on a case-by-case basis by a qualified engineer.

## C-13 SECURING THE LOAD AFTER LANDING

The load should be secured as soon as practical after it has landed at the desired location. The method selected for securing the load should be capable of restraining the load during the full range of wind velocities that may occur or are anticipated to occur while the load remains at the location. The load should not be detached from the LHE until the designated person confirms that the load is in the correct location and is adequately supported and secured (e.g., guy wires, temporary bracing, and blocking).

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## C-14 CONTINGENCY PLANNING

Wind is highly variable by nature and thus could increase in velocity or change direction without notice. The lift planner should develop a contingency plan that includes measures to control the load, to land and secure the load in an alternate location, and to secure the LHE. The plan should be such that site personnel will be able to implement it immediately should the need arise. The plan should address the following scenarios:

*(a)* The forecast predicts a wind speed at which an out-of-service LHE must be secured (per manufacturer guidelines or legislative requirements).

*(b)* A revised forecast predicts that the wind speed will exceed the LWS during an ongoing LHA.

*(c)* The measured wind speed is close to or exceeds the LWS.

*(d)* An unattended LHE.

## C-15 PERSONNEL LIFTING

For LHAs involving the lifting of personnel, regulatory agencies may require, and/or company- or site-specific limitations may indicate the need for, an LWS lower than the one determined per section C-9. The lift planner shall consider these personnel-lifting requirements when developing the LHA plan. Guidance can be found in ASME B30.23.

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**Figure C-4-1**
**Wind Effect on LHE**

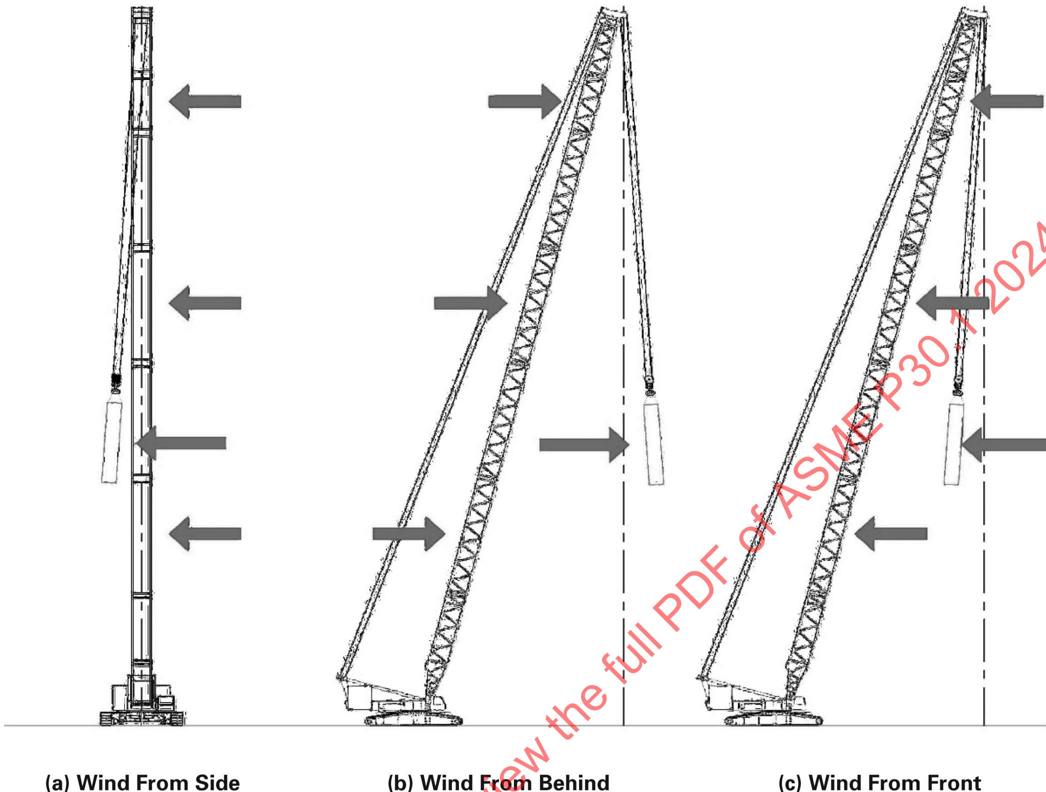


**Figure C-5-1**
**Effects of Wind on Load**

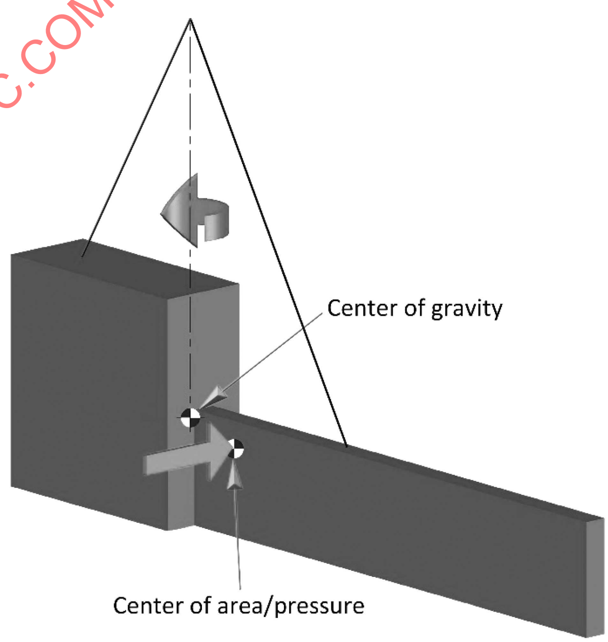


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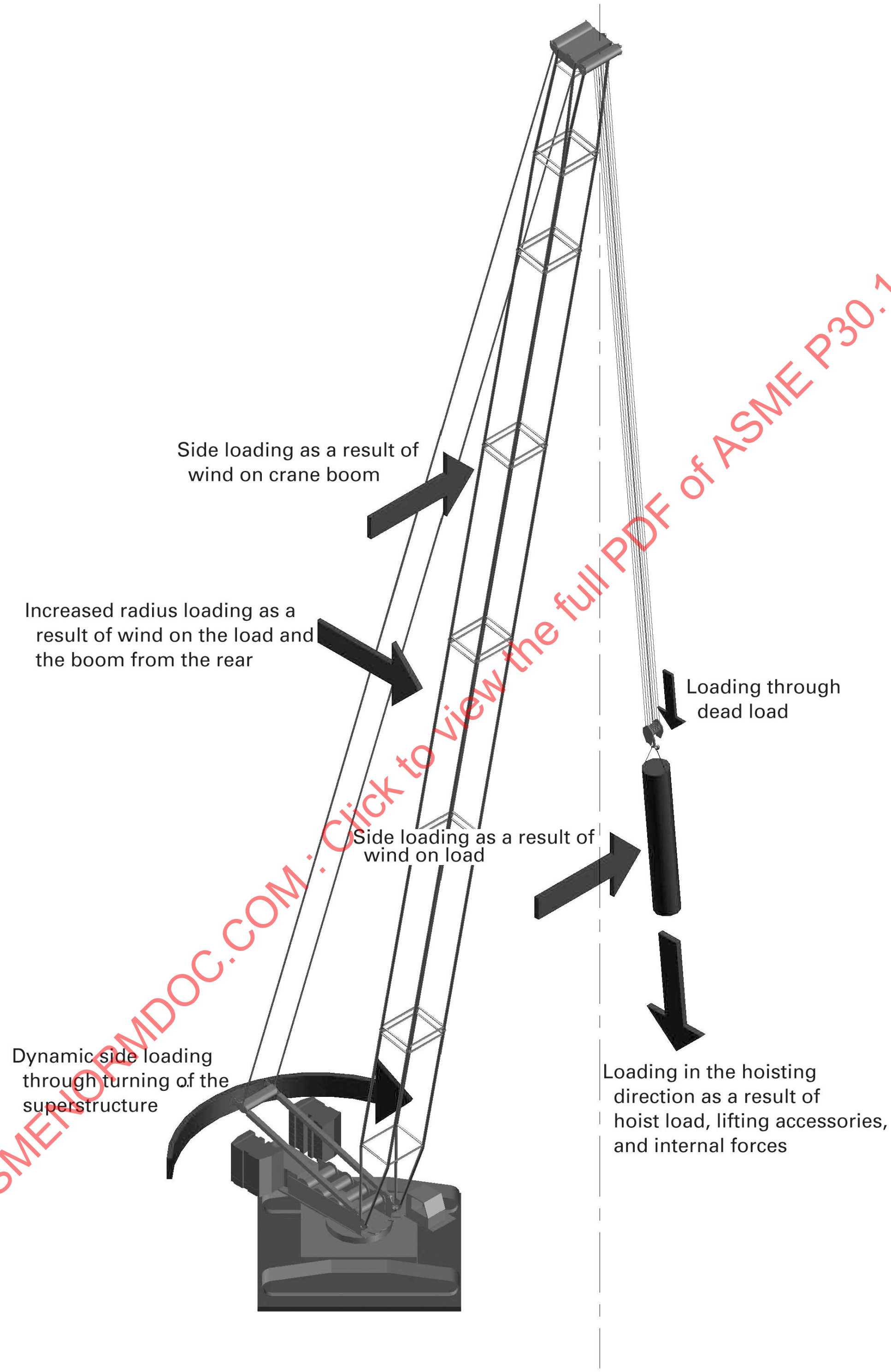
**Figure C-6-1**
**Side Loading**

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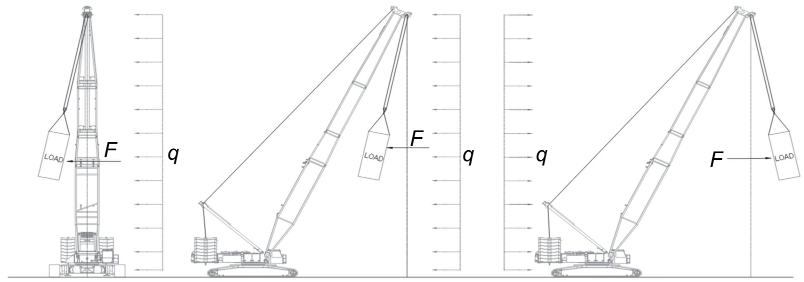
# Figure C-7-1
## Limiting Wind Speed Calculations for Mobile and Locomotive Cranes

By: _____ Rev: _____

Ckd: _____ Date: _____




(a) Wind From Side (b) Wind From Front (c) Wind From Behind

**Effect of Wind on Load**

### Drag Area Check

| | | | U.S. Customary Units | SI Units |
|---|---|---|---|---|
| (1) Crane load chart capacity | | LC: | lb | 0.0 tonne |
| Area exposed to wind per mass unit | | $A_{unit}$: | 0.00585 $ft^2/lb$ | 1.2 $m^2/tonne$ |
| (2) Allowable area exposed to wind | $A_{allow} = LC \times A_{unit}$ | $A_{allow}$: | 0 $ft^2$ | 0.0 $m^2$ |
| Payload surface area | $A_s = L \times W$ | $A_s$: | $ft^2$ | 0.0 $m^2$ |
| Drag coefficient | | $C$: | | |
| (3) Drag area | $A_w = A_s \times C$ | $A_w$: | 0 $ft^2$ | 0.0 $m^2$ |
| (4) Does a new LWS need to be calculated? | | | | If $A_{allow} > A_w \rightarrow$ No<br>If $A_{allow} < A_w \rightarrow$ Yes |

### Limiting Wind Speed (LWS)

| | | | | |
|---|---|---|---|---|
| (5) Manufacturer permissible wind speed | | $LWS_{CHART}$: | mph | |
| (6) Load mass effect | | M: | lb | 0.0 tonne |
| (7) Limiting wind speed | $LWS = LWS_{CHART} \times \sqrt{\frac{A_{unit} \times M}{A_w}}$ | LWS: | 0.00 m/s | 0.0 ft/s 0.0 mph |
| (8) Wind pressure created by velocity | $q = 0.00256 \times LWS^2$ | $q$: | 0.00 $lb/ft^2$ | |
| (9) Wind force on LHE | $F = qCA_s$ | $F$: | 0 lb | |

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## Figure C-7-2
## LHA and Corresponding LHE Load Chart

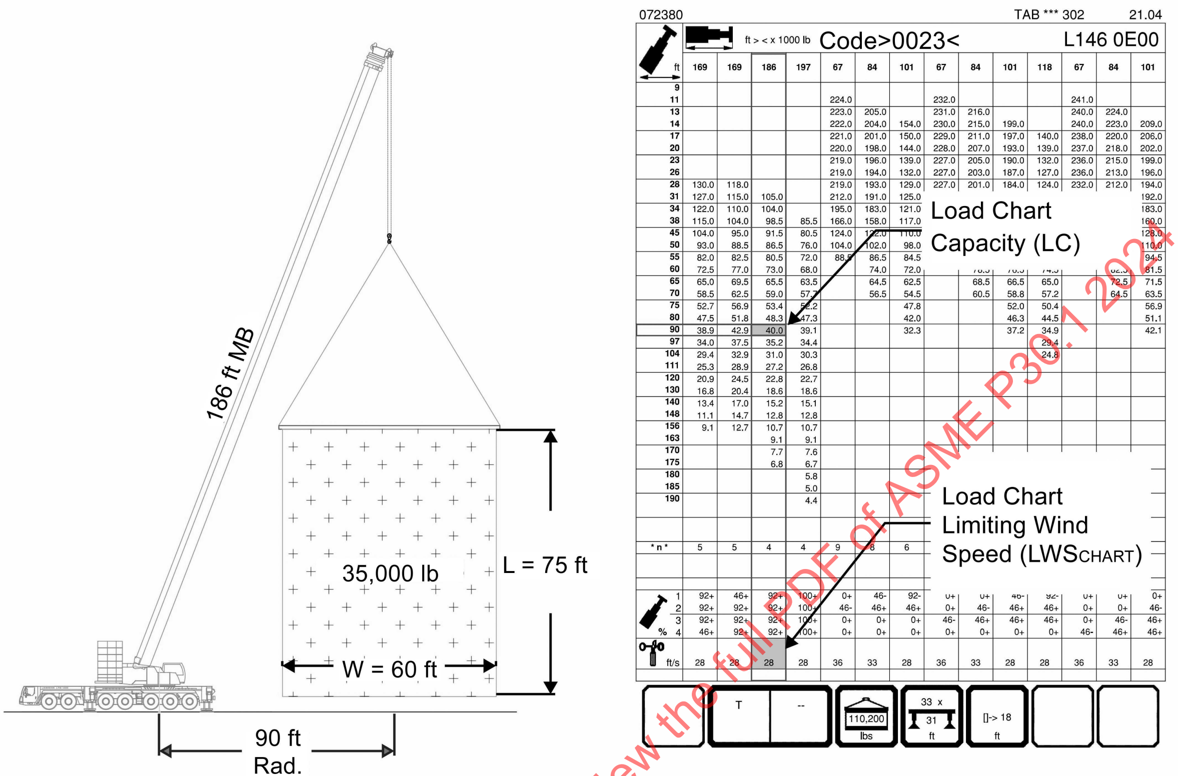


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**Figure C-8-1**
**Suspended Loads and Taglines**

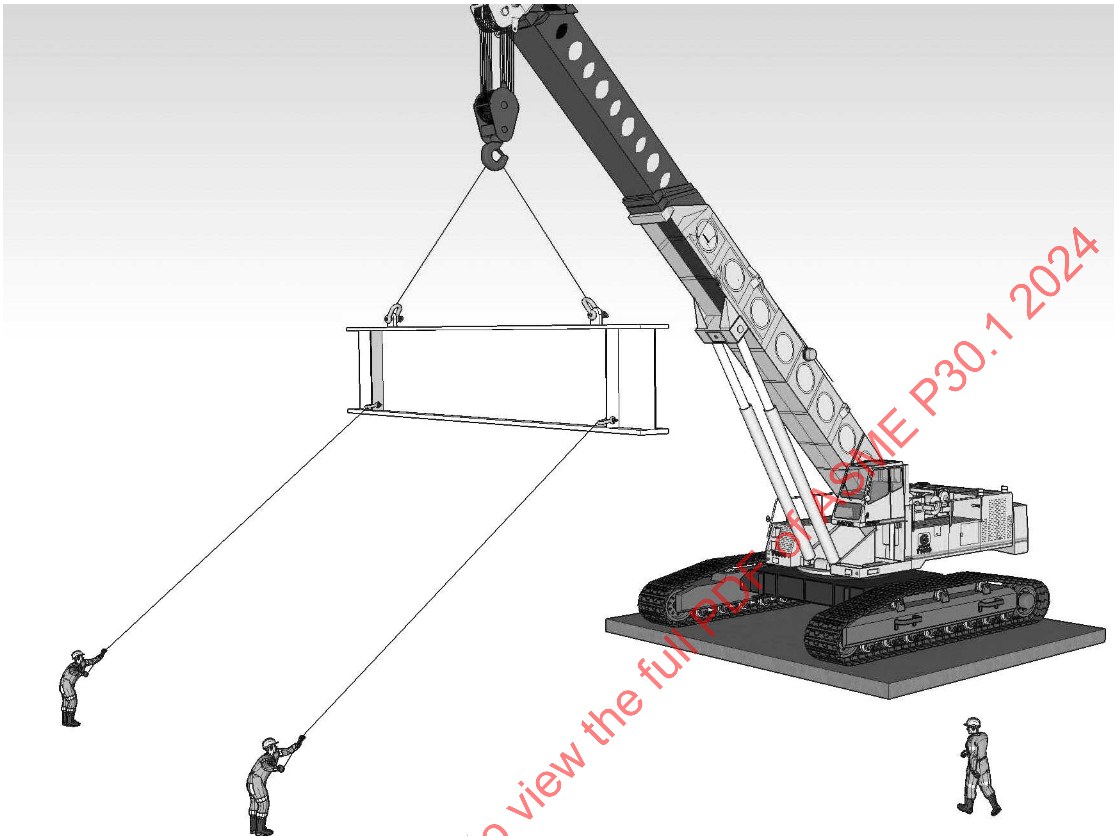

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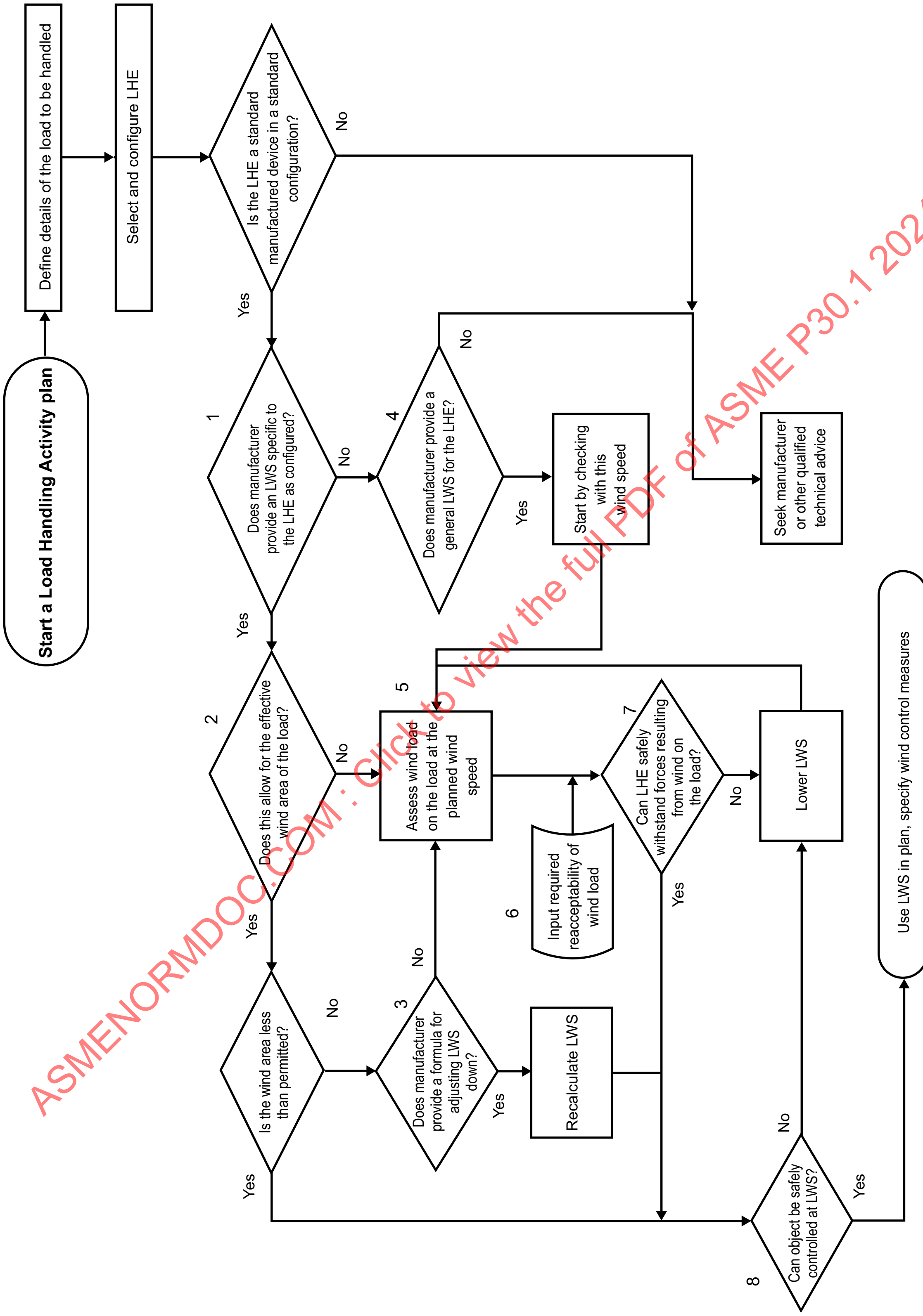
**Figure C-9-1**
**Establishing a Limiting Wind Speed for a Load Handling Activity**

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# NONMANDATORY APPENDIX D PLANNING FOR LHE FOUNDATION AND SUPPORT

(24)

## D-1 INTRODUCTION

The purpose of this Appendix is to provide guidance on the following topics to those involved with planning load handling activities using an LHE:

*(a)* assessing the forces and pressures that the LHE will impose during the various phases of the load handling activity

*(b)* establishing the capacity of the supporting surface at the site of the load handling activity

*(c)* outlining potential solutions to distribute loads imposed by the LHE into the supporting surface within the allowable limits

There are instances where the LHE is installed with an engineered foundation or support (e.g., mass concrete, pile caps, structural frames, barges, crane rails). This Appendix does not fully address these applications. Guidance may be found in published sources.

## D-2 ROLES AND RESPONSIBILITIES

See Chapter 3 for roles and responsibilities.

## D-3 GUIDANCE FOR LIFT PLANNERS

The lift plan should address support of the LHE throughout the load handling activity.

### D-3.1 LHE Installation Conditions

*(a)* When the installation is long term or permanent, the support under the LHE may require verification of and conformance with the original design conditions.

*(b)* When the installation is short term, the lift plan should include an evaluation of the loads on the various support points and develop a system to distribute those loads to the supporting surface.

*(c)* When the LHE is supported by an independent structure, the lift plan should include an evaluation of the structure for loads imposed.

### D-3.2 Equipment Assessment

When planning the LHE foundation and support, the lift plan should address at a minimum the following:

*(a)* Will there be simultaneous load handling activities or other activities on the work site that affect one another?

*(b)* What loads are expected beneath the LHE during each planned load handling activity?

*(c)* Can loads be optimized through choice of the LHE, configuration, and operating procedure?

*(d)* When not involved in a load handling activity, what loads are imposed by the LHE? The greatest loads may occur when the LHE is out of service, during assembly, or during disassembly.

*(e)* Where will the LHE be assembled, and will additional LHE be required for assembly?

*(f)* Will the LHE travel between load handling activities?

*(g)* What is the condition and capacity of the travel path?

*(h)* How will the LHE be configured and positioned, and what loads will be imposed by the LHE during travel?

*(i)* Will there be environmental conditions that will change loads?

### D-3.3 Initial Site Assessment

A site assessment should be performed as part of the lift plan and should address the following:

*(a)* Identify conditions that may affect the capacity of the supporting surface. This includes any current or previous disturbance to the soil, including backfill and compaction or soil stabilization. This may be recent site preparation work, but it also should include historic activities.

*(b)* Identify adjacent or parallel construction activities that could affect load handling activities. Examples include work on nearby foundations, underground utilities, vibration, site drainage, and site dewatering.

*(c)* Identify open pits, voids, or underground structures such as basements, tunnels, drainage systems, or underground utilities that may affect load handling activities. Manholes, drainage grates, utility boxes, or pipeline warning markers may provide an indication of what may lie beneath. The absence of surface indicators is not proof underground structures do not exist.

*(d)* Identify environmental conditions such as climate, season, and weather. Moisture content, frost depth, ice, and recent thaws may affect soil bearing capacity.

### D-3.4 Establishing Design Loads and Allowable Ground Bearing Pressure

The loads imposed by the outrigger floats or crawler tracks of an LHE in use could be greater than the ground can safely withstand without some form of

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load distribution system. If a matting system is the appropriate solution, there are two primary factors to be considered.

(a) the maximum loads the LHE will impose

(b) the support capacity of the supporting surface (native or improved)

Sections D-4 through D-8 provide guidance for determining these factors.

The process is outlined in Figure D-3.4-1.

## D-4 IDENTIFYING THE LOADS IMPOSED BY THE LHE

### D-4.1 LHE Loading Scenarios

Figure D-4.1-1 is an example of how loads may be distributed on each outrigger. The outrigger loads change with slew and boom angles and the lifted load. This is a typical case based on crane type and outrigger configuration. The maximum outrigger loads may occur at different slew angles than shown.

Figure D-4.1-2 is an example of how loads are distributed by a crawler crane. The shape of the load distribution and bearing length along the tracks change with slew and boom angles and the lifted load.

### D-4.2 Manufacturer's Information

Many manufacturers provide ground bearing pressure calculators. The outrigger loads or track pressures are calculated based on the configuration and parameters for the load handling activity entered by the lift planner. The calculator will usually give results for over the front, over the side, and critical slew angle.

A lift planner could conservatively design for the maximum load the crane could impose during use, a value that might be found in the crane manual.

### D-4.3 Lift Planning Software

There are lift planning software packages available to determine outrigger loads or track pressures.

### D-4.4 LHE Fleet Company Software

Some crane operating companies have proprietary software.

### D-4.5 Engineering Principles (Manual Calculation)

Imposed loads can be calculated manually if the dimensions, weights, and centers of gravity of the major components of the LHE are known.

### D-4.6 Methods to Reduce LHE Imposed Loads

There are multiple ways to reduce the imposed loads by the LHE.

(a) reconfiguring the LHE

(b) selecting a different LHE

(c) reducing the lifting radius

(d) reducing the size or weight of the loads to be lifted.

(e) minimizing operations in unfavorable directions

### D-4.7 Other Considerations

The maximum loads imposed by the LHE might not occur when lifting.

Other considerations may include

(a) during assembly, disassembly, and reconfiguration

(b) raising and lowering the boom

(c) stacking counterweights

(d) minimum radius, no load on hook, or retracted boom

(e) when traveling

(f) reduced counterweight configuration

(g) nonstandard attachment or accessory

(h) various outrigger or crawler positions

(i) out-of-service storm wind

The lift planner should determine if there are other factors that may have an influence on the loads imposed, such as wind, levelness, uniformity of the ground, and environmental conditions.

## D-5 ASSESSMENT OF THE GROUND CONDITIONS

### D-5.1 Introduction

For safe operation of an LHE, the supporting surface should withstand the imposed loads such that the LHE remains level within the manufacturer's tolerance. There is enormous variety in the locations in which lifting activities take place and the nature of the operations to be conducted: from green field to brown field, swamp to rock, improved or unimproved, existing facilities, and new construction. It is necessary to assess the ground conditions to determine general suitability and load-bearing capability. This in turn will guide whether improvements are necessary and the extent of load distribution required.

### D-5.2 Data Collection — Available Documented Information

Information relating to the supporting surface may be obtained or compiled from a variety of sources, such as the following:

(a) the facility owner

(b) the controlling entity

(c) project and client geotechnical sources, e.g., an allowable ground bearing pressure (GBP) for the whole site or a defined area (from a competent source)

(d) preexisting geotechnical engineering report for the site and/or LHE location (Check its continued validity.)

(e) government geological survey records

(f) governing authority of the site, city, or state sources

(g) records of demolition contractor's on-site reinstatement on brown field sites

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**Figure D-3.4-1**
**Process Map**

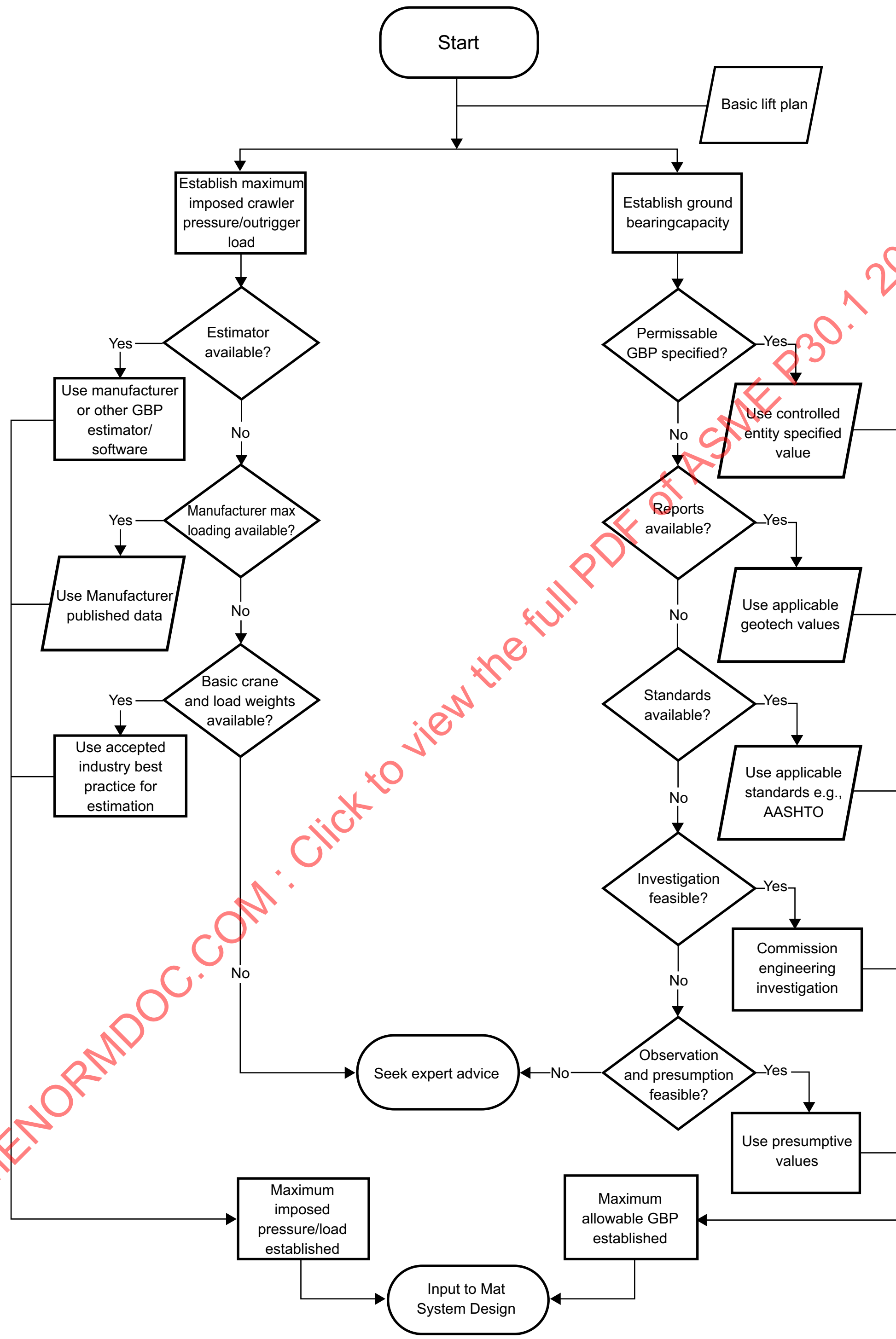


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**Figure D-4.1-1**
**Outrigger-Supported LHE Loading**

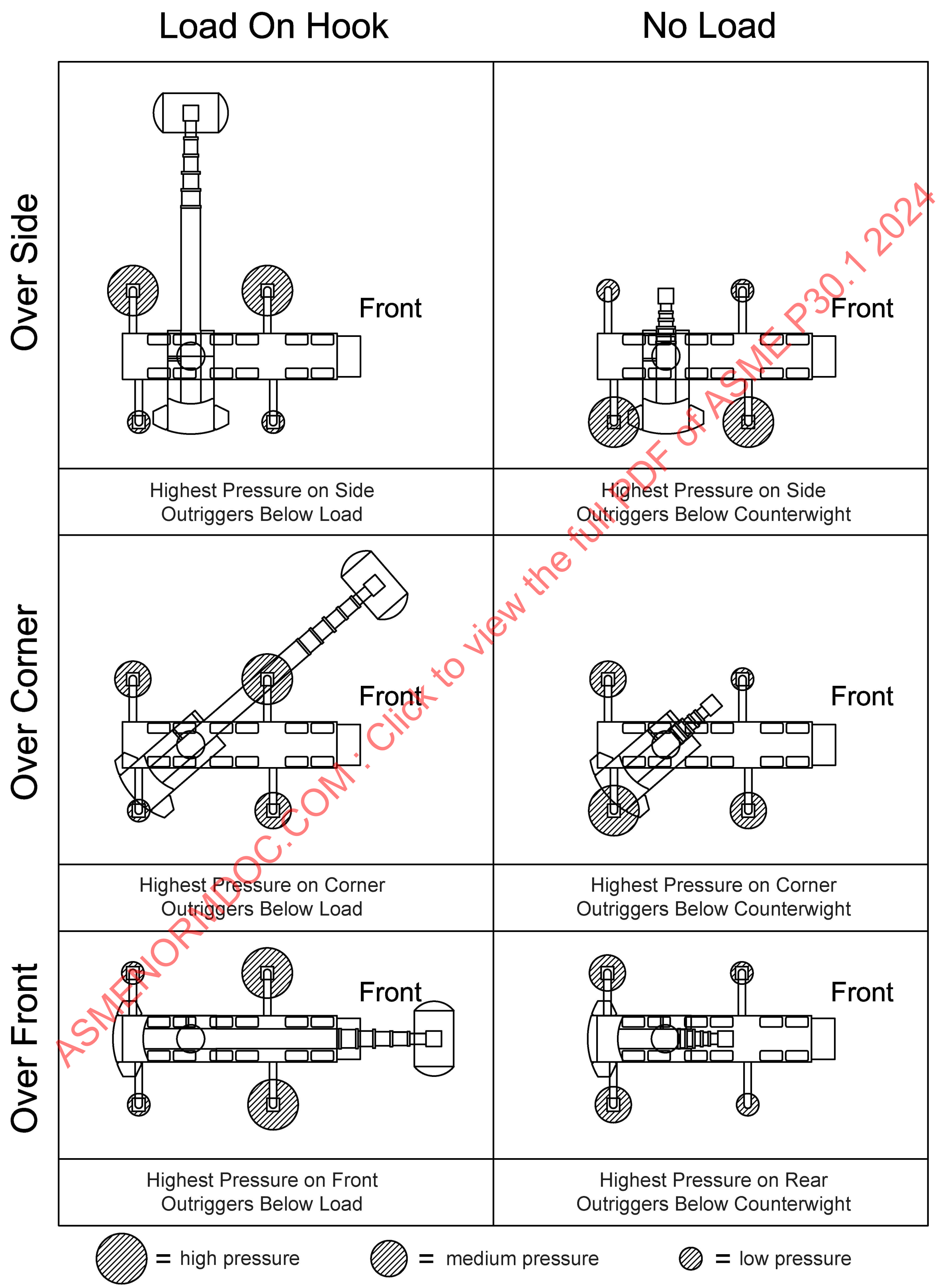


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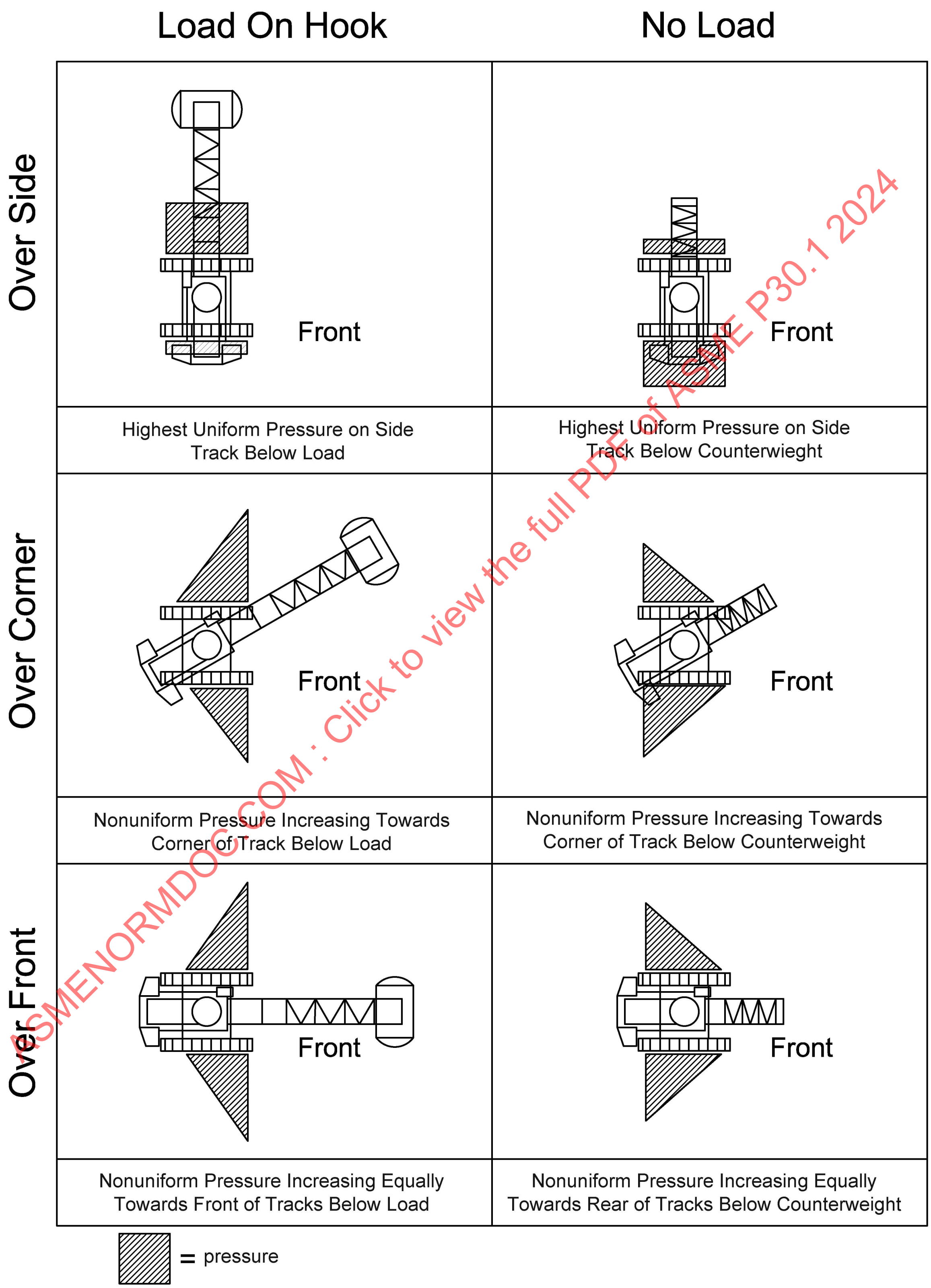
**Figure D-4.1-2**
**Crawler Crane Loading**

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(h) records of fill placement and compaction
(i) a detailed site inspection and/or subsurface investigation
(j) local knowledge — local building codes
(k) applicable standards such as American Association of State Highway and Transportation Officials (AASHTO) or similar

If an LHE is to be set up on a bridge, building, or structure, the suitability should be assessed by an engineer, preferably the engineer of record.

**5.2.1** The location should be evaluated for underground or adjacent items that could affect the support of the LHE or could be adversely impacted, such as the following:
(a) structures (i.e., adjacent or underground)
(b) embankments or retaining walls
(c) buried or surface utilities (e.g., services, manhole covers, curb drains)
(d) excavations
(e) voids
(f) tanks

**5.2.2** The controlling entity may have available information, such as the following:
(a) design drawings
(b) as-built drawings
(c) surveys
(d) photographs

## D-5.3 Data Collection — Physical Observation

Without available site-specific information, it is difficult to determine an allowable ground bearing pressure for the LHE. At a minimum, the top layer (surface) of the site can provide some clues as to the immediate soil type just below the LHE, such as the following:
(a) soft, compressible, or loose soils observed at the ground surface
(b) rock (or rock outcrops) observed at the ground surface
(c) variability of support surfaces, such as the following:
(1) hard next to soft
(2) multiple colorations of soils
(3) concrete pad next to fill
(4) stiffness of support under the same track on a crawler
(5) surface discontinuity
(d) condition of subgrade disturbance from construction activities or inclement weather
(1) when there is a presence of washed-in material
(2) when subgrade is visually disturbed from excavation
(3) when subgrade is visually firm and stable
(e) temperature of soils
(1) freeze thaw cycle of soils
(2) frozen soil
(f) condition of surfaces such as pavement or concrete (e.g., undulating pavement can indicate the presence of soft, compressible soils)
(g) topographical properties
(1) gradient and flatness
(2) minor or major obstacles, e.g., rock protrusions
(h) water
(1) groundwater, underground springs, streams, ditches, wet areas, and land drain indicators
(2) potential for liquefaction of the soil
(3) rainfall — recent history or likely effect of fresh rainfall
(4) proximity to bodies of water
(i) underground structures
(1) backfilled areas cracking or differential settlement at junction with undisturbed ground
(2) manhole and valve covers

## D-5.4 Presumptive Bearing Capacities Based on Observation

A detailed investigation or testing is often neither practical nor justified for routine lifting operations. In such cases, the observations from para. D-5.3 can be used to establish a presumptive bearing capacity. Presumptive bearing capacities are the allowable bearing capacity based only on visual classification of surface soil.

The approach should be to observe the location and its designed use and, if satisfactory by inspection, select a conservatively low presumptive bearing capacity from a source, such as those presented in Table D-5.4-1. When matched to a conservatively high estimate of the loads the LHE could impose, load distribution mats (or equivalent) of an adequate effective area can be specified. If in doubt, err on the side of caution, use a low bearing capacity, and distribute the load over a larger area.

The use of presumptive bearing capacities is based on an assumption that ground conditions, such as compaction, soil type, and consistency, are uniform throughout its depth and layers. The purpose of Table D-5.4-1 is to provide very generalized allowable bearing capacity values. This table can be used before a soil analysis has been conducted and used as a reference value when developing the initial plan.

Table D-5.4-1 can be used to determine a presumptive ground bearing capacity. This table is a general value for allowable GBP. Allowable GBP should be based on a qualified person's evaluation of the subsurface conditions.

## D-5.5 Investigation and Testing

If an allowable ground bearing pressure cannot be provided or determined by the methods in paras. D-5.2 through D-5.4, the preferred method to establish a value is through investigation and testing to determine the ground conditions. This option requires competent geotechnical expertise.

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**Table D-5.4-1**
**Presumptive Values of Allowable Bearing Pressures for Spread Foundations**

| Type of Bearing Material | Consistency in Place | Allowable Bearing Pressure Tons per sq ft | |
|---|---|---|---|
| | | Range | Recommended Value for Use |
| Massive crystalline igneous and metamorphic rock: granite, diorite, basalt, gneiss, thoroughly cemented conglomerate (sound condition allows minor cracks). | Hard, sound rock | 60 to 100 | 80.0 |
| Foliated metamorphic rock: slate, schist (sound condition allows minor cracks). | Medium hard sound rock | 30 to 40 | 35.0 |
| Sedimentary rock: hard cemented shales, siltstone. sandstone, limestone without cavities. | Medium hard sound rock | 15 to 25 | 20.0 |
| Weathered or broken bedrock of any kind except highly argillaceous rock (shale). RQD less than 25. | Soft rock | 8 to 12 | 10.0 |
| Compaction shale or other highly argillaceous rock in sound condition. | Soft rock | 8 to 12 | 10.0 |
| Well graded mixture of fine and coarse-grained soil: glacial till, hardpan, boulder clay (GW-GC, GC, SC). | Very compact | 8 to 12 | 10.0 |
| Gravel, gravel–sand mixtures, boulder gravel mixtures (SW, SP, SW, SP). | Very compact | 6 to 10 | 7.0 |
| | Medium to compact | 4 to 7 | 5.0 |
| | Loose | 2 to 6 | 3.0 |
| Coarse to medium sand, sand with little gravel (SW, SP). | Very compact | 4 to 6 | 4.0 |
| | Medium to compact | 2 to 4 | 3.0 |
| | Loose | 1 to 3 | 1.5 |
| Fine to medium sand, silty or clayey medium to coarse sand (SW, SM, SC). | Very compact | 3 to 5 | 3.0 |
| | Medium to compact | 2 to 4 | 2.5 |
| | Loose | 1 to 2 | 1.5 |
| Homogenous inorganic clay, sandy or silty clay (CL, CH). | Very stiff to hard | 3 to 6 | 4.0 |
| | Medium to stiff | 1 to 3 | 2.0 |
| | Soft | 0.5 to 1 | 0.5 |
| Inorganic silt, sandy or clayey silt, varved silt–clay–fine sand. | Very stiff to hard | 2 to 4 | 3.0 |
| | Medium to stiff | 1 to 3 | 1.5 |
| | Soft | 0.5 to 1 | 0.5 |

GENERAL NOTE: The table is from NAVFAC DM-7.02 (1982), Foundations and Earth Structures.

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**D-5.5.1** The extent of the investigation will depend on the requirements of the supporting materials and loaded areas that can include some or all of the following in-situ and laboratory tests:

*(a)* identification and limits of soil and rock types and groundwater elevation

*(b)* soil characterization, soil strength tests, soil compressibility tests, and any other evaluation of the soil's engineering properties

*(c)* on-site tests to confirm the adequacy of the ground investigation during installation of the support measures and/or the LHE

**D-5.5.2** Field tests may include the following:

*(a)* evaluation of subgrade through excavation of test pits

*(b)* collection of soil samples by boring

*(c)* collection of rock samples by coring

*(d)* measurement of groundwater monitoring wells

*(e)* in-situ shear strength testing

*(f)* plate bearing test

**D-5.5.3** Laboratory tests may include the following:

*(a)* soil characterization

*(b)* maximum dry density

*(c)* compressibility or consolidation

*(d)* shear strength testing

*(e)* rock quality and fracture orientation

*(f)* rock strength

**D-5.5.4** Although proof rolling is also often suggested as a method to verify the allowable bearing capacity of an area, this method has the following limitations:

*(a)* Proof rolling typically finds defects or helps stabilize the very top layer of soil. It can also identify large deficiencies. Some of these issues can also be visualized, such as rutting from truck traffic.

*(b)* It is important to put the weights and bearing areas of the LHE versus the proof rolling equipment into perspective. LHE typically impose significant pressure on deeper strata. Proof rolling is not capable of mobilizing deeper strata engaged by heavy LHE loading; this is the same reason why backfill is compacted in layers.

For these reasons, proof rolling is not a reliable method to confirm the allowable ground bearing pressure.

## D-6 USE OF GEOTECHNICAL REPORT TO DETERMINE ALLOWABLE GROUND BEARING PRESSURE

### D-6.1 Introduction

The best and most reliable means of assessing the allowable GBP for an LHE is to use a geotechnical report prepared for the site by a qualified person. New construction sites will often have such a report that should be available upon request. However, other sites may require site investigations, including borings or test pits to determine an allowable GBP. Alternately, historical data for nearby areas may be available. In that case, consideration should be given to historical activity in the area and its effect to the subgrade.

A comprehensive geotechnical report will provide specific information on subsurface soil, rock, and groundwater conditions. Interpretation of the site investigation information, by a qualified person, results in design and construction recommendations for a project site.

### D-6.2 Boring Logs

A boring log is a geotechnical exploration record of subsurface conditions. This log presents a variety of data used in analyzing and assessing ground conditions. Figures D-6.2-1 through D-6.2-3 are examples of information presented in a boring log report.

Geotechnical test methods used to characterize in-situ subsurface conditions include the standard penetration test (SPT), the cone penetration test (CPT), and the dynamic cone penetration test (DCPT). These tests provide soil resistance data essential for determining the allowable GBP.

SPT uses auger drilling to open a small diameter excavation to a given depth, where a split spoon sample tube is then placed in contact with the bottom of the borehole. A triphammer then drives the sample tube into the ground with the number of blows required to drive the sampler a predetermined distance being recorded. Based on the number of hammer blows required to advance the tube, i.e., the blow count or *N* value, for that soil layer is shown in the boring log. Using the *N* value, the allowable GBP can then be calculated.

CPT, rather than using a hammering technique, collects data continuously as a cone-tipped rod of specified dimension is advanced at a uniform rate into the ground. As the cone is advanced deeper into the soil, the system measures the tip resistance or stress, which is then used to calculate the allowable GBP.

DCPT incorporates features of both SPT and CPT. Like SPT, DCPT is performed by dropping a standardized weight hammer from a specified height and measuring the penetration depth per blow. The shape of DCPT probe is a cone, similar to that of the CPT penetrometer. DCPT data are then correlated with California bearing ratio (CBR) values to calculate the allowable GBP.

SPT, CPT, and DCPT geotechnical methods provide empirical data useful in calculating the allowable GBP. These methods collect data at individual, discrete locations with conditions interpolated between test points across a site. These methods do not identify other underground conditions at the specific LHE location, such as voids, groundwater, or underground utilities, that could have significant effect on LHE support. Noninvasive, geophysical test methods, such as ground penetrating radar (GPR) or electromagnetic induction surveys, may also be used to provide a more complete characterization of underground conditions.

### D-6.3 Boring Log Interpretation

Boring logs can provide required properties of the subgrade present immediately beneath the placement area of an LHE. The following key areas are most needed for subgrade analysis, all of which should be found on a boring log:

*(a)* soil type: cohesive (silt and clay) and noncohesive (sand and gravel)

*(b)* groundwater table

*(c)* soil consistency

*(1)* silt/clay — soft to hard

*(2)* sand/gravel — loose to dense

With this knowledge, a qualified person has the information needed to evaluate the existing conditions and determine the ultimate bearing capacity of the soil.

### D-6.4 Allowable Ground Bearing Pressure

Once the ultimate bearing capacity ($q_{\text{ult}}$) has been determined, the allowable GBP ($q_a$) is found by reducing the ultimate by a factor of safety (FOS).

$$q_a = q_{\text{ult}}/\text{FOS}$$

Permanent structure foundations are typically designed with an FOS of 3. Because of the temporary nature of LHE installations, sufficiently defined LHE loading, and higher tolerance for settlement compared to a permanent structure, a FOS of 2 is often acceptable.

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**Figure D-6.2-1**
**Boring Log**

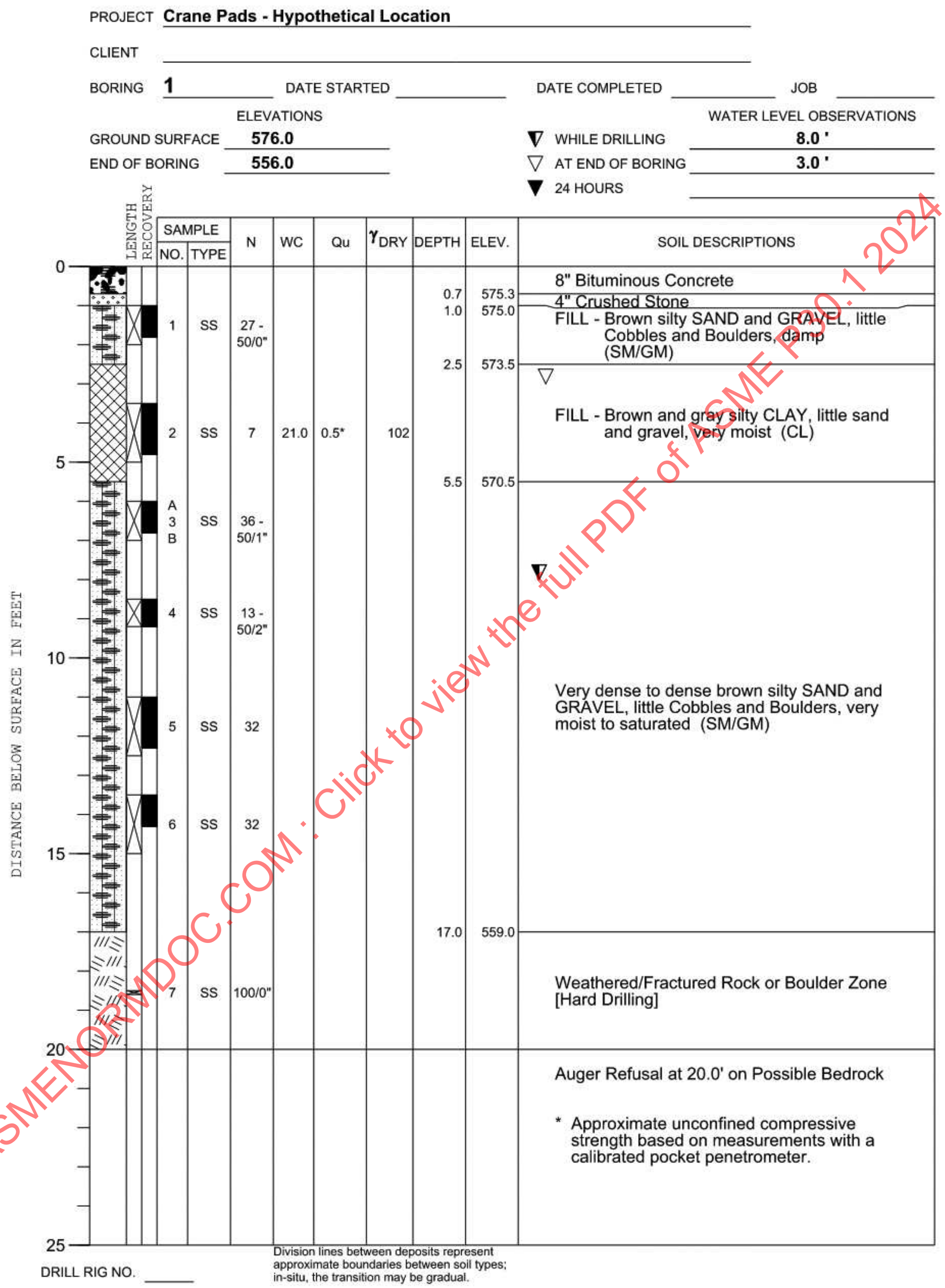


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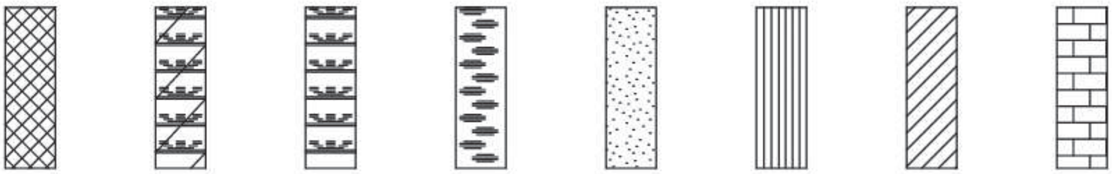
**Figure D-6.2-2**
**Boring Log Legend**



| Fill | Topsoil | Peat | Gravel | Sand | Silt | Clay | Dolomite |
|---|---|---|---|---|---|---|---|

Sample Type

| | | |
|---|---|---|
| SS | = | split spoon |
| ST | = | thin-walled tube |
| A | = | auger |
| MC | = | macro-core (geo probe) |

Water Levels

| | |
|---|---|
| ▼ (with bar) | while drilling |
| ▽ | end of boring |
| ▼ | 24 hr |

Field and Laboratory Test Data

| | | |
|---|---|---|
| N | = | standard penetration resistance in blows per foot |
| WC | = | in-situ water content |
| Qu | = | unconfined compressive strength in tons per square foot |
| | * | pocket penetrometer measurement: maximum reading = 4.5 tsf |
| $Y_{DRY}$ | = | dry unit weight in pounds per cubic foot |

Soil Description

| Material | Particle Size Range |
|---|---|
| Boulder | Over 12 in. |
| Cobble | 12 in. to 3 in. |
| Coarse gravel | 3 in. to ¾ in. |
| Small gravel | ¾ in. to No. 4 sieve |
| Coarse sand | No. 4 sieve to No. 10 sieve |
| Medium sand | no. 10 sieve to No. 40 sieve |
| Fine sand | No. 40 sieve to No. 200 sieve |
| Silt and clay | Passing No. 200 sieve |

| Cohesive Soils | | Cohesionless Soils | |
|---|---|---|---|
| Consistency | Qu (tsf) | Relative Density | *N* (bpf) |
| Very soft | Less than 0.3 | Very loose | 0 to 4 |
| Soft | 0.3 to 0.6 | Loose | 4 to 10 |
| Stiff | 0.6 to 1.0 | Firm | 10 to 30 |
| Tough | 1.0 to 2.0 | Dense | 30 to 50 |
| Very tough | 2.0 to 4.0 | Very dense | 50 and over |
| Hard | 4.0 and over | | |

| Modifying Term | Percent by Weight |
|---|---|
| Trace | 1 to 10 |
| Little | 10 to 20 |
| Some | 20 to 35 |

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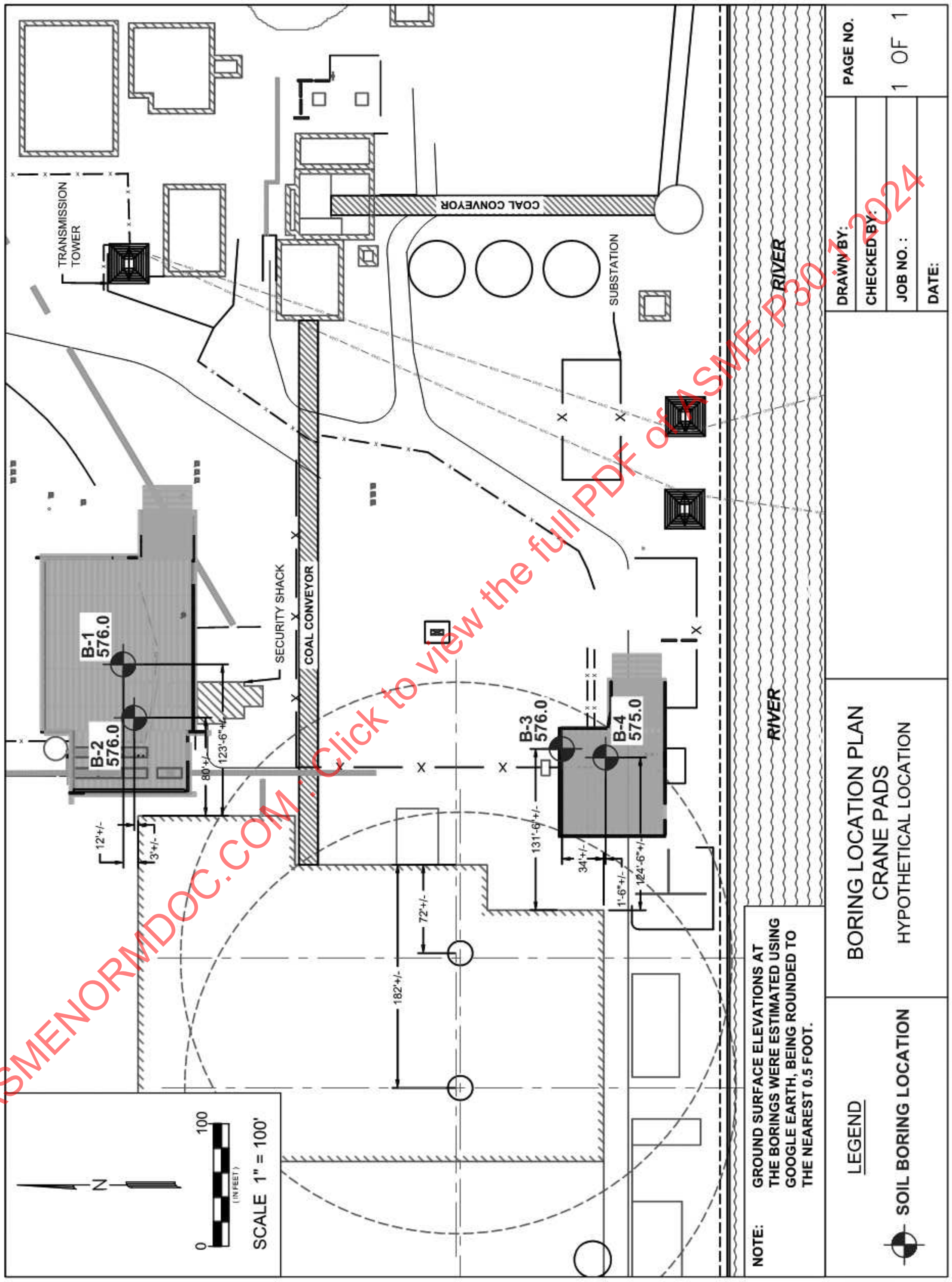
**Figure D-6.2-3**
**Boring Location Plan**

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## D-7 METHODS TO IMPROVE SOIL PROPERTIES

### D-7.1 Introduction

There are many methods and techniques for subgrade improvement and stabilization, though most are not practical for lift planning in general. Regardless of the method used, the work should be performed under the guidance of a qualified person.

When results from a subsurface exploration indicate less than adequate bearing capacity, and LHE foundation options have been maximized, soil improvement options should be considered. There are extreme cases where pile foundations or large-scale site improvements are required. These occurrences and several other techniques are beyond the scope of this Appendix. However, there are effective methods that can increase bearing capacity and stability of subgrades for LHA needs

Most soil issues, when supporting LHEs, occur with high void ratios, low-strength materials, and unsatisfactory water content, where the subgrade is composed of loose sands and silts, wet clays, organic soils, or a combination of these materials. The basic soil modification techniques in paras. D-7.2 through D-7.4 are suitable options.

### D-7.2 Structural Fill

Structural fill is the simplest of the two methods and requires minor site preparation work. The foundation of the LHE is placed on a layer of structural fill that has been placed on top of the existing subgrade. The structural fill should be placed in lifts, compacted, and leveled throughout. The structural fill should minimally cover the full extent of the LHE footprint.

The bearing capacity of the existing subgrade does not increase. Instead, the LHE foundation bearing area increases by a factor of the structural fill depth. This increase in area produces a decrease in bearing pressure from the LHE. Figure D-7.2-1 illustrates the influence line of the LHE foundation through the structural fill layer. The figure presents a typical distribution; however, the ratio may vary based on fill type and installation. The area beneath the fill can then be calculated. The structural fill weight should be added to the reduced LHE bearing pressure and still be within the allowable bearing capacity of the subgrade.

The use of this technique could be limited by the following conditions:

*(a)* excessive fill depths

*(b)* insufficient area to increase the length and width

*(c)* mobilization of the LHE onto an elevated surface

*(d)* uneven settlement of the subgrade affecting the LHE levelness

### D-7.3 Remove (Undercut) and Replace

As the name implies, this method removes the unsuitable materials to expose a desirable subgrade and replaces it with a layer of structural fill placed in lifts and compacted. Depending on the depth of the undercut, support of excavation design may be required. As an alternative to the structural replacement fill, the excavated material may be treated with chemical admixtures, such as lime, fly ash, or cement; however, this process may not be permissible for temporary works. Adding a layer of geotextile at the bottom of excavations prior to replacement of structural fill can increase the soil capacity and bridge over localized soft spots. The structural fill can also be used to increase the loaded area as in para. D-7.2.

One disadvantage to this method may be the need for dewatering if the water table influences the excavation.

### D-7.4 Other Specialized Techniques

*(a)* In-situ stabilization provides subgrade improvement by applying a stabilizing agent without removing subgrade materials. This technology offers the benefit of improving subgrade for deep foundations, shallow foundations, and contaminated sites.

This technique involves the injection of a cementitious material or lime in dry or wet forms into the subgrade.

*(b)* Deep mixing involves the stabilization of the subgrade at a depth in which a wet or dry binder is injected into the ground and blended with the in-situ soft subgrade with a mechanical mixing tool.

*(c)* Wet mixing involves a binder turned into slurry form, which is then injected into the subgrade through the nozzles located at the end of the auger or mixing tool.

*(d)* Dry mixing involves the use of dry binders injected and mixed with the subgrade.

*(e)* Jet grouting involves the injection of a stabilizing fluid into the subgrade under high pressure and velocity.

### D-7.5 Considerations

The following factors negatively affect subgrade stabilization:

*(a)* The presence of organic matter retards the hydration process and affects the hardening of the stabilized subgrade.

*(b)* The presence of environmental contaminants may impact results.

*(c)* Insufficient moisture may affect subgrade stabilization.

*(d)* Temperature affects the reaction process. In colder temperatures, the reaction process may be slowed to the point of being ineffective, resulting in a lower strength of the stabilized mass.

*(e)* The stabilized subgrade cannot withstand freeze-thaw cycles; therefore, it may be necessary to protect the stabilized subgrade against frost damage.

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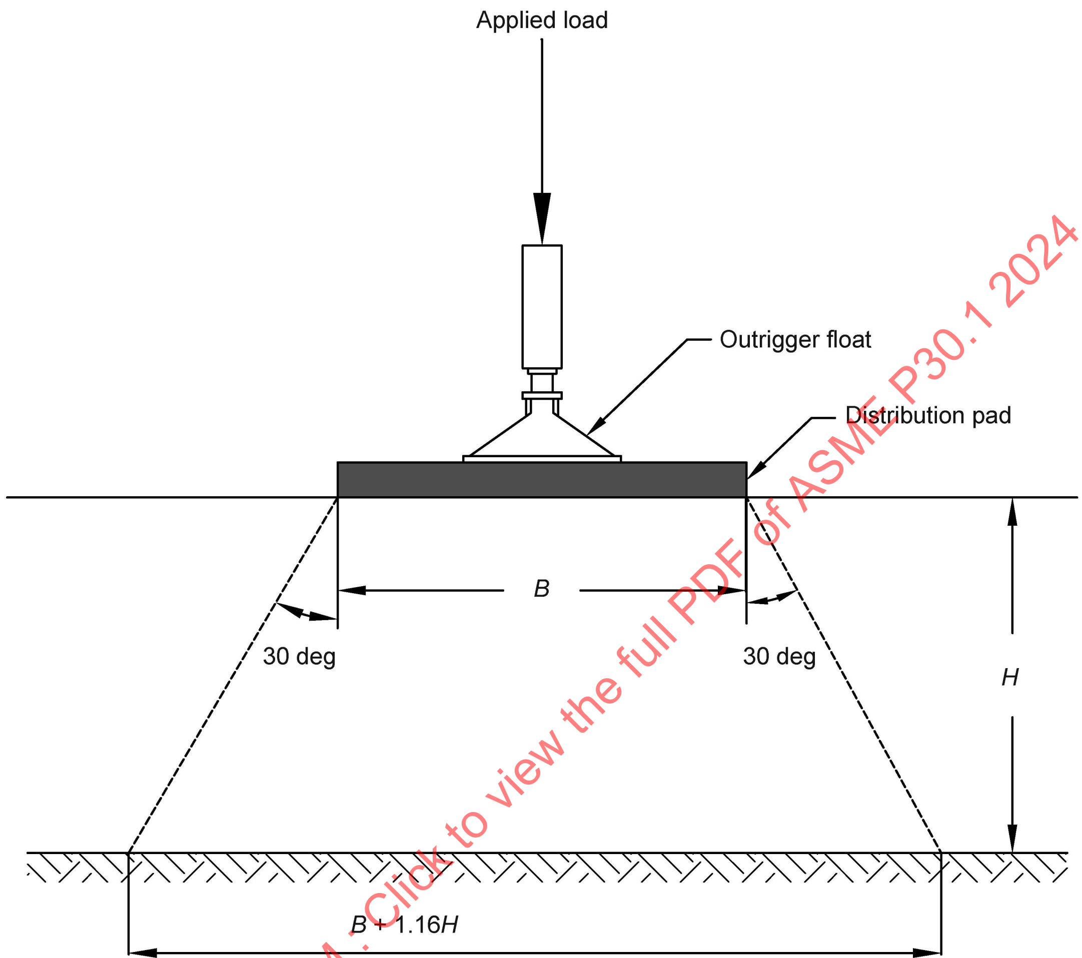
**Figure D-7.2-1**
**Load Distribution Through a Layer of Fill**

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## D-8 METHODS TO DISTRIBUTE IMPOSED LOADS

### D-8.1 Manner of Transmission of Imposed Loads Into the Ground

To effectively establish the methods available to distribute loads imposed by the LHE during a load handling activity or when traversing the jobsite, it is necessary first to understand how those loads are transmitted to the supporting surface under the LHE.

There are two important principles to understand. The first is the manner in which loads are distributed to the surface of the ground via the supporting structure of the LHE, i.e., wheels, tracks, or outrigger floats. The second is the way ground pressures are distributed through the subgrade.

The supporting material beneath the LHE should

*(a)* provide an effective bearing area great enough to result in a bearing pressure less than the allowable ground bearing pressure

*(b)* be rigid enough to prevent excessive deflection

*(c)* be strong enough to withstand the forces imposed

*(d)* account for any asymmetrical load distribution

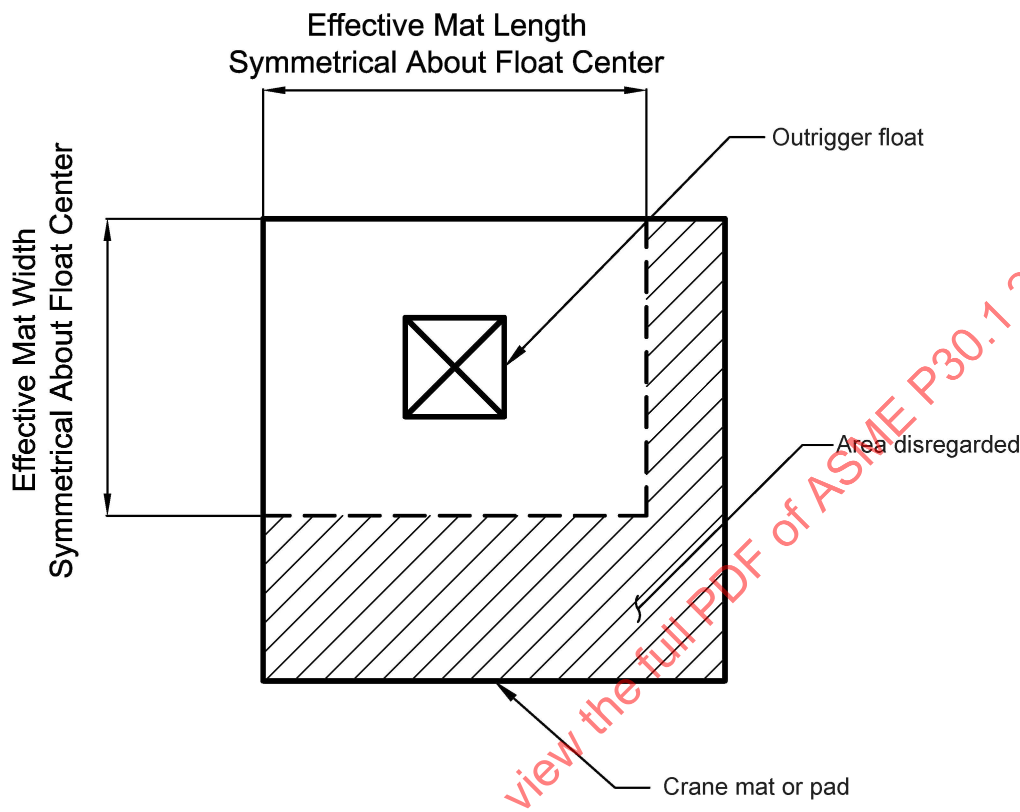
### D-8.2 Matting Systems

The most common methods used to distribute LHE loads into the supporting surface include outrigger pads and crane mats typically constructed of timber, steel, or synthetics, possibly a combination of the three.

Ground mats generally are not appropriate for distribution of substantial loads to the subsurface. A qualified person should evaluate the use of ground mats when supporting LHE. When choosing supporting materials, consider the following:

*(a)* strength, stiffness, and material properties

**Figure D-8.4-1**
**Area Disregarded Due to Eccentric Loading**

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*(b)* application requirements such as bridging
*(c)* close dimensional tolerances
*(d)* consistency of material properties
*(e)* resistance to degradation
*(f)* combining different materials to achieve desired results

### D-8.3 Strength Versus Stiffness

Strength and stiffness are determined by the material and dimensions. Strength and stiffness are not directly proportional to thickness. For solid rectangular sections, doubling the thickness increases the strength four times and the stiffness eight times.

Two identical pads or mats stacked do not have the same strength or stiffness as a single pad or mat of the same total thickness. The two pads function independently of each other as they deflect.

It is important to understand that a pad may have adequate strength but may lack the stiffness to distribute the load over the required effective bearing area. If the pad is less rigid than the supporting surface, the bearing pressure will be concentrated on a smaller area.

A rigid surface, such as rock or concrete, may not allow the mat or pad to deflect to distribute the load to the edges of the mat or pad. Instead, the load will pass directly through the supporting material without significant distribution. Deflection could be a limiting condition for supporting materials with a long cantilever or with low stiffness.

Placing the supporting materials partially on ground and partially on concrete foundations will result in concentration of loads into the stiffer elements.

### D-8.4 Eccentric Loading

The load from the LHE should be centrally located on the mats or pads. If this placement is not possible, accommodation for eccentric loading should be made. See Figure D-8.4-1. This may include

*(a)* disregarding the pad area outside of the area of symmetry
*(b)* evaluating the GBP for the peak value as an unequal distribution
*(c)* seeking the advice of a qualified person

For any pad loaded eccentrically, ensure the pad is constructed in a manner to support the load at the loaded location.

## D-9 INSPECTION CRITERIA

### D-9.1 Introduction

The following provides guidance to evaluate crane mat or outrigger pad condition. Crane mats and outrigger pads are tools and should be inspected before each use. Mats and pads should be clean to allow proper inspection of all surfaces. Inspections should be performed, and any deficiency identified should be examined and a determination made by a qualified person as to whether it constitutes a hazard and, if so, what additional steps need to be taken to address the hazard.

### D-9.2 Timber

**D-9.2.1 Visual Techniques.** Visual inspection is the first step in assessment. This step identifies the following issues:

*(a)* missing or damaged components
*(b)* environmental damage, including weather exposure or fungus
*(c)* splitting and cracking that may reduce the mat strength and create pathways for agents of decay to get deep into the mat interior
*(d)* damage by burrowing insects as evidenced by frass or mud tubes

**D-9.2.2 Probing Techniques.** Probing techniques use a sharp or pointed tool to identify surface rot and assess the condition of the mat surface. Soft surfaces or the lack of resistance to probe insertion are indicators of decay. The use of a probe for mat assessment is a simple technique but requires the inspector to have knowledge of wood behavior in both sound and decayed conditions.

**D-9.2.3 Sounding Techniques.** A sounding test is performed by striking the timber with a blunt object, such as a hammer. The inspector determines the likely presence of rot by both the feel of the hammer at impact and the resulting sound of the impact. A sharp, ringing sound is indicative of sound wood. A hollow sound or a damped "thud" are indicative of internal decay. Sounding will often reveal advanced decay or hollowed centers but is unlikely to reveal incipient or moderate decay. To be effective, a relatively heavy (3 lb to 4 lb) hammer should be used for larger cross-section materials. The interpretation and effectiveness of sounding are dependent on the experience of the inspector.

**D-9.2.4 Drilling Techniques.** Sudden decreases in resistance during drilling or coring are indicative of voids or areas of rot. Once the defect size is estimated, then a decision can be made regarding treatment, reinforcement, or replacement

**D-9.2.5 Loss of Strength Over Time.** The service life of a timber mat is dependent on numerous factors. It is incumbent on the user to verify that the condition of the mat is and remains suitable for its intended use. It should be noted that a small reduction in timber cross section, such as that caused by decay, weathering, or mechanical damage due to aggressive use or improper storage, causes large reductions in strength and stiffness.

### D-9.3 Steel

Steel mats and pads are not subject to the same environmental degradation as a timber mat. It is still important that their suitability be verified by the user.

The following points should be used for inspection:

*(a)* Confirm individual elements meet specified steel grade, shape, and dimensions.
*(b)* Check for deformation that affects load bearing.
*(c)* Check all sides of elements for defects, such as cracks, pits, impact damage, corrosion, and flakes.
*(d)* Check all connections (e.g., bolted and welded).

### D-9.4 Synthetic

Synthetic mats and pads vary greatly in their design and manufacture. Follow the criteria and guidelines of the manufacturer or qualified person for inspections. At a minimum, the following items should be inspected:

*(a)* modifications outside of the guidance of the manufacturer or qualified person
*(b)* racking, misalignment, delamination, or deformation
*(c)* evidence of bending, such as strain hardening or whitening
*(d)* surface degradation, such as cracking, spalling, blistering, or significant discoloration
*(e)* loose, missing, deformed, or corroded components and hardware

## D-10 METHODS TO CALCULATE THE EFFECTIVE BEARING AREA

### D-10.1 Crane Mat Analysis

Rigorous analysis of the pressure distribution beneath a crane mat and exact calculation of the stresses induced in the mat is neither justified nor practical in most cases. Such an analysis would require data such as the soil elastic properties or the modulus of subgrade reaction that are not readily available.

The effective bearing area calculation method is a simplified, practical, but conservative approach that requires only the mat properties, the maximum imposed load from the LHE, and the allowable ground bearing pressure. This method determines an effective length ($L_{eff}$) for the mat over which the pressure can be considered uniform. The effective length is calculated through consideration of the soil bearing capacity and the

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**Table D-10.2-1**
**Commonly Used Timber Species for Crane Mats**

| Species Combination | Species Excluded for Crane Mats |
|---|---|
| Beech–birch–hickory | None excluded |
| Mixed maple | Silver maple |
| Northern red oak | None excluded |
| Red oak | None excluded |
| White oak | Bur oak |
| Douglas fir-larch | None excluded |
| Eastern hemlock | None excluded |

mat bending strength and stiffness. Knowledge of the soil's elastic properties is not required.

The analysis quantifies the maximum load that can be imposed on the mat without exceeding the following:

*(a)* the allowable bending stress
*(b)* the allowable shear stress
*(c)* an established deflection limit

Finding the three limiting conditions and simplifying the analysis, the pressure distribution under the mat is considered uniform and equal to the allowable ground bearing pressure. This allows the maximum load carried by the mat to be simply expressed as a function of the allowable ground bearing pressure (a constant) and an effective length over which the allowable ground bearing pressure is applied (a variable). That, in turn, allows the bending stress, shear stress, and deflection all to be expressed in three equations where $L_{eff}$ is the only variable, allowing a solution for $L_{eff}$ for each of the three criteria. The lowest value of $L_{eff}$ governs. The allowable load to the mat may be calculated. Knowing the allowable load that is to be designed, the percentage utilization may be calculated and should not exceed 100%.

## D-10.2 Wood Crane Mat Construction

Crane mats should be constructed using full dimension and continuous length timbers of good quality. The timbers are typically one or more of the species listed in Table D-10.2-1.

Table D-10.2-2 provides commonly used design values for mats constructed from timbers of the species listed in Table D-10.2-1. These values are suitable for the evaluation of mats with the mat section properties calculated using the nominal dimensions of the timbers.

The appropriate design values for timber mats should be determined by the mat producer or a qualified person. Differences from these provisions may include using timbers of different species or different qualities.

## D-10.3 Assumptions and Limitations for the Effective Bearing Area Method

The effective bearing area calculation method is applicable to a single layer of supporting materials with the following assumptions and limitations:

*(a)* The crane mat or outrigger pad should be in good serviceable condition. See section D-9 for inspection criteria.

*(b)* For crane mats, the effective bearing method assumes a load bears across the entire width of the mat. This can be accomplished with a transition layer capable of distributing the load from the float to all timbers in the assembly (see Figure D-10.3-1).

*(c)* The load should be centrally located on the crane mat or outrigger pad (see para. D-8.4).

*(d)* The crane mats or outrigger pads are to be located on a level surface within the LHE manufacturer's specification and with uniform contact on the supporting surface.

*(e)* If the crane mat or outrigger pad is located close to subsurface structures, engage a qualified person to assess the impact on the structures.

*(f)* If the crane mat or outrigger pad is located close to excavations, slopes, embankments, retaining walls, or bulkheads, engage a qualified person to assess the impact on the allowable GBP.

*(g)* The supporting surface should provide uniform support to the crane mat or outrigger pad.

## D-10.4 Sample Spreadsheet for Wood Mats

To simplify the calculation, a spreadsheet can be developed to automate the process. Figure D-10.4-1 is an example of such a spreadsheet. The commonly used bending and shear stresses for wood crane mats as described in para. D-10.2 are used in this example.

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**Table D-10.2-2**
**Commonly Used Wood Crane Mat Design Values**

| Design Property | Design Value, psi |
|---|---|
| Allowable bending stress, $F_b$ | 1,400 |
| Allowable shear stress, $F_v$ | 200 |
| Allowable compression stress perpendicular to the grain — hardwoods, $F_c$ | 750 |
| Allowable compression stress perpendicular to the grain — softwoods, $F_c$ | 575 |
| Modulus of elasticity, $E$ | 1,200,000 |