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Chapter 1

Knowledge About Light Capacity Mobile Cranes

1.1 Mobile Crane Definition, Operator Qualifications, and Terminology

1.1.1 Definition

Mobile cranes are defined as “Machinery that lifts loads and transports them horizontally using motive power. These machines have built-in prime movers installed and can be moved to unspecified locations”. Among these, mobile cranes that have a lifting load of one or more tons and less than five tons are called “light capacity mobile cranes”.

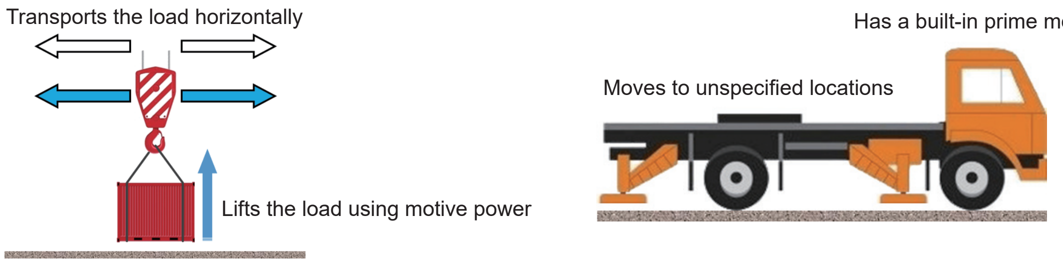


Fig. 1-1 Definition of Mobile Cranes

1.1.2 Operator Qualifications

The qualifications required for operating a mobile crane are classified according to the lifting load of each mobile crane. To operate the mobile cranes shown in Table 1-1, it is required to obtain the mobile crane operator license or to complete a skill training course or special education for mobile crane operation. The qualifications are only classified based on the lifting load and capabilities of the mobile crane to be operated, and are not classified based on the actual mass of the load to be lifted.

Table 1-1 Operable Mobile Cranes by Operator Qualifications

Lifting Load	Mobile Crane Operator’s License	Skill Training Course for Light Capacity Mobile Crane Operation	Special Education for Mobile Crane Operation	Comments
Five tons or more	○	×	×	This excludes operations that involve driving on roads
One or more tons and less than five tons	○	○	×	
0.5 or more tons and less than one ton	○	○	○	

1.1.3 Terminology

(1) Hoisting/Lowering, Jib Derricking, Telescoping and Slewing

Mobile crane operation is performed using a combination of hoisting/lowering, jib derricking, telescoping or slewing.

Fig. 1-2 Mobile Crane Motions

(2) Jib

A jib is an arm whose fulcrum is at the end of the slewing upper structure of a mobile crane. There are box jibs and lattice jibs depending on the shape. Nearly all light capacity mobile cranes with a lifting load of less than five tons have box jibs.

The additional jib installed on the end of the main jib is called the auxiliary jib. The main jib of a mobile crane is generally referred to as the boom. Additionally, hydraulic excavators with crane functions use articulated jibs. The part close to the bucket is called the arm; the part close to the operator's seat is called the boom (See Fig. 1-14, p.11 (en)).

(3) Working Radius

The working radius is the horizontal distance from the center of slewing to the vertical line that passes through the center of the hook (Fig. 1-3). Note that it is not the distance from the foot pin to the center of the hook.

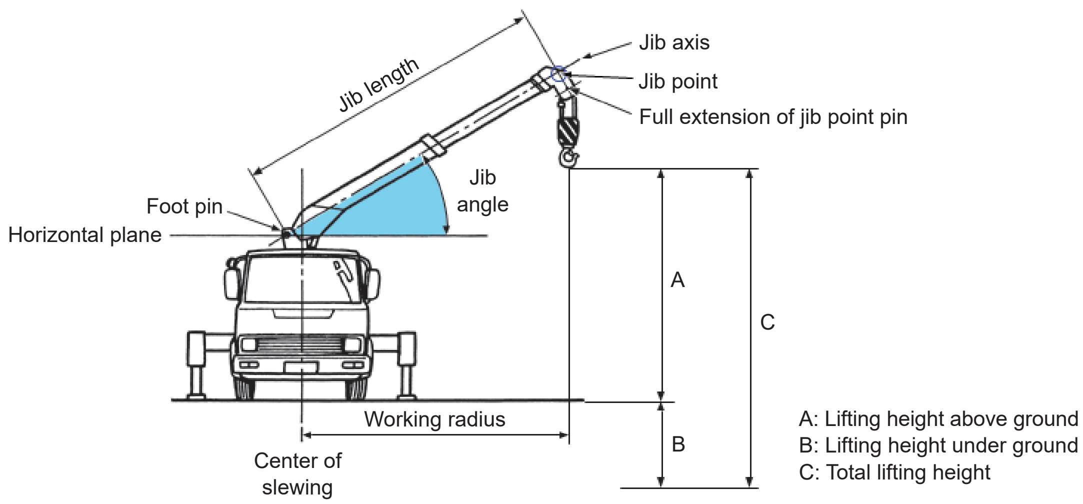


Fig. 1-3 Jib Terminology

(4) Lifting Load

The lifting load is the maximum load that can be laid when the outrigger is fully extended and the working radius is minimized (which is the state when the jib length is fully minimized and the jib angle is maximized). The lifting load includes the mass of load-lifting attachment such as hooks and grab buckets.

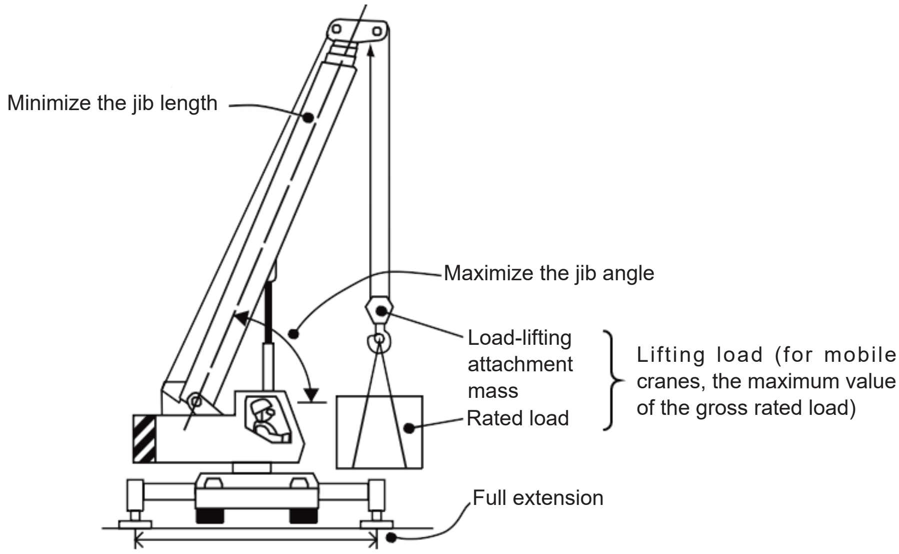


Fig. 1-4 Lifting Load

(5) Rated Load

The rated load is the load obtained by subtracting the mass of load-lifting attachment (such as hooks or grab buckets) from the maximum load that can be laid on a mobile crane according to its construction, component materials, jib angle, and jib length.

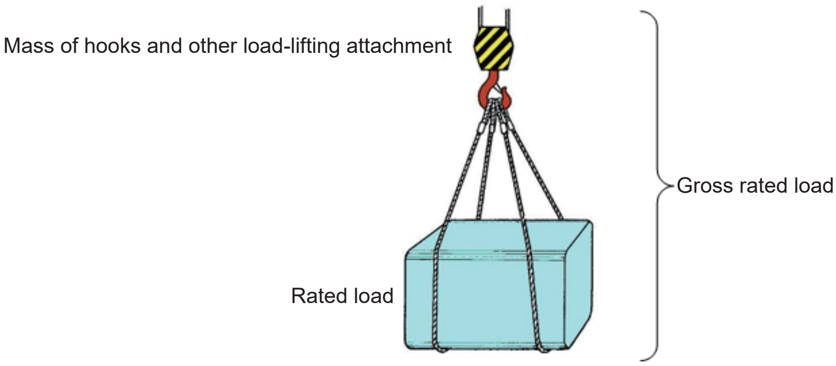


Fig. 1-5 Gross Rated Load

(6) Gross Rated Load

The gross rated load is the mass obtained by adding the mass of the hook or any other load-lifting attachment to the rated load (Fig. 1-5, p.5 (en)). For mobile cranes, the several hooks are often used depending on the type of work. Even when the jib length and working radius are the same, the rated load varies when a different hook is used. Thus, the gross rated load obtained by adding the mass of the hook or any other load-lifting attachment to the rated load is generally displayed. The maximum value of the gross rated load equals to the lifting load.

(7) Gross Rated Load at Non-loaded Condition

The gross rated load at non-loaded condition is a term used only for truck loader cranes. It is determined based on crane stability when there is no load on the cargo bed (unloaded state) as well as the strength of the jib and other components. It indicates the mobile crane's performance when the outrigger is at its full extension width (which grants maximum crane stability) and when the jib is facing the over-rear and over-side area.

(8) Jigiri (Liftoff)

Jigiri (Liftoff) refers to hoisting the load such that it is slightly above the ground, work platform, or bearer blocks.

During hoisting operations, lift the load quietly with slight movement, stop once the load has been lifted off of the ground, and confirm the stability of the lifted load. And then, confirm the condition of the tamagake (rigging) gear by checking whether it is hanging in place on the hook to ensure the safety.

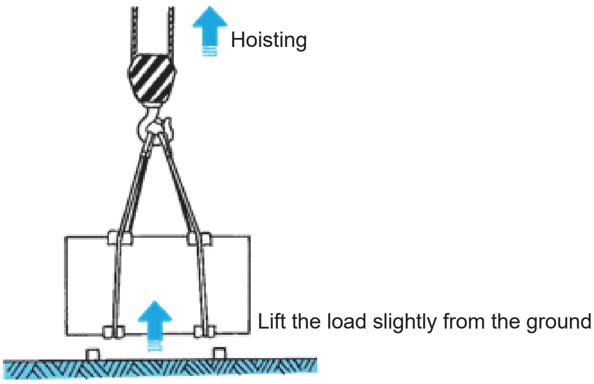


Fig. 1-6 Jigiri (Liftoff)

(9) Lifting Height

The lifting height is the vertical distance between the upper and lower limits within which the hook or other load-lifting attachment can be effectively lifted and lowered based on the jib length and jib angle. The range of lifting height upward from the ground (the surface on which the mobile crane has been mounted) is called the "lifting height above ground", the range of lifting height downward is called the "lifting height under ground", and the total is called the "maximum lifting height" (total lifting height) (Fig. 1-3, p.4 (en)). In general, with truck loader cranes, the lifting height above ground when the jib is at maximum length is set as the maximum lifting height above ground, and the lifting height under ground is not set.

1.2 Types of Mobile Cranes

1.2.1 Truck Cranes

(1) Truck Cranes

Truck cranes with a lifting load of less than five tons often have a reinforced standard truck chassis with a slewing upper structure (crane equipment) installed, and are equipped with an outrigger to increase stability during crane operations.

Additionally, two cabs are installed on each truck crane, one for operating the crane and the other for driving the crane. A hydraulic system or mechanical system transmits power to the crane equipment. The majority of mobile cranes with a lifting load of less than five tons use hydraulic systems.

Fig. 1-7 Truck Cranes

(2) Truck Loader Cranes

Truck loader cranes load light capacity crane equipment between the cargo bed and cab, and operate the crane equipment by extracting motive power from the prime mover (engine) for driving the crane. Many types have a lifting load of less than three tons. There are two types of jib shapes such as straight jibs and articulated jibs.

Straight jib

Articulated jib

Fig. 1-8 Truck Loader Cranes

1.2.2 Wheel Cranes

(1) Wheel Cranes

Wheel cranes are equipped with a custom trolley on which a slewing upper structure (crane equipment) is installed. Wheel cranes allow for both driving and crane operations to be performed from a single cab with a single prime mover. There are four-wheel and three-wheel (two front wheels, one rear wheel) types. While many cranes are equipped with outriggers to increase stability, there are a few equipped with iron rings on the exterior of the front tires. The iron rings come into contact with the ground during lifting and increase stability.

Fig. 1-9 Wheel Cranes

(2) Rough Terrain Cranes

Rough terrain cranes are self-propelling cranes that allow for crane operation and driving from a single cab. Rough terrain cranes are included under the wheel crane classification. These cranes can be driven on uneven and relatively soft ground due to being equipped with large tires and all-wheel drive. These cranes are also equipped with four types of steering methods (front two-wheel steering, rear two-wheel steering, four-wheel steering, and crab steering); therefore, they have excellent mobility in narrow spaces.

Fig. 1-10 Rough Terrain Cranes

(3) Crawler Cranes

Crawler cranes are equipped with a crawler for movement, which is a driving frame with a slewing upper structure installed on it; therefore, their contact area is wider than that of the tires. This allows crawler cranes to be driven even in soft, uneven locations. Some light capacity crawler crane models, referred to as mini crawler cranes, are equipped with outriggers to increase stability.

Fig. 1-11 Light Capacity Crawler Cranes

1.2.3 Railway Cranes

Railway cranes have crane equipment (slewing upper structure) installed on top of a trolley with wheels that run on top of railway lines. Railway cranes are used in railway construction.

Fig. 1-12 Railway Cranes

1.2.4 Floating Cranes

Floating cranes have crane equipment installed on top of a barge. There are types in which the jib does not perform derricking or slewing. Floating cranes move across the water’s surface either through self-propulsion or non-self-propulsion, and many have impressive capabilities for handling large and heavy loads.

Fig. 1-13 Floating Cranes

1.2.5 Other Mobile Cranes

Another type of mobile crane is the drag shovel-type (hydraulic excavators with crane functions [Fig. 1-14]). These are equipped with crane functionality such as hooks for lifting loads on hydraulic excavators, and safety devices. Specifically, a custom hook is attached to the rear of the bucket (retractable hooks that can be stored in the rear of the bucket are common [Fig. 1-15]), and by setting up the hook and the Crane Mode or Excavator Mode in accordance with the operation, it is possible to use a single crane for both excavation and crane operations. Note that this does not include cranes in which a custom hook is simply attached to the rear of a bucket.

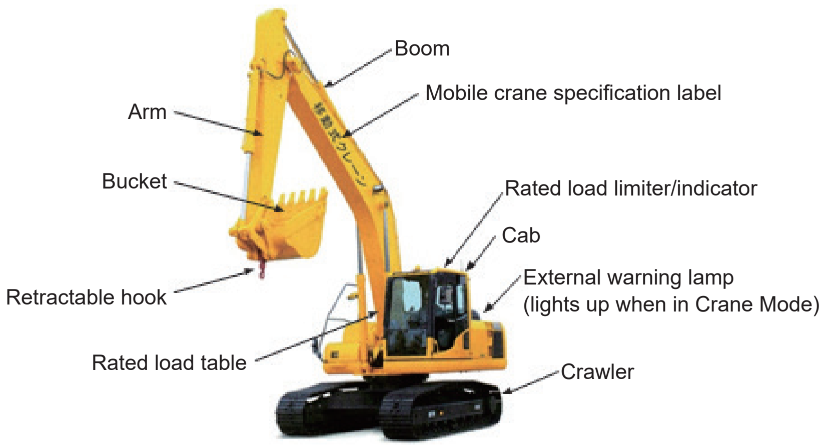


Fig. 1-14 Hydraulic Excavator with Crane Function

(a) Not retracted

(b) Retracted

Fig. 1-15 Retractable Hook

1.3 Principal Structures of Mobile Cranes

1.3.1 Slewing Upper Structure

A slewing upper structure refers to a structure in which a jib and hoisting/derricking crane equipment or the like are installed in the frame of a welded structure called a “slewing frame”. The slewing frame is mounted on top of the base carrier through the slewing bearing. The entire body slews left and right.

In the slewing upper structures of rough terrain cranes, a jib, derricking mechanism (derricking cylinder), hoisting mechanism, and a cab for performing crane operations and driving operations are installed in the slewing base situated on the slewing frame (Fig. 1-16, p.13 (en)). A counterweight or other weighted structure for maintaining balance is installed in the rear of the hoisting mechanism.

For the truck cranes, the upper structures are nearly the same, but a cab only for crane operation is installed in the slewing frame. The cab for driving operations is provided in the base carrier. The slewing upper structure of truck loader cranes contains a hoisting mechanism and derricking mechanism (derricking cylinder) in the slewing frame, and the jib is installed in the upper portion (Fig. 1-17, p.13 (en)). Additionally, operating devices are provided on both sides of the base carrier. The jib is equivalent to an arm when lifting a load, and it primarily exerts a bending force (bending load). There are box jibs and lattice jibs, and the shape of box jib cross sections is primarily rectangular or polygonal to provide the strength needed to withstand the bending force (Fig. 1-20 and Fig. 1-21, p.13 (en)). Most light capacity mobile crane jibs are box jibs.

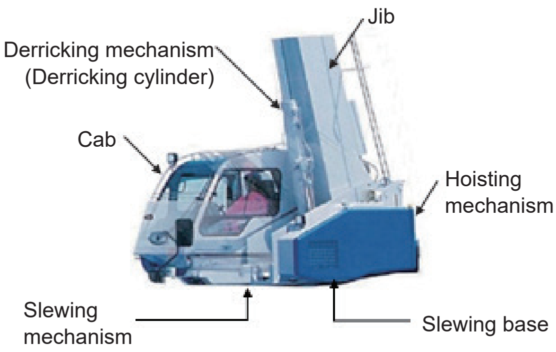


Fig. 1-16 Rough Terrain Crane Slewing Upper Structure

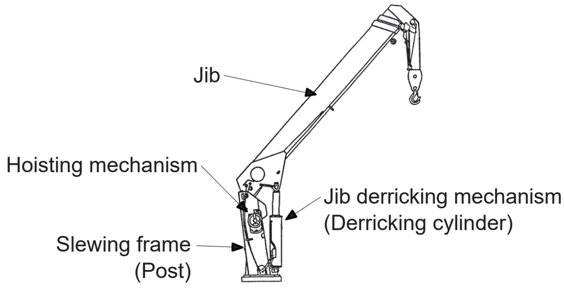
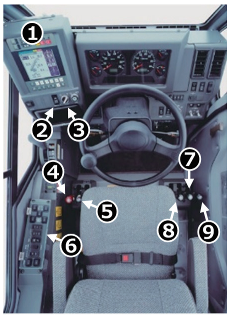
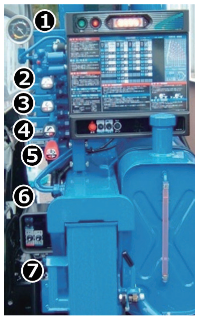


Fig. 1-17 Truck Loader Crane Slewing Upper Structure



❶ Load moment limiter
❷ Slewing brake switch
❸ PTO switch
❹ Slewing lever
❺ Telescoping lever
❻ Outrigger operating switch
❼ Main hoisting lever
❽ Auxiliary hoisting lever
❾ Derricking lever

Fig. 1-18 Example of Rough Terrain Crane Cab



❶ Load meter
❷ Telescoping lever
❸ Hoisting lever
❹ Derricking lever
❺ Slewing lever
❻ Hook retraction/
extraction switch
❼ Jack switch

Fig. 1-19 Example of Truck Loader Crane Control Lever/Switch

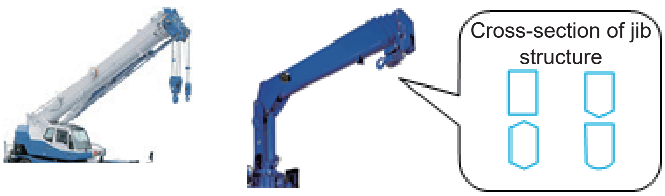


Fig. 1-20 Box Jib

Fig. 1-21 Lattice Jib

1.3.2 Slewing Mechanism

The slewing mechanism is a device that rotates the slewing upper structure left and right while installed in the base carrier. Many have a structure in which the slewing bearing is installed to the upper part of the base carrier frame and the slewing upper structure is installed in the upper surface of the slewing bearing. With this type of slewing mechanism, limitless 360° rotation is possible. (See “Slewing Mechanism” (p.24) (en))

1.3.3 Base Carrier

The base carrier is a substructure that is loaded onto the slewing upper structure and drives the crane. It comes in the following types based on the driving system.

(1) Truck Loader Crane Base Carrier

For truck loader cranes, cargo trucks are used that reinforce the location to which crane equipment is mounted (between the cab and cargo bed of normal cargo trucks). There are also models where the crane equipment is installed in the cargo bed or the rear.

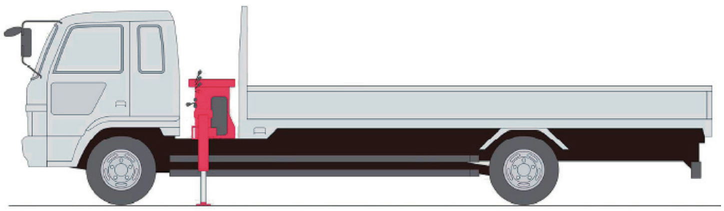


Fig. 1-22 Truck Loader Crane Base Carrier

(2) Wheel Crane (Including Rough Terrain Crane) Base Carrier

Wheel crane base carriers are specially manufactured for use in wheel cranes. There are usually two axles, and four-wheel drive (4WD) models are common, with types that enable four-wheel steering being the norm. Motive power for driving and crane operation is provided by a single engine and all operations are performed from a single driver’s seat. While wheel cranes are equipped with outriggers, some models are not equipped with them; these models have a structure in which iron rings with diameters slightly smaller than the tires are installed on the tire exteriors. These iron rings come into contact with the ground during crane operation and increase stability.

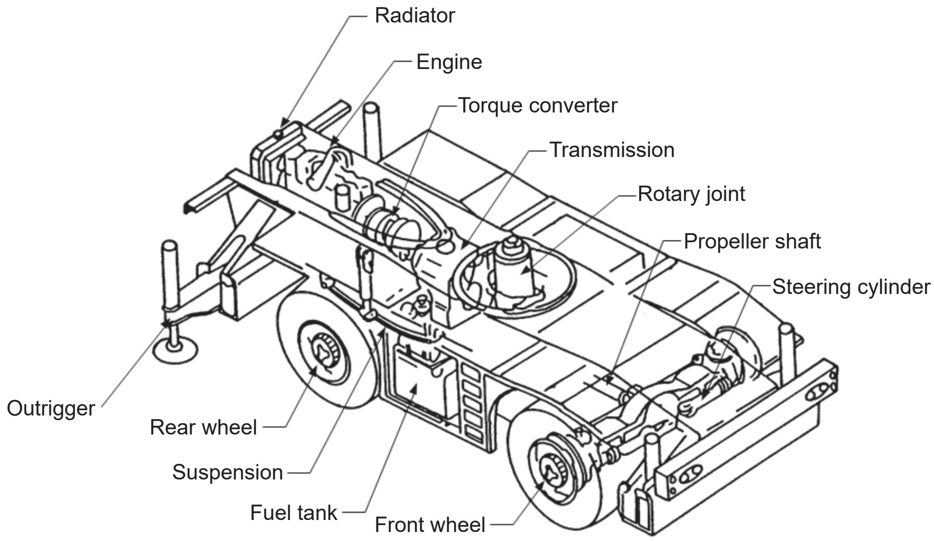


Fig. 1-23 Wheel Crane Base Carrier

(3) Outrigger

Outriggers are installed in truck cranes, wheel cranes (including rough terrain cranes), and truck loader cranes to increase the stability during operations. Outriggers operate using hydraulic systems. There are H-type outriggers and X-type outriggers.

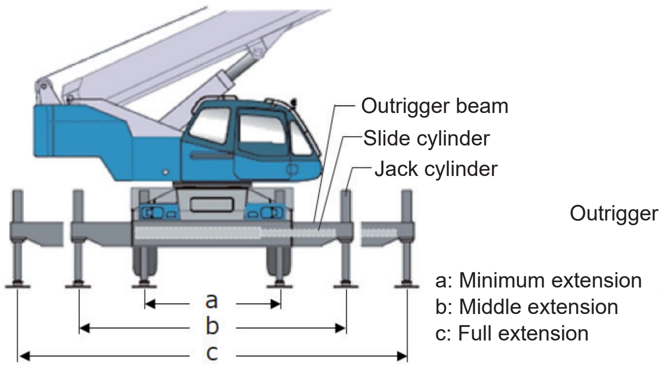


Fig. 1-24 H-type Outrigger (Rough Terrain Crane)

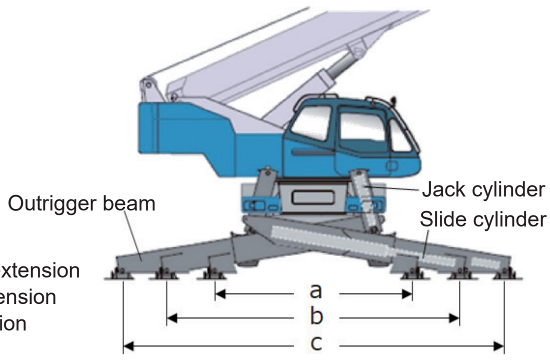


Fig. 1-25 X-type Outrigger (Rough Terrain Crane)

It is required that the outrigger beam is at the set extension width and fixed with the lock pin when performing operations. For truck loader cranes, most outriggers are manually extended to the side of the crane and vertical movement of the jack is done hydraulically.

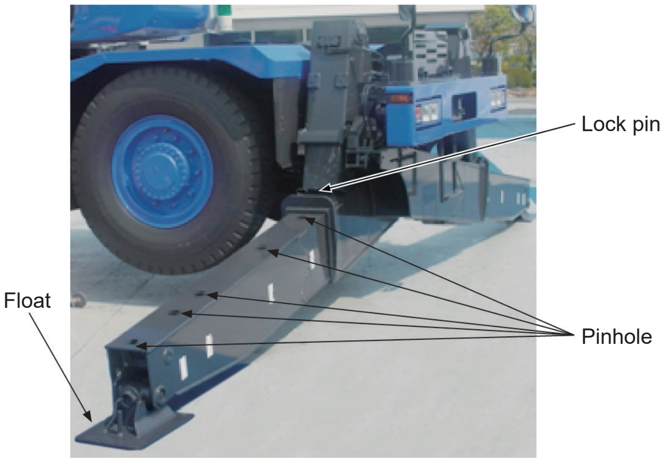


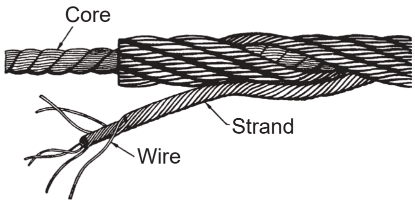
Fig. 1-26 X-type Outrigger Lock Pin and Pinhole

1.3.4 Wire Rope

Wire ropes attached to the hoisting drum on the body of the mobile crane are used for hoisting. These wire ropes must be particularly strong; thus, the specifications used for them are different than those used for tamagake. Regarding its strength, a safety factor of 4.5 or higher is stipulated for wire rope for hoisting and jib derricking, 3.55 or higher for jib telescoping, and 3.75 or higher for wire rope used to support the jib. The safety factor is the breaking load of the wire rope divided by the maximum value of the load applied to the wire rope.

(1) Wire Rope Structure

Wire rope is manufactured by twisting several strands together. Each strand is prepared by twisting together dozens of cold-worked seamless wires made with high quality carbon steel.



Core: A general term for fiber cores, strand cores and rope cores. (This forms the center of a rope or strand.)

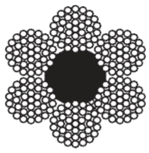
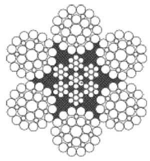
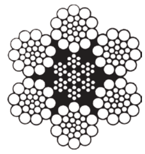
Strand: A component of a wire rope made of multiple wires twisted together.

Wire: The steel wires that make up a strand. There are naked wires and plated wires.

Fig. 1-27 Wire Rope Structure

The fiber core or rope core at the center of the wire rope works to maintain the rope shape, provide flexibility, and absorb shocks and vibrations to prevent the strands from breaking. This is the mechanism of the core. For mobile cranes, wire ropes consisting of six strands twisted together are commonly used. The structure of wire rope is usually indicated by a structural code, (the number of strands) x (the number of wires contained in each strand), such as 6 x 37. Among different wire ropes of a given diameter, those made with a larger number of thinner wires in general have greater flexibility.

Table 1-2 Wire Rope Structural Codes and Cross-sections

Structural Code	6 x 37	IWRC6 x Fi(29)	IWRC6 x WS(26)
Sectional View			
Properties	The core is made of fiber, granting good flexibility.	A single independent wire rope is used as a core and the core consists of filler wires bundled together. This is used when a high breaking load is required.	A single independent wire rope is used as a core. It has excellent flexibility and wear resistance.
Usage	Hoisting/Tamagake	Hoisting/Tamagake	Hoisting

(2) Types of Lays

When the wire rope lay and the strand lay are in opposite directions, this is called “Ordinary Lay”; when these are in the same direction, this is called a “Lang’s Lay”. These are further divided into “Z Lay” and “S Lay”, depending on the wire rope lay direction.

Compared with a Lang’s Lay wire rope, an Ordinary Lay wire rope wears away sooner, but is easier to handle because it is less liable to untwist or kink. Thus, Ordinary Z Lay wire ropes are commonly used.

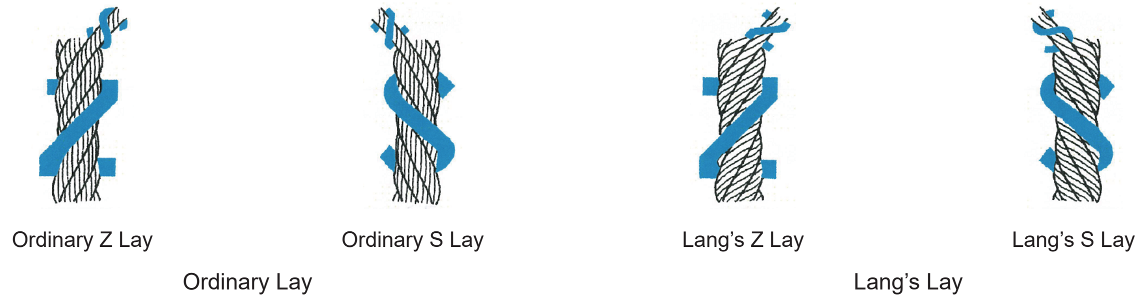


Fig. 1-28 Types of Lays

(3) Wire Rope Diameter

The diameter of a wire rope is represented by the diameter of a circle circumscribing its cross-section. It is determined by measuring the diameter of the wire rope with slide calipers in three directions at a given cross-section and then averaging the measured results. The tolerance against the nominal diameter determined at the time of production (the nominal diameter according to JIS) must be 0% to +7% (note that this is 0% to +10% for wire ropes with diameters below 10 mm).

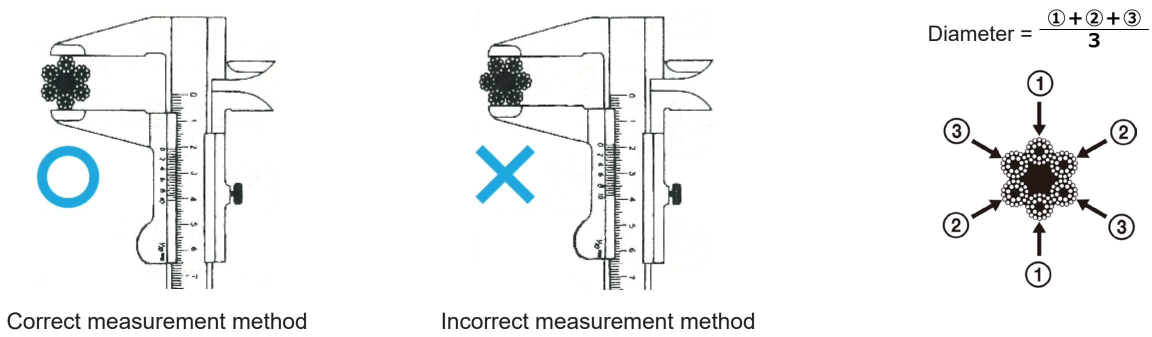


Fig. 1-29 Measuring Method for Diameter of Wire Rope

(4) Wire Rope Check

a. Check Points for Wire Rope

- Broken wires
- Decreased diameter and wear
- Kinks and deformation
- Corrosion
- Abnormalities in terminations and other joints

b. Criteria for Prohibited Wire Ropes

- Broken wires: Within each lay of the wire rope, if more than 10 percent of the total number of wires (excluding filler wires) is broken.

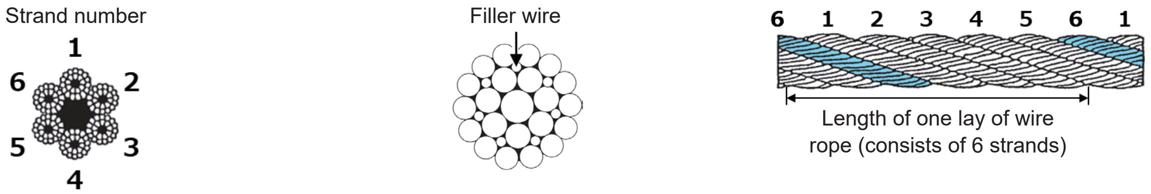


Fig. 1-30 One Lay of Wire Rope

- Decreased diameter: Wires that have decreased in diameter by more than seven percent of the nominal diameter.
- Deformation: Wires that have kinks (In this case, do not repair and reuse).

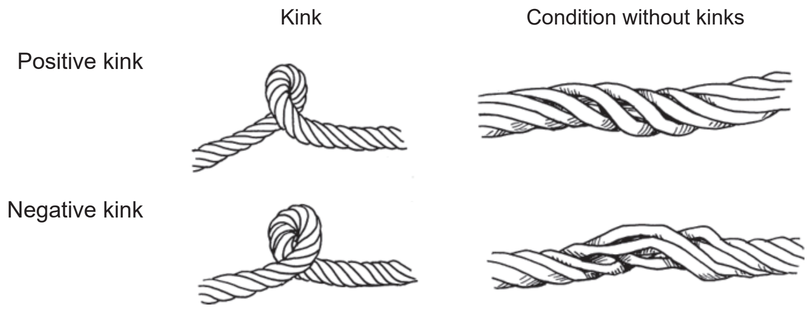
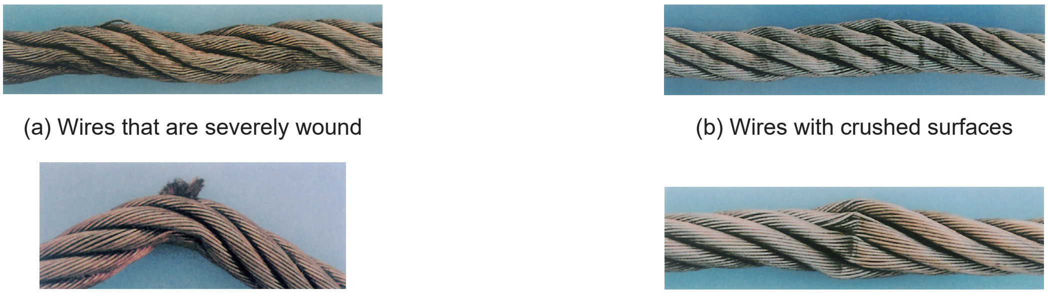


Fig. 1-31 Kink

- Corrosion: Wires that are severely deformed and/or corroded. (Fig. 1-32 and Fig. 1-33)



(a) Wires that are severely wound

(b) Wires with crushed surfaces

(c) Wires with severe curving

(d) Wires with severe damage

Fig. 1-32 Severe Deformation

The aforementioned wire rope criteria are removal criteria stipulated by laws and regulations. It is desirable that wire ropes with broken wires or an appreciable decrease in diameter be replaced with new ones at an earlier state, before they reach the state of the criteria specified above.

In addition, wire ropes should be removed in cases where a wire rope is affected by a combination of two or more issues, such as deformation, wear and tear, or broken wires. This means that even if individual damage is below the removal criteria, the wire ropes should be removed when the combined total damage from these causes reaches a certain level.

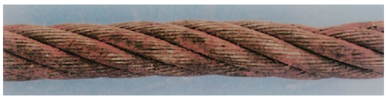
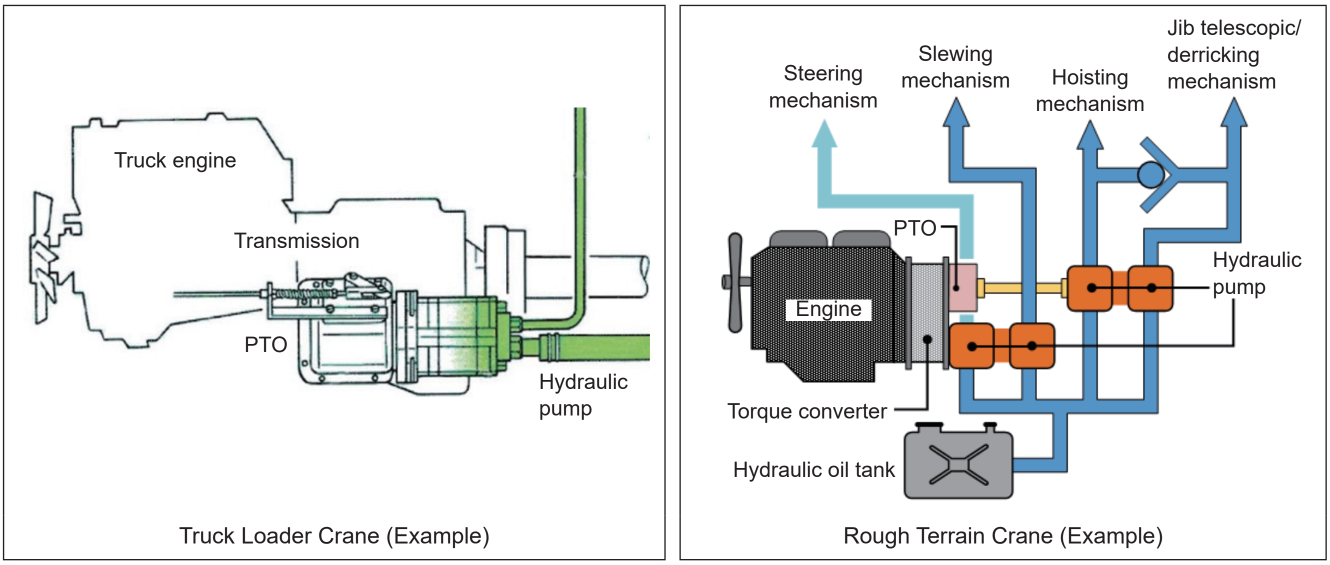


Fig. 1-33 Severe Corrosion

1.4 Mechanisms for Lifting, Derricking, Slewing, and Other Operations

1.4.1 PTO (Power Take Off)

This mechanism draws motive power from the engine that powers movement and uses it to operate the crane. It is used by switching it ON and OFF. The PTO is attached to the joint installed in the driving device transmission or other parts, drawing motive power from the engine by engaging the gears. It then drives a hydraulic pump used for cranes and, with the hydraulic pressure generated, operates the driving gear of the crane equipment (such as hydraulic motor and hydraulic cylinder).



Truck Loader Crane (Example)
Rough Terrain Crane (Example)

Fig. 1-34 Crane Equipment Power Source

1.4.2 Hoisting Mechanism

The hoisting mechanism consists of the hydraulic motor, hoisting speed reduction gear, hoisting drum, and other parts. The drum is rotated using the torque of the hydraulic motor for winding/unwinding the wire rope and to hoist and lower the load.

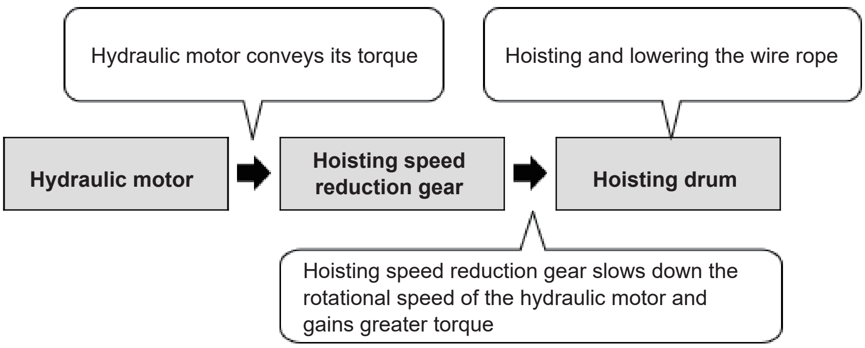


Fig. 1-35 Hoisting Mechanism Structure

(1) Rough Terrain Crane Hoisting Mechanism

At present, most rough terrain cranes are equipped with two hoisting mechanisms: one for the main hoisting operations using the main jib, and one for auxiliary hoisting operations with the auxiliary jib. The brake is an automatic brake type that automatically operates when the winch control lever is not being operated.

(2) Truck Loader Crane Hoisting Mechanism

Truck loader cranes are normally equipped with only a single main hoisting mechanism. These cranes do not allow for "freefall" — lowering the hook by disengaging the clutch and letting the drum to descend freely (controlling its speed with a foot brake). The hoisting mechanism consists of a hydraulic motor, reduction gear, a mechanical brake, and a hoisting drum.

(3) Truck Loader Crane Brake Mechanism

For truck loader cranes, because of a lack of installation space, mechanical brakes are used. These brakes are built into the hoisting mechanism reduction gear. Mechanical brakes operate automatically when the control lever is set to neutral, and the automatic brakes can hold the load in position.

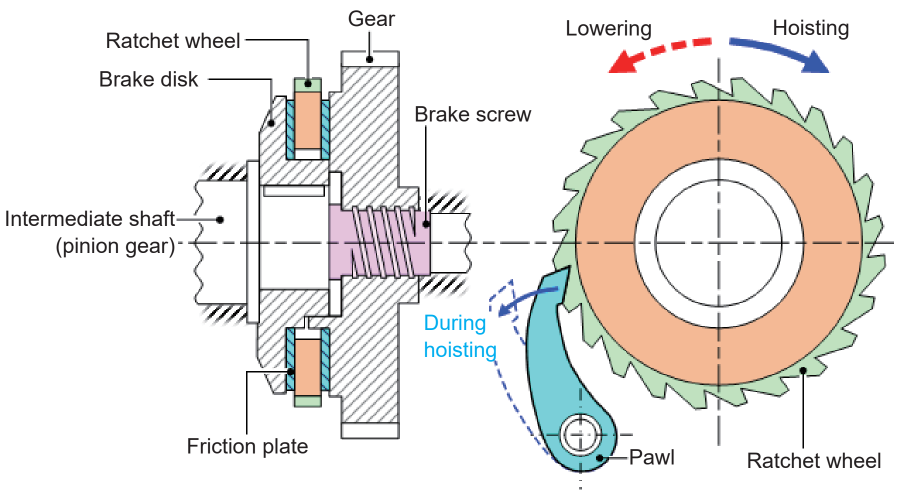


Fig. 1-36 Mechanical Brake Mechanism

1.4.3 Slewing Mechanism

The slewing mechanism is a device that consists of the hydraulic motor, reduction gear, pinion, and slewing bearing, and it slews the slewing upper structure left and right. The slewing bearing is installed in the upper part of the base carrier frame, and the slewing upper structure is installed in the upper surface of the slewing bearing.

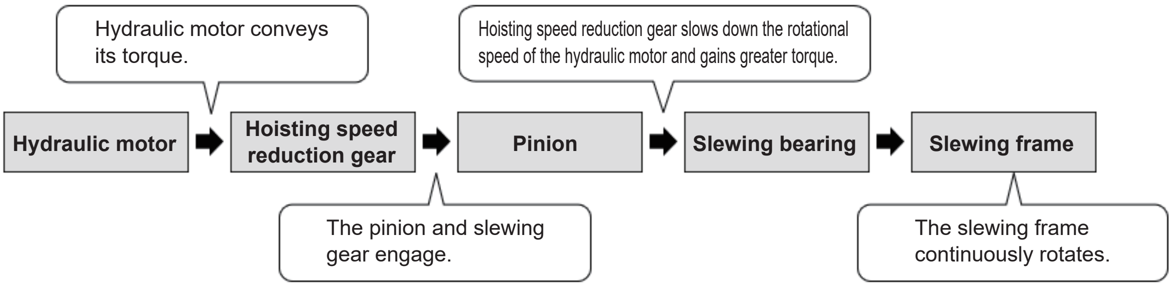


Fig. 1-37 Slewing Mechanism Structure

(1) Rough Terrain Crane Slewing Mechanism

In the slewing mechanisms for rough terrain cranes, the slewing bearing is installed in the upper part of the base carrier frame, and the slewing upper structure is installed in the upper surface of the slewing bearing. The rotary power from the hydraulic motor which is installed to the slewing upper structure is reduced and conveyed to the pinion; this causes engagement with the slewing bearing gear. This causes further deceleration and turns the slewing upper structure that is fixed to the inner race. In light capacity mobile cranes, the slewing bearing gear is provided on the exterior.

(2) Truck Loader Crane Slewing Mechanism

The operating device for truck loader cranes is installed in the base carrier, so the pinion gear that is attached to the end of the slewing reduction gear output shaft is installed in the exterior of the slewing bearing. The slewing bearing forms the external teeth.

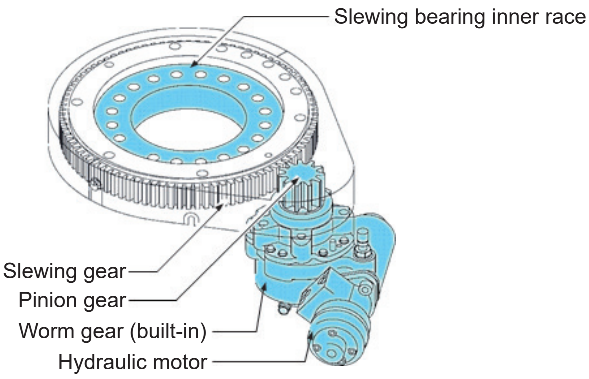


Fig. 1-38 Truck Loader Crane Slewing Mechanism (Slewing Bearing Type)

The slewing mechanism for truck loader cranes also contains a rack gear mechanism that uses a system in which the hydraulic cylinder makes the rack gear that is machined to one side of the rod move left and right and rotate the slewing gear. This system does not allow for limitless 360° rotation, so use of it has declined.

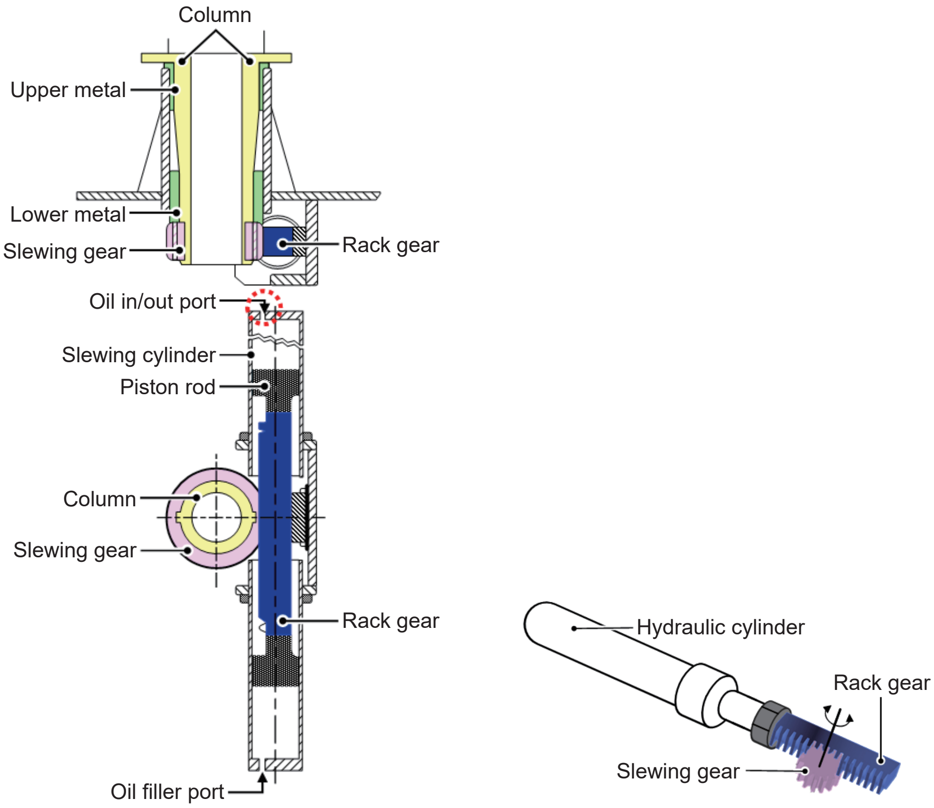


Fig. 1-39 Truck Loader Crane Slewing Mechanism (Rack Gear Type)

1.4.4 Jib Derricking Mechanism

Jib derricking is performed either using a hydraulic derricking cylinder or using a derricking drum to wind and unwind the derricking wire rope, but it has become less common to use wire ropes for derricking. Most light capacity mobile cranes with a lifting load of less than five tons use hydraulic cylinders for derricking. Additionally, types that use hydraulic cylinders are divided into pull-up types and push-types, and in recent years the push-type has become more common. The derricking mechanisms in most rough terrain cranes and truck loader cranes use push-type hydraulic cylinders. Jib derricking is generally performed with hydraulic derricking cylinders; or, in hydraulic excavators that have crane functions, the booms are push-type hydraulic cylinders and the arms are pull-up hydraulic cylinders.

Fig. 1-40 Derricking Mechanism That Uses Hydraulic Cylinder

1.4.5 Telescopic Mechanism

Jib telescoping is performed either only with a hydraulic cylinder or with a combination of a hydraulic cylinder and a telescopic wire rope to make the empty weight of the jib lighter. Jibs with up to three stages often use hydraulic cylinders, and those with four or more stages often use a combination of a hydraulic cylinder and a telescopic wire rope. Additionally, with regard to jib telescoping methods, there is the “sequential telescoping type” in which telescoping occurs sequentially. For example, the third stage extending when the second stage has finished extending, and the fourth stage extending when the third stage has finished extending. There is also a “synchronized telescoping type” in which telescoping occurs simultaneously for the second, third, and fourth stages. When performing jib telescoping operations, the hook either hoists or lowers depending on the jib telescopic movement; therefore, be careful of the hook position when performing jib telescoping. There are also models that have a function that automatically maintains spacing between the hook and jib end in conjunction with the jib telescoping.

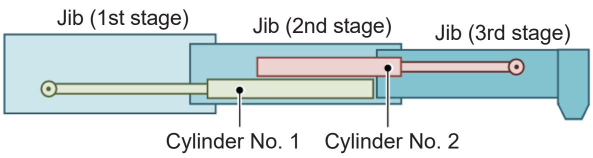


Fig. 1-41 3-stage Sequential Telescoping Jib Structure

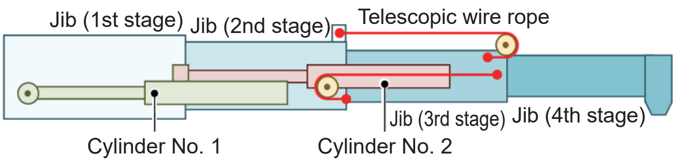
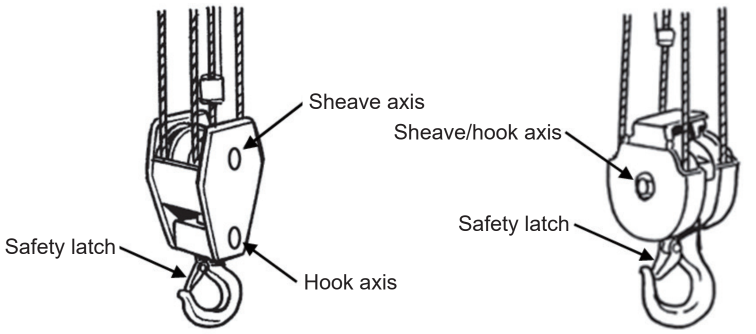


Fig. 1-42 4-stage Sequential/Synchronized Telescoping Jib Structure

1.4.6 Other

(1) Hook

Light capacity mobile cranes generally use a single hook. Because rough terrain cranes and other cranes are equipped with main hoisting and auxiliary hoisting mechanisms, they are equipped with a dual-axis hook for main hoisting and a hook for auxiliary hoisting. Truck loader cranes have a single hoisting mechanism, so they only have a main hoisting hook, and generally have single-axis hooks that allow for large lifting heights. Hooks must be equipped with a safety latch for tamagake wire rope.



(a) Dual-axis hook for main hoisting

(b) Single-axis hook

Fig. 1-43 Main Hoisting Hook

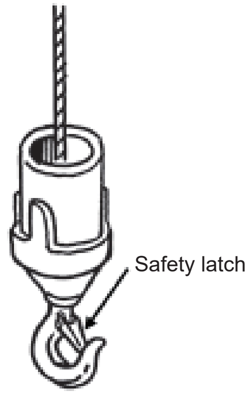


Fig. 1-44 Auxiliary Hoisting Hook

(2) Hook Retraction Mechanism

Many recent truck loader cranes and rough terrain cranes are furnished with a mechanism for storing the hook inside the end of the jib when work has ended. The storing process starts by fully lifting the hook; meanwhile, the overwinding preventive device is activated. Once the winding stops (for types that have only an alarm, stop winding the hook when the overwinding warning device sounds), storing is initiated using the hook storage switch or hook storage lever. The hook will be automatically stored in the undersurface of the jib.

Fig. 1-45 Hook Retraction Mechanism

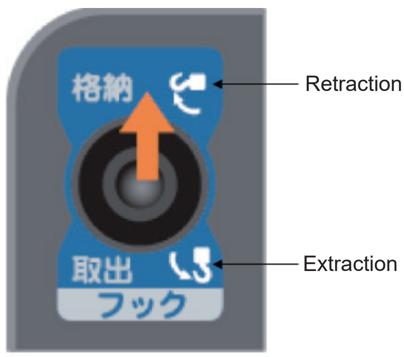


Fig. 1-46 Hook Retraction/Extraction Switch

1.5 Mobile Crane Safety Devices and Brake Functions

Mobile cranes are equipped with safety devices and brake functions to carry out work safely. The safety devices have the functions of sounding alarms or automatically stopping operations (such as an overwinding preventive device and overwinding warning device). These are activated when work exceeds a mobile crane's capacity or operations are performed out of the specified range. The safety devices include devices to protect the machine from excessive applications of force (such as a load moment limiter and device for preventing overloading), devices to prevent abnormal pressure increase in the hydraulic circuit and protect the hydraulic equipment (such as a relief valve), and devices to prevent the load from suddenly descending at abnormal pressure drop (such as a check valve). The brake functions include the brakes needed to brake movement, maintain a stopped state, and brake the descent of the load or jib.

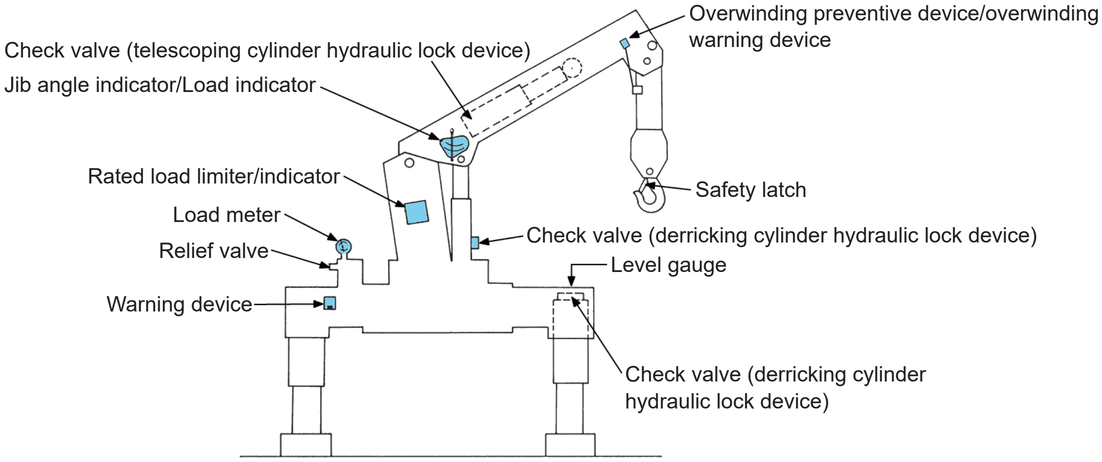


Fig. 1-47 Truck Loader Crane Safety Device

1.5.1 Overwinding Preventive Devices

Overwinding a hoisting wire rope or further extending the jib without lowering the hook can result in accidents, such as a hook assembly collision with the jib which damages the hook assembly, top sheave and jib; hoisting wire rope breakage; or a hoisted load falling. The devices used to prevent these accidents are called the following: the “overwinding warning device”, which, when the hook approaches the maximum height, activates the switch by raising the weight lowered along the hoisting wire rope and sounds an alarm; and the “overwinding preventive device (direct driven type overwinding preventive device)”, which implements the automatic stop. To make these devices function effectively, the vertical distance between the upper surface of a load-lifting attachment, such as a hook (including the upper surface of the said attachment’s hoisting sheave), and the lower surface of the sheave of the jib end that may come in contact with the said upper surface, is specified by the Structural Standard for Mobile Cranes as follows below. It must be adjusted accordingly.

- The overwinding warning device must sound the alarm by the time the length (m) reaches the value equivalent to 1.5 times the maximum lifting velocity (m/sec) (or 1.0 times for mobile cranes in which hoisting of the load-lifting attachment or extension of the jib can be stopped by a single operation).
- For the overwinding preventive device, hoisting must be stopped at 0.25 m or more (0.05 m or more for direct driven type overwinding preventive devices).

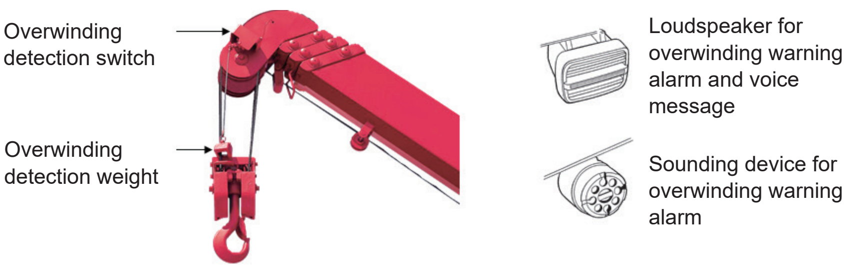


Fig. 1-48 Overwinding Warning Device

1.5.2 Devices That Prevent Overload

Cranes with jibs, such as jib cranes and mobile cranes, may overturn, or the jib may break when hanging a load that exceeds the rated load. The performance of mobile cranes is defined by the jib length based on work position, the jib angle (working radius), whether or not an auxiliary jib is used, the outrigger extension width, the working area (jib direction), etc. These properties determine the gross rated load. Exceeding the range of this determined gross rated load may cause the mobile crane to overturn or damage the body. Therefore, installation of either the following “load moment limiter” or a “device for preventing overloading other than load moment limiter” is mandatory to prevent loads exceeding the range of the determined gross rated load from being applied.

(1) Load Moment Limiter

In the Structural Standard for Mobile Cranes, mobile cranes with a lifting load of three tons or more must have a load moment limiter. If the lifted load approaches the gross rated load within the working radius, either an alarm sounds to call the operator's attention, or crane operation automatically stops when the gross rated load is exceeded. Even if the crane automatically stops, safe operations such as lowering the load and retracting or raising the jib are enabled.

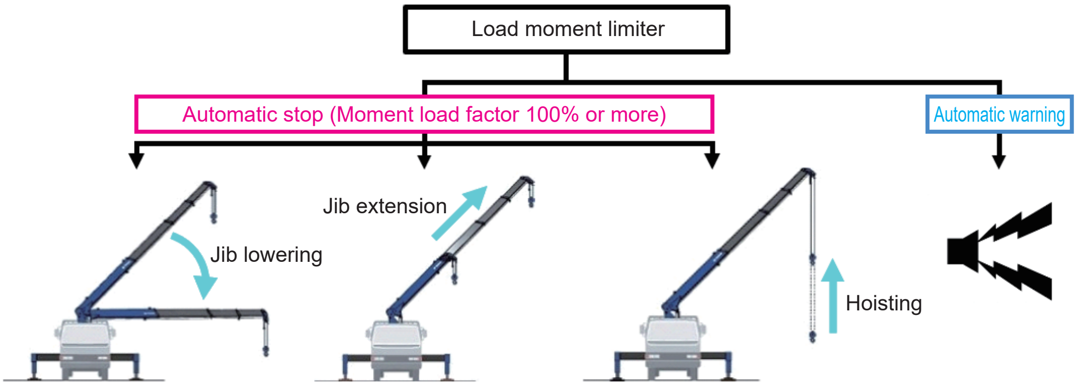


Fig. 1-49 Load Moment Limiter

(2) Device for Preventing Overloading Other Than Load Moment Limiter

For the following cranes prescribed in Article 27 of the Structural Standard for Mobile Cranes, installing the "device for preventing overloading other than load moment limiter" is deemed acceptable, instead of the load moment limiter.

- Mobile cranes with a lifting load of less than three tons
- Mobile cranes with fixed jib angles and lengths

Conventionally, rough terrain cranes are equipped with load moment limiters due to their lifting loads of three tons or more. As for truck loader cranes with lifting loads of less than three tons, load meters that detect the lifted load were installed instead of the load moment limiters. However, since March 1, 2018, the load meter has been excluded from "devices for preventing overloading other than a load moment limiter" in the Structural Standard for Mobile Cranes. Thus, it became mandatory to install a rated load limiter or a rated load indicator.

- Rated load limiter: A device capable of immediately and automatically stopping mobile crane operation if the rated load is exceeded.
- Rated load indicator: A device capable of sounding an alarm before the load exceeds the rated load, when there is a risk of exceeding the rated load.

As a transitional measure, the load meters can still be used for models equipped with load meters which have been in operation since before the above revision of the Structural Standard for Mobile Cranes. The load meters include: hydraulic load meters and digital load meters.

1) Hydraulic Load Meter

This load meter converts the operating pressure of the hydraulic motor for the hoisting mechanism into a load. Thus, the load mass is displayed only when hoisting a load using the hoisting mechanism, and is not displayed when stopping, lowering, or another operation in progress. Therefore, sufficient understanding of the manufacturer's instructions is required for use. Load mass measurements using the load meter are generally conducted as follows.

1. Slow the engine speed.
2. Perform a hoisting operation without a load being lifted (no-load state) and adjust the engine speed so that the load meter needle points at zero.
3. Select the scale mark to be read based on the number of ropes on the hook of the hoisting wire rope to be used.
4. Apply a load to the hook and lift it slightly. Read the scale value (load mass) indicated by the load meter needle based on the selected scale mark during lifting.

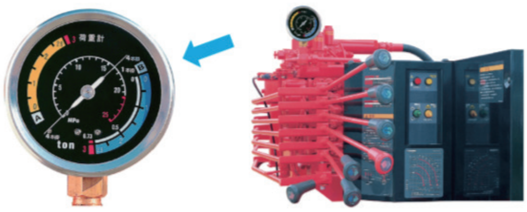


Fig. 1-50 Hydraulic Load Meter

2) Digital Load Meter

This load meter digitally displays the load mass on the load display screen. In recent years, the number of truck loader cranes equipped with this has been increasing. Unlike the hydraulic load meter, the digital load meter can constantly display the load mass while the load is being lifted.

Fig. 1-51 Digital Load Meter

1.5.3 Relief Valve

The relief valve refers to a pressure control valve in the Safety Ordinance for Cranes. When the hydraulic pressure in the hydraulic circuit reaches the specified pressure, a pressure control valve automatically releases part or all of the oil to prevent the specified pressure from being exceeded and protects the hydraulic equipment.

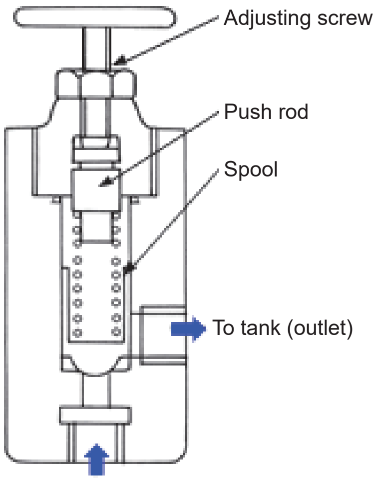


Fig. 1-52 Relief Valve

1.5.4 Safety Latch

The safety latch prevents the tamagake wire rope from slipping off the hook when a mobile crane lifts a load. There are spring-type and weight-type structures, while most light capacity mobile cranes use the spring-type.

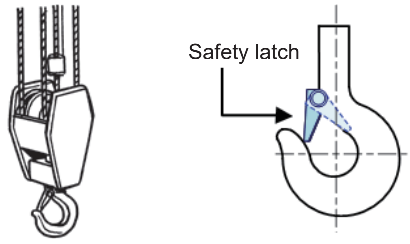
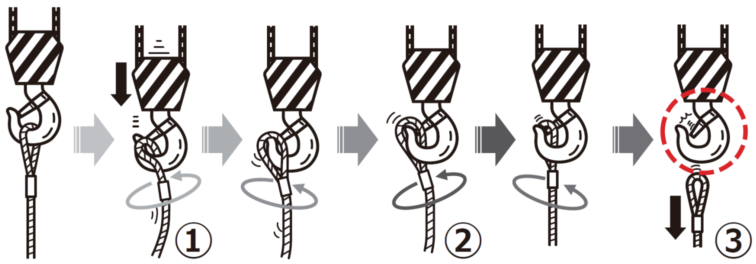


Fig. 1-53 Safety Latch

Depending on work conditions, the tamagake wire ropes may slip off the hook. Therefore, two latch devices are used in some cases. Fig. 1-54 shows the mechanism of the “slipping-off”.



When twisted wire ropes slacken, they rotate largely along the hook (①), eventually going past the tip of the hook (②), and entering between the hook tip and the safety latch to slip off (③).

Fig. 1-54 How It Slips Off

1.5.5 Working Range Limit Device

The working range limit device controls functions such as jib telescoping, derricking, and slewing. It also restricts the working area to limit operations that exceed the pre-registered working range, including working height and radius, and slewing range. More specifically, the functions of the working range limit device are as follows.

- Limiting jib raising and extension: This function prevents the jib from coming near power lines, railway wires, etc.
- Limiting slewing: This function limits the slewing area for lateral movement and slewing angle to prevent the jib from, for example, entering the course on the opposite side.
- Detecting the preliminary winding number and stopping automatically (with pressing roller for wire rope): The operation stops automatically, during lowering, when the number of remaining turns of the wire rope in the drum is three, to prevent further lowering.

1.5.6 Warning Device

Warning devices prevent accidents such as getting caught between the crane and another object by sounding an alarm to those nearby when the mobile crane is slewing. The alarm switch is installed at the slewing lever in the cab for the rough terrain cranes, and at the control panel for truck loader cranes.

Fig. 1-55 Rough Terrain Crane Warning Device (Example)

1.5.7 Brake Functions

Mobile cranes are provided with two types of brakes: a base carrier brake and brake for a lifting mechanism, etc.

(1) Base Carrier Brake

The base carrier brakes have two different types and they are provided independently: the brake for a mobile crane's movement; and the brake for maintaining the stopped state. For the brake for a mobile crane’s movement, the necessary stopping distance is specified according to the mobile crane’s total mass, maximum driving speed and initial braking speed.

(2) Brake for the Lifting Mechanism, etc.

The lifting, derricking and telescopic mechanism have a brake for braking the descent of the load or jib. The braking torque is 1.5 times or more the torque value of the mobile crane lifting, derricking or telescopic mechanism when the mobile crane lifts a load equivalent to the rated load.

1.5.8 Level Gauge

The level gauge is a measuring instrument used to level the crane body. Since the mobile crane performance (such as gross rated load) is defined with the body placed horizontally, the rough terrain cranes are equipped with the level gauge that allows for checking the levelness of the body. Truck loader crane performance is also determined on the condition that all directions of the crane body are level. Therefore, confirm that all directions are level using the level gauge at installation.

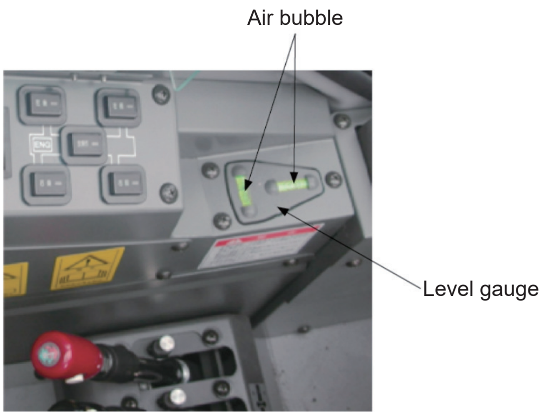


Fig. 1-56 Rough Terrain Crane Level Gauge

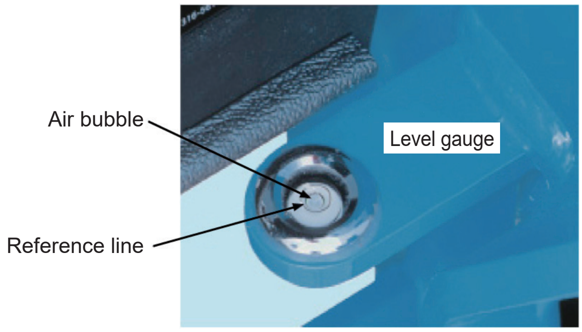


Fig. 1-57 Truck Loader Crane Level Gauge

1.6 Handling the Mobile Crane Operating Devices

1.6.1 Operating Device Arrangement

(1) Rough Terrain Cranes

Rough terrain crane cabs are equipped with control levers for operating the crane, pedals, switches, gauges, a load moment limiter, and warning device, etc.

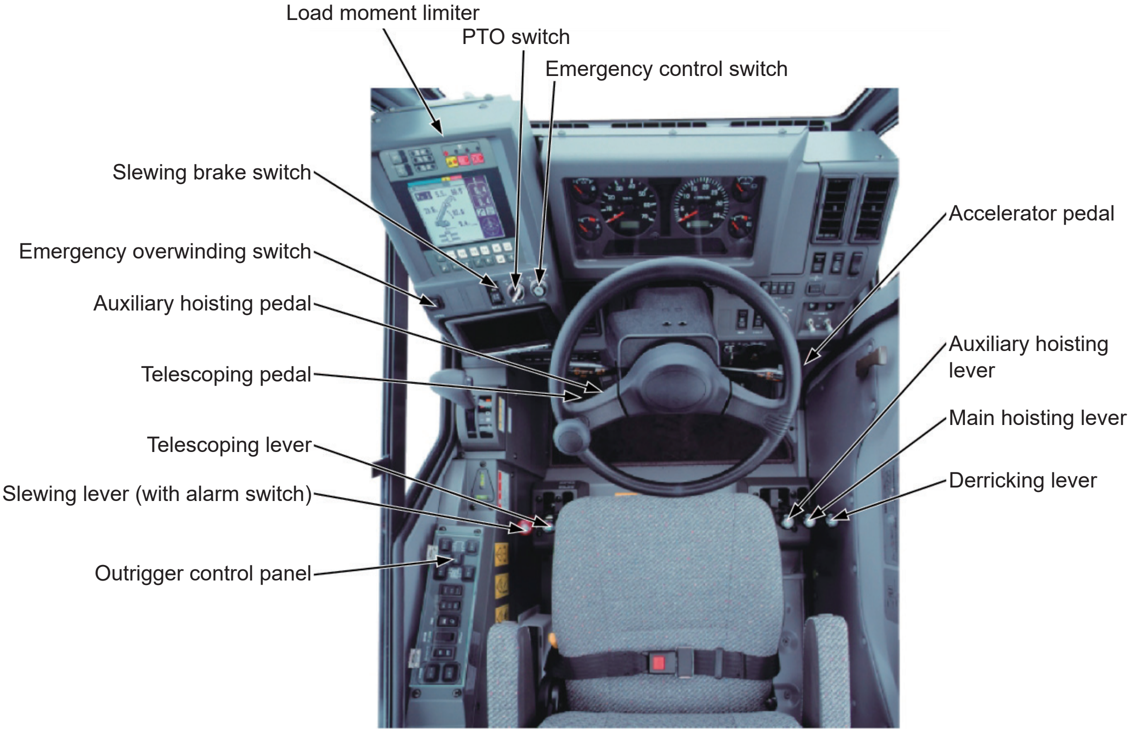


Fig. 1-58 Arrangement of Operating Devices in Rough Terrain Crane Cab (Example)

(2) Truck Loader Cranes

In truck loader cranes, the operating device (control levers) is generally installed at the left and right of the crane equipment and can be operated from either side. Recently, remote control devices that allow operators to perform operations at a safe place away from the control levers is widespread. For the remote control devices, a wired operation type (remote control) and a wireless operation type (radio control) are available.

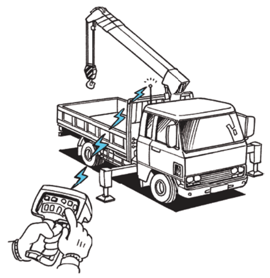


Fig. 1-59 Wireless Operation Type (Radio Control Type)

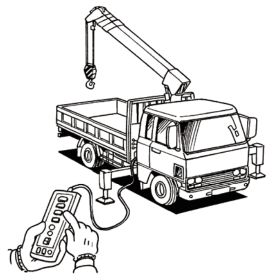


Fig. 1-60 Wired Operation Type (Remote Control Type)

1) Direct Control Type

The operating device for direct control type includes devices for the four operations of hook hoisting/lowering, jib derricking, jib telescoping, and slewing. It also has devices for operating the outrigger and hook, accelerator lever, etc.

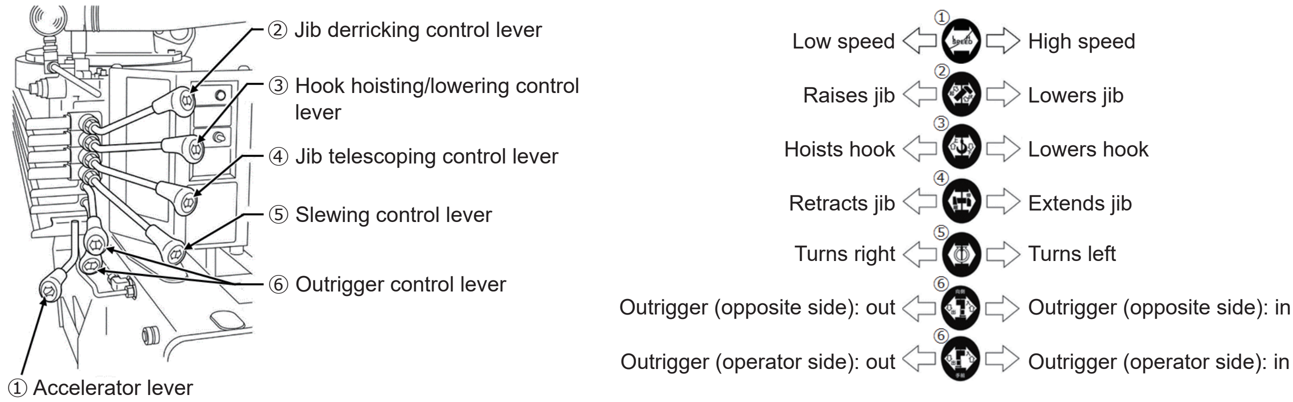


Fig. 1-61 Direct Control Method Control Levers for Truck Loader Crane (Example)

2) Wired Operation Type (Remote Control Type)

The remote control type is not affected by noise and radio interference, but caution is required when maneuvering the control cable. Also, some remote control type operating devices do not have the load display. Thus, it is necessary to check the load being lifted using the load meter or other indicators on the crane body.

3) Wireless Operation Type (Radio Control Type)

The radio control type has no control cable, which allows the operator to move with ease. Thus, most remote control devices are this type. As it is susceptible to noise and radio interference, it is equipped with a function to avoid interfering frequencies.

❶ Accelerator lever (velocity lever)
❷ Load display
❸ Operation selection switch
❹ Slewing switch
❺ Derricking switch
❻ Hook hoisting/lowering switch
❼ Telescoping switch

Fig. 1-62 Truck Loader Crane Remote Control Device (Radio Control Type) (Example)

1.6.2 Operation Method for Operating Devices

Mobile crane operation is performed using a combination of hoisting/lowering, jib derricking/telescoping, and slewing. Loads can be moved between all points within the crane's performance range determined by gross rated load, working radius, lifting height, etc.

(1) Operation of Control Levers

1) Operations Using the Crane Body Control Levers

The crane body has levers for the crane's respective functions (Fig. 1-58, p.38 (en)). The mechanism of the levers is: when the operator releases the control levers, they automatically return to the neutral positions and stop the operation. The control lever layout varies depending on the manufacturer, so it is important to fully read the instruction manual supplied with the crane.

2) Operation via Remote Control Devices (Wireless or Wired)

The remote control devices for truck loader cranes include wireless operation type (radio control) and wired operation type (remote control), which allow for remote operation of the crane. Many use the specified low-power wireless, whose frequency is changed by turning the device OFF and back ON if interference occurs. The layout of operation switches on remote control devices varies depending on the manufacturer, so it is important to fully read the instruction manual supplied with the crane.

(2) PTO (Power Take Off)

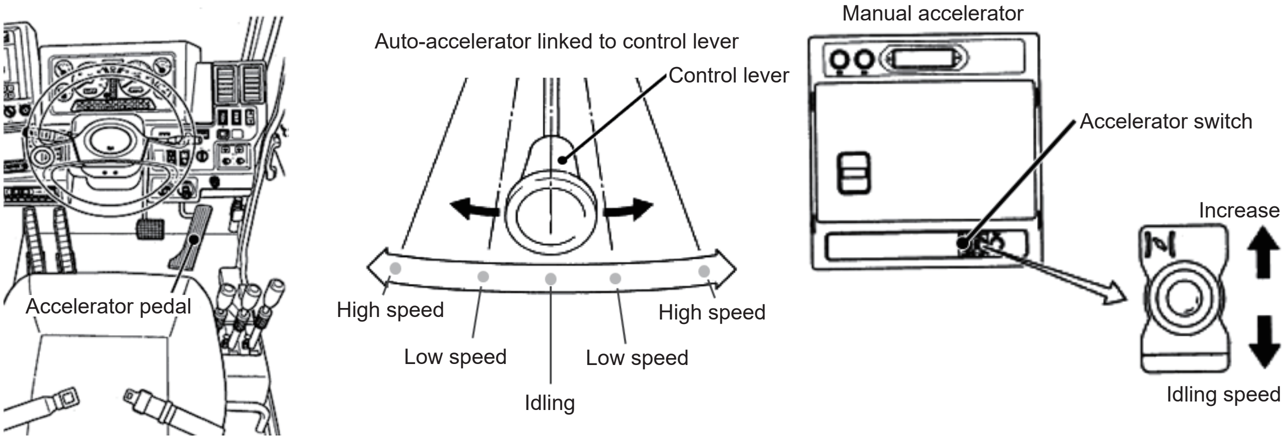
The PTO is a mechanism to use the power of the engine for driving as power for operating the crane. The PTO powers the hydraulic pump when switched from OFF to ON before crane operations start after on-road driving.

Likewise, before on-road driving after crane operations is finished, switch the PTO from ON to OFF to stop the hydraulic pump.

(3) Accelerator

In rough terrain cranes, the accelerator pedal for driving also serves as the accelerator pedal for the crane. Truck loader cranes generally use the auto-accelerator system, which links the truck accelerator to the control levers for the respective functions. The operation speed can be adjusted based on the amount of lever movement, allowing slow- to high-speed operations to be performed with a single lever. A manual accelerator is also provided.

When using a remote control type, the speed can be adjusted using the velocity lever provided on the remote control device.



(a) Rough terrain crane

(b) Truck loader crane

Fig. 1-63 Accelerator Operation

(4) Outrigger

The outrigger operating devices of rough terrain cranes are installed in the cab of the slewing upper structure and on the side face of the base carrier. In truck loader cranes, the outriggers are usually extended using manual extension systems, but some use hydraulic cylinders. Jacks are usually driven with hydraulic cylinders through the control lever or electric switch operation. Recently, some jacks are operated with remote control or radio control.

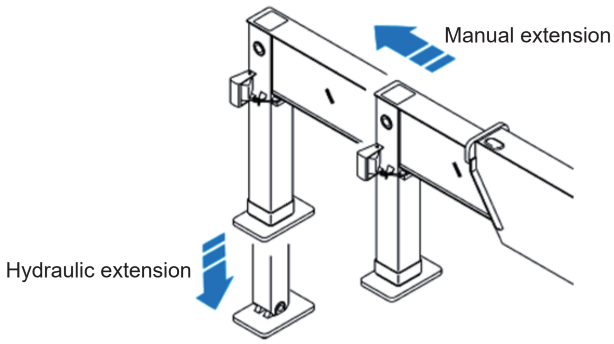


Fig. 1-64 Manual Outrigger Extension (Truck Loader Crane)

When extending truck loader crane outriggers, release the lock lever and grip the one-touch lever (directly connected to the lock pin), that makes the lock pin come off, before extending the outrigger. Recently, load moment limiter that allows the operator to check and register the outrigger status manually are on the increase. Some are equipped with an outrigger extension width detector, which prohibits the operator from registering the wrong outrigger status by detecting where the lock pin is inserted.

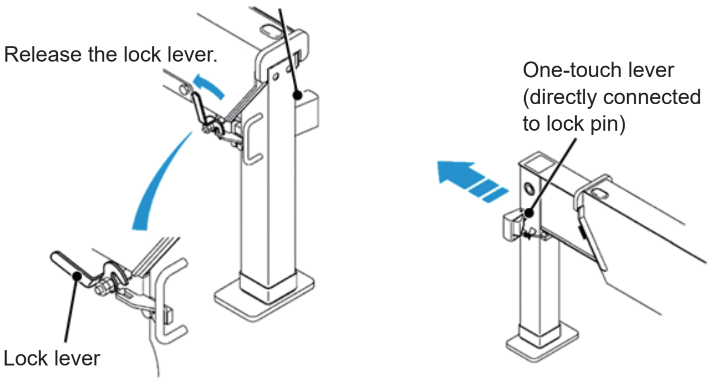


Fig. 1-65 Outrigger Lock

1.6.3 Handling Mobile Cranes

When operating mobile cranes, sufficient understanding of their performance and functions is required. In particular, working range diagrams including working radius - lifting height diagrams, and gross rated load tables must be thoroughly understood and memorized. Regularly learning and practicing handling and operation methods are also a key. In handling a mobile crane, the most important aspect to be careful of is taking such measures to prevent overturning as checking the ground where the crane body is installed, using the outrigger appropriately, and always activating safety devices.

(1) The Mindset of an Operator

- The first step to safety is to be sure to follow workplace rules.
- Make sufficient preparations in terms of clothing, safety helmet, safety shoes, etc.
- Fully understand the mobile crane’s performance and functions to operate the machine properly.
- Do not perform operations with the safety devices disabled.
- Do not be afraid to refuse to perform unsafe operations even if you are asked to do so.
- In high-place work (2 m or more high) for inspection or maintenance, be sure to use fall prevention equipment with the required performance.
- Verbally repeat the signals given by signalers.

(2) Formulating a Work Plan

To operate a mobile crane safely and efficiently, it is essential to fully understand the mobile crane's performance. Therefore, it is important to confirm the mobile crane's lifting performance (gross rated load determined by the working radius in relation to extension width of the outrigger and jib length), decide where to place the crane and work methods, and check whether the crane can be operated safely.

1) The Three Factors That Determine Mobile Crane Performance

a. Hoisting Power

The maximum hoisting power according to hoisting mechanism performance.

b. Crane Stability

When lifting a load, stability is greater near the center of slewing, while it decreases as the working radius expands. Therefore, if the gross rated load appropriate for the working radius is exceeded, the crane becomes overloaded and overturns due to losing stability.

c. Crane Strength

Crane strength is primarily determined by jib strength and overloading may result in jib breakage or cause other damage. Even without immediate overturning or jib breakage, overloading is dangerous as it may cause fatigue on crane parts, making them easier to break. For the jib strength, buckling strength is important at around the center of slewing, while bending strength becomes more important as the working radius expands to a larger.

As described above, the mobile crane lifting performance (gross rated load) is designed so as not to exceed the limits of these three factors.

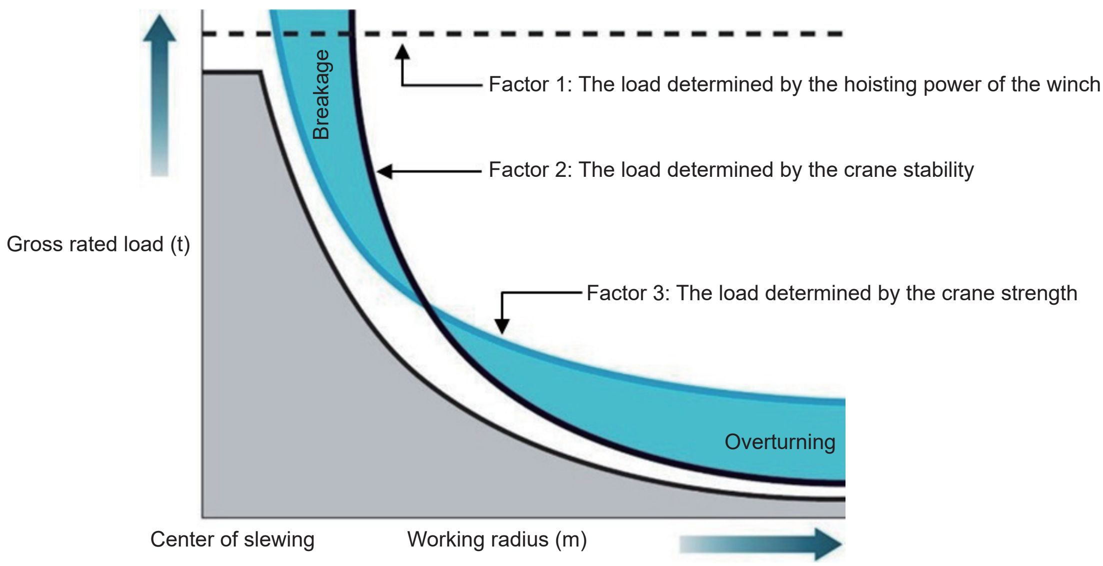


Fig. 1-66 Curve of Three Factors That Determine Mobile Crane Performance (Example)

2) Plates

The operator's seat in light capacity mobile cranes is equipped with various plates for providing the information necessary for operation.

3) Reading the Working Radius - Lifting Height Diagram (Working Range Diagram)

For work with mobile cranes, it is important to confirm how many tons of load are to be lifted, and to consider aspects such as distance (meters) for lifting the load off the ground, working radius (meters) from the mobile crane position, most suitable length (meters) of the jib for safe operations, and the angle of the jib. The working radius-lifting height diagram (working range diagram) indicates the range in which a load can be lifted according to changes in the jib length and angle. Normally, the horizontal axis shows the working radius and the vertical axis shows the lifting height above ground. This diagram allows for an understanding of the relationship between the working radius and lifting height above ground changing depending on the jib length, auxiliary jib length and jib angle. The working radius-lifting height diagram is shown in the specifications along with the gross rated load table. In addition, it is also provided in the crane cab so that it is used not only during operations, but also when setting up work plans. For truck loader cranes with the working radius-lifting height diagram shown in Fig. 1-67, when the jib is extended to the fourth stage (a jib length of 10 meters) at a jib angle of 60 degrees, the lifting height above ground reads 10.2 meters and the working radius reads 4.8 meters.

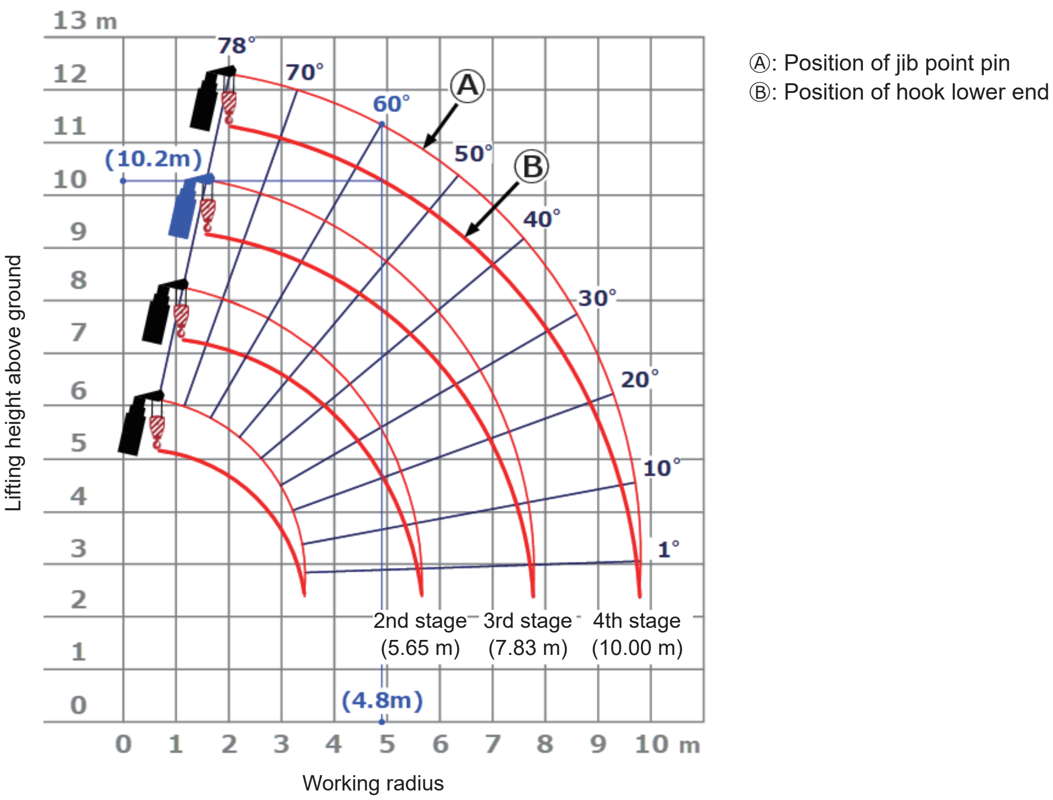


Fig. 1-67 Truck Loader Crane Working Radius - Lifting Height Diagram

4) Notes for Reading Working Radius - Lifting Height Diagrams

- The working radius-lifting height diagram does not include jib deflection. When lifting a load, the jib bends and makes the working radius slightly larger. This results in the gross rated load value smaller.
- For work at the lifting height under ground, confirm the unwinding amount (two or more turns remaining in the drum), determine the lifting height under ground where operations are possible, and select the model.

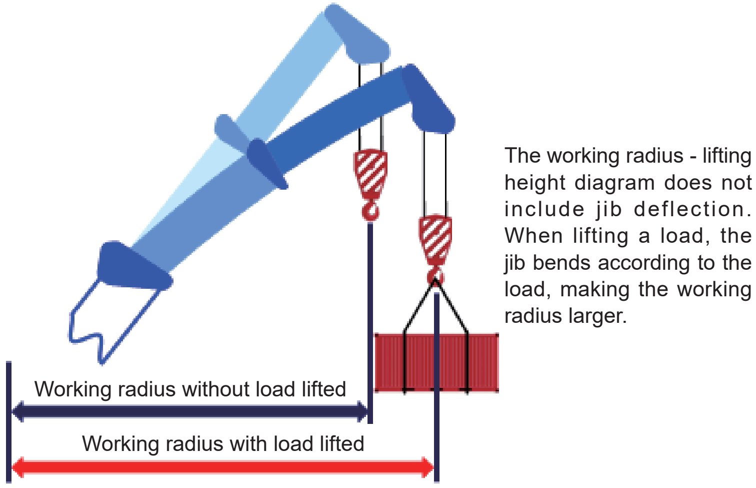


Fig. 1-68 Changes in Working Radius Due to Deflection

5) Reading the Gross Rated Load Table

Mobile crane gross rated load varies depending on such things as outrigger extension width and working area (over-front, over-side, over-rear), and the jib length. Also, as the mobile crane gross rated load values are estimated assuming that the crane is placed horizontally on the firm ground, slanted ground and soft ground must be reinforced with blocks and outrigger pads to place the crane body horizontally. The crane must operate with the outrigger at full extension, in principle.

6) Reading Gross Rated Load Table at Non-loaded Condition

The gross rated load at non-loaded condition is a term used only for truck loader cranes, and determined based on the crane stability with no load on the cargo bed (non-loaded condition). On the gross rated load table at non-loaded condition shown in Table 1-3, with the outrigger fully extended and the 3.54 m or 5.78 m jib used, the gross rated load at non-loaded condition is 1.33 t at a working radius of 4.0 m. However, with the outrigger at the middle or at minimum extension, the gross rated load at non-loaded condition is 0.53 t.

Table 1-3 Gross Rated Load Table at Non-loaded Condition (Over-side, Over-rear Areas) Unit: (t)

Jib Length (m)	Working Radius (m) / Outrigger	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.59	6.0	6.5	7.0	7.79	8.0	9.0	9.95	10.0	11.0	12.11
3.58/ 5.78	Full extension	2.93	2.93	2.78	2.23	1.68	1.33	1.08	0.88	0.73										
	Minimum extension	1.73	1.73	1.23	0.88	0.68	0.53	0.43	0.38	0.28										
7.98	Full extension	2.23	2.23	2.23	2.03	1.68	1.33	1.08	0.88	—	0.63	0.55	—	0.38						
	Minimum extension	0.63	0.63	0.63	0.53	0.43	0.33	0.28	0.23	—	0.13	Operation prohibited								
10.14	Full extension		1.03	1.03	1.03	1.03	1.03	0.93	0.83	—	0.63	—	0.48	—	0.35	0.30	0.28			
	Minimum extension		Operation prohibited																	
12.3	Full extension				0.76	0.76	0.76	0.76	0.63	—	0.48	—	0.40	—	0.35	0.30	—	0.28	0.25	0.20
	Minimum extension				Operation prohibited															

- "Operation prohibited" (colored in light brown) refers to areas where operations are prohibited in consideration of crane stability, since overturning may occur with no load.
- "Blank" (colored in gray) refers to areas where work is not possible with cranes due to their mechanism. For example, areas the jib cannot access or areas the hook cannot be brought near even when the jib is fully raised.
- A value that shows the working radius to two decimal digits is the maximum working radius at the corresponding jib length. Values for other jib lengths at these working radius are not displayed (shown as "—").

(3) Working Area

When mobile cranes slew while lifting a load, the lifting performance (stability of the body) varies depending on the working area (over-front, over-rear, over-side). Therefore, it is important that mobile crane operators understand the crane's working areas. In slewing from a working area with high lifting performance in a direction with low lifting performance (for example, from the rear to the side), the body may overturn, so caution is required. Overturning of truck loader cranes often occurs during slewing from a stable position in which a load on the cargo bed is lifted, to the side of the crane (an unstable direction). The boundaries of mobile crane working areas vary depending on the crane type and manufacturer, but can be defined as follows.

1) For Truck Loader Cranes

In lifting a load with a truck loader crane, the crane stability varies among the over-rear area, over-side area, and over-front area of the truck.

Over-rear area: with the highest stability.

Over-side area: with the second-highest stability. However, the red ranges Ⓐ shown in the figure have particularly poor stability. For this reason, gross rated load at non-loaded condition over the side and rear area is defined by these ranges. Slewing from a highly stable over-rear area to an over-side area with poorer stability can easily result in overturning; therefore, caution is required.

Over-front area: with the least stability. Work should be performed with 25% or less of the lifting performance of the over-rear and over-side areas. In particular, lifting in the over-side area and slewing to the over-front area may easily cause overloading; therefore, sufficient caution is required.

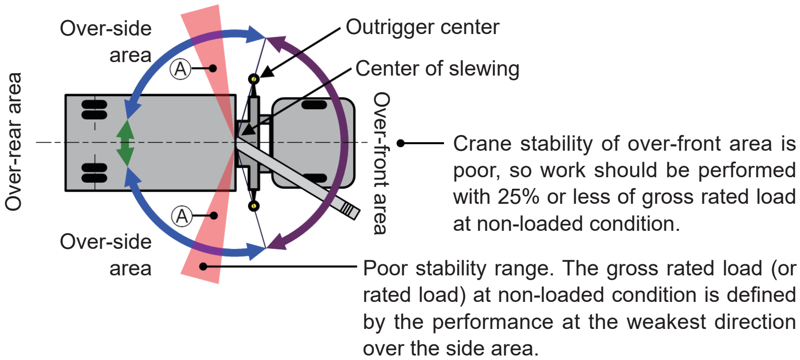


Fig. 1-69 Truck Loader Crane Working Area

2) For Rough Terrain Cranes

The gross rated load table for rough terrain cranes is set for each outrigger usage condition, jib length, and auxiliary jib length. However, the working area is limited due to the crane's performance with the outriggers at middle extension. With the outrigger at full extension, the jib and auxiliary jib have the same performance for the entire perimeter. Between the middle extension and minimum extension of the outrigger, the over-front and over-rear areas have the same performance as when the outrigger is at full extension. Only the over-side area has a gross rated load specified according to the extension width (Fig. 1-70(a), p.48 (en)).

In addition, the lifting performance of the over-front area of truck cranes is 21% to 54% of the gross rated load of the over-side and over-rear areas (Fig. 1-70(b), p.48 (en)).

3) For Crawler Cranes (Including Crawler-type Hydraulic Excavators with Crane Functions)

The working area is common and the gross rated load is constant for the entire perimeter (Fig. 1-70(c)).

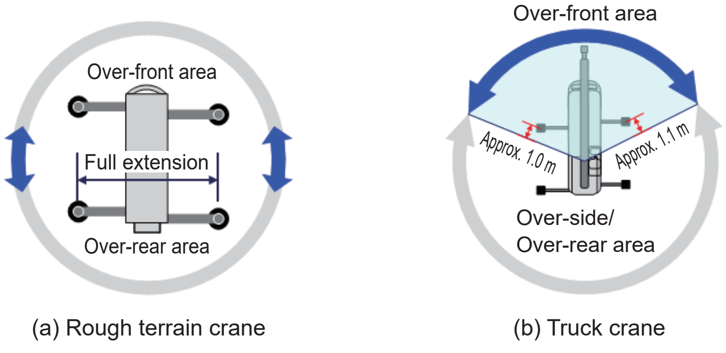


Fig. 1-70 Other Cranes Working Area

(4) Crane Stability

Crane stability indicates the probability of a mobile crane overturning or not. Normally, this is expressed as a ratio, with the stability moment as the numerator and the tipping moment as the denominator. As this value increases, the stability becomes greater. The mobile cranes must pass the crane stability test of the Safety Ordinance for Cranes, in which they lift a load 1.27 times the rated load.

(5) Clear Indication of the Work Site

Prohibit any workers who are not involved with the work from entering the work site, and post warnings about this at visible places.

(6) Mobile Crane Installation

1) Confirming the Working Radius

The working radius indicates the horizontal distance from the slewing center of the mobile crane to the vertical line extending downwards from the hook's center. Therefore, when deciding the location of the mobile crane for work, consider the working range and the extension of the working radius due to the jib deflection, as well as the distance from the slewing center to the outrigger tip or from the slewing center to the vehicle end (front/rear).

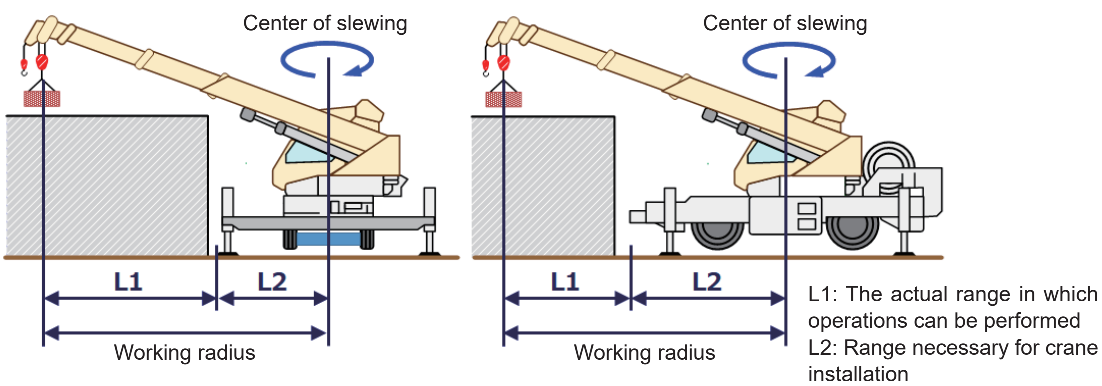
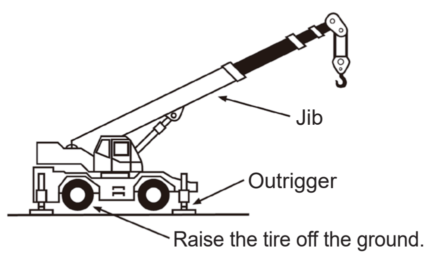


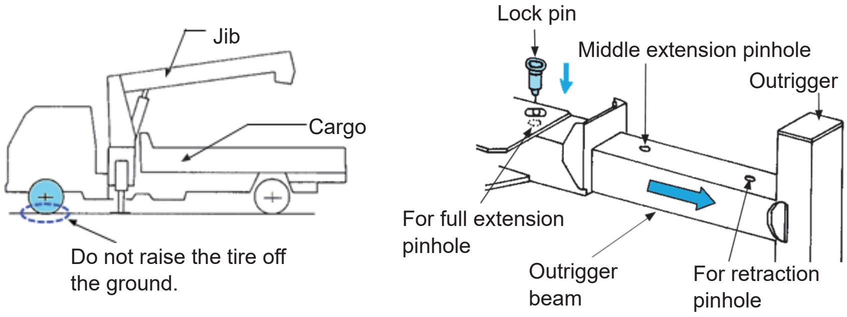
Fig. 1-71 Actual Working Range

2) Mobile Crane Installation Overview

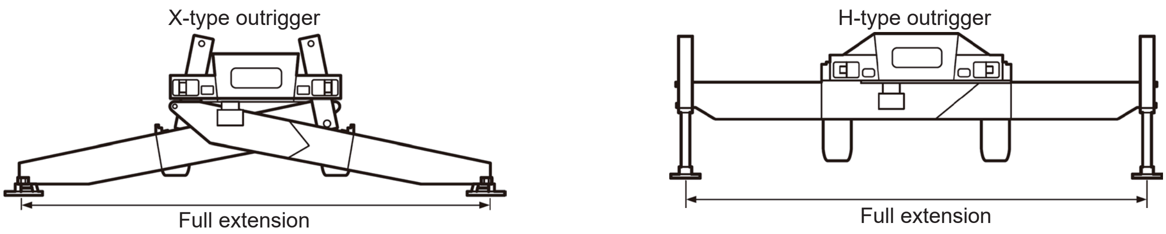
Install the mobile crane on level and firm ground so that the body is horizontal.



(a) Rough terrain crane



(b) Truck loader crane

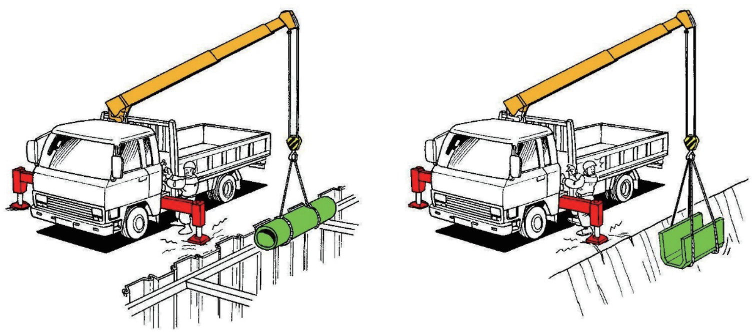


(c) Rough terrain cranes

Fig. 1-72 Mobile Crane Installation Overview

For soft ground, lay a sufficiently high-strength pad (for example, a square timber, floor plate, or iron plate) under the outrigger float, and make sure the outrigger float does not sink into the ground. Also, the outrigger should in principle be fully extended for installation. Fully extend the outrigger beams evenly on both sides, then insert the lock pin to fasten them. Middle extension or minimum extension can be used only if the installation site is confined and full extension is not possible. Be sure to fasten the outrigger beams with the lock pin.

The ground near excavation sites with landslide protection walls or the road shoulders is weak; therefore, install the outrigger away from such places.



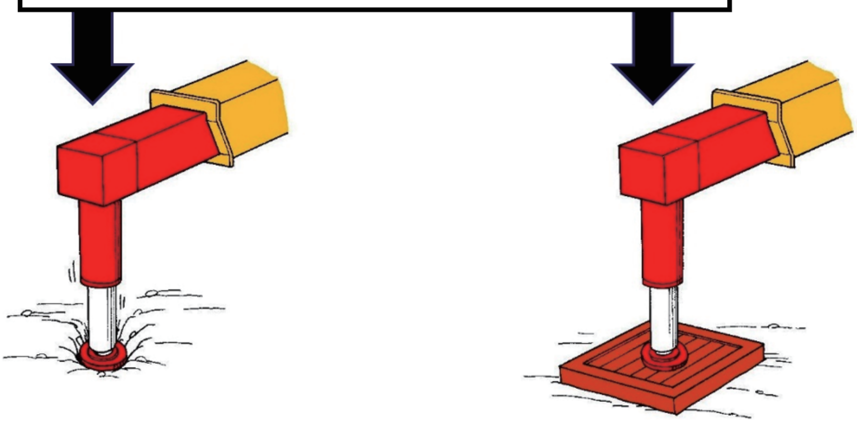
Installing outriggers near the sheet piles of landslide protection walls is dangerous (the same is the case for the road shoulders)

Fig. 1-73 Dangerous Outrigger Installation (Examples)

(7) Knowledge about the Ground

When installing mobile cranes, it is important to check the condition of the ground so that the outrigger does not sink. This requires knowledge of matters such as soil properties and ground firmness. In civil engineering works, ground firmness is surveyed and confirmed beforehand, but the preliminary survey is often omitted when installing light capacity mobile cranes. Therefore, ground firmness is normally judged by checking the depth of footprints left by people walking or of tire tracks left while driving machines such as truck cranes, or by visually checking soil type and properties and using them as a guide. Firmness can be increased by applying reinforcement or compaction, or by laying something like iron plates or outrigger pads.

The maximum load applied to one outrigger float is equivalent to 70% to 80% of the total mass of the crane body and the load actually lifted.



If the float is directly placed on the ground, the load applied to the outrigger is concentrated on a small surface, causing the ground to subside.

Expanding the supporting surface using large, robust outrigger pads will keep the ground from subsiding.

Fig. 1-74 Outrigger Installation

(8) Work Precautions

1) Roadside Work

When installing a truck loader crane near, for example, a guardrail, in order to unload, an evacuation direction and area should be decided prior to starting work. If the crane overturns during work, there is no evacuation space on the guardrail side, which is extremely dangerous (Fig. 1-75). The same situation applies when unloading near loads if there is no space by them; therefore, be careful of the work location (Fig. 1-76).

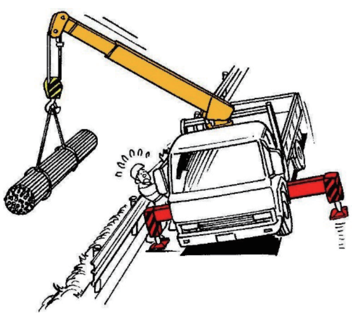


Fig. 1-75 Roadside Work

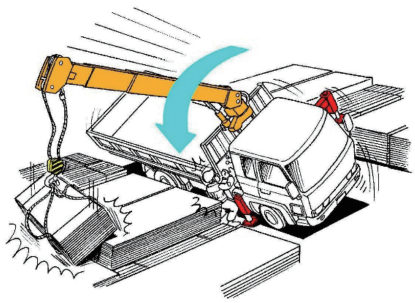


Fig. 1-76 Unloading Work Near Loads

2) Remote Control

In operations using remote control (such as radio control), do not turn your back to the load while working. Not only turn your back to the crane body and look just at the load, also be careful of crane movement. If you see any signs of danger such as overturning, immediately unload the load or evacuate. Perform operations at safe places and do not use your hands to support a hanging load during operations.

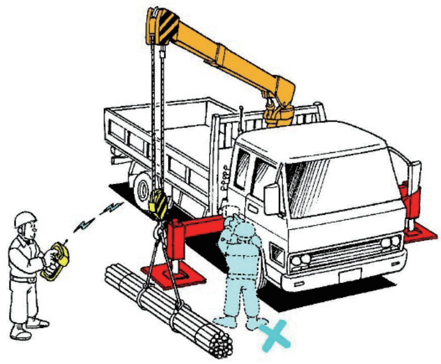


Fig. 1-77 Remote Control

3) Prohibition on Pulling Load Sideways

Do not pull the load sideways before performing jigiri or lift the load diagonally. An unexpected large load by pulling load sideways may cause damage to the crane or significant swinging at the moment the load leaves the ground or when a hanging load slips off.

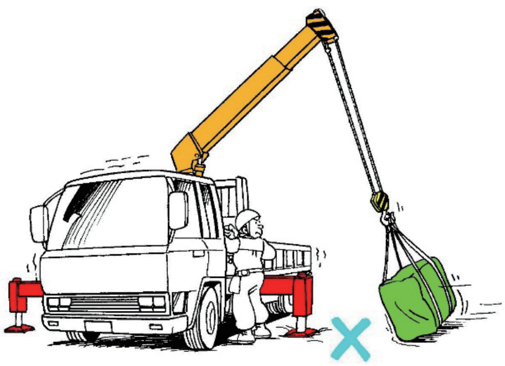


Fig. 1-78 Prohibition on Pulling Load Sideways or Lifting It Diagonally

4) Hook Position

When lifting, position the hook directly above the load's center of gravity (Fig. 1-79). If the load's center of gravity and the vertical line extending downward from the center of the hook are misaligned, the load swings at the moment it is lifted. Also, lifting without the hook positioned just above the load's center of gravity causes the load to move by the amount of misalignment between the hook position and load's center of gravity. This may cause the load to collide with people or objects around it, or the operator to get caught (Fig. 1-80).

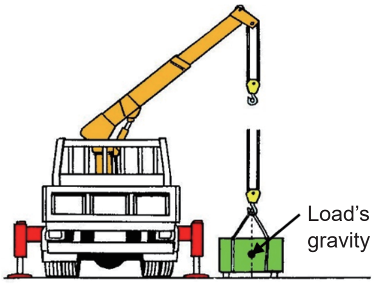


Fig. 1-79 Hook Position When Lifting

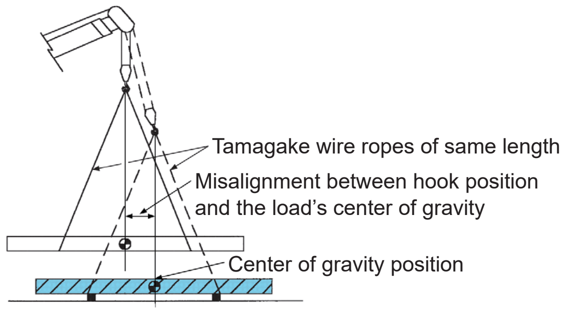


Fig. 1-80 Center of Gravity and Load Movement

5) Jigiri and Confirmation

With the signaler's hoisting signals, confirm the load mass with the load meter while tensing the tamagake wire rope and stop temporarily. If the load mass is within the gross rated load range, perform jigiri and stop temporarily again before confirming the condition of the tamagake.

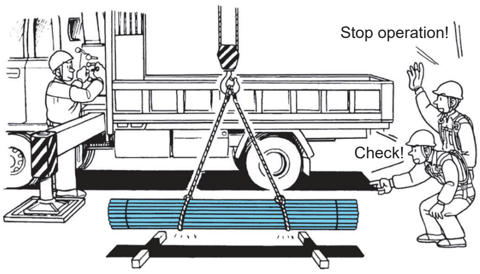


Fig. 1-81 Jigiri and Confirmation

6) Confirming with Safety Devices

With mobile cranes, work must be performed with functioning safety devices such as a load moment limiter. When moving to a dangerous side with a load lifted, pay attention to the load moment limiter value and alarm.

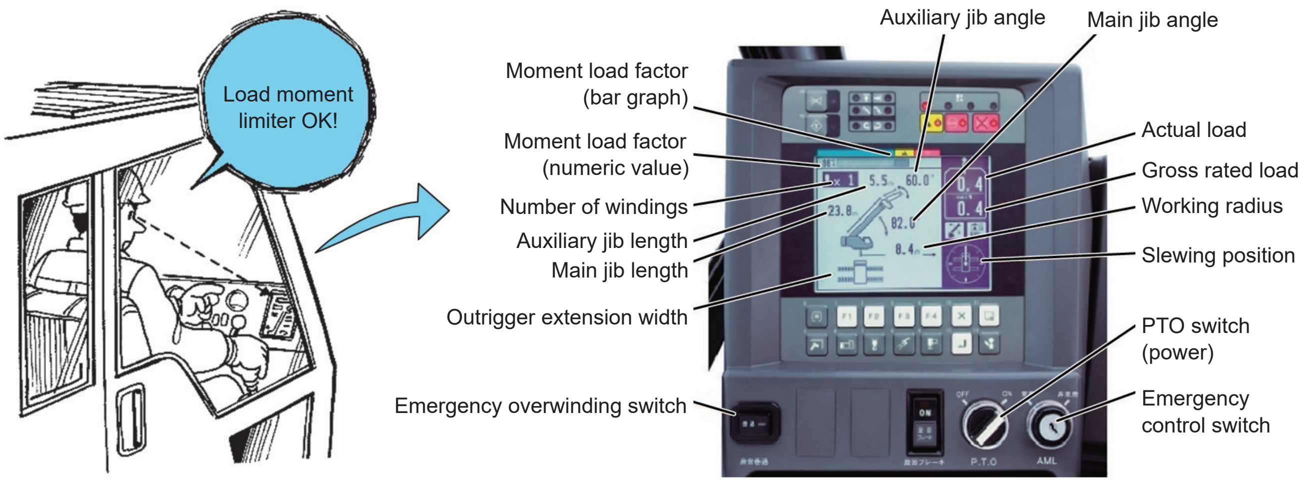


Fig. 1-82 Load Moment Limiter Display Example (Rough Terrain Crane)

7) Prohibition of Operations Based on Assumptions

During operations, verbally repeat the signaler's signals and operate in accordance with the signals. Do not perform operations based on assumptions; that is dangerous. Even when working in isolation, stop temporarily just after jigiri and confirm the condition of the tamagake.

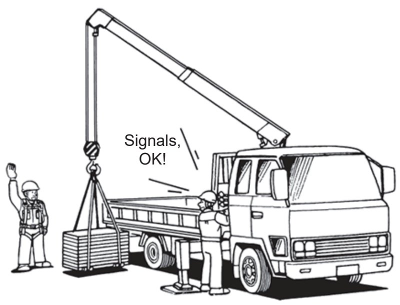


Fig. 1-83 Prohibition of Operations Based on Assumptions

8) Prohibition of Riding and Entering

Do not lift a load with someone riding on the top of the load (Fig. 1-84). Also, do not allow anyone to enter the area under a lifted load or within the load slewing range (Fig. 1-85). If there is anyone within the range of the direction the load is to be moved, let them evacuate before moving the load.

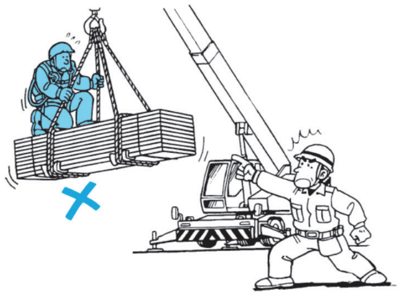


Fig. 1-84 Prohibition of Riding

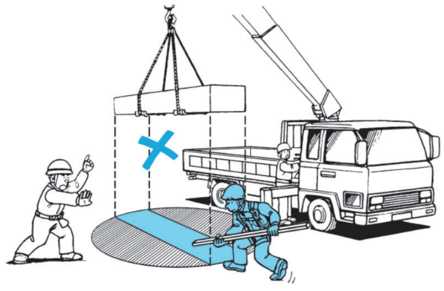


Fig. 1-85 Prohibition of Dangerous Proximity

9) Precautions for Slewing

When slewing, follow the signaler’s signals. When hoisting a heavy load, be sure to slew at low speed. At a fast slewing speed, the load is swung outward due to centrifugal force, resulting in the same state as with a large working radius. As a result, the crane may overturn. Truck loader cranes have lower stability at over-side area; therefore, be careful not to overturn the crane when slewing.

10) Loads Falling from the Cargo Bed

When unloading a load from truck loader cranes, pay attention to the unloading order, to prevent the collapse of the cargo loads. Stack loads in a stable condition and bind them if necessary to prevent collapse or falling due to the vibrations or other movement while driving.

11) Lifting Load Over the Front Area

For mobile cranes, stability and lifting performance for each working area vary depending on the model. In lifting the load over the front area of the truck loader crane in particular, when slewing toward the direction with poor stability, the model that automatically stops has the overturning prevention function and the crane stops within the capability range. On the other hand, the model that does not automatically stop has a risk of overturning when slewing toward the over-front area, as the stability decreases to 25% or less of the gross rated load at non-loaded condition.

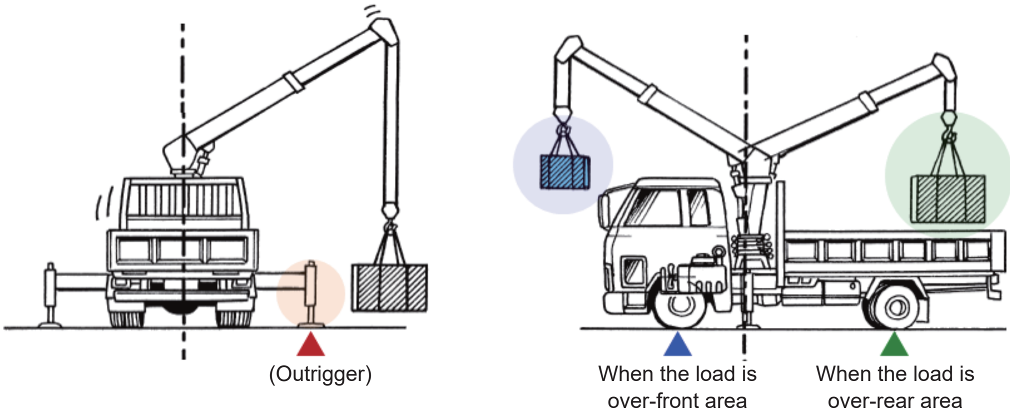


Fig. 1-86 Truck Loader Crane Tipping Points

12) Brake Operation

Do not stop the mobile crane by suddenly braking or with abrupt lever operation, which may make the crane unstable due to impact, resulting in overturning or damage to structural elements.

13) Load Landing

When landing a lifted load, lower the load at low speed and stop just above the ground, then gently land the load by following the signaler’s signals. Upon landing, stop temporarily, confirm that the load is stable, and then lower it further.

14) Pulling Out the Tamagake Wire Rope

When pulling the tamagake wire rope out of the load, there is a risk that the tamagake wire rope will get caught on the load, causing the load to collapse. Therefore, never pull the tamagake wire rope out using crane hoisting operations.

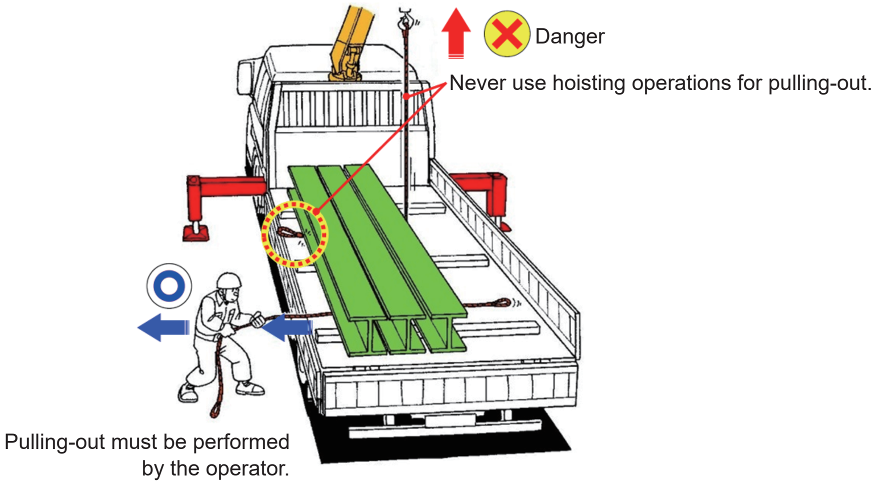


Fig. 1-87 Pulling Out the Tamagake Wire Rope

15) Hoisting Wire Rope Termination

See Fig. 1-88 and Fig. 1-89.

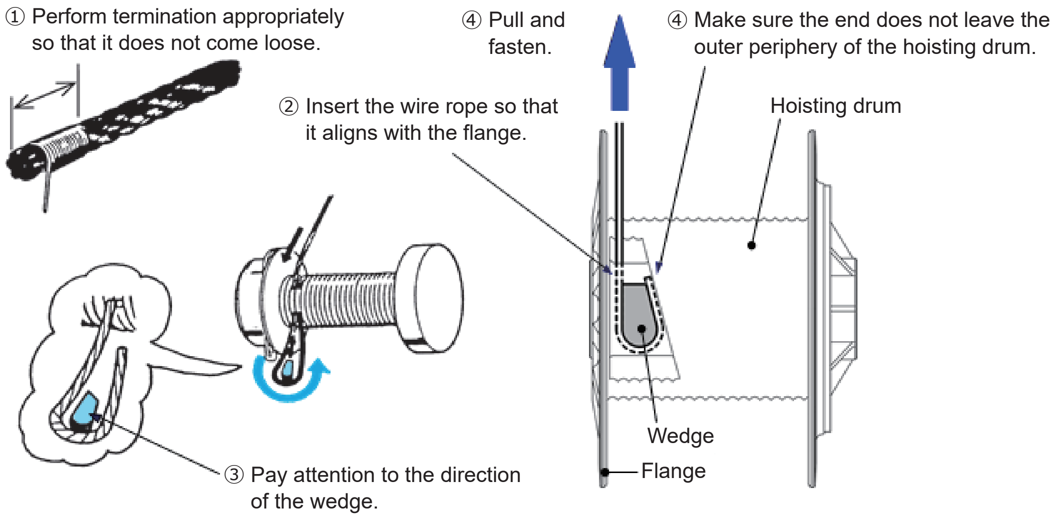


Fig. 1-88 Hoisting Drum-side Termination

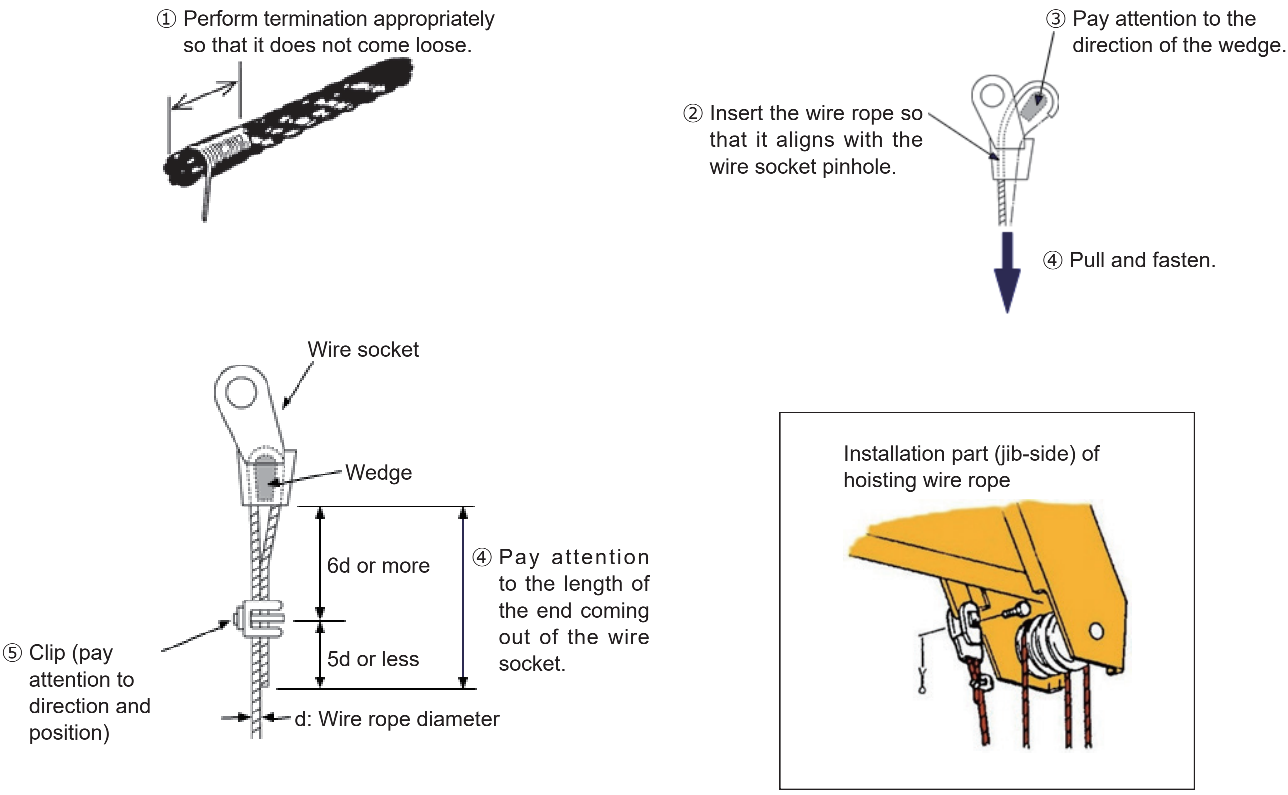


Fig. 1-89 Jib-side Termination

16) Precautions When Using Hoisting Wire Rope

a. Eliminating Twisting

If the hoisting wire rope twists and the hook rotates, this can lead to accidents such as the load falling or the hoisting wire rope breaking. Therefore, twisting must be removed. If the hoisting wire rope twists, follow the steps in Fig. 1-90 to remove the twisting. However, do not twist it five or more times at once. If the above method does not remove the twisting, the rope must be replaced with a new wire rope.

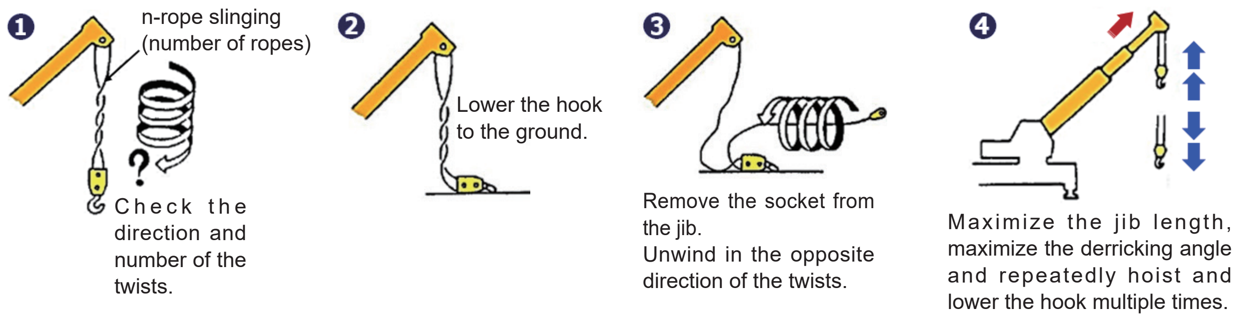


Fig. 1-90 Removing Twists from the Hoisting Wire Rope

b. Minimum Number of Windings for Hoisting Drum

When lowering the hoisting wire rope to the maximum extent, leave at least two preliminary windings on the hoisting drum. For work at the lifting height under ground, check the unwinding amount in particular (the amount remaining in the drum), and determine the workable lifting height under ground.

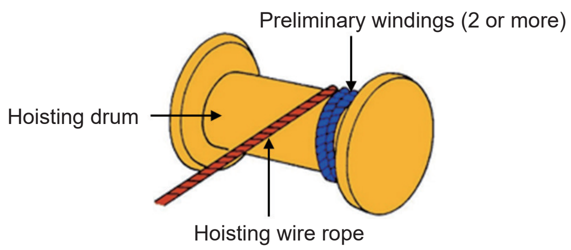


Fig. 1-91 Minimum Number of Windings for Hoisting Drum

17) Prohibition of Leaving the Operating Position

Operators must not leave the operating position with the load lifted. The operators must also lower the load to the ground when suspending work.

18) Abnormalities During Operations

While operating the mobile crane, attention needs to be paid to abnormalities, vibrations, heat, and odor coming from the equipment such as operation devices, safety devices, and displays. If a problem occurs, such as an abnormality in a device function, the disappearance of the display, an abnormal noise, or abnormal vibrations, immediately stop operations. Then, investigate the cause, report it to your supervisor, and seek instructions on the solutions.

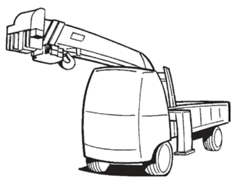
19) Prohibition of Checking and Other Actions During Operation

While the prime mover is operating, do not perform such actions as cleaning, refueling, and repairs.

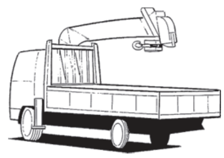
(9) End-of-work Procedure

1) Positioning When Ending Work and Moving

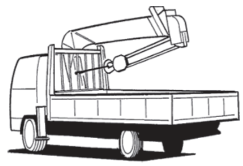
On completion of work, store the hook and turn the PTO OFF. When returning to the office or moving to another work site, drive in the designated positioning.



Front storage



Rear storage (hook stored)



Rear storage (fixed rope)

(a) Truck loader crane

(b) Rough terrain truck crane

Fig. 1-92 Positioning While Driving

2) End-of-work Checks

Perform the following checks once work has ended.

- Re-inspect and confirm spots where abnormalities were detected during operation and emergency measures were taken.
- Confirm the amounts of fuel, oil, grease, and other fluids, clean the crane, and store it in the designated location. Additionally, record the condition of the crane during work in the work log.

3) Turning Over the Operation of a Mobile Crane

When turning over the operation of a mobile crane to another person, be sure to inform that person of the crane's condition and whether there are any abnormalities.

(10) Other

1) Precautions for Driving

a. Hook Retraction and Various Locks

When driving, be sure to operate the hook retraction mechanism, or fasten the hook in place to prevent it from swinging while driving, and lock the slewing lock (slewing brake). Also, store the outrigger and then confirm that the outrigger lock, which fastens the outrigger beam in crane operation, and the driving lock, which prevents outrigger protrusion while driving, are locked.

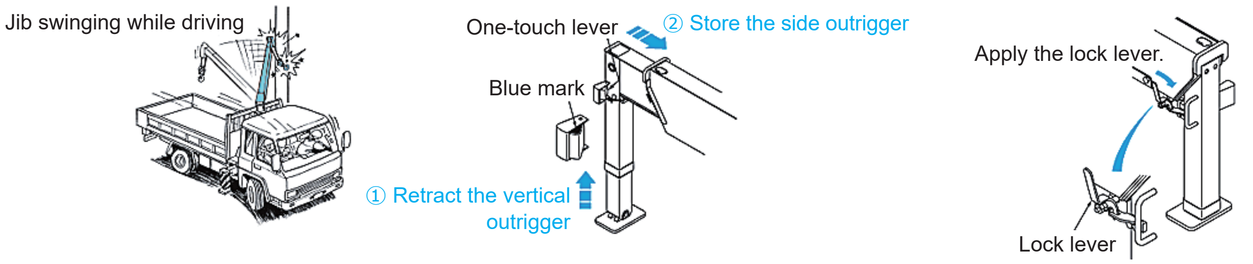


Fig. 1-93 Precautions for Driving (Truck Loader Crane)

b. PTO Lever

Set all of the control levers to neutral and turn the PTO lever OFF. If the lever is left ON, the crane equipment may operate while driving.

c. Driving on Roads

When passing under overpasses or other infrastructure with height restrictions, reduce speed while making sure the equipment, including the jib, does not make contact with such infrastructure, giving due attention to the height limit. In places where the view is obstructed or visibility from the operator’s seat is poor due to the jib, confirm that the situation is safe before driving.

2) Precautions for Bad Weather

For mobile cranes that work outdoors, the weather must be considered. If the average wind speed for 10 minutes is 10 m/sec or higher when performing work with a mobile crane, work must be suspended. This is because the load may swing or spin due to the wind, which puts workers in danger. Also, when lifting a load reaching the rated load, wind pressure may cause the working radius of the load to increase, which may apply a load that exceeds the rated load. Mobile cranes are more susceptible to wind the heavier the load being lifted is, the higher the load is lifted, the longer the jib is, or the higher the jib is raised.

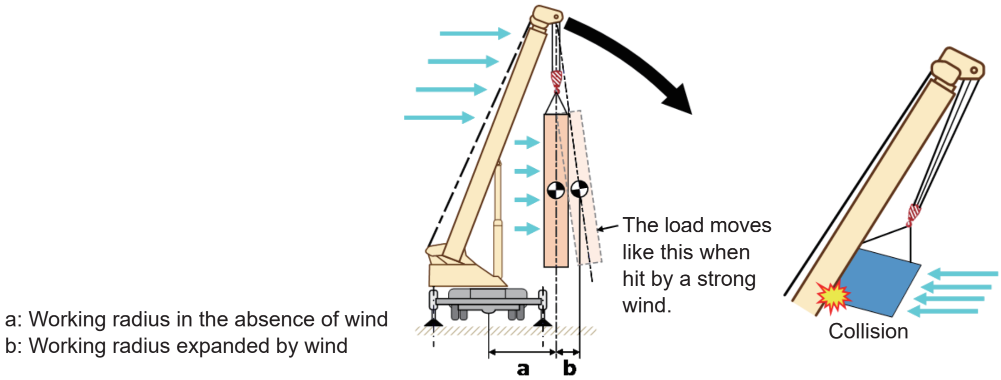


Fig. 1-94 Impact of Wind

When lifting a load with a large area to receive wind, such as an iron plate, wind that blows from the front, rear, or side of the jib may cause the crane to overturn or damage the jib. Wind from the front of the jib may also cause the load to collide with the jib and damage it. With the jib fully raised with no load, the crane may overturn to the rear if the wind blows from the front of the jib. Further, since mobile crane stability is calculated without considering wind load, the risk of overturning in strong winds increases for, in particular, long jibs that are highly susceptible to wind.

1.6.4 Check/Inspection and Maintenance

To ensure safety during work and improve work efficiency, it is important to keep all parts of the mobile crane in the best shape. To do so, perform pre-work checks, periodic self-inspections, and performance inspections. If any abnormalities are found, immediately repair them. Failure to perform proper inspections and maintenance may result in accidents, so the following inspections and checks are mandated by law.

(1) Pre-work Checks

Prior to starting work, the operator of the mobile crane must perform the following checks on the condition of the machine to be operated. The pre-work checks must be done according to the check table of the model provided by the manufacturer. If an abnormality is found, it must be immediately reported to the supervisor and the appropriate repairs must be made before work.

- To check the function of the overwinding warning device, hoist the hook, raise a weight, and listen to the alarm. For the function of the overwinding preventive device, hoist the hook, raise a weight, and confirm whether the hoisting mechanism stops.
- To check the function of the rated load indicator and the load moment limiter, use the methods indicated by the manufacturer.
- To check the function of other warning devices, turn the switch ON and listen for the alarm.
- To check the function of the hoisting mechanism brake and clutch, operate the hoisting mechanism control lever and check the condition of the hoisted hook.
- To check the function of the control levers (controllers), check the movement of the various control levers.

(2) End-of-work Check

1) Periodic Monthly Self-inspection

The periodic monthly self-inspection is mandatory for all businesses that own mobile cranes. The periodic inspection should be performed once per month and the results should be recorded and stored for three years.

2) Periodic Annual Self-inspection

The periodic annual self-inspection is mandatory for all businesses that own mobile cranes. This periodic inspection should be performed once per year and the results should be recorded and stored for three years. At the time of inspection, a load test[*1] is performed during the periodic annual self-inspection in accordance with the "Mobile Crane Periodical Self-inspection Guidelines". It is preferable that those engaged in the periodic annual self-inspection should have received a certain amount of training[*2].

*1 A load that is equivalent to the rated load is lifted, and actions such as lifting, slewing, and driving are performed at the rated speed.
*2 Those who have completed the Mobile Crane Periodical Self-inspection Inspector Safety Training, administered by the Japan Crane Association, etc.

3) Other Inspections

In addition to the periodic self-inspections, the law requires that mobile cranes with a lifting load of three tons or more undergo a performance inspection once every two years by a registered performance inspection agency as well as an alteration inspection when replacing the jib or other parts.

4) Precautions for Checks and Inspections

In mobile crane checks and inspections, failure to use the most effective procedure may waste time, resulting in check points being missed. To prevent this, thoroughly understand the structure and functions of the cranes to be inspected, and to make pre-check/pre-inspection preparations with the following items in mind, to perform systematic checks and inspection.

- During checks and inspections, it should be clearly indicated that the mobile crane is “under inspection”. This prevents third parties from entering the inspection area and ensures safety.
- The cranes to be checked and inspected must be parked on steady, level ground. Safety devices should be activated. When it is necessary to lift the crane body in accordance with the check and inspection details, ensure safety by placing lumber between the body and the ground to keep it in place.
- If any abnormalities are found during checks and inspections, immediately notify your supervisor and have maintenance and repair performed by a specialized maintenance provider.

Chapter 2

Knowledge About Prime Movers and Electricity

2.1 Prime Mover

Prime movers convert various types of energy into mechanical energy. Some of the prime movers used in light capacity mobile cranes are electric motors, but most of them are internal combustion engines.

2.1.1 Internal Combustion Engine

Internal combustion engines include diesel engines that use light oil as fuel and gasoline engines using gasoline. As prime movers, they are suitable for mobile cranes of which mobility is required. Some light capacity mobile cranes use gasoline engines, but most use diesel engines due to the superiority shown in Table 2-1.

Table 2-1 Comparison of Diesel Engine and Gasoline Engine

Item	Type	
	Diesel Engine	Gasoline Engine
Fuel type	Light oil	Gasoline
Ignition type	Self-ignition by air compression heat	Ignition by electric spark
Engine mass per horsepower	Large	Small
Engine price per horsepower	High	Low
Thermal efficiency	Good (30% - 40%)	Poor (20% - 28%)
Operating costs	Low	High
Fire risk	Low	High
Noise and vibration	Large	Small
Ability to start in cold weather	Poor	Good

Diesel engines consist of the devices shown in Fig. 2-1.

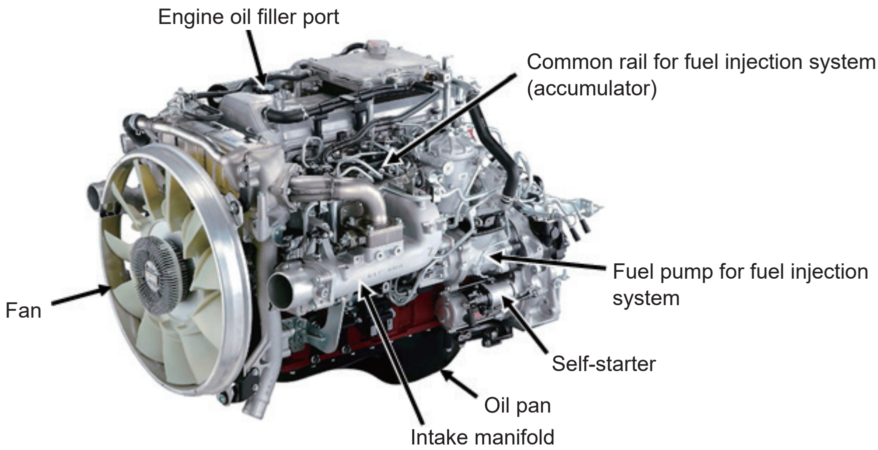


Fig. 2-1 Diesel Engine

2.1.2 Operation

The engine is the heart of a crane. Therefore, the precautions listed below must be observed to avoid the total breakdown of the mobile crane's functions due to the misoperation of or damage to the engine.

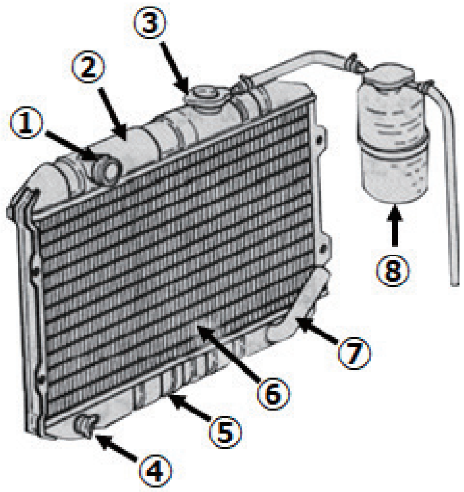
(1) Precautions Before Starting Engine

a. Engine Oil

Check that the specified amount of engine oil remains using the oil level gauge. Replenish the oil if the amount is insufficient.

b. Coolant

To inspect the amount of coolant, check the water level in the sub-tank (reservoir tank) after confirming that the engine is definitely cool. Replenish the coolant if the amount is insufficient. The cooling systems of most water-cooled engines are pressure-type. Thus, removing the radiator cap with the engine heated may cause steam or hot water to gush out, resulting in burns. For this reason, do not open the radiator cap with the engine heated under normal circumstances.



① Upper hose mounting port
② Upper tank
③ Radiator cap
④ Drain plug
⑤ Lower tank
⑥ Radiator core
⑦ Lower hose mounting port
⑧ Reservoir tank

Fig. 2-2 Radiator

c. Fuel

Check the amount of fuel with the fuel gauge and replenish it if the amount is insufficient.

d. Fan Belt

Check that the fan belt is not loose or damaged, and that oil or other materials are not adhering to it.

(2) Precautions When Starting Engine

- Confirm that the area surrounding the machine is safe.
- Check that all control levers are set to the neutral positions.
- Check that the parking brake is engaged. Check that the transmission shift lever is set to the neutral position.
- Check that the PTO lever is in the OFF position.

After confirming the above conditions, start the engine, fully step on the clutch pedal, shift the PTO lever to ON, and slowly release the clutch pedal.

(3) Precautions for Warm-up Operations

- Check that hydraulic pressure, air pressure, and other indicators indicate normal values.
- Check for any leakage of water or oil.
- Check that the color of the exhaust gas is normal.
- Check that the engine is running normal.

(4) Precautions for Operation

- Check that the hydraulic pressure is correct.
- Check that the coolant temperature is appropriate.
- Check that the battery is sufficiently charged.
- Check for any abnormal sounds.

(5) Precautions for End of Operations

- Check that the jib and outrigger are securely stored.
- Shift the PTO lever to the OFF position and check that the PTO indicator lamp is turned off. (Do not drive with PTO turned ON.)
- After confirming the above conditions, stop the engine and fill the fuel tank.
- After refueling, remove the engine key and store it.

2.2 Hydraulic System

With the development of hydraulic technology, most mobile cranes have used hydraulic systems in recent years. Table 2-2 shows examples of the advantages and disadvantages of hydraulic systems.

Table 2-2 Hydraulic System Advantage/Disadvantage

Advantages	Disadvantages
• Compact and lightweight. • Easy to prevent overloading among the crane equipment. • Easy to achieve stepless speed change. • Low vibration and smooth operation. • Easy to perform remote control.	• Difficult to lay out piping. • Hydraulic oil is flammable, leaks easily, and is susceptible to contaminants. • The efficiency of the machine varies depending on hydraulic oil temperature.

2.2.1 Hydraulic Pressure Principle

The principles of hydraulic pressure are based on Pascal's law. As shown in Fig. 2-3, in a container that combines two cylinders that have pistons with areas of 10 cm^2 and 1 cm^2 respectively, applying a force of 10 N (Newtons) to the smaller piston transmits a force of 100 N to the area of the larger-area piston. That is, the force applied to the smaller piston is magnified proportionately with the area of the larger one.

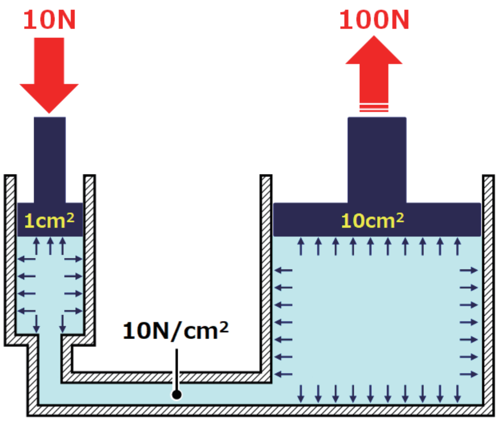


Fig. 2-3 Relationship between Piston Area and Force

2.2.2 Hydraulic System Structure and Mechanism

(1) Hydraulic System Structure

The hydraulic system consists of the following devices.

- Hydraulic system
  - Hydraulic pressure generator
    - Hydraulic pump
  - Hydraulic actuators
    - Hydraulic cylinders
    - Hydraulic motors
  - Hydraulic control valves
    - Directional control valves
    - Flow control valve
    - Pressure control valves
  - Accessories
    - Hydraulic oil tank
    - Filter, pressure gauge, etc.
    - Rotary joint
    - Piping (Piping, coupling)

(2) Hydraulic System Mechanism

As shown in Fig. 2-4, pulling the control lever moves the selector valve spool to the left, and the oil discharged from the hydraulic pump flows to side ① of the cylinder to move the piston to the right. The oil on side ② returns to the hydraulic oil tank via the selector valve. Conversely, pushing the control lever moves the selector valve to the right, and the oil flows to side ② of the cylinder to move the piston to the left.

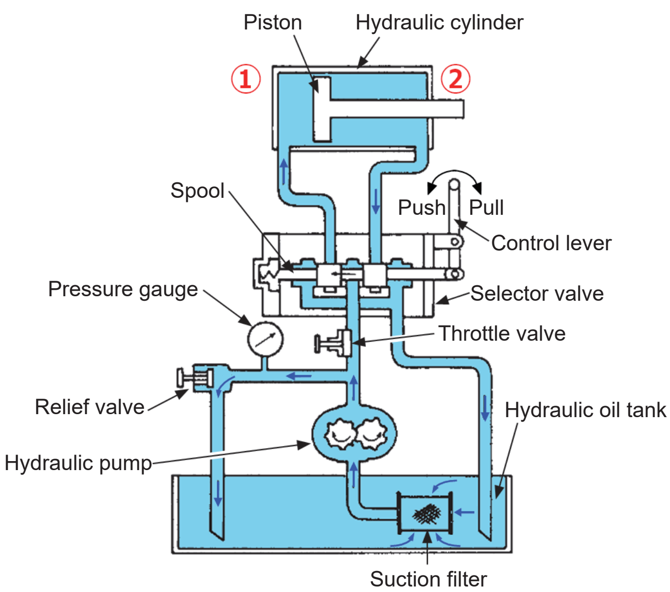


Fig. 2-4 Hydraulic System Mechanism

2.2.3 Mobile Crane Hydraulic System

Operating the hydraulic pump using engine power sends the hydraulic oil pressurized by the pump to the hydraulic cylinder (jib telescoping cylinder) or the hydraulic motor via the directional control valve. This leads to telescoping of the hydraulic cylinder and rotation of the hydraulic motor, resulting in the various devices being driven. The hydraulic oil discharged from the hydraulic motor or hydraulic cylinder decreases in pressure, and returns to the hydraulic oil tank via the control valve.

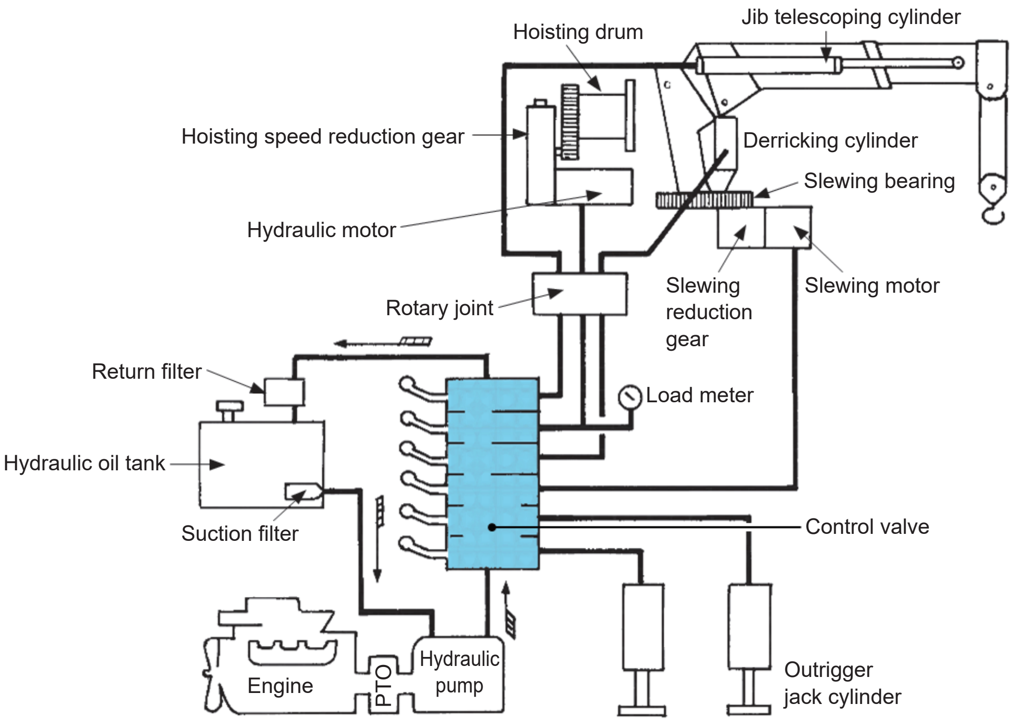


Fig. 2-5 Truck Loader Crane Hydraulic Circuit

(1) Hydraulic Pressure Generator

The hydraulic pump used for the hydraulic pressure generator is driven by the engine and electric motor. The oil is sucked from the hydraulic oil tank, discharged as pressure oil, and sent to the hydraulic actuator. For the hydraulic pumps of mobile cranes, truck loader cranes mainly use gear pumps (Fig. 2-6) and rough terrain cranes mainly use plunger (piston) pumps (Fig. 2-7).

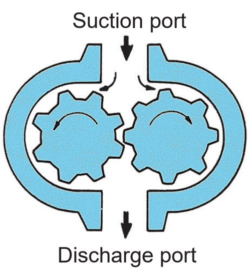


Fig. 2-6 Gear Pump

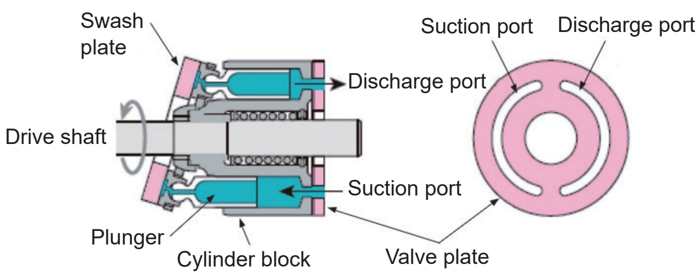


Fig. 2-7 Plunger Pump

(2) Hydraulic Actuators

Hydraulic actuators convert the pressure oil sent from the hydraulic pump into mechanical motion. These actuators are broadly divided based on how they move: hydraulic cylinders for linear motion and hydraulic motors for rotary motion.

1) Hydraulic Cylinders

The hydraulic cylinders of mobile cranes are generally double-acting single rod cylinders. These double-acting cylinders have hydraulic oil gateways on both sides. Hydraulic oil flows in and out through these gateways in a back-and-forth motion.

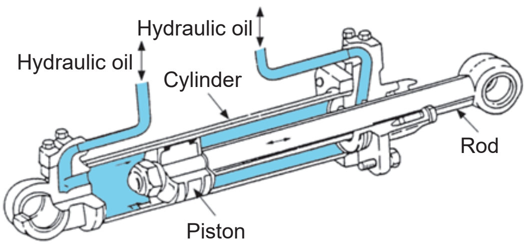


Fig. 2-8 Hydraulic Cylinder (Double-acting)

2) Hydraulic Motors

Unlike the hydraulic pump, the hydraulic motor rotates the drive shaft when pressure oil is injected in to the hydraulic motor. Mobile cranes normally use plunger motors as the hydraulic motor for hoisting, slewing and driving. Axial plunger motors (Fig. 2-9) have plungers arranged in the same direction as the rotation axis, whereas radial plunger motors (Fig. 2-10) have plungers arranged perpendicularly to the rotation axis. In both types, the output shaft rotates with the plungers' reciprocating motion by the pressure oil.

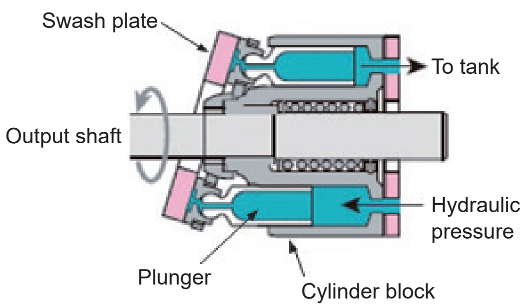


Fig. 2-9 Axial Plunger Motor

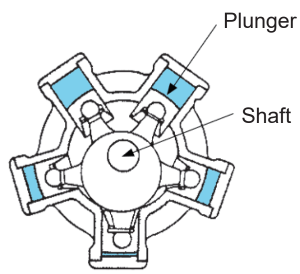


Fig. 2-10 Radial Plunger Motor

(3) Hydraulic Control Valves

The hydraulic control valves control the flow direction, the pressure, and the flow rate of the hydraulic oil. The following control valves are used at different points in the hydraulic circuit based on their functions and characteristics.

- Directional control valves
  - Selector valve
  - Check valve
  - Pilot check valve
- Flow control valves
  - Throttle valve
  - Shut-off valve
- Pressure control valves
  - Relief valve
  - Pressure reducing valve
  - Sequence valve
  - Counter-balance valve

The outlines of these valves are as follows.

1) Directional Control Valves

Directional control valves control the following: switching the direction of hydraulic oil flow; one-way movement of hydraulic oil flow; and starting and stopping of the hydraulic actuator.

a. Selector Valve

Selector valves switch the direction of oil flow to change the direction of hydraulic cylinder motion and hydraulic motor rotation. The levers that operate mobile crane hoisting and lowering, jib derricking, jib telescoping, and the slewing are controlled by operating the selector valve.

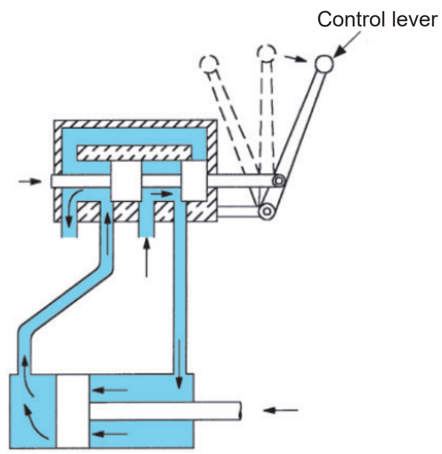


Fig. 2-11 Selector Valve

b. Pilot Check Valve

Check valves allow oil to pass freely in one direction, but prohibit it from flowing in the opposite direction. In contrast, pilot check valves allow for oil to flow in the opposite direction as well. The pilot check valves are used as a safety device for when the outrigger hydraulic circuit fails in mobile cranes.

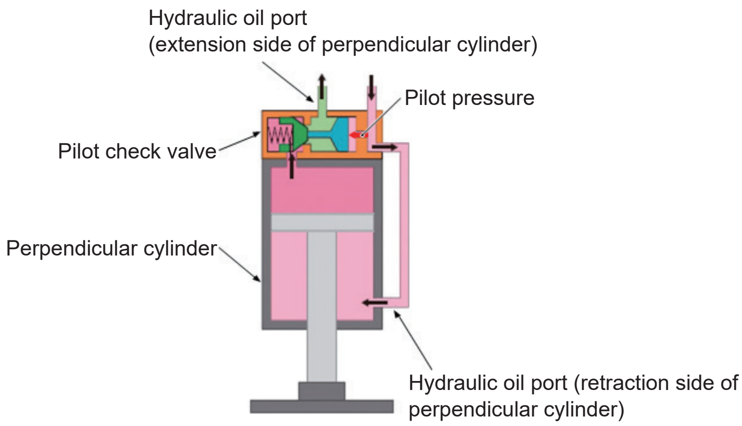


Fig. 2-12 Pilot Check Valve

2) Pressure Control Valves

Pressure control valves control the hydraulic oil pressure to operate hydraulic systems safely and maintain the power necessary for crane operation. Pressure control valves include the relief valves shown in Fig. 1-52 (p.34(en)), pressure reducing valves that make the hydraulic pressure at a part of the hydraulic circuit lower than that at other parts, sequence valves used in the mobile crane's jib telescoping circuit, and counter-balance valves to maintain decreasing velocity constant when performing lowering operations on mobile cranes.

(4) Accessories

1) Hydraulic Oil Tank

Hydraulic oil, pressurized by the hydraulic pump, operates crane equipment by activating the hydraulic actuator via ducts. Thus, the hydraulic oil tank, which stores the hydraulic oil, is equipped with an air breather to keep dust and contaminants out. It is also equipped with a filter to remove contaminants from the oil, so that the oil tank is always supplied with cleaned and cooled oil.

2) Pressure Gauges

The pressure gauge provides a reading of the pressure in the circuit. Bourdon-tube pressure gauges are used widely and are also used in truck loader cranes as load meters. Note, however, that installing pressure gauges as a device for preventing overloading is not permitted after March 2019.

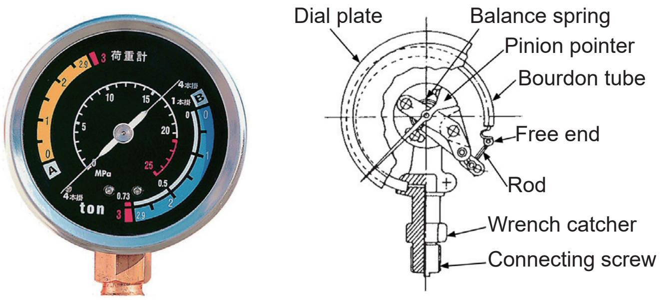


Fig. 2-13 Pressure Gauge

3) Oil Coolers

Oil coolers cool the oil when its temperature rises abnormally. Oil temperature rises when hydraulic systems are operated continuously. Since 55°C - 60°C is preferable for use as an oil temperature, exceeding this level causes various troubles. Thus, the oil cooler is installed to prevent increases in the oil temperature.

4) Rotary Joints

Rotary joints are used to connect the hydraulic circuits between the slewing upper structure and the base carrier. Additionally, in rough terrain cranes, they are also used in the clutch operation circuits of automatic brake hoisting mechanisms equipped with devices that allow for freefall.

2.2.4 Hydraulic System Maintenance

The purpose of maintenance is to keep the individual parts of the hydraulic system in the best condition to ensure safety during crane operation and improve operating efficiency. The majority of hydraulic system failures are related to contaminants in the hydraulic oil and oil leakages in the duct lines. Therefore, it is essential to prioritize the maintenance and inspection of these.

(1) Replacing and Evaluating the Hydraulic Oil

The air that enters hydraulic oil tanks always carries in contaminants and moisture. In addition, hydraulic equipment gradually generates debris from wear as it operates. Thus, replace the hydraulic oil periodically. If the hydraulic oil is significantly dirty, replace it even before the replacement period, and replace the filter element as well.

Table 2-3 How to Evaluate Hydraulic Oil through Appearance

Appearance	Odor	Causes		Countermeasures
Transparent, no change in color	Good	—		Continue using as is
Transparent, but the color is faint	Good	Another type of oil mixed in		Check the viscosity, and use as is if appropriate
Changed to milky white	Good	Air bubbles and water mixed in		Replace the hydraulic oil
Changed to dark brown	Bad	Deterioration		Replace the hydraulic oil
Transparent, but small black spots are visible	Good	Contaminants mixed in		Ask the manufacture to filter the hydraulic oil, or replace it
Foaming	—	Grease mixed in		Replace the hydraulic oil
		Air mixed in	Suction filter clogging	Clean or replace the suction filter
			The oil surface disturbed in the suction tank	Check the hydraulic oil, and replenish if insufficient
			Air bubbles formed in pump	Optimize the hydraulic oil temperature, cut off the hydraulic power source and leave it as it is

Check the amount of hydraulic oil with the crane in position for being driven. The oil level must be between the HIGH (upper limit) and LOW (lower limit) marks. While checking the amount of oil, the hydraulic oil will expand and the oil level will rise when the oil temperature is high. Conversely, if the oil temperature is low (for example, in cold-climate regions), the oil will contract and the oil level will decrease. Therefore, it is preferable to keep the hydraulic oil temperature at room temperature (approx. 20°C - 30°C) for checking the amount of oil.

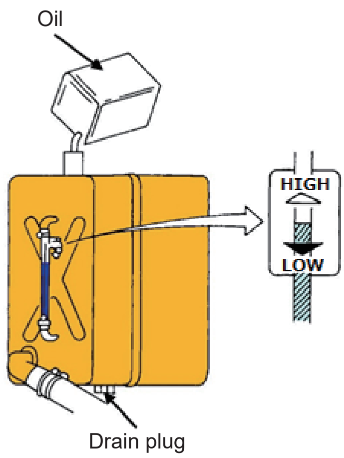


Fig. 2-14 How to Confirm Oil Level

(2) Filter

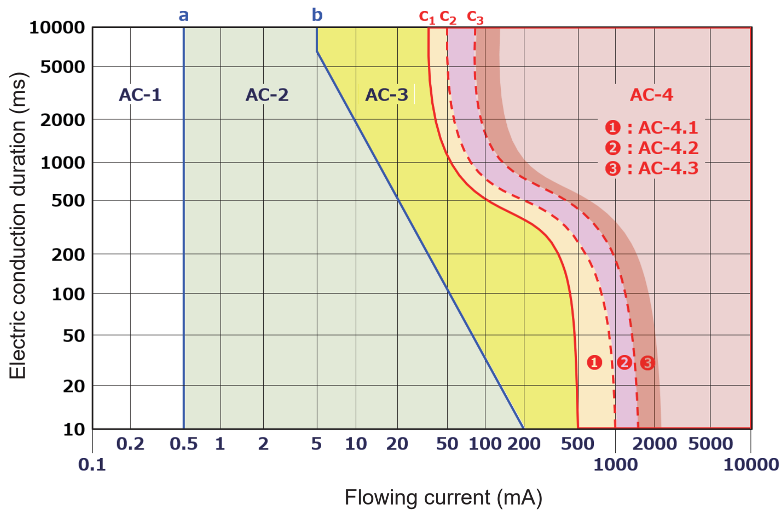
The filter is extremely important. It removes contaminants from the hydraulic oil to constantly keep the oil clean, which prevents the hydraulic equipment from causing damage and increases the hydraulic equipment's lifespan. Accordingly, replace the filter periodically based on how long the machine has been operating (usage time). In addition, a suction filter (strainer) is provided on the suction side of the hydraulic oil tank. Remove the suction filter every time the hydraulic oil is replaced. After doing so, wash the filter with clean light oil or cleaning liquid, and then thoroughly dry and reinstall it.

2.3 The Dangers of Electric Shock

(1) Precautions Related to Electric Shock

Electric shock refers to an electric current flowing through a person's body and causing pain or other effects. The degree of the impact caused by the electric shock depends on such things as: the magnitude of the current, the duration of the electric conduction, the type of current (e.g. an alternating current or a direct current), and the physical constitution and health condition of individuals. In particular, the magnitude of the current and duration of electric conduction have a major impact. Fatal accidents do occur because of electric shock; ventricular fibrillation (so-called heart failure) and respiratory arrest occur at low voltages. In addition to such accidents, at high voltages, burns occur due to arc heat resulting from making contact or Joule heat caused by passage of the current. Ventricular fibrillation is an arrhythmia in the ventricular pulsations due to an electrical current flowing to the cardiac region. This prevents the heart from contracting and expanding and causes a loss of blood circulation. This results in death. Ventricular fibrillation is an irreversible phenomenon. Even if the electric shock is stopped, recovery from ventricular fibrillation will not occur unless defibrillation is performed using an AED (automated external defibrillator). In addition, electrical burns can penetrate deeply into the body as well as destroy the body's cells in a way similar to burns from an external heat source.

While criteria for evaluating the danger of electric shock are often indicated only with the values of electrical currents, the International Electrotechnical Commission (IEC) indicates the criteria by the product of electric current and time, as shown in Fig. 2-15. The values in this diagram assume that electricity is flowing from the left hand to both feet. The diagram shows that ventricular fibrillation is caused by exposure to an electric current of 50 mA for 1000 ms, a current of 100 mA for 500 ms, and a current of 500 mA for 10 ms. These pose a risk of death. However, even if the human body is exposed to a high voltage, with an extremely high current flowing through the body, this may end up causing only burns if the duration of the electric conduction is extremely short.



AC-1: Perceptible, but usually no 'startled' reaction.

AC-2: Involuntary muscular contractions, with no harmful physiological effects usually.

AC-3: Strong involuntary muscular contractions, breathing difficulty, and reversible disturbances of heart function, with no damage to organs usually.

AC-4: Patho-physiological effects such as cardiac arrest, breathing arrest, and burns. Probability of ventricular fibrillation increases with current and time.

AC-4.1: Probability of ventricular fibrillation: about 5% or less

AC-4.2: Probability of ventricular fibrillation: about 50% or less

AC-4.3: Probability of ventricular fibrillation: over 50%.

Fig. 2-15 Safety Limit on Electric Shock Current (Amendment of IEC60479-1)

The risk of electric shock is determined by the current, but power supply is generally indicated by voltage. Accordingly, it is easier to understand if the risk of electric shock is indicated by voltage. Therefore, some countries specify that voltages that do not dangerously effect the human body are safe voltages. For example, 24 V is considered safe in Germany and England, while 50 V is considered safe in the Netherlands. Further, jibs and wire ropes are conductors that allow electricity to flow through them easily. As a result, even if they merely approach a high-voltage power line (and do not make contact), electricity may flow from the jib via the crane body to the ground due to electric discharge. Thus, it is necessary to secure a minimum approach distance from the power lines, and be careful not to come close to them.

(2) Precautions for Work near Power Lines

Power transmission refers to the transmission of electricity from power plants to substations and switching stations. Power distribution refers to the transmission of electricity from substations and switching stations to end users. Electricity (Power = Voltage x Current) is transmitted at high voltages to minimize loss. Therefore, electricity is transmitted to substations and switching stations at an extra-high voltage (22,000 V - 500,000 V). It is then transmitted to general users at a high voltage (6,600 V), and further lowered to 100 V - 200 V for home use via pole transformers. For industrial use, however, it is supplied at 200 V - 400 V or 6,600 V. To set up a work plan that requires approaching the power lines, it is required to sufficiently discuss the work schedule in advance with the power line owner, for example the local electric company; topics such as work method, protective measures, and supervision methods need to be discussed.

When performing work, ensure that the workers involved sufficiently understand the work plan. Furthermore, confirm that measures are taken to prevent electric shock, such as line guards for construction and elevated warning lines/barricades, and that monitoring supervisors are assigned. For mobile cranes with working range limit devices, register a work range that secures a sufficient separation distance from the power lines in advance.

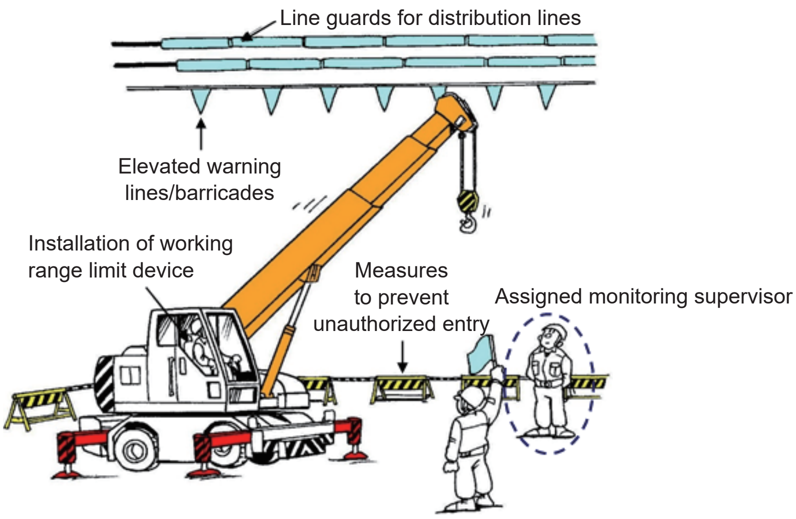


Fig. 2-16 Work near Power Lines

As mentioned above, high-voltage power transmission lines may discharge even if the jib or wire rope does not directly contact the electric line. Therefore, electric power companies have specified the minimum approach distances from the electric line at respective voltages for safe work. Ensure that these distances are observed. Be sufficiently careful when performing jib extension, raising, or slewing near the electric lines. Allowing the jib or wire rope to approach or make contact with power lines by mistake will cause the operator and the tamagake (rigging) worker to receive an electric shock.

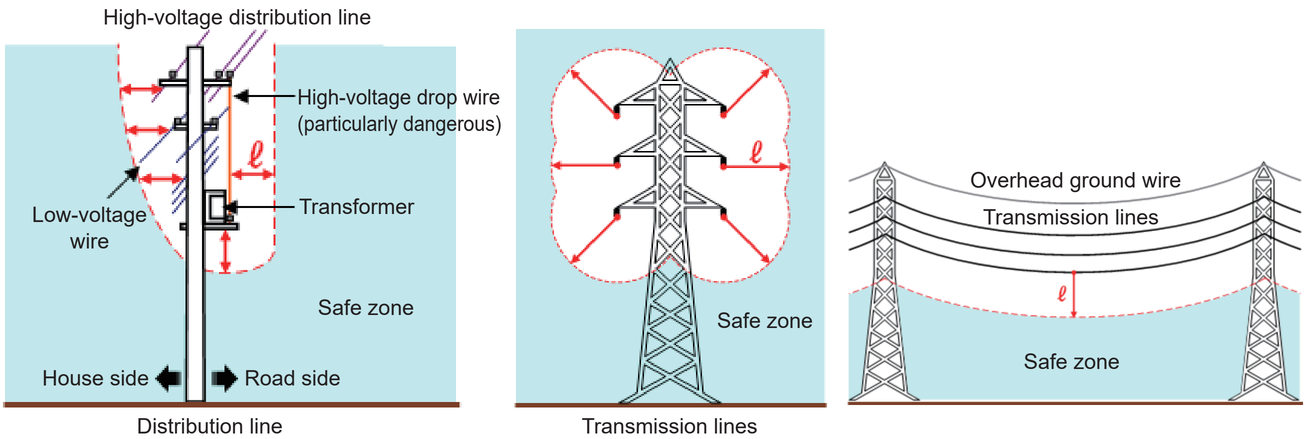


Fig. 2-17 Minimum Approach Distance (Separation Distance) (ℓ in the Figure: Danger Zones)

Table 2-4 Minimum Approach Distances and Number of Insulators Used by Electric Power Companies

Type	Nominal Voltage (V)	Minimum Approach Distance (m)											Number of Insulators (Reference Value)
		Hokkaido-epco	Tohoku-epco	Tokyo-epco	Chubu-epco	Hokuriku-epco	Kansai-epco	Chugoku-epco	Shikoku-epco	Kyushu-epco	Okinawa-epco	J-POWER	
Low voltage (distribution line)	100	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	—	1
	200	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	—	1
High voltage (distribution line)	6,600	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	—	1 - 2
Extra-high voltage (transmission line)	11,000	—	—	3.0	3.0	—	—	—	—	—	—	—	
	13,800	—	—	—	—	—	—	—	—	—	2.0	—	
	22,000	3.0	3.0	3.0	3.0	—	3.0	3.0	—	2.0	2.0	—	2 - 4
	33,000	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	—	2.0	
	44,000	—	—	—	3.0	—	—	—	—	—	—	—	
	66,000	4.0	4.0	4.0	4.0	4.0	—	4.0	4.0	4.0	2.2	2.2	5 - 8
	77,000	—	—	—	4.0	4.0	4.0	4.0	—	—	—	2.4	
	110,000	5.0	—	—	—	—	—	5.0	5.0	4.0	—	3.0	
	132,000	—	—	—	—	—	—	—	—	—	3.6	—	
	154,000	—	5.0	5.0	5.0	5.0	5.0	—	—	—	—	4.0	10 - 16
	187,000	7.0	—	—	—	—	—	—	6.0	—	—	4.6	
	220,000	—	—	—	—	—	—	6.0	—	6.0	—	5.2	
	275,000	10.0	7.0	7.0	7.0	7.0	7.0	—	—	—	—	6.4	16 - 24
	500,000	—	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	—	10.8	35

In addition to the power companies indicated in the table, other companies such as JR manage power lines. Thus, it is required to confirm the minimum approach distances from these companies.

If the jib or wire rope of a mobile crane with a cab accidentally makes contact with a power line during use, the operator must immediately move the part that has made contact away from the power line and leave the cab after securing the minimum approach distance. If the crane cannot be operated, stay inside the cab until the power transmission stops. If leaving the cab is absolutely necessary, the operator must do so without descending down the steps or touching the railing. This is because the electricity may be transmitted again even if it stops once. Instead, the operator should jump down as far as possible away from the body of the crane, being careful not to let his/her body be a conduit for electricity. At that time, other people on the ground must not make contact with the body of the crane, wire ropes, or any other parts. For cranes that operators operate from the ground, such as truck loader cranes, workers must not make contact with the crane body or a lifted load, including the control levers, after an electrical accident. Workers must carefully check mobile cranes that have been energized for wire rope damage, foot pin burning, and damage to the electrical systems (including the load moment limiter).

(3) Crane Damage Due to Radio Waves (Reference)

The jibs and wire ropes of climbing cranes and mobile cranes may work as antennae by receiving radio waves transmitted from nearby middle-wave (AM) transmission towers. This may generate an abnormal voltage and cause the tamagake worker to receive an electric shock.

1) Main Phenomena

- Making contact with the crane hook or wire rope, causing an electric shock and a burn.
- The crane control unit, such as the computer circuit board, is damaged.
- The load moment limiter malfunctions.
- The crane hook or wire rope comes into contact with the steel frame, causing sparks and damaging the wire rope.

2) Examples of Countermeasures

- Using a belt sling (JIS-certified) for the tamagake equipment.
- Coating the hook with an epoxy resin (to be laminated with glass fiber).
- Requiring the tamagake workers to wear rubber gloves (for work with high-voltage live wires) if necessary.
- Coating control cables with wiring shield materials , or replace with shield wiring.
- Covering the control panel with wire netting.
- Making sure that the hoisting wire rope does not make contact with surrounding steel frames.

Chapter 3

Knowledge About Dynamics Necessary for the Light Capacity Mobile Crane Operation

3.1 Matters Related to Force

3.1.1 Three Elements of Force

Force has magnitude and direction. If the point of action on an object is changed, its effect on the object changes; the same is the case when the magnitude or direction is changed. In this way, force always consists of magnitude, direction, and point of action, which are called the "three elements of force". To represent force in a diagram, as shown in Fig. 3-1, the point of action is set at A and a straight line is drawn from A in the direction of force to obtain length AB, which is proportional to the force magnitude. For example, given that 1 N is equivalent to 1 m long, 5 N will be 5 m long. The straight line extended from AB is called the “line of action”. The direction of the force is indicated by an arrow. The point of action of the force has the same effect no matter where it is moved on the line of action.

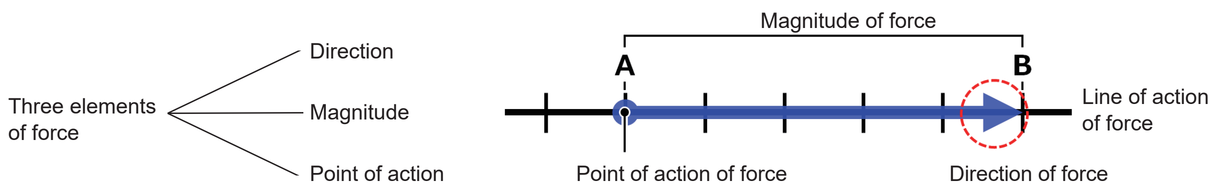


Fig. 3-1 Three Elements of Force

3.1.2 Action and Reaction

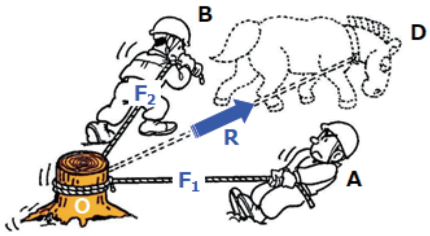
When one of two objects exerts a force on the other object, the second object always exerts another force on the first object. The initial force is called “action” and the other force is called “reaction”. Action and reaction act on the same straight line, with the same magnitude, and in opposite directions to each other.

3.1.3 Composition of Forces

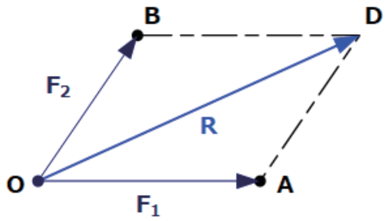
Two or more forces that act on a single object can be combined into a single force with the exact same effect. This combined single force is called the “resultant force” of the prior two or more forces. The determination of the resultant force is called the “composition of forces”.

For example, as shown in Fig. 3-2(a), when two people pull a stump with a rope, the stump is pulled in the direction of the arrow. In this way, two forces acting on an object are replaced with one force (the resultant force) that has the same effect.

Fig. 3-2(b) shows how to determine the resultant force. If a parallelogram (OBDA) is created whose two sides are formed by forces that have different directions, F_1 and F_2, acting on point O, then diagonal R represents the magnitude and direction of the resultant force being determined. This is called the “parallelogram law”.



(a)



(b)

Fig. 3-2 Resultant Force

For resultant forces where three or more forces act on a single point, the resultant forces can be obtained by repeatedly creating parallelograms. For example, consider forces F_1, F_2, F_3, and F_4 acting on point O, as shown in Fig. 3-3. Resultant force R_1 for F_1 and F_2 is obtained by the parallelogram law. Resultant force R_2 for R_1 and F_3 are obtained in the same way, and the resultant force of R_2 and F_4, which is resultant force R acting on point O, is also obtained.

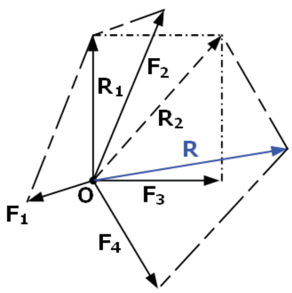
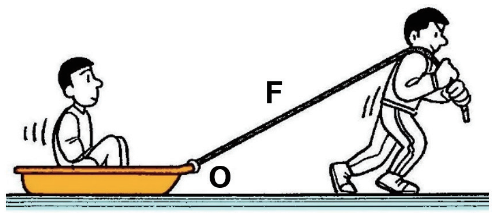


Fig. 3-3 Composition of Forces

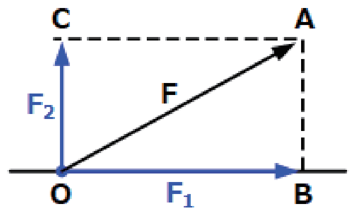
3.1.4 Decomposition of Forces

The decomposition of forces is the resolution of a single force acting on an object into two or more forces that have certain angles to each other. Each of the forces into which the single force is resolved is called a “component force” of the original force. To obtain the component force, the parallelogram law, which is described in Composition of Forces, is used reversely to resolve the single force into two or more forces with certain angles to each other.

For example, consider a sled being pulled, as shown in Fig. 3-4(a). The rope is pulled diagonally upward, but the sled is simultaneously lifted upward and pulled in a horizontal direction. As shown in Fig. 3-4(b), force F (OA) can be resolved into F_1 (OB) and F_2 (OC) using the parallelogram law reversely. This is the decomposition of forces, which shows that the horizontal force of the sled is F_1 (OB).



(a)



(b)

Fig. 3-4 Decomposition of Forces

3.1.5 Moment of Force

The moment of force is the effect of a force trying to turn an object. When tightening a nut with a wrench, a smaller force is required when holding the wrench near the shaft end than when holding it in the middle, as shown in Fig. 3-5.

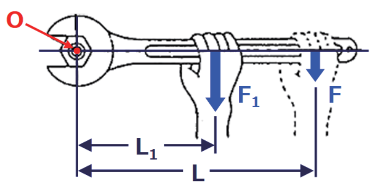


Fig. 3-5 Magnitude of Force and Length of Arm

In this way, the moment of force is an amount represented by the product of the magnitude of a force and the length of the arm, for a given axis or fulcrum of rotation. Thus, if the magnitude of a force is F and the length of the arm is L, the moment of force M is M = F x L. When expressing the magnitude of force F in N (Newtons) and length of arm L in m (meters), the moment of force M is expressed in N·m (Newton meters).

3.1.6 Balance of Forces

If an object does not move even if multiple forces act on it, these forces are balanced. For example, in Fig. 3-6, loads are shown being carried with a pole. To keep the pole at shoulder level, the pole should be held right in the middle when the two loads are equal in mass. When the masses differ from each other, the pole should be held at a point nearer to the heavier load. To balance the parallel forces is to balance the moments of forces; that is, it is to equalize the counterclockwise and clockwise moments in relation to the center of rotation.

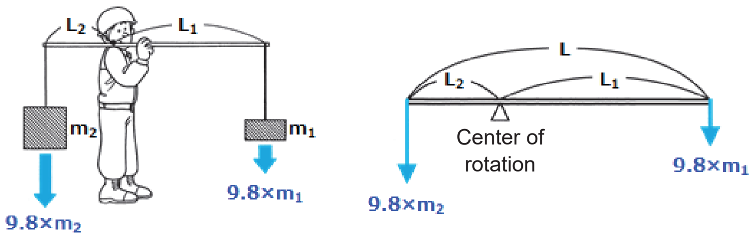


Fig. 3-6 Balance of Forces

In this way, considering the shoulder to be the center of rotation for the moment of forces, if the load-supporting positions (horizontal distances between the loads and the shoulder) on a pole with load masses of m_1 and m_2 are L_1 and L_2,

the clockwise moment is $M_1 = 9.8 \times m_1 \times L_1$,

the counterclockwise moment is $M_2 = 9.8 \times m_2 \times L_2$, and

$M_1 = M_2$ according to the condition of the balance of moments in relation to the center of rotation.

Considering a case like the one shown in Fig. 3-7, in which a truck loader crane is lifting a load with a mass of m_1, the moment that acts to overturn the crane is different between when the jib is lowered to A and when it is lowered to B. With the outrigger as the tipping point, the arm lengths for the clockwise moment (called the “tipping moment”) are L_1 and L_2 respectively, and $L_1 < L_2$. Therefore, the moments are $9.8 \times m_1 \times L_1 < 9.8 \times m_1 \times L_2$. The tipping moment is larger when the jib is lowered to B.

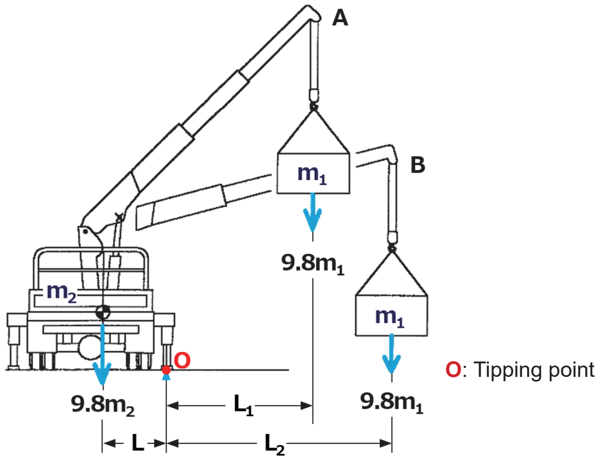


Fig. 3-7 Truck Loader Crane Moment

In this Figure, when stabilizing the crane, the counterclockwise moment (called the “stability moment”) $9.8 \times m_2 \times L$ is constant. Decreasing the jib angle or extending the jib makes the arm longer, even with the same load mass, which causes the tipping moment to increase. The crane overturns when the clockwise moment exceeds the counterclockwise moment.

Therefore, in work performed with mobile cranes, it is important to operate the crane with the stability moment larger than the tipping moment. If the outrigger is at the middle extension or minimum extension (full retracted state), the stability moment decreases as outrigger extension width L decreases. Hence, the gross rated load (rated load) is set lower with respect to the full extension in order to decrease the tipping moment and prevent the mobile crane from overturning.

3.2 Mass and Center of Gravity

3.2.1 Mass

Table 3-1 shows approximate mass per cubic meter (m^3) for different materials. By using this table reversely, the mass of an object can be obtained if its volume (m^3) is known. For example, to obtain mass m (t) of a load, multiply load volume V (m^3) by mass d (t) per cubic meter according to the load material (m = d x v).

Table 3-1 Mass of Objects per Cubic Meter

Object Type	Mass per Cubic Meter (t)	Object Type	Mass per Cubic Meter (t)
Lead	11.4	Sand	1.9
Copper	8.9	Coal powder	1.0
Steel	7.8	Piece of coal	0.8
Cast iron	7.2	Coke	0.5
Aluminum	2.7	Water	1.0
Granite	2.6	Oak	0.9
Concrete	2.3	Cedar	0.4
Soil	2.0	Cypress	0.4
Gravel	1.9	Paulownia	0.3

3.2.2 Specific Gravity

The specific gravity of an object is the ratio of its mass to the mass of pure water at 4°C with the same volume. It is expressed by the following equation.

Specific gravity = Mass of object / Mass of pure water at 4°C with the same volume

The mass of pure water at 4°C is 1 kg for 1 L and 1 t for 1 m^3, so the approximate specific gravity values for various materials are as shown in Table 3-1.

3.2.3 Center of Gravity

Gravity acts on all objects. Assuming these objects are divided into multiple parts, the gravity acts on each part. For the resultant force of these gravities, all of the gravities can be considered to be concentrated on a single point. The point of action of this resultant force is called the "center of gravity". The center of gravity of an object is a constant point. Even if the object's position or placement changes, the center of gravity does not change (Fig. 3-8(a)). Moreover, the center of gravity is not necessarily inside the object (Fig. 3-8(b)).

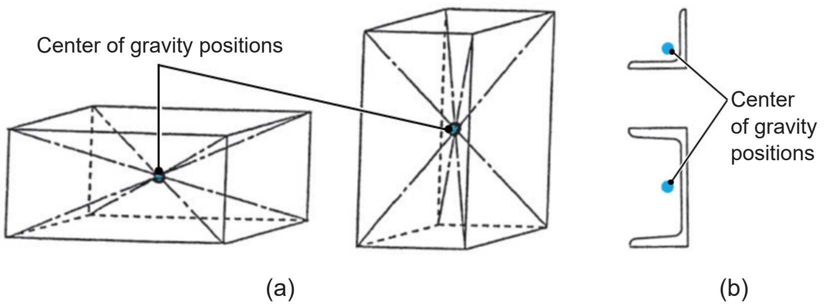


Fig. 3-8 Center of Gravity Positions

3.2.4 Object Stability

If a stationary object tilted by hand tries to return to its previous place when the hand is released, it is considered stable (Fig. 3-9(a)). Conversely, if the object overturns, it is considered unstable (Fig. 3-9(b)). For instance, if an object placed on a level surface is tilted as in Fig. 3-9(a) and then the hand is released, it returns to its previous place.

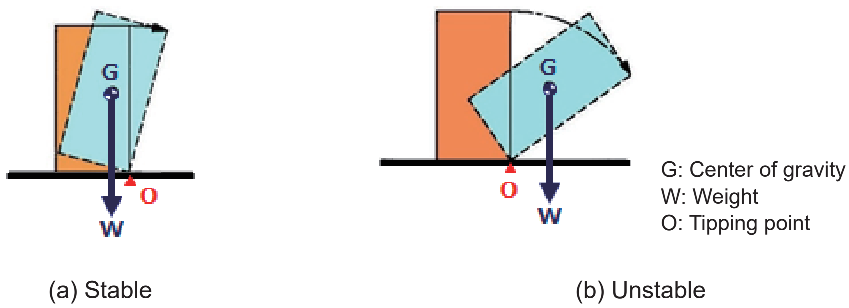


Fig. 3-9 Object Stability

This is because the gravity acting on center of gravity G exerts a moment in the direction of returning the object to its previous place, with the rotation center O as a fulcrum. If the object is tilted until the vertical line passing through the center of gravity goes outside the tipping point O, as shown in Fig. 3-9(b), the object does not return to its previous place, but overturns.

3.3 Motion

3.3.1 Motion

An object changing its position relative to another object is called “motion”. Motion can be divided into uniform motion and non-uniform motion. In uniform motion, speed remains constant at all times. In non-uniform motion, as shown in Fig. 3-10, speed is 0 at the departure point, reaches maximum speed at a certain point, decelerates just before the destination, and becomes 0 again. This is similar to vehicle that is being driven.

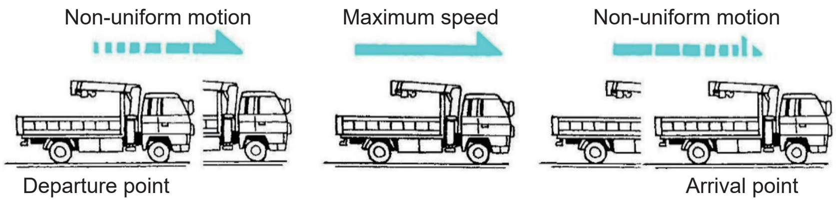


Fig. 3-10 Motion

3.3.2 Speed/Velocity

“Speed” refers to the distance a moving object travels per a certain time. If an object moving in uniform motion moves 50 m in 10 seconds, its speed is 5 m/sec. To determine the motion of an object, however, it is insufficient to consider speed alone; motion direction must be considered as well. Velocity is an amount expressed by both the direction and speed of motion.

3.3.3 Inertia

An object tends to remain at rest when standing still, and tends to remain in motion in a straight line forever when moving in a straight line, unless it is affected by some external force. This tendency is called “inertia”. The magnitude of inertia depends on the object’s mass. Inertia grows as the mass increases.

If a stopped train suddenly starts, the people standing inside are likely to fall in the direction opposite to the direction the train is moving, as shown in Fig. 3-11. Furthermore, if a moving train suddenly stops, the people standing inside are likely to fall in the direction the train was going. For example, if the crane operation suddenly stops while a load is moving horizontally, the load does not immediately stop, but swings. This is due to the inertial force.

Fig. 3-11 Inertia

3.3.4 Centrifugal and Centripetal Forces

When an object is in circular motion, two forces are exerted on it: a centrifugal force that works to make the object fly out of the circle and a centripetal force that directs it toward the rotation axis to keep it from jumping out. These forces maintain the object's balance. These centrifugal and centripetal forces have the same magnitude and opposite directions.

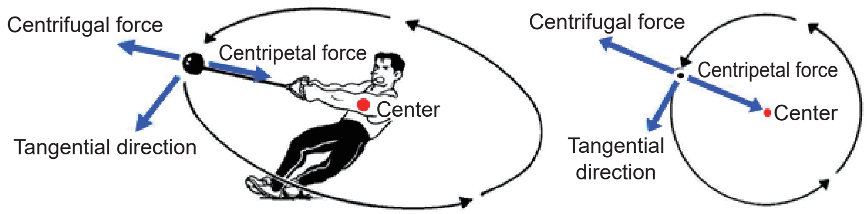


Fig. 3-12 Centrifugal and Centripetal Forces

The greater an object's mass and velocity, the greater the centrifugal and centripetal forces. As a load's rotation speed increases resulting in the load flying farther outward.

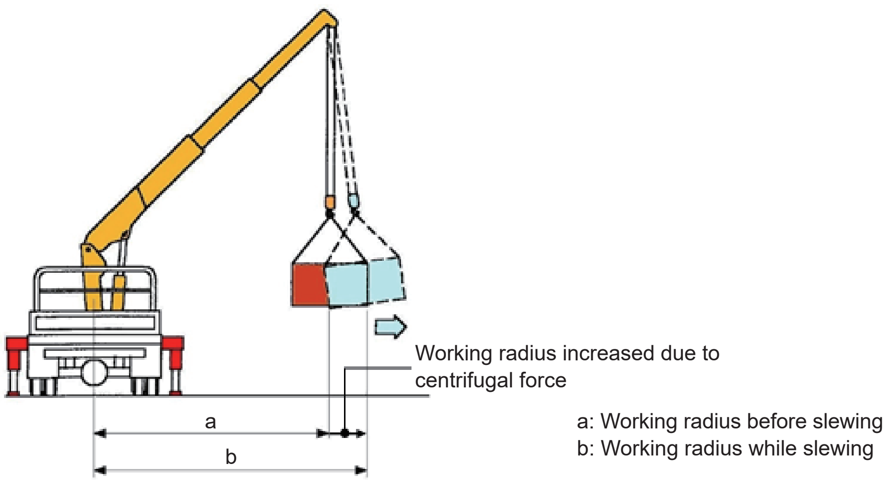


Fig. 3-13 Flying-out of Load by Centrifugal Force, and Working Radius

In such cases, the moment that works to overturn a mobile crane dramatically increases, compared to cases where a load is at rest. It is necessary to be careful, since the crane may overturn.

3.3.5 Frictional Force

If a pull force is applied to an object on the floor, it pulls the object along the floor surface and produces a resistance between the floor surface and the object. This inhibits the object's movement. The object does not move with a small pull force, but starts to move when the force exceeds a certain level. The resistance exerted on the contact surface of a stationary object is called "static frictional force". The frictional force exerted on an object that moves while in contact with another object is called "dynamic frictional force". Both of these frictional forces are proportional to the vertical force, regardless of the contact surface area. The dynamic frictional force is smaller than the static frictional force. That is, a stationary object requires greater force to start moving on the floor surface.

3.3.6 Sheave Block

When lifting a load with a wire rope, the heavier the load being lifted, the more force required. Sheave blocks are used to reduce the force lifting the load or to change the direction of the force. Sheave blocks for cranes can be divided into the following types:

(1) Stationary Sheave

The stationary sheave is fixed in a specified position, as shown in Fig. 3-14. It is used to change the direction of the force. In using it, simply pulling the rope downward allows the load to be lifted upward. While the direction of the force is changed, the magnitude of the required force remains unchanged. To lift a load 1 m, pull the rope down 1 m.

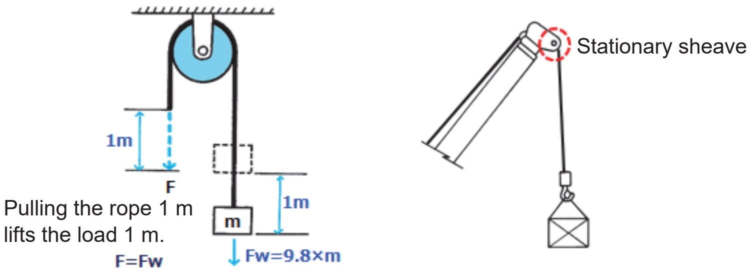


Fig. 3-14 Stationary Sheave

(2) Movable Sheave

The movable sheave is used in the hook assemblies of cranes as shown in Fig. 3-15. It moves up and down when the rope attached on it is moved up or down.

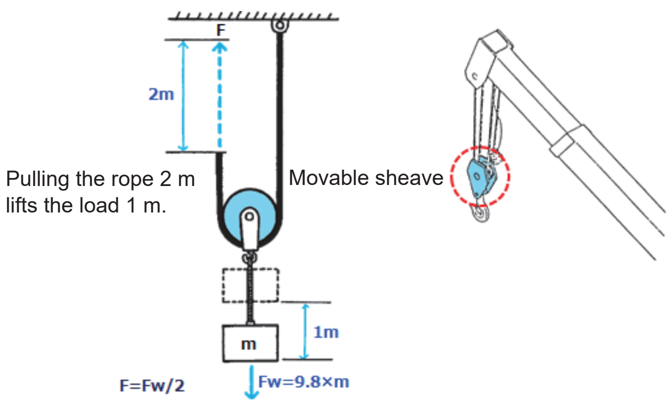
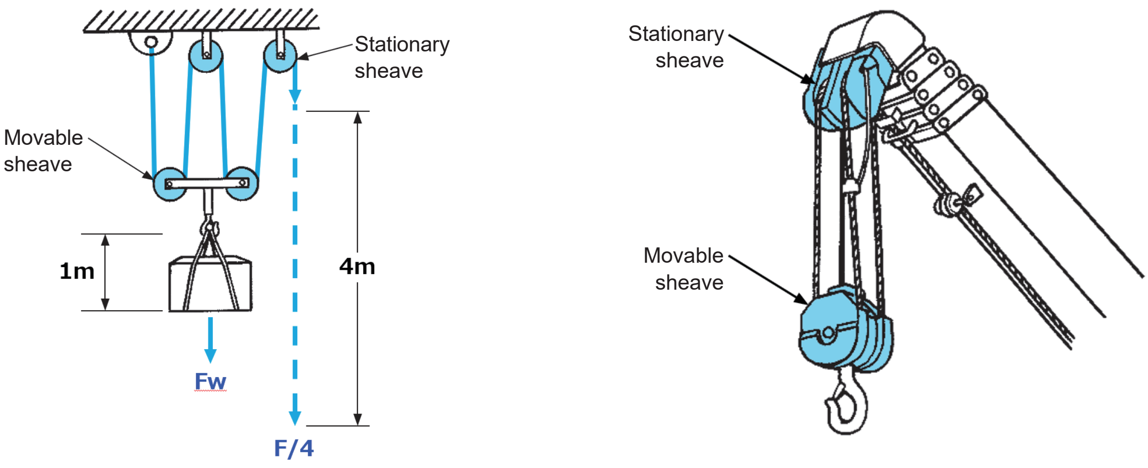


Fig. 3-15 Movable Sheave

The movable sheave is used to decrease the force pulling the rope. When using the movable sheave to lift a load, a force half the load weight (the downward force produced by a mass) is enough, but lifting the load 1 m requires pulling the rope 2 m. That is, the less force is required with the sheave, but the distance pulled is doubled. Furthermore, the direction of the pulling force is upward; this is the same direction in which the load is moving, so the direction of the force does not change.

(3) Combination Sheave

The combination sheave combines several movable and stationary sheaves. It can lift or lower a heavy load with a small force. A combination of two movable sheaves and two stationary ones, as illustrated in Fig. 3-16(a), can lift a load with a force only one-fourth the load weight, assuming there is no sheave friction and the hook assembly, including the movable sheaves, does not itself have any weight. However, lifting a load 1 m requires pulling the rope 4 m. Fig. 3-16(b) shows an example of a combination sheave used in mobile cranes.



(a) (b)

Fig. 3-16 Combination Sheave

3.4 Load, Stress, Strength of Materials

3.4.1 Load

A load is a force working externally on an object (an external force). In this section, it is treated as an external force (units: N, kN). It can be divided in different ways according to how the force works.

(1) Classification by Direction of Force (Load)

1) Tensile Load

The “tensile load” is a force that works to stretch a material. As shown in Fig. 3-17, force F works in the longitudinal axis of the rod to pull it; this is the tensile load. This load is applied to a wire rope lifting a load.

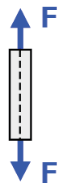


Fig. 3-17 Tensile Load

2) Compressive Load

The “compressive load” is a force that works to compress a material, in contrast to the tensile load. As shown in Fig. 3-18, force F works to compress a rod longitudinally; this is the compressive load. This load is applied to the outrigger jack.

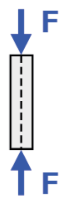


Fig. 3-18 Compressive Load

3) Shearing Load

The “shearing load” is a force that works similarly to a pair of scissors cutting a material. As shown in Fig. 3-19, force F works to cut a bolt tightening two steel plates along a plane parallel to force F.

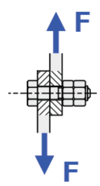
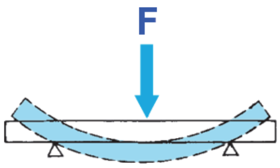


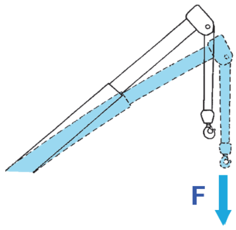
Fig. 3-19 Shearing Load

4) Bending Load

The “bending load” is a force that works to bend a material. As shown in Fig. 3-20(a) , a beam supported at both ends bends if a perpendicular force F acts on it; this is the bending load. It includes the weight of a load or trolley applied to the girder of an overhead traveling crane, or a load working to bend the jib of a crane, as in Fig. 3-20(b).



(a)



(b)

Fig. 3-20 Bending Load

5) Twisting Load

The “twisting load” is a force that works to twist a material. A shaft is twisted if one end of it is fixed and the forces F, working in the opposite direction to each other, are applied to the circumference of the other end, as shown in Fig. 3-21. This is the load applied on the hoisting drum shaft that is pulled and twisted with the wire rope.

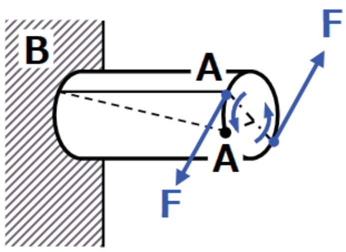


Fig. 3-21 Twisting Load

6) Combined Load

The aforementioned loads act on the parts of a crane more frequently in combination, rather than alone.

For instance, the wire rope and hook are both subject to the tensile and bending loads, while general power shafts are subject to the bending and twisting loads.

3.5 Strength of Wire Rope, Hook, and Other Load-lifting Attachments

During actual crane work, it is common to use multiple tamagake (rigging) wire ropes and tamagake chains to perform tamagake and lift loads. The maximum load that these tamagake wire ropes and tamagake chains can lift, according to the number of ropes/chains and the lifting angle, is called the “working load limit”.

Furthermore, the load that breaks tamagake equipment, including tamagake wire ropes and tamagake hooks, is called the “breaking load”. The ratio between the breaking load and the forces corresponding to the working load limit is called the “safety coefficient”.

(1) Breaking Load

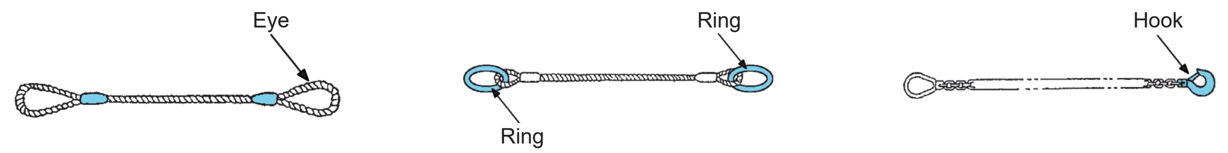
The breaking load is the maximum load at which a single tamagake wire rope or tamagake equipment break (unit: kN).

(2) Safety Coefficient

The safety coefficient is the ratio of the breaking load for tamagake equipment, for example a tamagake wire rope or tamagake chain to the maximum load to be applied during use. The type, shape, material, and usage method of tamagake equipment are taken into consideration in defining the safety coefficient. The safety coefficient for tamagake equipment is defined as follows in the Safety Ordinance for Cranes.

- Tamagake wire rope: 6 or more
- Tamagake chain: 5 or more (or 4 or more when certain conditions are met)
- Tamagake hook and shackle: 5 or more

Fig. 3-22 shows diagrams of typical tamagake wire ropes and tamagake chains.



(a) Wire rope with eyes at both ends (b) Wire rope with rings (c) Chain with a hook

Fig. 3-22 Typical Tamagake Wire Ropes and Tamagake Chain

(3) Standard Working Load Limit

The standard working load limit is the maximum load that can be lifted vertically using a single tamagake wire rope, taking the safety coefficient into consideration. It can be obtained with the following equation.

Standard working load limit (t) = [Breaking load (kN)] / [9.8 x Safety coefficient]

(4) Working Load Limit

The “working load limit” (working load) is the maximum load (t) that can be lifted using the tamagake equipment, including tamagake wire ropes and tamagake chains, according to the lifting angle and the number of ropes/chains.

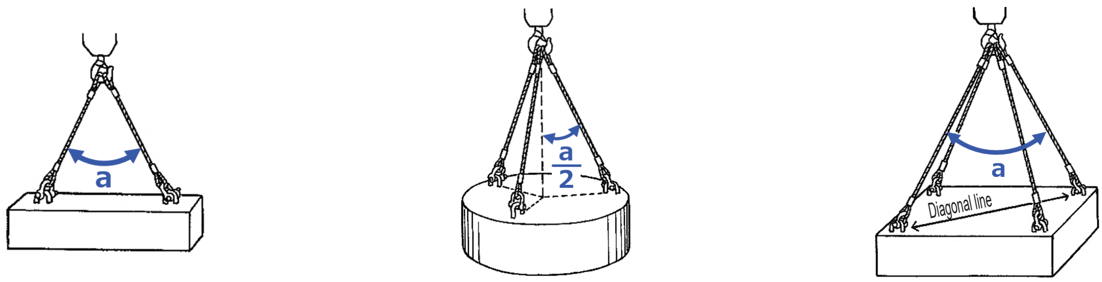
3.6 Relationship Between Number of Tamagake Wire Ropes, Lifting Angles and Load

3.6.1 Concept of Load Applied to Wire Rope

The load applied to the wire rope varies depending on the mass of the load, number of wire ropes, and lifting angle.

(1) Number of Ropes and Lifting Angle

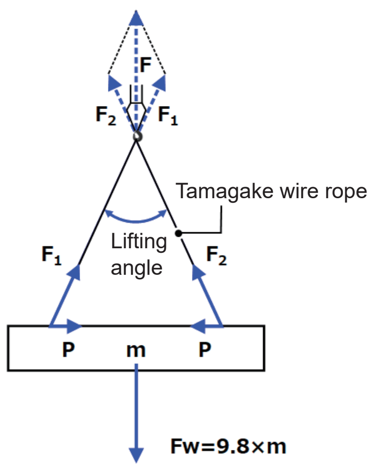
The "number of ropes" refers to the number of wire ropes. It is expressed as a "Single-leg sling with two-point", "Two-leg sling with two-point", "Three-leg sling with three-point" or "Four-leg sling with four-point", depending on the number of slinging points at the load side. The "lifting angle" is the angle between the tamagake wire ropes attached to the hook.



Two-leg sling with two-point　　Three-leg sling with three-point　　Four-leg sling with four-point

Fig. 3-23 Number of Ropes and Lifting Angle ("a" in the Diagram refers to Lifting Angle)

As shown in Fig. 3-24, when lifting a load with two wire ropes, the force supporting the load mass m is resultant force (F) of tensions (F_1, F_2) applied to the two wire ropes. F_1 and F_2 are greater than F/2, respectively. Even with a load of the same mass, as the lifting angle becomes greater, wire rope tensions F_1 and F_2 increase. Also, as the lifting angle becomes greater, horizontal component force P of F_1 and F_2 increases. This horizontal component force P acts on the load as a compressive force, trying to pull the wire ropes inward, so attention must be paid to greater lifting angles.



m: Load mass (t)
Fw: 9.8 x m (kN)
F_1, F_2: Tamagake wire rope tension
F: Resultant force (F=Fw)
P: Force pulling tamagake wire ropes inward (kN)

Fig. 3-24 Tamagake Wire Rope Tension

(2) Tension Factor

“Tension factor” is the value for calculating the load (tension) applied to a tamagake wire rope or other tamagake equipment by a lifting angle. The tension per wire rope can be calculated by using the tension factor and number of ropes, even if the number of ropes is changed.

Fig. 3-25 shows the relationship between the lifting angle and the tension of wire ropes. As the lifting angle increases, the tension applied to the wire rope increases, even with the load mass remaining unchanged. Therefore, the thicker wire ropes must be used. Additionally, if the lifting angle increases too much, the eye of the tamagake wire rope may come off the hook , so ensure that the lifting angle is 60 degrees or less.

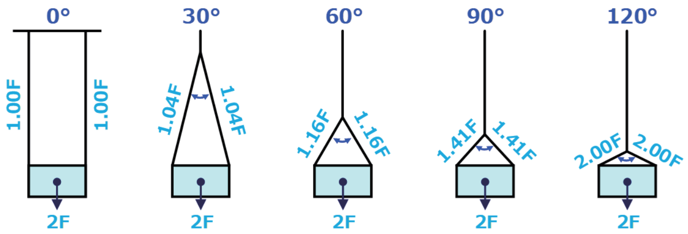


Fig. 3-25 Relationship Between Lifting Angle and Tension Applied to Tamagake Wire Ropes

(3) Mode Factor

The “mode factor” is the ratio of the working load limit of the tamagake wire ropes or other tamagake equipment at a certain number of ropes and a certain lifting angle, to the standard working load limit. The mode factor value originally varies depending on the lifting angle, but is set as constant for each of the lifting angle ranges grouped at a certain interval, for convenience in use.

Chapter 4

Signals for Light Capacity Mobile Crane Operation

4.1 Signals for Light Capacity Mobile Crane Operation

Signals which the signalers use to communicate with the mobile crane operators include hand signals and flag signals, while if necessary whistles are sometimes used in combination to supplement them. However, the signalers must not use whistles alone for signals, because that may easily lead to accidents. In general, hand signals are widely used; however, it is important to perform the specified actions clearly.

By law, the employer must, when carrying out work using mobile cranes, set fixed signals for the operation of the mobile cranes, designate signalers, and have the signalers give those signals. The designated signalers must give the fixed signals. Since it is prescribed that workers engaging in the work must follow the signals, the operators who are operating the mobile cranes must confirm and follow the signals from the signalers.

It is important for mobile crane operators working at construction sites to confirm the signals to be used. Moreover, to prevent any accidents arising from improper signals, the operators must stop mobile crane operations temporarily in the following instances:

- When the signal is unclear
- When the mobile crane operators receive a signal other than the fixed signals
- When mobile crane operators receive signals from two or more signalers
- When workers other than the designated signaler gives a signal

Chapter 5
Applicable Laws and Regulations (Overview)

5.1 Industrial Safety and Health Act

Chapter 4 Measures for Preventing the Dangers or Health Impairment of Workers

(Measures to Be Taken by Employers)

Article 20

The employer must take the necessary measures to prevent dangers caused by machinery and other equipment; explosive, combustible and inflammable substances; and electricity, heat and other energy.

[Ordinance on Industrial Safety and Health]

(Use of Machinery and Other Equipment Comply with Standards)

Article 27

The employer must not use machinery and other equipment unless they meet the standards set forth in the Act by the Minister of Health, Labour and Welfare.

(Effective Maintenance of Safety Devices)

Article 28

The employer must check and maintain safety devices so that safety devices are used in effective conditions.

(Prevention of Electric Shocks)

Article 349

The employer must take one or more of the following measures as appropriate when there is a risk of electric shock to the worker during work or when passing by.

1. Relocate charged circuits.

2. Install an enclosure to prevent the danger of electric shock.

3. Equip charged circuits with insulating protective equipment.

4. If the above are extremely difficult to do, assign supervisors and have them monitor the work.

Article 21

The employer must take the necessary measures to prevent dangers arising from work methods involved in operations such as excavation, quarrying, cargo handling or logging.

2. The employer must take the necessary measures to prevent dangers related to places from which workers may fall or where there is a risk of landslides.

Article 24

The employer must take the necessary measures to prevent industrial accidents arising from workers' operation activities.

Article 25

The employer must immediately stop operations if there is an imminent danger of an industrial accident and take the necessary measures to evacuate the workers from the work site.

[Ordinance on Industrial Safety and Health]

Article 29

The worker must not remove safety devices or disable their functions. If it is necessary to do so, the worker must obtain the employer's permission in advance. After such actions are no longer necessary, the safety devices must be immediately restored to their original conditions. If the worker finds that they have been removed/disabled, the worker must inform the employer of it.

(Measures to Be Taken by Lessors of Machinery and Other Such Equipment)

Article 33

The lessor of machinery must take the necessary measures to prevent industrial accidents due to the relevant machinery, at the workplace of the employer renting it.

2. The employer who rents machinery from the lessor must take the necessary measures to prevent industrial accidents due to the operation of the relevant machinery if the operator of this machinery is not a worker employed thereby.
3. A worker that operates machinery must observe the necessary rules in accordance with the measures that the employer renting this machinery takes.

[Order for Enforcement of Industrial Safety and Health Act]

(Machinery Defined by Cabinet Order Set Forth in Paragraph (1) of Article 33 of the Act)

Article 10

The machinery defined by the Cabinet Order set forth in Paragraph (1) of Article 33 of the Act shall be mobile cranes having a lifting capacity of 0.5 tons or more.

[Ordinance on Industrial Safety and Health]

(Unification of Signals for Operating a Crane)

Article 639

The specified principal employer must set unified signals for the operation of cranes, in case workers of the specified principal employer and the related contractors carry out work at the same place using cranes. The specified principle employer make unified signals known to related contractors.

(Measures to Be Taken by Lessors of Machinery and Other Such Equipment)

Article 666

Lessors of machinery must take the following measures when leasing the relevant machinery to other employers.

1. Check the relevant machinery in advance and perform repairs and other necessary maintenance if any abnormalities are found.
2. Issue a document indicating the capabilities, characteristics, and caution items for the relevant machinery to the employer to which these are leased.

Chapter 5 Regulations on Machinery and Hazardous Substances

(Issuance of Inspection Certificate)

Article 39

Mobile cranes (with a lifting capacity of three tons or more) must undergo manufacturing inspections by a registered agency for post-manufacturing inspections when these machines have been manufactured, imported, re-installed, or reused. An inspection certificate will be issued if the inspection has been passed. When mobile cranes' primary structural components have been altered, these machines must undergo an inspection by the Chief of the Labour Standards Inspection Office. An inspection certificate is issued or an already-issued inspection certificate is endorsed if the inspection has been passed.

(Use Restrictions)

Article 40

Mobile cranes (with a lifting load of three tons or more) for which inspection certificates have not been issued must not be used. These cranes must not be transferred or leased out unless accompanied by the inspection certificates.

(Valid Term of Inspection Certificate)

Article 41

A person who intends to renew the term of validity of an inspection certificate must undergo a performance inspection by a registered agency for performance inspections.

(Restrictions on Transfer)

Article 42

Machinery that is not specified by the Cabinet Order set forth in paragraph (1) of Article 37 of the Act, but which necessitates dangerous or hazardous work operations; is used in a dangerous place or is used to prevent the endangerment of workers and impairment of workers' health; and that is prescribed by Cabinet Order, must not be transferred, leased out, or installed unless it is equipped with safety devices or it fulfills the standards prescribed by the Minister of Health, Labour and Welfare.

[Order for Enforcement of Industrial Safety and Health Act]

(Machinery Subject to Being in Conformity with Standards or Equipped with Safety Devices Designated by the Minister of Health, Labour and Welfare)

Article 13

The machinery as defined by the Cabinet Order set forth in Article 42 of the Act, shall be mobile cranes with a lifting load of 0.5 tons or more but less than three tons.

(Periodic Self-inspections)

Article 45

The employer must, pursuant to Cabinet Order, perform inspections and record the results on machinery and other equipment, such as boilers, as provided by Cabinet Order. The Minister of Health, Labour and Welfare shall release the necessary guidelines for self-inspections, and if necessary may provide the necessary guidance on those guidelines for self-inspections to employers, registered inspection agencies, and associations thereof.

[Order for Enforcement of Industrial Safety and Health Act]

(Machinery and Other Equipment Subject to Carry out Periodical Self Inspection)

Article 15

Self-inspections must be performed on mobile cranes and load moment limiters and their results must be recorded.

Chapter 6 Measures at the Time of Hiring Workers

(Safety and Health Education)

Article 59

When employing a new worker, the employer must educate that worker in safety or health related to the operations in which the worker is to be engaged, pursuant to the Ordinance of the Ministry of Health, Labour and Welfare.

[Ordinance on Industrial Safety and Health]

(Work Necessitating Special Education)

Article 36

Dangerous or harmful operations set forth in Article 59 of the Act refer to the following.

16. Operations involving mobile cranes with a lifting capacity of less than one ton (excluding operations that involve driving on roads)

Article 60

The employer must conduct safety or health education for foremen who have newly taken on that role and other workers who have newly taken on a role directly guiding or supervising workers in operations (except for operations chiefs).

[Guidelines on Safety and Health Education for Those Who Are Currently Engaged in Dangerous or Hazardous Operations]

Safety and Health Education for Mobile Crane Operators

For workers engaged in work that requires a Mobile Crane Operator's License, the completion of the Skill Training Course for Light Capacity Mobile Crane Operation, or Special Education for Mobile Crane Operation, safety and health education must be conducted at regular intervals or when machinery and equipment is replaced by new ones. Furthermore, it is preferable to provide safety and health education for the following: workers who will be engaged in the relevant work for the first time more than 3 years after obtaining their qualifications; and workers who have not been engaged in the relevant work for more than 5 years and will again be engaged in the relevant work.

(Appendix: Crane Operator Safety and Health Education Curriculum, Total 6 Hours)

Subject	Contents	Time
Recent cranes and safety devices	Structures and control mechanisms	2.0 hours
Crane handling and maintenance	Operation method, work plan, inspection and maintenance	2.5 hours
Accident cases and related laws	Preventive measures and Order for Enforcement of Industrial Safety and Health Act	1.5 hours

(Restrictions on Engagement)

Article 61

The employer must not assign workers to the operation of cranes or any other operations prescribed by Cabinet Order unless the workers have obtained a license from the Director of the Prefectural Labour Bureau, have completed a skill training course, or have other qualifications specified by Cabinet Order. At the time of engagement in these operations, the workers must carry a document evidencing their qualifications.

[Order for Enforcement of Industrial Safety and Health Act]

(Operations Pertaining to Restriction on Engagement)

Article 20

The operations set forth in Article 61 of the Act shall be as follows.

7. Operation of mobile cranes with a lifting capacity of one ton or more (excluding operation that involves driving on roads)

16. Tamagake (rigging) work involving cranes and mobile cranes with a lifting capacity of one ton or more

[Ordinance on Industrial Safety and Health]

(Qualifications Regarding Restriction on Employment)

Article 41

For the operations set forth in Item 7 of Article 20 of the Order for Enforcement of Industrial Safety and Health Act, workers who are eligible to engage in the operation of mobile cranes with a lifting capacity of less than five tons must have obtained the Mobile Crane Operator’s License or completed the Skill Training Course for Light Capacity Mobile Crane Operation.

5.2 Safety Ordinance for Cranes

Chapter 1 General Provisions

(Exemption of Application)

Article 2

This Ministerial Ordinance does not apply to cranes, mobile cranes, or derricks with a lifting capacity of less than 0.5 ton.

Chapter 3 Mobile Cranes

Section 1 Manufacture and Installation

(Manufacturing Inspection)

Article 55

The employer who have manufactured a mobile crane with a lifting capacity of three tons or more must undergo the inspection of the mobile crane (manufacturing inspection) by the Director of the Competent Prefectural Labour Bureau.

2. The manufacturing inspection entails examining the structure and function of each part of the mobile cranes and performing load tests and stability tests.
3. The load test entails performing lifting, slewing, driving, and other operations while lifting a load equivalent to 1.25 times of the rated load.
4. The stability test entails performing jigiri (liftoff) under the most unfavorable conditions for stability while lifting a load equivalent to 1.27 times of the rated load.

(Inspection Certificate for Mobile Crane)

Article 59

The Director of the Competent Prefectural Labour Bureau or the Director of the Prefectural Labour Bureau is to issue an inspection certificate for mobile cranes which passed the manufacturing inspection or the use inspection respectively.

2. If the mobile crane inspection certificate is damaged or lost, it must be reissued.
3. If there is a reallocation of the worker who has installed the mobile crane, the mobile crane inspection certificate must be renewed within 10 days of the reallocation.

(Validity Term of Inspection Certificate)

Article 60

The mobile crane inspection certificate is valid for a term of two years. However, based on the results of the manufacturing inspection or use inspection, the relevant term of validity may be restricted to less than two years.

(Report for Installation)

Article 61

The employer that intends to install a mobile crane must submit a mobile crane installation report with the specifications for the mobile crane and the mobile crane inspection certificate, to the Chief of the Competent Labour Standards Inspection Office in advance. This does not apply to employers who have been given the accreditation.

(Load Test, etc.)

Article 62

The employer that installed a mobile crane must perform the load test and the crane stability test.

Section 2 Use and Operation

(Providing with Inspection Certificate)

Article 63

The employer must provide a mobile crane inspection certificate for a mobile crane when carrying out work using the mobile crane.

(Use Restrictions)

Article 64

The employer must not use mobile cranes that do not comply with the standards prescribed by the Minister of Health, Labour and Welfare.

(Loading Conditions as to Design Base)

Article 64-2

The employer shall take into account the loading conditions upon which the design of the mobile crane is based.

(Adjustment on Overwinding Preventive Device)

Article 65

Mobile crane overwinding preventive devices must be adjusted such that the distance is 0.25 meters or more (0.05 meters or more for direct driven-type overwinding preventive devices) from the upper surface of the load-lifting attachment.

(Adjustments of Relief Valves)

Article 66

Relief valves must be adjusted such that they operate at no more than the maximum rated load.

Article 66-2

To prevent danger to workers, the employer must establish mobile crane operation methods, mobile crane overturn prevention methods, the placement of workers, and a work direction system pertaining to the mobile crane operation.

(Use of Safety Latch)

Article 66-3

When lifting a load using a mobile crane, safety latches must be used.

(Restrictions on Engagement)

Article 68

With regard to the operation of mobile cranes with a lifting capacity of 1 ton or more and less than 5 tons (light capacity mobile cranes), workers who have completed the Skill Training Course for Light Capacity Mobile Crane Operation may be engaged in the work.

(Limitation on Overload)

Article 69

The employer must not use a mobile crane being loaded with a load that exceeds its rated load.

(Limitations of Jib Angle)

Article 70

The employer must not use a mobile crane with a jib angle that exceeds the angle range stated in the mobile crane specifications.

(Indication for Rated Capacity)

Article 70-2

The employer must take measures of indicating the rated load so that mobile crane operators and tamagake operators are always able to confirm it.

(Prohibition of Use)

Article 70-3

The employer must not use mobile cranes for work in a place where there is a risk of overturning due to soft ground or damage to buried objects. However, this does not apply to cases where overturning prevention measures (floor plates, steel plates, etc.) have been taken in the relevant place.

(Positions of Outriggers)

Article 70-4

The employer must, when carrying out operations using a mobile crane that uses outriggers, set them on outrigger pads such as steel plates at the position where there is no risk of the mobile crane overturning.

(Extension of Outriggers)

Article 70-5

The employer must set the outriggers at full extension when carrying out operation using a mobile crane equipped with outriggers. However, this does not apply to cases outrigger cannot be fully extended and the load to be applied to the mobile crane is clearly estimated not to exceed the rated load corresponding to the extended width of the outriggers.

(Signals for Operation)

Article 71

The employer must, when carrying out work using a mobile crane, set the fixed signals for operation of the mobile crane, designate a worker who gives these signals, and have this worker give the fixed signals. However, this does not apply to cases where a mobile crane operator carries out the work alone.

(Restriction on Riding)

Article 72

The employer must not carry workers with a mobile crane, nor allow workers to work while hanging from the mobile crane.

Article 73

The employer may provide dedicated riding equipment on the load-lifting attachment and allow workers to ride on the mobile crane, in cases where this is unavoidable due to the nature of the work or in cases where such equipment is necessary to carry out the work safely.

(Prohibition of Entry)

Article 74

The employer must not allow workers to enter places where there is a risk of endangering the workers by making contact with the slewing upper structure of the mobile crane.

Article 74-2

The employer must not allow workers to go under a lifted load in cases falling under any of the following items.

1. When a load lifted using lifting hooks.
2. When a load lifted using a single clamp.
3. When a load lifted by a single-leg sling with one point using a wire rope
4. When multiple loads lifted and they are not fixed, such as bundled and kept in a box.
5. When a load lifted using a load-lifting attachment or tamagake equipment that adheres due to magnetic force or negative pressure.
6. When a load or load-lifting attachment is lowered by methods other than power lowering.

(Suspension of Work in Strong Winds)

Article 74-3

The employer must suspend work pertaining to mobile cranes when strong winds are expected to make performing the relevant work dangerous.

(Prevention of Overturning in Strong Winds)

Article 74-4

When the work is suspended due to strong winds, the employer must take measures, like fastening the jib, to prevent endangering workers when there is a risk of mobile cranes overturning.

(Prohibition of Leaving Mobile Cranes Unattended)

Article 75

The mobile crane operator must not leave the operating position with the load lifted.

(Jib Assembly Work)

Article 75-2

Paragraph (1)

The employer must take the following measures when assembling or disassembling a mobile crane jib.

1. Designate a person to supervise the work and have workers carry it out under the supervision by the said person.
2. Prohibit anyone other than workers involved in the work from entering the work site and display notices indicating this prohibition.
3. Not allow workers to engage in work when bad weather is expected to cause danger in performing the work.

Paragraph (2)

The employer must have the worker who supervises the work carry out the following matters.

1. Determine the work method and placement of workers, and supervise the work.
2. Check defects in materials, the function of instruments and tools, and remove defective items.
3. Monitor the use of fall prevention equipment with the required performance and safety helmets during the work.

Section 3 Periodic Self-inspections

(Periodic Self-inspections)

Article 76

The employer must periodically perform annual self-inspection of the mobile crane once a year, after installation of the mobile crane.

3. The employer must perform a load test in the annual self-inspection. However, this does not apply to the mobile crane for which the term of validity of the inspection certificate is set to expire.
4. The load test is to be performed for operations such as lifting, slewing, and driving at the rated speed while lifting a load with a mass corresponding to the rated load.

Article 77

The employer must periodically perform monthly self-inspections of the following items for the mobile crane once a month.

1. Abnormalities on safety devices, warning devices, brakes, and clutches
2. Damages to wire ropes and lifting chains
3. Damages to load-lifting attachments such as hooks and grab buckets
4. Damages to the wiring, switchboards, and controllers

(Pre-work Check Prior to Starting Work)

Article 78

The employer must check the functions of overwinding preventive devices, rated load indicator, and other warning devices, brakes, clutches, and controllers before commencing work for the day when carrying out work using the mobile crane.

(Records of Self-inspections)

Article 79

The employer must record the results of self-inspections and keep these records for three years.

(Repairs)

Article 80

The employer must perform repairs immediately when any abnormality is found during the self-inspection or check.

Section 4 Performance Inspections

(Performance Inspections)

Article 81

For mobile crane performance inspections, in addition to examining the structure and function of each part of the mobile crane, a load test is to be performed.

(Renewal for Term of Validity of Inspection Certificates)

Article 84

The registered performance inspection agency shall renew the term of validity of the mobile crane inspection certificate when the mobile crane has passed the performance inspection.

Section 5 Alterations, Suspension of Use and Disuse

(Notification for Alteration)

Article 85

The employer who intends to alter any of the parts listed among the following items must submit a mobile crane alteration notification with drawings to the Chief of the Competent Labour Standards Inspection Office.

1. Jibs or other structural parts

2. Prime movers

3. Brakes

4. Lifting mechanism

5. Wire ropes or lifting chains

6. Load-lifting attachments such as hooks and grab buckets

7. Chassis frame

Chapter 8 Tamagake

Section 1 Tamagake Equipment

(Safety Coefficient of Tamagake Wire Rope)

Article 213

The employer must not use a wire rope as tamagake equipment for a crane, a mobile crane, or a derrick unless the safety coefficient is 6 or more.

(Safety Coefficient of Tamagake Chain)

Article 213-2

The employer must not use a chain unless its safety coefficient is equal to or larger than the following values based on the type of chain.

1. Chain with tensile strength value of 400 N/mm^2 or more: 4
2. Chain with tensile strength value less than 400 N/mm^2: 5

(Prohibition of Use of Inadequate Wire Rope)

Article 215

The employer must not use a wire rope falling under any of the following items for the tamagake equipment of a crane, a mobile crane, or a derrick:

1. Broken wires: Within each lay of the wire rope, if more than 10 percent of the total number of wires (excluding filler wires)is broken.
2. Decreased diameter: Wires that have decreased in diameter by more than seven percent of the nominal diameter.
3. Deformation: Wires that have kinks.
4. Corrosion: Wires that are severely deformed and/or corroded.

Section 2 Restrictions on Employment

(Restrictions on Employment)

Article 221

The employer must not have workers engage in tamagake work for cranes with a lifting load of one ton or more unless the workers falls under one or more of the following.

1. Workers who have completed the Skill Training Course for Tamagake
2. Workers who have completed the tamagake training course under the Human Resources Development Promotion Act
3. Others that have been specified by the Minister of Health, Labour and Welfare

Skill Training Course
for Light Capacity Mobile Crane Operation

Exercise Book

Please find the correct answer for each question after the question section.
You will also find the answers and explanations in Japanese at the end of the book.

英語版

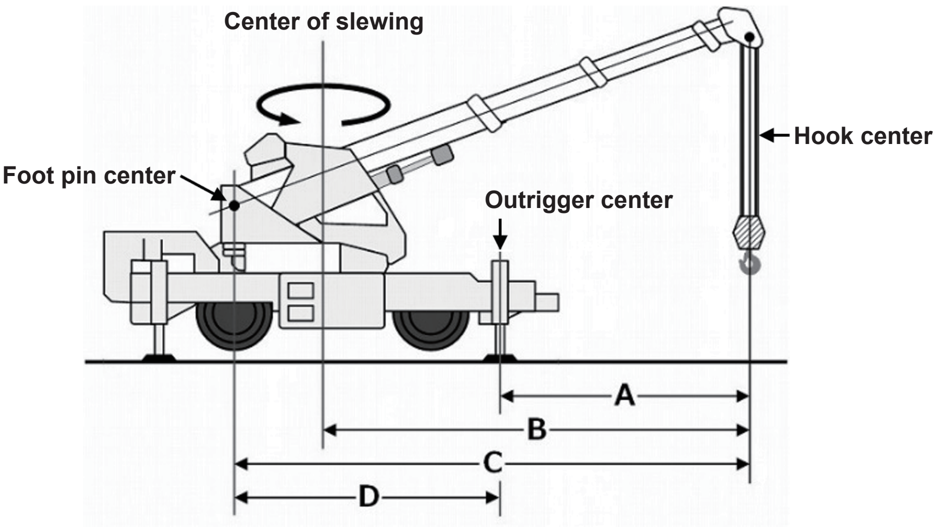
« I. Knowledge About Light Capacity Mobile Cranes »

en

[Question 1]

Which of the following correctly indicates the working radius of the mobile crane in the illustration?

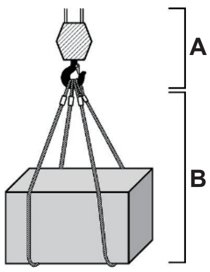
(1) A (2) B
(3) C (4) D



[Question 2]

Which of the following correctly indicates the gross rated load in the illustration?

(1) A (2) B
(3) A+B (4) B-A



[Question 3]

Select the correct answer and fill in the bracket.

[ ] is a term used only for truck loader cranes. It is determined based on crane stability when there is no load on the cargo bed.

(1) Rated load
(2) Lifting load
(3) Gross rated load
(4) Gross rated load at non-loaded condition

[Question 4]

Which of the following descriptions about mobile crane terminology is NOT correct?

(1) Hoisting and lowering refer to the operations that hoist or lower the hook.
(2) Driving refers to the act of driving a mobile crane with its own motive power.
(3) Jib angle refers to the angle between the jib axis and horizontal plane.
(4) Jib derricking refers to the operation that changes the length of the jib.

[Question 5]

Which of the following descriptions about the structure and functionality of mobile cranes is NOT correct?

(1) Lifting height refers to the vertical distance between the upper and lower limits within which load-lifting attachments can effectively be lifted or lowered.
(2) Lifting load refers to the maximum load that can be laid on a mobile crane in accordance with its structure and component materials.
(3) Jigiri (liftoff) refers to the operations that hoist a load approximately 2 m off the ground and pause.
(4) Jib derricking refers to the operation that changes the jib angle.

en

[Question 6]

Which of the following descriptions about the definition of mobile cranes is correct?

(1) Machinery that can only lift or lower loads using motive power.
(2) Machinery that can lift loads manually and transport them horizontally.
(3) Machinery that can lift loads and transport them horizontally using motive power. It has a built-in prime mover and can be moved to unspecified locations.
(4) Machinery that can lift loads using motive power but cannot transport them horizontally.

[Question 7]

Select the correct answer and fill in the bracket.

Most truck loader cranes have crane equipment between the cargo bed and cab, with a [ ] of less than three tonnes.

(1) lifting load
(2) gross rated load
(3) rated load
(4) capacity

[Question 8]

Select the correct answer and fill in the bracket.

Rough terrain cranes can [ ] on uneven and relatively soft ground.

(1) be driven
(2) stop suddenly
(3) be driven at high speeds
(4) start moving suddenly

en

[Question 9]

Which of the following descriptions about the characteristics of mobile cranes or of base carriers is NOT correct?

(1) Railway cranes have base carriers that are equipped with chassis frame with wheels that run on top of railway lines.

(2) Base carriers for rough terrain cranes are specially manufactured for use in rough terrain cranes.

(3) Truck loader cranes are characterized by having crane equipment for loading and unloading, and cargo beds for loading cargo.

(4) Crane operation for truck loader cranes is generally performed inside of the cab for driving.

[Question 10]

The description below is of a certain type of mobile crane. Which of the following cranes is being described?

This type of crane has a driving speed that is slower than that of truck cranes. It can be driven in a special steering mode, such as crab steering, and has a small turning radius. Therefore, it can enter narrow areas, such as in urban areas.

(1) Crawler cranes (2) Floating cranes

(3) Railway cranes (4) Rough terrain cranes

[Question 11]

Which of the following is NOT a point of concern in setting up mobile crane outriggers?

(1) Setting up the outriggers on firm and level ground so that the crane body is placed horizontally.

(2) Laying large and robust outrigger pads because the maximum load applied to one outrigger float can be equivalent to 70% to 80% of the total mass of the crane body and the load actually lifted.

(3) When setting up the truck loader crane outriggers, raising the front wheel tires off the ground.

(4) When setting up the outriggers, fully extending the outrigger beams equally to the left and right and inserting lock pins to fasten them.

en

[Question 12]

Select the correct answer and fill in the bracket.

Jib telescoping is performed either with only a hydraulic cylinder, or with a combination of a hydraulic cylinder and a telescopic [ ] to make the empty weight of the jib lighter.

(1) hydraulic motor
(2) wire rope
(3) spring
(4) gear

[Question 13]

Select the correct answer and fill in the bracket.

Use of wire rope is prohibited if more than [ ] percent of the total number of wires (excluding filler wires) is broken within each lay of the wire rope.

(1) 3
(2) 5
(3) 7
(4) 10

[Question 14]

Select the correct answer and fill in the bracket.

When lowering the hoisting wire rope to the maximum extent, leave [ ] preliminary windings on the hoisting drum.

(1) at least 1 or more
(2) at least 2 or more
(3) at least 3 or more
(4) at least 4 or more

[Question 15]

Which of the following descriptions about the mobile crane hoisting mechanism or hooks is NOT correct?

(1) The hoisting mechanism consists of a hydraulic motor, hoisting speed reduction gear, hoisting drum, clutch, brake, etc.
(2) Crane hooks include single hooks and double hooks. Most light capacity mobile cranes use double hooks.
(3) Hoisting and lowering refer to the operations that hoist or lower the hook.
(4) Hoisting speed is determined by the speed at which the hoisting mechanism winds up the hoisting wire rope and the number of wire ropes.

en

[Question 16]

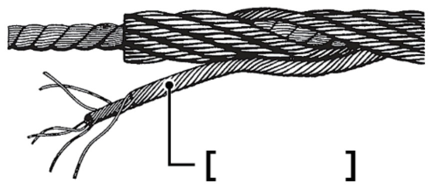
Which of the following descriptions about mobile crane jibs is NOT correct?

(1) The jib is equivalent to an arm when lifting a load.
(2) When the jib angle increases, the working radius expands.
(3) Jib telescoping refers to a change in the jib length by extending or retracting the jib.
(4) Lattice jibs are often used in relatively large crawler cranes.

[Question 17]

Select the correct answer and fill in the bracket in the wire rope illustration below.

(1) Strand (2) Kink
(3) Hook (4) Sheave



[Question 18]

Which of the following descriptions about wire ropes is NOT correct?

(1) It is important to periodically check wire ropes and lubricate them depending on their condition.
(2) Wire rope lays can be an “Ordinary Lay” or a “Lang’s Lay”.
(3) Wire ropes with kinks or corrosion must not be used.
(4) The wire rope diameter is represented by the inscribed circle diameter, and it is determined by the average of the measurements taken in two directions at a given cross-section.

[Question 19]

Which of the following descriptions about outriggers is NOT correct?

(1) Outriggers are devices for improving the stability of the crane body when engaging in loading work.
(2) Outriggers are safety devices that act when the crane body is about to overturn.
(3) The load applied to the outrigger float changes depending on the jib direction.
(4) The ground near landslide protection walls or road shoulders is weak, so outriggers must be set up away from such places.

en

[Question 20]

Which of the following descriptions about mobile crane safety devices is NOT correct?

(1) Load moment limiters are devices for preventing impact loads from being applied to hoisting wire ropes.

(2) Jib angle indicators and load indicators are devices that indicate not only jib angles, but also the relationship between gross rated loads and jib lengths.

(3) Level gauges are measuring instruments for checking the levelness of crane bodies.

(4) Relief valves prevent abnormal pressure increases in hydraulic circuits.

[Question 21]

Select the correct answer and fill in the bracket.

Mobile cranes manufactured before March 1, 2019 that have a lifting load of less than 3 tonnes are equipped with a [ ] instead of a device for preventing overloading.

(1) load meter
(2) flow meter
(3) weight indicator
(4) tester

[Question 22]

Select the correct answer and fill in the bracket.

The [ ] is a device for preventing the tamagake (rigging) wire rope from slipping off the hook when lifting a load.

(1) relief valve
(2) warning device
(3) detector
(4) safety latch

[Question 23]

Select the correct answer and fill in the bracket.

The [ ] is a device for preventing damage to the jib end or wire rope due to overwinding of the hoisting wire rope.

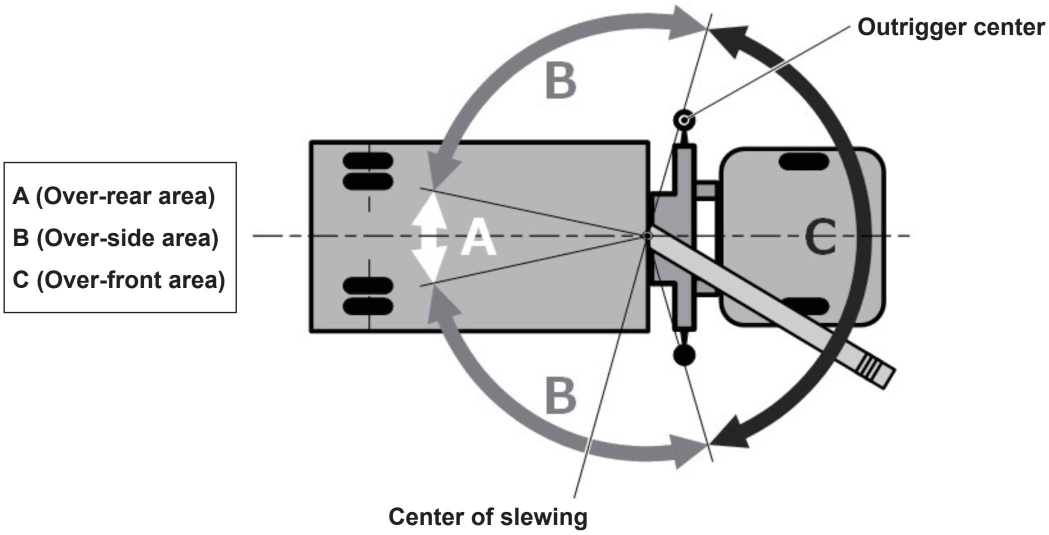
(1) overwinding preventive device
(2) relief valve
(3) outrigger
(4) level gauge

[Question 24]

The illustration below shows the working area for a truck loader crane. Which of the following areas is the most stable?

(1) A (Over-rear area)
(2) B (Over-side area)
(3) C (Over-front area)
(4) A and B (Over-rear/Over-side area)

en



[Question 25]

Select the correct answer and fill in the bracket.

Crane operation is often performed on unpaved ground. When installing mobile cranes, check the condition of the [ ] so that the outriggers do not sink.

(1) crane body
(2) tire
(3) ground
(4) levelness

[Question 26]

Select the correct answer and fill in the bracket.

The gross rated load of a mobile crane depends on conditions such as the outrigger [ ], working radius, and jib length.

(1) float
(2) extension width
(3) telescoping width
(4) installation ground

en

[Question 27]

Select the correct answer and fill in the bracket.

With truck loader cranes, crane operation in the over-front area is the least stable. Thus, such work must be performed with [ ]% or less of the lifting performance of the over-rear and over-side areas.

(1) 10 (2) 15
(3) 25 (4) 100

[Question 28]

Select the correct answer and fill in the bracket.

Crane stability indicates the probability of a mobile crane [ ] or not.

(1) overturning (2) stabilizing
(3) vibrating (4) self-standing

[Question 29]

Which of the following precautions is NOT correct for mobile crane operators?

(1) Not performing cleaning, refueling, or repair during crane operations.
(2) Operating the crane in accordance with signals given by the signaler.
(3) Immediately stopping work and investigating the cause if abnormal noises, vibrations, heat, odors, or other abnormalities are noticed during operation.
(4) Disabling the safety device functions for a short time if it is necessary to perform work exceeding the mobile crane's lifting performance.

[Question 30]

Select the correct answer and fill in the bracket.

The lifting performance of a mobile crane is determined by hoisting power, crane stability, and [ ].

(1) lifting height (2) working radius
(3) telescoping speed (4) crane strength

[Question 31]

Which of the following general precautions is NOT correct for mobile crane operation?

(1) Making sufficient preparations in terms of clothing, safety helmet, safety shoes, etc.

(2) Checking work site conditions and whether there are any obstacles on the work site.

(3) Following instructions even if you are asked to perform unsafe operations.

(4) Confirming that one's operator's license is carried with one's person.

[Question 32]

Which of the following is NOT correct for mobile crane performance or as a point of concern during operation?

(1) It is important to confirm the mobile crane's lifting performance.

(2) The values shown in the gross rated load table are the sum of the actual mass of the load to be lifted and load-lifting attachment mass. Thus, the actual load mass to be lifted must be calculated.

(3) The gross rated load value for truck loader cranes is determined based on the crane strength (mainly the jib strength) regardless of the working radius.

(4) The crane lifting performance of truck loader cranes varies depending on the presence of a load on the cargo bed.

[Question 33]

Which of the following descriptions about mobile crane performance is correct?

(1) If the slewing speed is too fast, the load is swung outward due to centrifugal force during slewing, and the working radius expands.

(2) The operation speeds of load hoisting, jib raising, jib extension, and slewing for mobile cranes are described when the crane is in a non-loaded state and the engine is at low speed.

(3) When lifting and slewing a load with a truck crane, the lifting performance does not vary depending on the working area.

(4) When a mobile crane is installed horizontally, the lifting performance does not vary depending on the outrigger extension width.

en

[Question 34]

Which of the following precautions is NOT correct for mobile crane operation?

(1) Not pulling the load sideways, vertically, or obliquely before performing jigiri (liftoff).
(2) When pulling the tamagake (rigging) wire rope out of the load, attaching the eye of the tamagake wire rope to the crane hook and pulling the wire rope by hoisting.
(3) When slewing during crane operations, following the signals given by the signaler.
(4) Performing a slewing operation at low speed because the load is swung outward due to centrifugal force, which may cause overturning.

[Question 35]

Select the correct answer and fill in the bracket.

Mobile crane operators must [ ] the crane they will be operating before starting work for the day.

(1) disassemble
(2) conduct a manufacturing inspection of
(3) conduct a performance inspection of
(4) check

[Question 36]

Which of the following precautions is NOT correct for mobile crane operation?

(1) Performing slewing at low speed.
(2) Paying attention to the hook position when telescoping the jib, because the hook gets hoisted or lowered in accordance with jib telescoping.
(3) Never stopping the mobile crane by braking suddenly or with abrupt lever operation, because they may cause the crane to overturn, damage the jib, or break the wire rope.
(4) Lifting and lowering a load with abrupt lever operations right before jigiri (liftoff) or the lowering of heavy loads.

[Question 37]

Which of the following descriptions about work or the completion of work for a mobile crane is NOT correct?

(1) After completing work, be sure to place the hook at the jigiri (liftoff) height.
(2) Do not transport the load while holding it.
(3) Do not perform jigiri (liftoff) by raising or extending the jib.
(4) After completing work, stow the jib and outriggers and put the crane in driving position.

[Question 38]

Which of the following descriptions about mobile crane operation near power lines is NOT correct?

(1) High-voltage power lines have a structure that prevents electric currents from flowing even if the jib or wire rope makes contact with them.

(2) High-voltage power lines may discharge even if the jib or wire rope does not make contact with them directly.

(3) When working near power lines, confirming that electric shock prevention measures such as line guards are taken or that a monitoring supervisor is assigned.

(4) Allowing the jib or wire rope to make contact with power lines by mistake during truck loader crane operations will cause a risk of electric shock to the operator or tamagake (rigging) worker.

[Question 39]

Which of the following is NOT a point of concern for mobile crane operation during bad weather?

(1) Even if there is thunder nearby during work, the jib acts as a lightning rod. Thus, there is no concern about lightning strike.

(2) Heavy rain deteriorates visibility and makes the ground easy to collapse, so the outrigger installation location may sink.

(3) Mobile cranes are susceptible to wind when the load is larger or hoisted higher, or the jib is longer.

(4) When the average wind speed for 10 minutes is 10 m/sec or higher, crane operation must be suspended.

[Question 40]

Which of the following precautions is NOT correct for mobile crane checks, or working near power lines or in bad weather?

(1) Allowing any person to enter the inspection and maintenance area.

(2) When thunder approaches, stopping operations, putting the jib in driving position, and evacuating.

(3) While checking, parking the crane on firm and level ground in a safe place.

(4) Fully understanding the instruction manual for the mobile crane to be checked.

« II. Knowledge About Prime Movers and Electricity »

en

[Question 1]

Which of the following functions of engine oil is NOT correct?

(1) Cooling
(2) Cleaning
(3) Drying
(4) Lubrication

[Question 2]

The description below is of a certain device. Which of the following devices is being described?

This device stores electricity and supplies power to other devices such as starting motors and lighting systems.

(1) Fan belt
(2) Battery
(3) Radiator
(4) Air cleaner

[Question 3]

Which of the following features of diesel engines is NOT correct?

(1) Low operating costs
(2) Loud noises and vibration
(3) Use of gasoline as fuel
(4) Good thermal efficiency

[Question 4]

Which of the following precautions is correct for engine operation?

(1) When the engine and hydraulic oil are cool, operating the engine at high speed until it reaches the appropriate temperature.
(2) When crane operations are completed, turning the PTO switch OFF and leaving the engine key inserted so that the crane can be started at any time.
(3) When crane operations are completed, being sure to turn the PTO switch off before driving.
(4) During mobile crane checks, starting the engine to perform cleaning, refueling or repair.

[Question 5]

Select the correct answer and fill in the bracket.

In hydraulic systems, the force transmitted to the [ ] in the smaller area is magnified in proportion to the larger area.

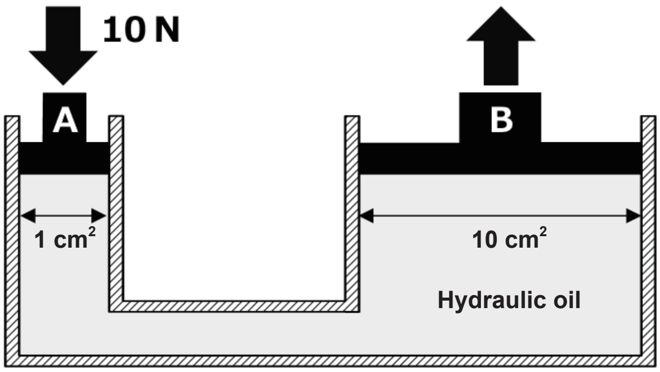
en

(1) valve (2) motor
(3) hydraulic oil tank (4) piston

[Question 6]

In the hydraulic system shown in the illustration, which of the following forces is transmitted to piston B when a force of 10 N is applied to piston A? For this question, do not consider the mass of the piston.

(1) 10 N (2) 50 N
(3) 100 N (4) 200 N



[Question 7]

Select the correct answer and fill in the bracket.

The principles of hydraulic pressure are based on Pascal's law that "pressure applied to a part of a confined [ ] is transmitted throughout the [ ] as it is."

(1) gas (2) fluid
(3) solid body (4) viscous body

en

[Question 8]

Which of the following descriptions about the advantages and disadvantages of hydraulic systems is NOT correct?

(1) They are compact and lightweight.

(2) There is no concern about hydraulic oil leaks at all, and they are easy to control remotely.

(3) Their piping is difficult to lay out.

(4) The efficiency of a machine varies depending on the hydraulic oil temperature.

[Question 9]

Select the correct answer and fill in the bracket.

Hydraulic control valves control the [ ] of the hydraulic oil, pressure, and flow rate.

(1) magnitude (2) piping

(3) direction (4) time

[Question 10]

The description below is of a hydraulic control valve. Which of the following hydraulic control valves is being described?

This valve allows hydraulic oil to pass freely in one direction, but prohibits it from flowing in the opposite direction.

(1) Selector valve (2) Check valve

(3) Sequence valve (4) Relief valve

[Question 11]

Which of the following descriptions about hydraulic systems is NOT correct?

(1) A hydraulic cylinder is a mechanical device that converts pressure oil that has been sent into linear motion.

(2) A hydraulic oil tank is equipment that stores oil.

(3) A hydraulic motor is a device that generates hydraulic pressure.

(4) A hydraulic control valve controls the direction of the hydraulic oil, pressure, and flow rate.

en

[Question 12]

Select the correct answer and fill in the bracket.

[   ] is driven by the engine and sucks oil from the hydraulic oil tank, discharges it as pressure oil, and sends it to the hydraulic actuator.

(1) A hydraulic pressure generator (2) A hydraulic control device
(3) An accessory (4) A pressure control device

[Question 13]

Select the correct answer and fill in the bracket.

Filters clean hydraulic oil and remove [   ].

(1) salt content (2) heat
(3) contaminants (4) electricity

[Question 14]

The description below is of a hydraulic control valve. Which of the following hydraulic control valves is being described?

A valve used to lower the pressure in part of a hydraulic circuit.

(1) Check valve (2) Pressure reducing valve
(3) Relief valve (4) Sequence valve

[Question 15]

Which of the following descriptions about the maintenance of hydraulic systems is correct?

(1) The majority of hydraulic system failures are related to contaminants in the hydraulic oil and oil leakages in the duct lines.
(2) Hydraulic system duct lines are sealed, so contaminants and moisture cannot get mixed in.
(3) If grease gets mixed in the hydraulic oil, it turns milky white. This has no effect on crane operation, thus there is no need to change the hydraulic oil.
(4) There is no need to replace the filter element even if the hydraulic oil is significantly dirty.

en

[Question 16]

Select the correct answer and fill in the bracket.

To keep hydraulic systems in the best condition, using hydraulic oil at an appropriate temperature and [ ] are important.

(1) air (2) moisture
(3) foaming (4) maintenance

[Question 17]

Which of the following correctly describes the appearance of hydraulic oil in which air bubbles or moisture has gotten mixed?

(1) Changed to dark brown (2) Foaming
(3) Changed to milky white (4) Transparent, with small black spots visible

[Question 18]

Which of the following descriptions about the dangers of electric shock is NOT correct?

(1) Human injury due to electric shock is a direct result of the nervous system being paralyzed by a current passing through the body.
(2) An alternating current of 50mA flowing through the human body will not cause death, although it is quite dangerous.
(3) The degree of electric shock depends on such things as: the body part suffering electric shock, the duration of the shock, the type of current, the magnitude of the current, and the physical constitution and health condition of the person being shocked.
(4) Electrical burns are dangerous, as they may destroy cells in the body and penetrate deeply into the skin.

en

[Question 19]

Which of the following descriptions about mobile crane work near power lines is NOT correct?

(1) Operators controlling the levers in truck loader cranes do not receive electric shock even if the jib or wire rope makes contact with power lines.

(2) High-voltage power transmission lines may discharge even if the jib or wire rope does not make contact with the power lines directly.

(3) Work near power lines (distribution lines) in the city must be conducted with a minimum approach distance of 2 m or more.

(4) When working near power lines, it is mandatory to consult with the power line owner, such as the local electric power company, in advance, in accordance with notification from the Director-General of the Labour Standards Bureau.

[Question 20]

Select the correct answer and fill in the bracket.

The formula for calculating electric power is [ ].

(1) Electric power = Resistance x Voltage

(2) Electric power = Resistance x Current

(3) Electric power = Voltage x Current

(4) Electric power = Current x Electric power amount

« III. Knowledge About Dynamics »

[Question 1]

Which of the following descriptions about force is NOT correct?

en

(1) Even with the same load mass, the more the jib is lowered, the greater the risk of overturning.

(2) A smaller force is required when holding the wrench near the shaft end when tightening a nut with a wrench.

(3) The amount represented by the product of the magnitude of a force and the length of the arm is called the “composition of forces”.

(4) If an object does not move even if multiple forces act on it, these forces are said to be “balanced”.

[Question 2]

Force consists of three elements. Which of the following combinations is correct?

(1) Magnitude, Direction, Speed

(2) Magnitude, Direction, Point of action

(3) Speed, Direction, Point of action

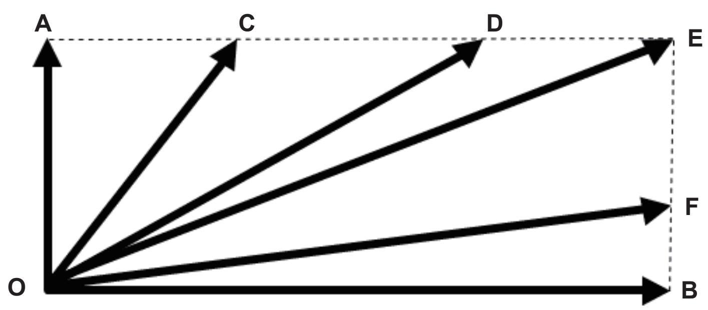
(4) Speed, Magnitude, Point of action

[Question 3]

Which of the following is the correct resultant force when forces OA and OB act on point O, as shown in the illustration?

(1) Force OC (2) Force OD

(3) Force OE (4) Force OF



[Question 4]

Which of the following descriptions about the moment of force is correct?

(1) The moment of force is the effect of a force trying to turn an object.

(2) When lifting an object with a lever, the closer the position of one's grip is to the fulcrum, the less force is required.

(3) With the same jib length, the tipping moment value remains unchanged when the jib is lowered while lifting a load with a mass equivalent to the rated load.

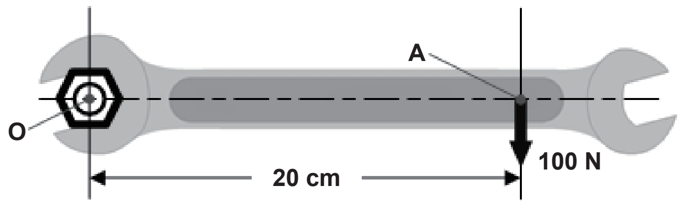
(4) The moment of force is determined only by the magnitude of the force.

[Question 5]

Which of the following is correct for the magnitude of the moment of force when tightening a nut using a wrench with a force of 100 N, as shown in the illustration? Note that the distance from point O to point A is 20 cm.

(1) 10 N·m (2) 20 N·m

(3) 100 N·m (4) 200 N·m



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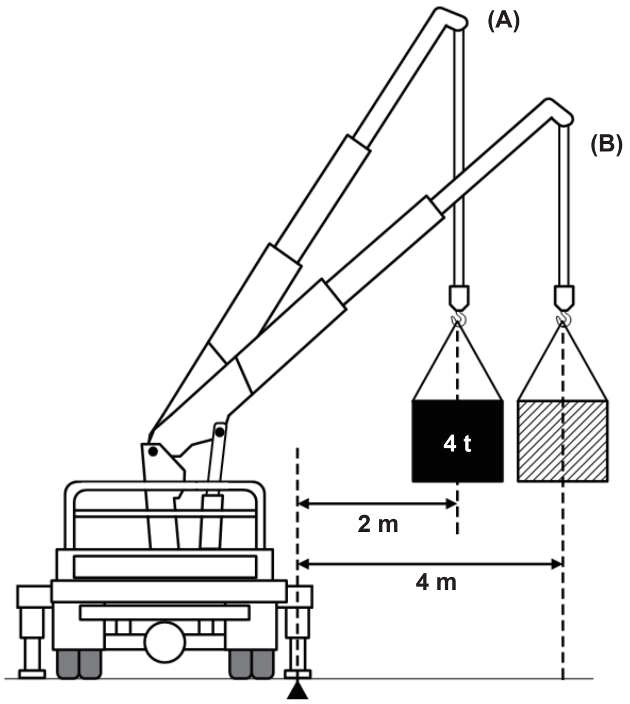
[Question 6]

In the illustration below, when the jib is in position (A), it can lift a load of up to 4 tonnes. When the jib is lowered to position (B), which of the following is correct for the maximum load that can be lifted? For this question, do not consider the mass of the jib.

(1) 1 t (2) 2 t

(3) 3 t (4) 4 t

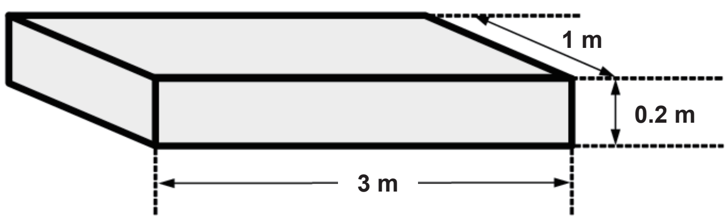


[Question 7]

Which of the following is correct for the mass (weight) of a concrete plate with a length of 1 m, a width of 3 m, and a height of 0.2 m? Note that the mass per cubic meter of a concrete plate is 2.3 t.

(1) 0.6 t (2) 1.38 t

(3) 6 t (4) 138 t



[Question 8]

Select the correct answer and fill in the bracket.

Even with the same load mass, the moment of force to overturn the crane becomes [ ] as the jib is lowered, resulting in the crane overturning.

(1) larger (2) longer
(3) smaller (4) shorter

[Question 9]

Select the correct answer and fill in the bracket.

The mass of a load to be lifted can be found by multiplying [ ] of the load by mass per cubic meter according to the load material.

(1) area (2) size
(3) volume (4) weight

[Question 10]

Which of the following descriptions about the center of gravity of objects is correct?

(1) Changing the position or placement of an object (solid body) changes the object's center of gravity.
(2) The center of gravity is always located inside the object regardless of its shape.
(3) The center of gravity of an object (solid body) is a constant point and does not change even if the position or placement of the object changes.
(4) The center of gravity of a parallelogram does not exist at the intersection of the diagonal lines.

[Question 11]

Which of the following descriptions about the center of gravity is NOT correct?

(1) Objects with wider bottom surfaces are more stable.
(2) Objects with higher centers of gravity are more stable.
(3) The center of gravity does not change even if the position or placement of the object changes.
(4) The center of gravity is the center of the weight of the object.

en

[Question 12]

Select the correct answer and fill in the bracket.

An object tends to remain at rest when standing still and tends to remain in motion in a straight line forever when moving, unless it is affected by some external force. This tendency is called “[ ]”.

(1) inertia (2) centrifugal force
(3) acceleration (4) centripetal force

[Question 13]

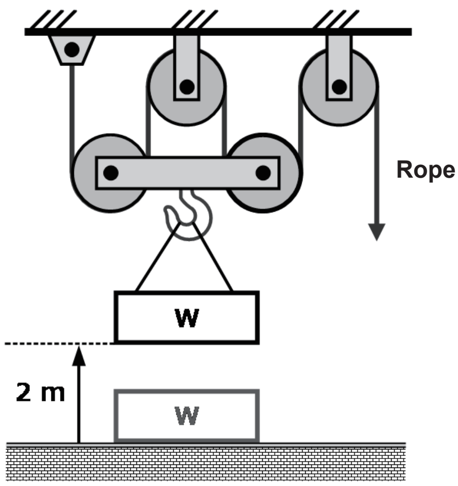
Which of the following descriptions about circular motion is NOT correct?

(1) As a load’s rotation speed increases, the centrifugal force increases, resulting in the crane overturning.
(2) The force that causes an object to move in a circular motion is called the frictional force.
(3) When an object is in circular motion, a force is exerted that directs the object toward the rotation axis constantly.
(4) The force that works to make the object in circular motion fly outward is called the centrifugal force.

[Question 14]

Load (W) is lifted 2 m above the ground using a sheave, as shown in the illustration. Which of the following is correct for the amount of the rope to be pulled?

(1) 4 m (2) 8 m
(3) 10 m (4) 12 m

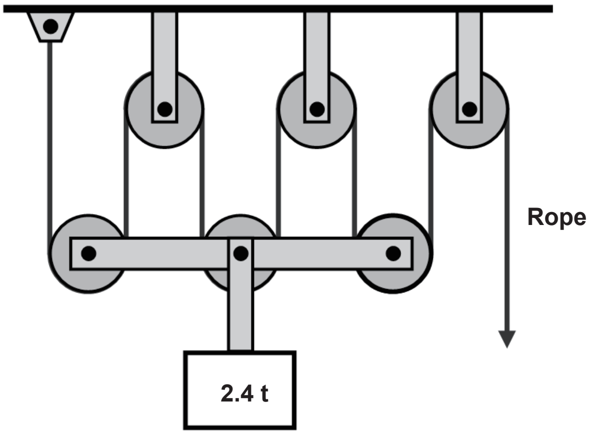


en

[Question 15]

When a load is lifted with a sheave, as shown in the illustration, which of the following is correct mass for balancing the load? For this question, do not consider the friction or mass of the sheave.

(1)	0.3 t	(2)	0.4 t
(3)	0.5 t	(4)	0.8 t



[Question 16]

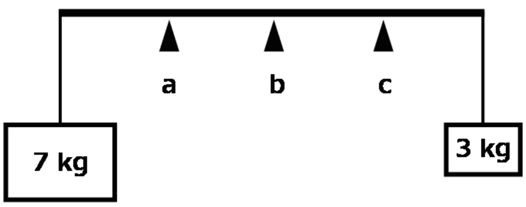
Which of the following is correct for the load applied to the hoisting wire rope when a mobile crane is lifting a load?

(1)	Twisting load	(2)	Shearing load
(3)	Tensile load	(4)	Compressive load

[Question 17]

In the illustration below, a 7 kg load is hung on the left side of a carrying pole and a 3 kg load on the right side. Which of the following is correct for the fulcrum that balances these loads? For this question, do not consider the mass of the carrying pole.

(1)	a (left side of the carrying pole)	(2)	b (center of the carrying pole)
(3)	c (right side of the carrying pole)	(4)	Farther to the right than c



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[Question 18]

Which of the following is correct for an external force (load) acting to stretch a cylindrical object in the longitudinal direction?

(1) Twisting load (2) Tensile load
(3) Bending load (4) Shearing load

[Question 19]

Select the correct answer and fill in the bracket.

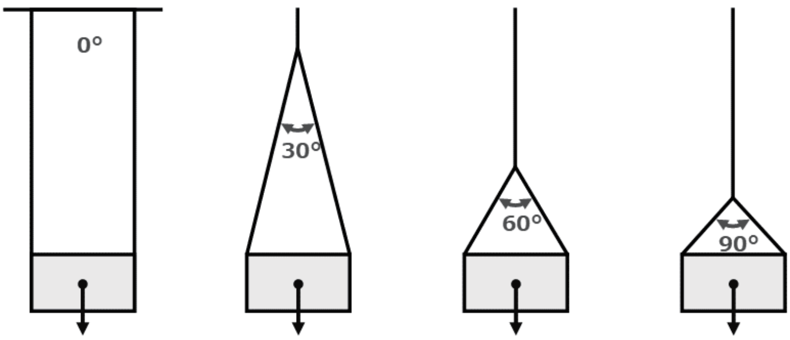
> **Applying a load to an object generates an "internal force" inside the object that resists the load. The internal force divided by the cross-section area of the object gives the force magnitude per unit area, which is called [ ].**

(1) the twisting load (2) strain
(3) stress (4) the bending load

[Question 20]

When a load is lifted using the tamagake (rigging) method as shown in the illustration, which of the following lifting methods applies the largest load to the tamagake wire rope?

(1) 0° (2) 30°
(3) 60° (4) 90°



« IV. Applicable Laws and Regulations »

[Question 1]

Which of the following types of accidents does NOT require reporting to the Chief of the Labour Standards Inspection Office?

(1) Jib breakage
(2) Wire rope breakage
(3) Overwinding preventive device malfunction
(4) Overturning

[Question 2]

Select the correct answer and fill in the bracket.

When performing mobile crane operation, the [ ] must be indicated, or other measures must be taken, so that mobile crane operators and tamagake (rigging) operators can confirm the [ ].

(1) rated speed
(2) load mass
(3) rated load
(4) hydraulic oil pressure

[Question 3]

Which of the following descriptions about mobile crane operation is NOT correct?

(1) In principle, outriggers must be fully extended.
(2) For mobile cranes with a lifting capacity of three tonnes or more, the employer must not use a mobile crane with a jib angle that exceeds the angle range stated in the specifications.
(3) The employer must not allow workers to enter places where there is a risk of endangering the workers by making contact with the slewing upper structure of the mobile crane.
(4) When leaving the operating location with a load lifted, the hoisting mechanism brake and the safety lock must be activated.

[Question 4]

Which of the following descriptions about mobile crane operation is NOT mandated by law?

(1) Safety latches must always be used.
(2) Stop operation when strong winds are expected to make performing the relevant work dangerous.
(3) When leaving the operating location, leave the load lifted 10 cm above the ground.
(4) Set up the outrigger on level and firm ground.

en

[Question 5]

Which of the following descriptions about mobile crane operation is NOT mandated by law?

(1) Lifting a load that exceeds its rated load is allowable in unavoidable circumstances

(2) The workers must not be carried with a crane nor allowed to work while being hanged from the crane.

(3) The workers must not be allowed to enter places where there is a risk of endangering them.

(4) When leaving the operating location, the load must always be lowered so that it is on the ground.

[Question 6]

Which of the following is correct for safety coefficients for tamagake (rigging) wire rope under the law?

(1) 10 or more
(2) 3 or more
(3) 6 or more
(4) 5 or more

[Question 7]

Which of the following workers are qualified to perform tamagake (rigging) work using mobile cranes with a lifting load of 1 tonne or more and less than 5 tonnes?

(1) Workers who have completed the skill training course for light capacity mobile crane operation

(2) Workers who have completed the special education for tamagake (rigging) work

(3) Workers who have completed the skill training course for tamagake (rigging) work

(4) Workers who have completed the special education for mobile crane operation

[Question 8]

Which of the following workers are qualified to engage in the operation of mobile cranes with a lifting load of 1 tonne or more and less than 5 tonnes?

(1) Workers who have completed the skill training course for light capacity mobile crane operation

(2) Workers who have completed the special education for mobile crane operation

(3) Workers who have completed the special education for tamagake (rigging) work

(4) Workers who have completed the skill training course for tamagake (rigging) work

[Question 9]

Which of the following descriptions about mobile crane checks and periodic self-inspections is correct?

(1) Periodic self-inspections for mobile cranes must be performed once a year after installation of the mobile crane.

(2) Load tests in annual periodic self-inspections are performed by lifting a load mass corresponding to 1.25 times the mobile crane rated load.

(3) Mobile cranes with a lifting load of less than 5 tonnes are exempt from the load test in annual periodic self-inspections.

(4) Pre-work checks prior to starting operations can be omitted for mobile cranes that have been operated daily.

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[Question 10]

Select the correct answer and fill in the bracket.

The periodic annual self-inspection is mandatory for all [   ] that own mobile cranes.

(1) vehicle managers (2) operators

(3) employers (4) safety supervisors

[Question 11]

Select the correct answer and fill in the bracket.

The registered [   ] agency shall renew the term of validity of the mobile crane inspection certificate when the mobile crane has passed the [   ].

(1) performance inspection (2) self-inspection

(3) special education (4) safety and health education

[Question 12]

Select the correct answer and fill in the bracket.

The employer must not use mobile cranes with loads that exceed [   ].

(1) crane stability (2) the rated load

(3) crane capacity (4) the lifting load

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[Question 13]

Select the correct answer and fill in the bracket.

> **Mobile crane overwinding preventive devices must be adjusted such that the distance is [ ] or more from the upper surface of load-lifting attachments, such as hooks and grab buckets, or the upper surface of the hoisting sheave and lower surface of the sheave of the jib end or any other object that may come in contact with the said upper surface.**

(1) 0.45 m　(2) 0.25 m
(3) 0.35 m　(4) 0.15 m

[Question 14]

Select the correct answer and fill in the bracket.

> **The employer must check the functions of the [ ], rated load indicator, and other warning devices, brakes, clutches, and controllers before commencing work for the day when carrying out work using mobile cranes.**

(1) wire rope　(2) hook assembly
(3) overwinding preventive device　(4) switchboards

[Question 15]

Select the correct answer and fill in the bracket.

> **The mobile crane inspection certificate is valid for a term of [ ] for mobile cranes with a lifting load of three tonnes or more.**

(1) 2 years　(2) 3 years
(3) 4 years　(4) 5 years

[Question 16]

Select the correct answer and fill in the bracket.

> **The employer must record the results of self-inspections and keep these records for [ ].**

(1) 3 years　(2) 2 years
(3) 1 years　(4) 8 years

[Question 17]

Select the correct answer and fill in the bracket.

The employer must [ ] immediately when any abnormalities are found during the self-inspection or checks.

(1) submit a report
(2) contact the appropriate person
(3) perform repairs
(4) consult with the appropriate person

[Question 18]

Select the correct answer and fill in the bracket.

The employer must provide a mobile crane [ ] when carrying out work using a mobile crane with a lifting load of three tonnes or more.

(1) license
(2) checklist
(3) inspection certificate
(4) certificate

[Question 19]

Which of the following is correct for loads applied in the stability test during mobile crane manufacturing inspections?

(1) A load equivalent to 1.25 times the lifting load
(2) A load equivalent to 1.27 times the rated load
(3) A load equivalent to 1.27 times the lifting load
(4) A load equivalent to 1.25 times the rated load

[Question 20]

Which of the following descriptions about mobile crane operation signals is NOT mandated by law?

(1) Only a designated signaler gives signals.
(2) The worker performing tamagake (rigging) work must give signals.
(3) Mobile crane operators must follow signals.
(4) Fixed signals must be set.

This is the end of the exam questions.

« I. Knowledge About Light Capacity Mobile Cranes » Answer

Question Number	Answer	Relevant Page*
1	(2)	p.4
2	(3)	p.5
3	(4)	p.6
4	(4)	p.2
5	(3)	p.6
6	(3)	p.1
7	(1)	p.8
8	(1)	p.9
9	(4)	p.59
10	(4)	p.9
11	(3)	p.97
12	(2)	p.37
13	(4)	p.24
14	(2)	p.112
15	(2)	p.38

Question Number	Answer	Relevant Page*
16	(2)	p.4
17	(1)	p.22
18	(4)	p.23
19	(2)	p.20
20	(1)	p.43
21	(1)	p.46
22	(4)	p.49
23	(1)	p.41
24	(1)	p.88
25	(3)	p.99
26	(2)	p.81
27	(3)	p.89
28	(1)	p.90
29	(4)	p.40
30	(4)	p.74

Question Number	Answer	Relevant Page*
31	(3)	p.73
32	(3)	p.83
33	(1)	p.74, p.85, p.88
34	(2)	p.109
35	(4)	p.122
36	(4)	p.6, p.108
37	(1)	p.114
38	(1)	p.162
39	(1)	p.120
40	(1)	p.95

* Please refer to the relevant pages in "Skill Training Course: Light Capacity Mobile Crane Operation" published by the Japan Crane Association (Revised August 1, 2019, 2nd Edition).

« II. Knowledge About Prime Movers and Electricity » Answers

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3	(3)	p.136
4	(3)	p.113, p.143
5	(4)	p.145
6	(3)	p.145
7	(2)	p.145
8	(2)	p.157
9	(3)	p.149
10	(2)	p.150

Question Number	Answer	Relevant Page*
11	(3)	p.148
12	(1)	p.147
13	(3)	p.160
14	(2)	p.152
15	(1)	p.157
17	(3)	p.158
18	(2)	p.160
19	(1)	p.162
20	(3)	p.162

* Please refer to the relevant pages in "Skill Training Course: Light Capacity Mobile Crane Operation" published by the Japan Crane Association (Revised August 1, 2019, 2nd Edition).

« III. Knowledge About Dynamics » Answers

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1	(3)	p.175
2	(2)	p.171
3	(3)	p.173
4	(1)	p.175, p.178, p.179
5	(2)	p.175
6	(2)	p.179
7	(2)	p.180
8	(1)	p.178, p.179
9	(3)	p.180
10	(3)	p.182, p.183

Question Number	Answer	Relevant Page*
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13	(2)	p.189
14	(2)	p.193
15	(2)	p.193
16	(3)	p.194
17	(1)	p.177
18	(2)	p.194
19	(3)	p.196
20	(4)	p.204

* Please refer to the relevant pages in “Skill Training Course: Light Capacity Mobile Crane Operation” published by the Japan Crane Association (Revised August 1, 2019, 2nd Edition).

« IV. Applicable Laws and Regulations » Answer

Question Number	Answer	Relevant Page*
1	(3)	p.225
2	(3)	p.230
3	(4)	p.232
4	(3)	p.232
5	(1)	p.230
6	(3)	p.236
7	(3)	p.239
8	(1)	p.222
9	(1)	p.233, p.234
10	(3)	p.233

Question Number	Answer	Relevant Page*
11	(1)	p.234
12	(2)	p.230
13	(2)	p.229
14	(3)	p.234
15	(1)	p.228
16	(1)	p.234
17	(3)	p.234
18	(3)	p.228
19	(2)	p.227
20	(2)	p.231

* Please refer to the relevant pages in “Skill Training Course: Light Capacity Mobile Crane Operation” published by the Japan Crane Association (Revised August 1, 2019, 2nd Edition).

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