2.0.0 CARRIER MOUNTINGS

Although the upper revolving ***superstructure*** is virtually the same on all cranes, that unit may be mounted on crawler tracks, a truck, or on wheels, as shown in *Figure 21-1*.

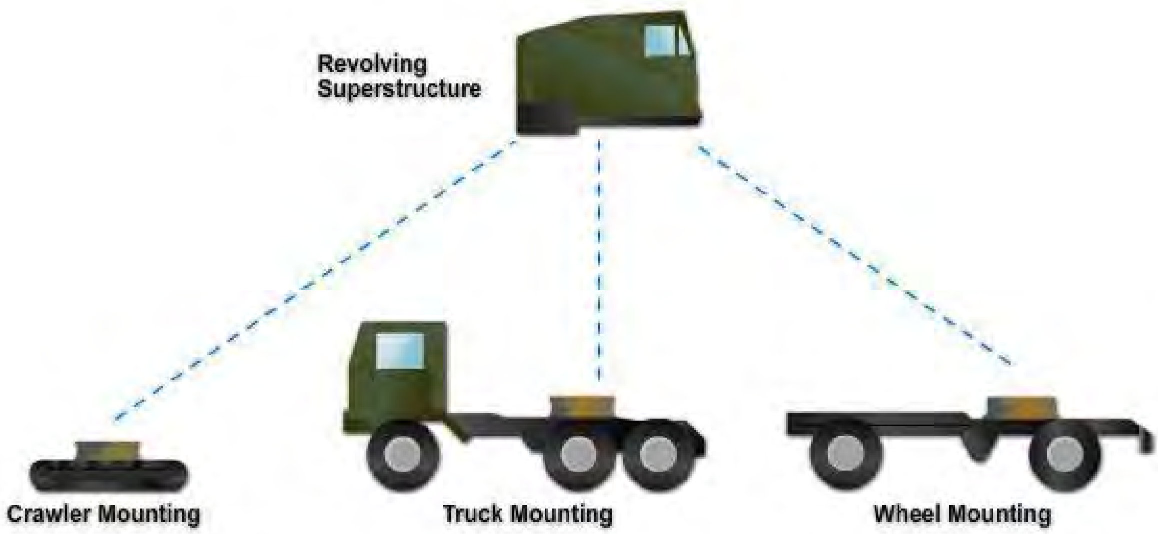

Figure 21-1 – Crane carrier mountings.

2.1.0 Crawler-Mounted Crane

Categorized under the 42-00000 USN number registration series, the crawler-mounted crane consists of a rotating superstructure with ***power plant***, operating machinery, and a boom capable of being raised or lowered, all of which are mounted on a base equipped with crawler treads for travel.

The travel unit of the crawler crane is shown in *Figure 21-2*. The travel unit includes travel reduction gears, upper and lower rollers, side frames, grousers, front idlers. Its superstructure rotates on a turntable bearing.

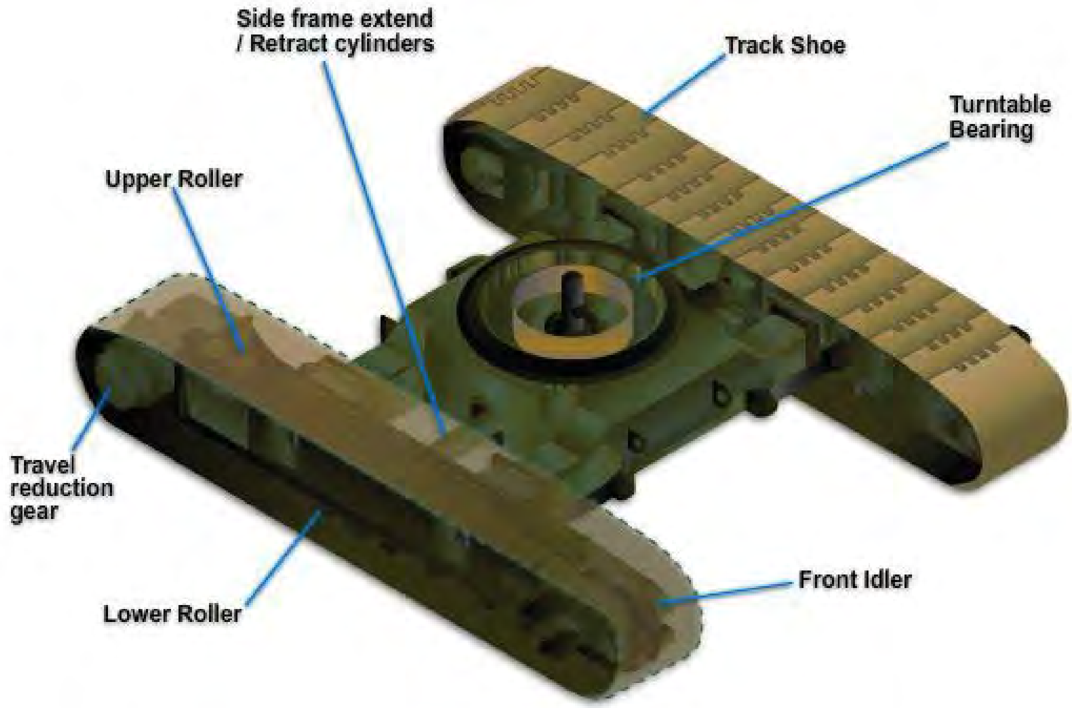

Figure 21-2 – Crawler crane travel unit.

The primary advantage of the crawler crane over the truck-mounted crane is that it is better suited for continuous work in remote areas that are not readily accessible to truck-mounted cranes because of terrain conditions. Also, the crawler crane has steering with positive traction that permits the crawler crane to travel and turn without cutting up the work area or roadway.

The size of the crawler treads spreads the weight of the crane over a large area. This feature gives the crawler crane low ground bearing pressure, providing the versatility needed to travel over soft terrain. The turning radius of the crawler crane is about the length of the tracks.

The crawler-mounted crane is slower and less mobile than the truck-mounted crane; however, the crawler-mounted crane provides a stable base for operation of the revolving superstructure. Because of the slow travel speed, it is not productive to try to travel more than 1 mile. Additionally, traveling the crane a long distance at one time causes extra wear to the tracks. When travel distance exceeds 1 mile, transport the crawler by tractor-trailer.

NOTE

Consult the operator's manual for detailed information if you are required to track travel for more than 1 mile.

Use caution when traveling with a crawler crane on and around slopes. Some older types of crawler cranes do not have travel brakes and power could be disengaged, causing the crawler to freewheel.

On-the-job maneuvering is easy for the crawler crane because of its small turning radius. Additionally, the crawler crane does not require the use of outriggers for stability, so it requires less room for setting up. On some models of crawler cranes, the tracks can extend outward with the use of side frames, providing the crane with more stability. Crawler crane models, on which the crawler tracks can extend, are rated at 85 percent of the maximum load chart capacity. Crawler models that do not have extendable tracks are rated at 75 percent.

Crane radius measurement is measured from the center of rotation to the center of the hook block after the boom deflects forward when under load, as shown in *Figure 21-3.*

Figure 21-3 – Crane radius measurement.

Depending on the make and model, most crawler cranes have a 360-degree working area. This working area is divided into operating areas called quadrants of operation. For a crawler-mounted crane, these quadrants are “over the side”, “over the drive end”, and “over the idler end” (*Figure 21-4*). The capacity of the crane may change when rotating a load from one quadrant to another. This information is provided by the crane load rating chart.

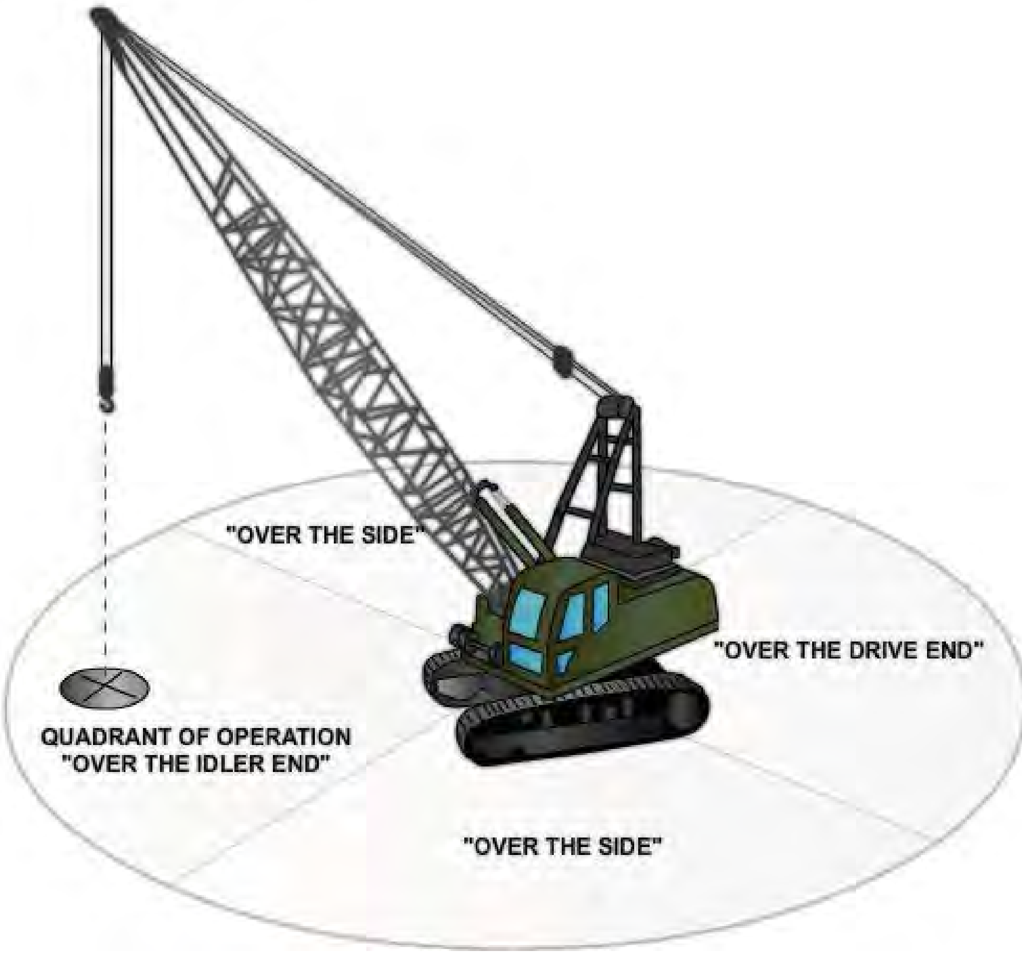

Figure 21-4 – Crawler-mounted crane quadrants of operation.

2.2.0 Truck-Mounted Crane

Categorized under the 82-00000 USN number registration series, the truck-mounted crane is very similar to a crawler-mounted crane except that it is mounted onto an automotive truck chassis with power plant that allows it to travel to jobsites.

Truck-mounted cranes have a high ground bearing pressure, due to the pneumatic tires on which they travel. On a firm, dry surface, a truck carrier can climb greater grades than the crawler-mounted crane; however, its large turning radius limits its maneuverability.

Truck- and wheel-mounted cranes are rated at 85 percent of the minimum weight that can cause the crane to tip at a specified radius with the basic boom. The truck carrier is equipped with outriggers that provide more stability for the crane. Always use these outriggers when lifting with these cranes.

Depending on the make and model, most truck-mounted cranes have a 270-degree working area. Some truck-mounted cranes are equipped with an optional front outrigger that provides a 360-degree working area. The quadrants of operation for truck-mounted cranes are over the side, over the rear, and over the front if equipped with a front outrigger as shown in *Figure 21-5*.

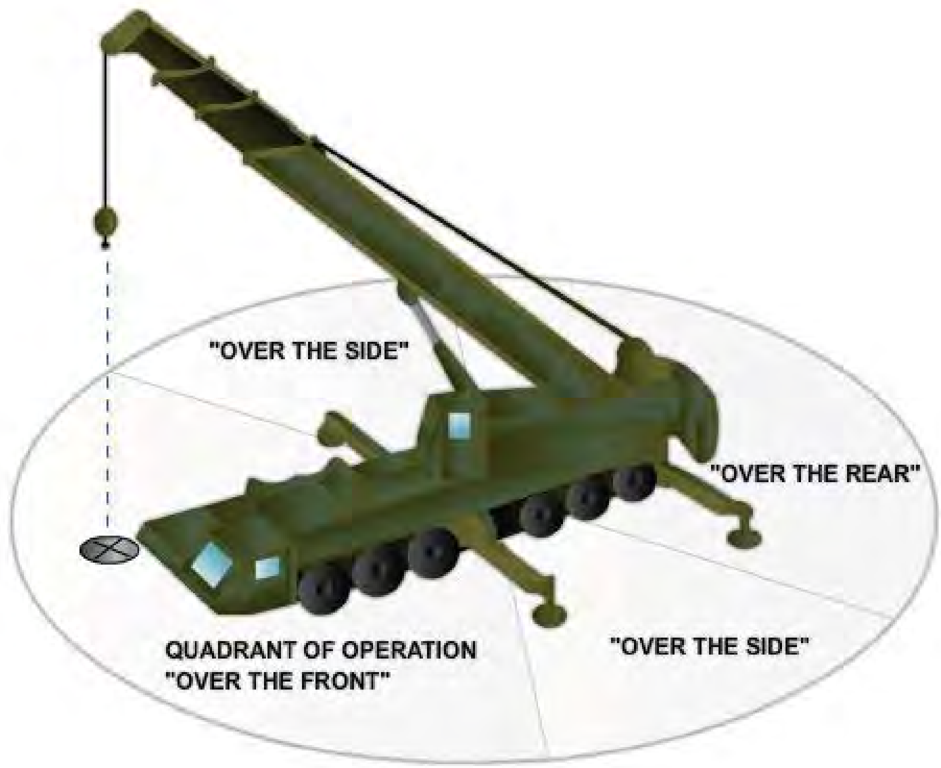

Figure 21-5 – Truck-mounted crane quadrants of operation.

NOTE

The capacity of the crane may change when the crane rotates a load from one quadrant to another. This information is provided by the crane's load rating chart.

2.3.0 Wheel-Mounted Crane

The wheel-mounted crane also consists of a rotating superstructure with power plant, operating machinery, and a boom; however these components are mounted on a base or platform equipped with axles and rubber-tired wheels for travel. The base is usually propelled by the engine in the superstructure, but it may be equipped with a separate engine controlled from the superstructure.

The wheel-mounted crane is available in various sizes and capacities. It has a ground bearing pressure less than that of the truck-mounted crane and a tighter turning radius; however, it is slower than the truck-mounted crane and normally has a lower lift capacity.

The wheel-mounted crane is a mobile and flexible crane that can be driven on or off roads over rough terrain. It is best suited for lifts around shops or for supporting fabrication projects that call for many varied, mobile lifts within a small working area.

Depending on the make and model, most wheel-mounted cranes have a 360-degree work area. The quadrants of operation for wheel-mounted cranes are over the side, over the rear, and over the front as shown in *Figure 21-6*. Remember that the capacity of the crane may change it rotates a load from one quadrant to another. This information is provided by the crane load rating chart.

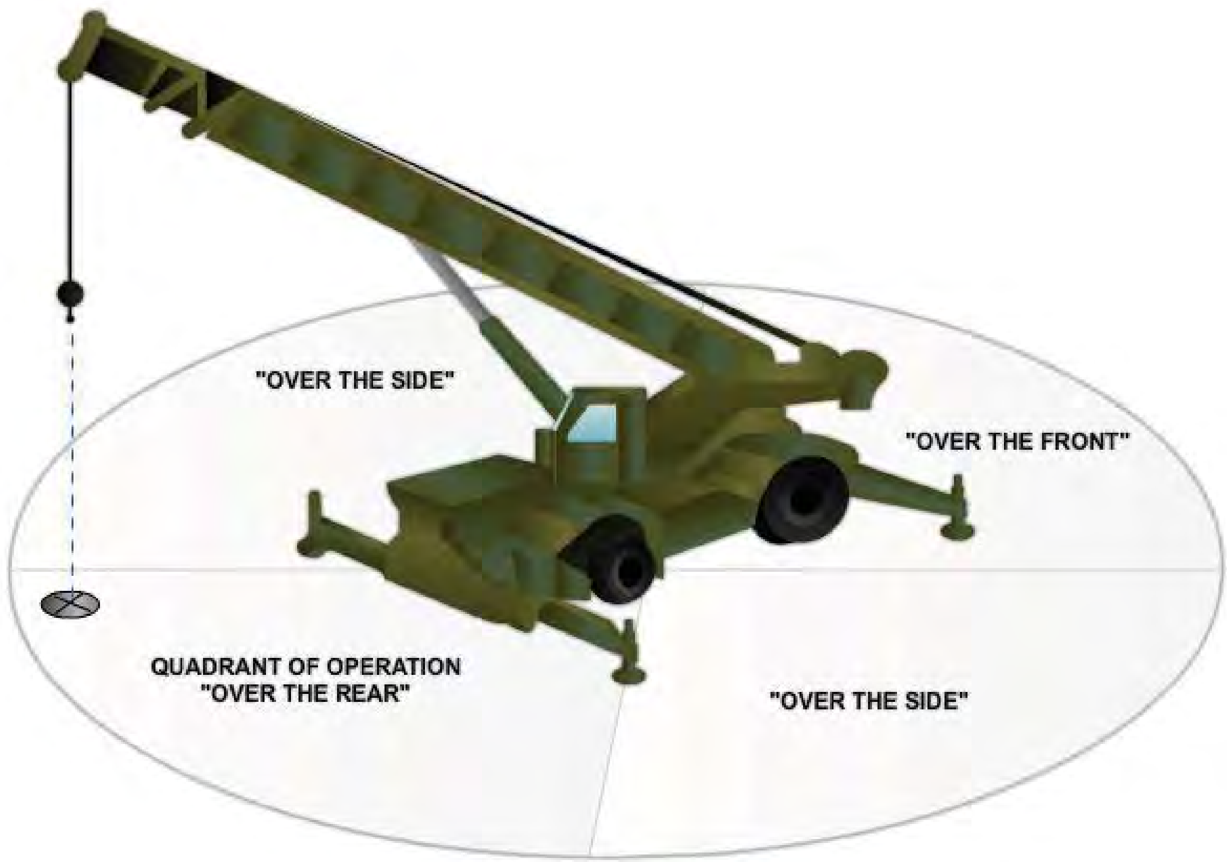

Figure 21-6 – Wheel-mounted crane quadrants of operation.

Test your Knowledge (Select the Correct Response)

2. What types of crane carriers are used by the NCF?

   A. Crawler only
   B. Truck and crawler only
   C. Wheel and truck only
   D. Crawler, truck, and wheel

3.0.0 LATTICE BOOM

On a crane, the boom supports the weight of the load as well as providing lift and reach. The basic boom consists of a boom base section and a boom tip section. Its length is increased by assembling additional sections, as in the case of the lattice boom, or by hydraulically extending sections, as in the case of the telescopic boom.

The lattice boom is the most common boom used by the NCF; it may be found on all types of carriers.

3.1.0 Major Components of a Lattice Boom Crawler-Mounted Crane

Major components and controls on cranes vary depending on type of carrier and boom and manufacturer. You are responsible for reading the operator's manual for specific information. *Figure 21-7* shows the major components of the Link-Belt LS-108H II lattice boom crawler-mounted crane. This particular crane has the rated capacity of 50 tons.

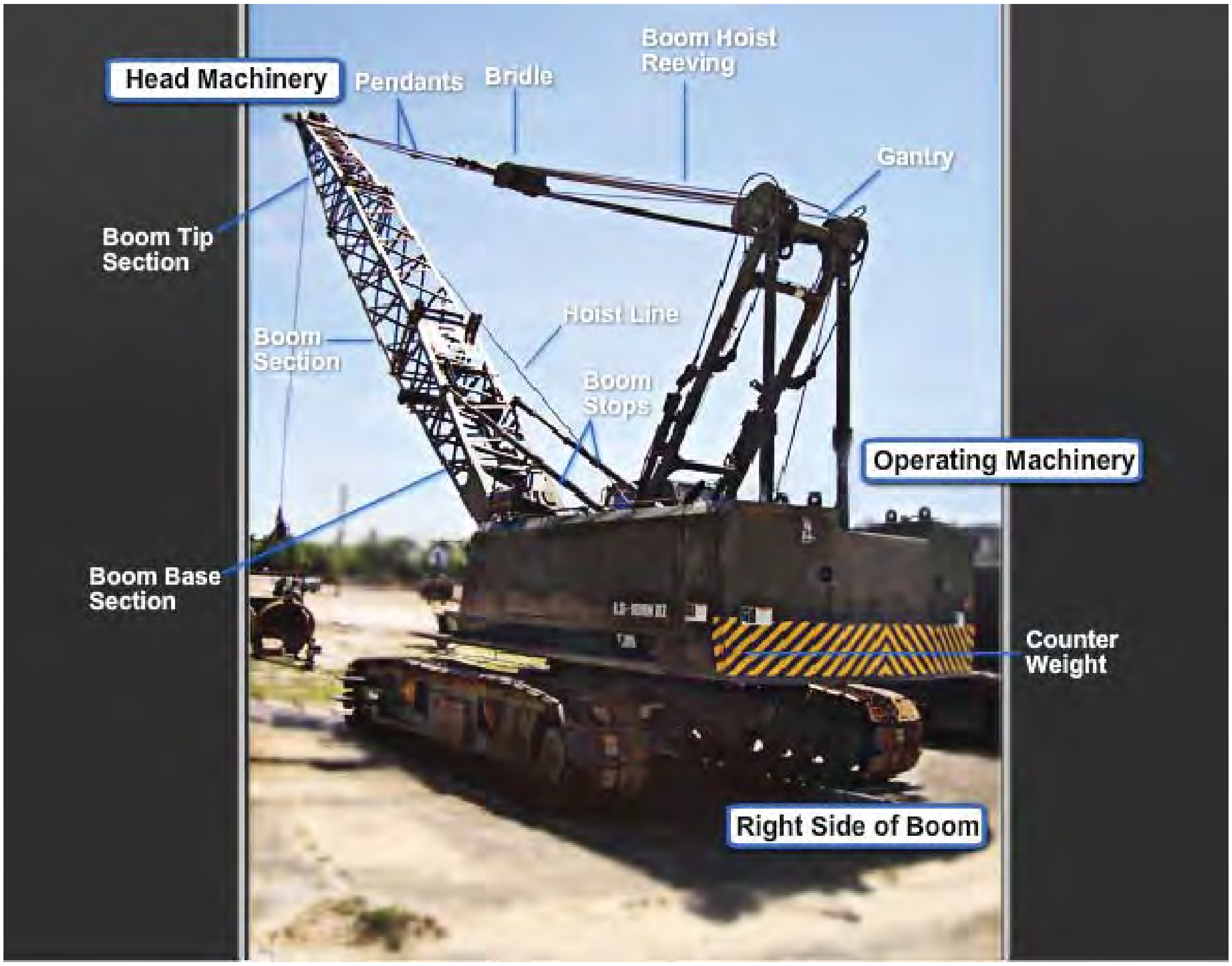

Figure 21-7 – Major components of a lattice boom crawler-mounted crane.

3.1.1 Superstructure

Sometimes called the machinery deck, the superstructure on a crawler-mounted crane includes the operator's cab, engine, counterweight, operating machinery, and boom base section onto which the lowermost boom section is assembled.

3.1.2 Operator's Cab

The operator's cab houses all of indicators, gauges, pedals, and controls use to operate the carrier and boom.

3.1.3 Engine

The engine provides power to the operating machinery through a gearbox or, in some cases, a drive chain reduction. On lattice boom crawler-mounted cranes, the engine is located in the superstructure.

3.1.4 Counterweight

The counterweight mounted to the rear of the superstructure creates additional stability when lifting loads. The counterweight rotates with the superstructure as it swings. Following the OEM's recommendations, most counterweights are removed to reduce the overall weight of the crane for transporting.

When positioning a crane at a jobsite, the crane crew must provide clearance for the entire crane including the counterweight. To prevent personnel from being struck or crushed by the crane, barricade the accessible areas within the swing radius of the rotating superstructure.

3.1.5 Operating Machinery

The operating machinery on a crane provides the mechanical power to raise and lower the boom and load as well as operate various attachments. On most cranes, the operating machinery consists of two winch drums, sometimes referred to as hoist drums, mounted one behind the other. On other cranes, such drums may be mounted parallel to each other. Drums are commonly referred to by their relative mounting (right or left, front or rear). A lifting operation requires the use of one drum; whereas, clamshell, dragline, and pile-driving operations require the use of two. Some cranes are equipped with a third auxiliary drum to assist with these operations.

Some drum models may have a smooth or grooved ***lagging*** as shown earlier in *Figure 21-7*. The diameters of the lagging differ depending on the make and model of the machine. Differences in lagging diameter provide different operating line speeds. For example, the lagging used for dragline operations may be smaller to provide a slower line with greater power.

3.1.6 Boom Sections

Lattice boom sections are made of lightweight, thin wall, high strength alloy tubular or angle steel, designed to take compression loads. The most common type of boom section is tubular, shown in *Figure 21-8*, consisting of four main chords connected with lattices also known as lacing. At the very bottom, where it becomes attached to the boom base section, are four pin connection lugs and a bracing member referred to as the diagonal. The square frame at each end of the boom insert is commonly referred to as the picture frame.

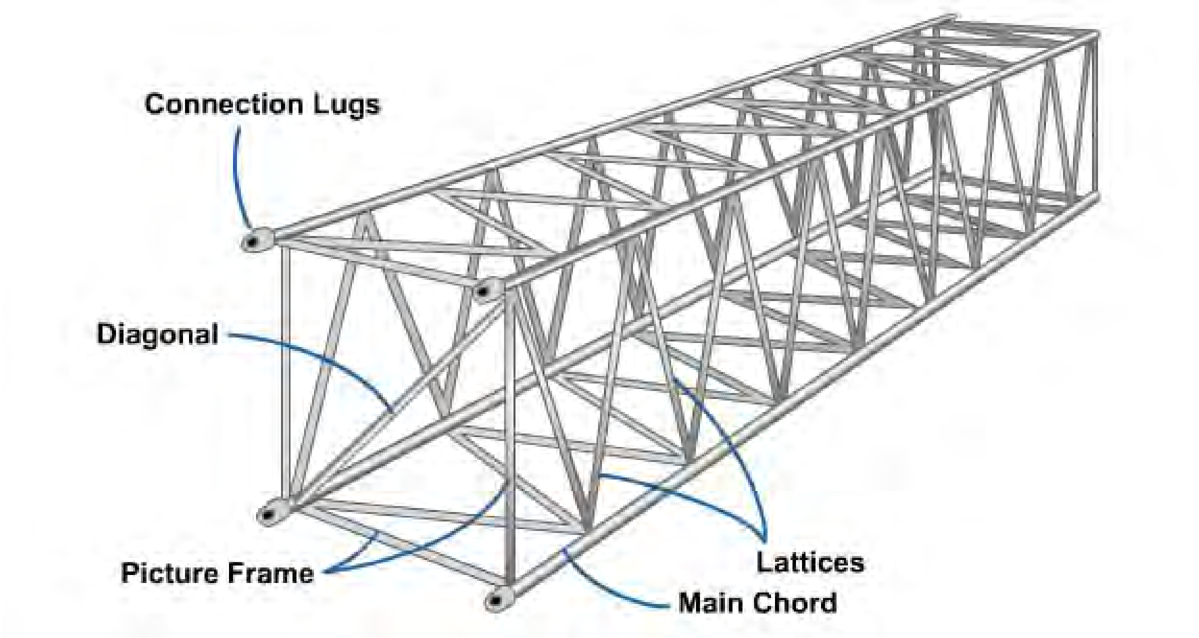

Figure 21-8 – Tubular boom section.

Manufacturers recommend not using a crane if it has rust, bent lacings or cords, cracked welds, and other problems that affect the strength of the lattice boom. This zero tolerance requires crane crews to use extreme care when handling unused sections with forklifts, storing unused sections away from traffic areas, transporting and securing sections on tractor-trailers, and preventing equipment or obstacles from running into the boom while mounted on the crane during transport, performing operations, or when parked.

The NCF uses sections that are normally 10 to 20 feet in length. When adding several sections of different lengths, check the operator's manual for boom section configuration. If this information is not in the operator's manual, a rule of thumb used when mixing short boom sections with long sections is to install the shorter sections closest to the boom base section; for example, if you use two 10-foot sections and one 20-foot section, install the two 10-foot sections closest to the boom base section. The boom sections are bolted by plate (flange) connections (*Figure 21-9*) or pin and clevis connections (*Figure 21-10*). The most common is the pin and clevis.

All boom sections that come with a crane will have an attachment identification number attached that assigns the boom section to a specific crane.

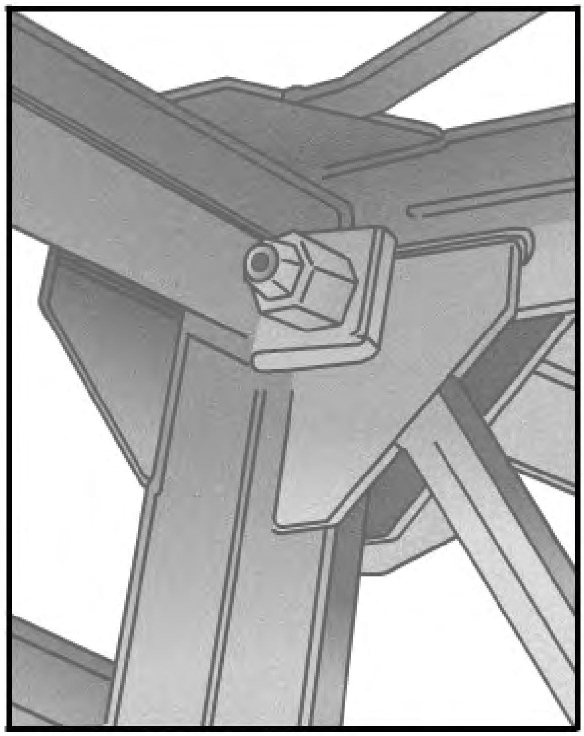

Figure 21-9 – Bolt connection.

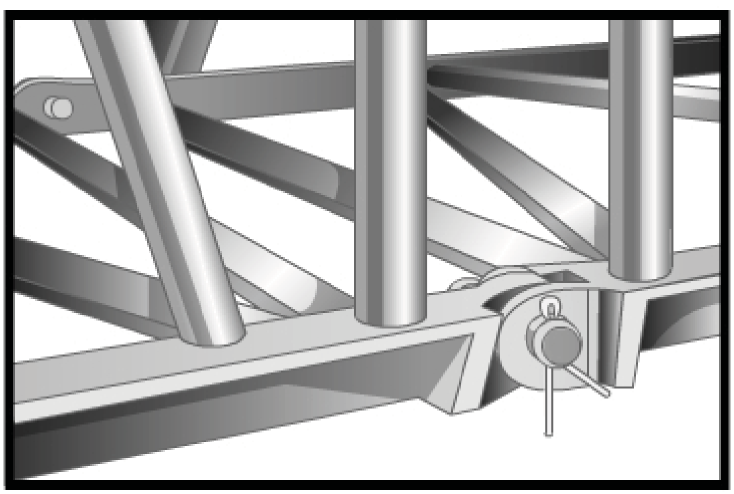

Figure 21-10 – Pin connection.

3.1.7 Boom Angle Indicator

The capacities that are listed on the crane load charts are also based on and vary with the boom angle of the crane. The boom angle, on lattice boom cranes is between the center line of the boom (from the boom base section pins to the head machinery) and the horizontal while the boom is under load (*Figure 21-11*).

Some cranes are equipped with boom angle indicators that are fluid type, mounted on the left of the operator's cab on the boom base section visually readable by the operator (*Figure 21-12*). This type of indicator must be adjusted properly, free from binding, and the crane must be level or it to accurately indicate boom angles. Even under these conditions its readings are only approximate.

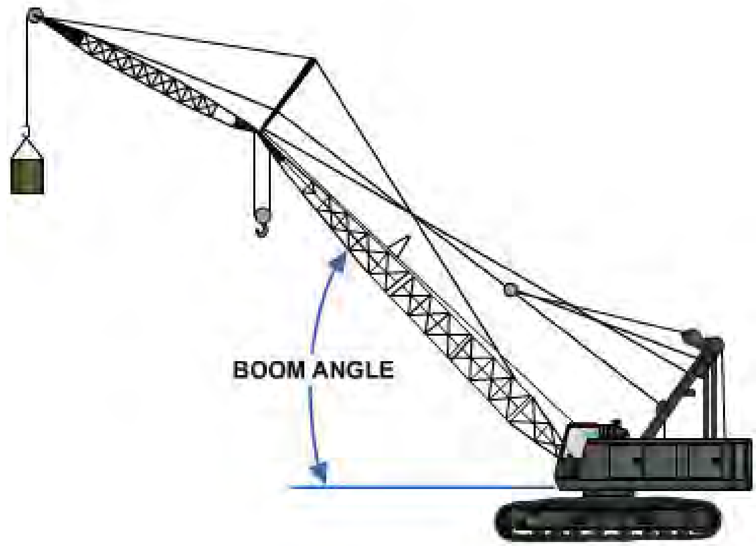

Figure 21-11 – Boom angle on a lattice boom crane.

On other type of cranes, the boom angle indicator consists of a metal plate with degree numbers (0 to 90 degrees) and a freely swinging arm that reacts as the boom angle changes. On such indicators, the numbers and arms should remain clean and visually readable at all times.

To check the accuracy of the boom angle indicator, place a 3-foot builder's level on the center boom section as shown in *Figure 21-13*. Raise and lower the boom until the level shows the boom is at zero degrees.

Figure 21-12 – Fluid type boom angle indicator.

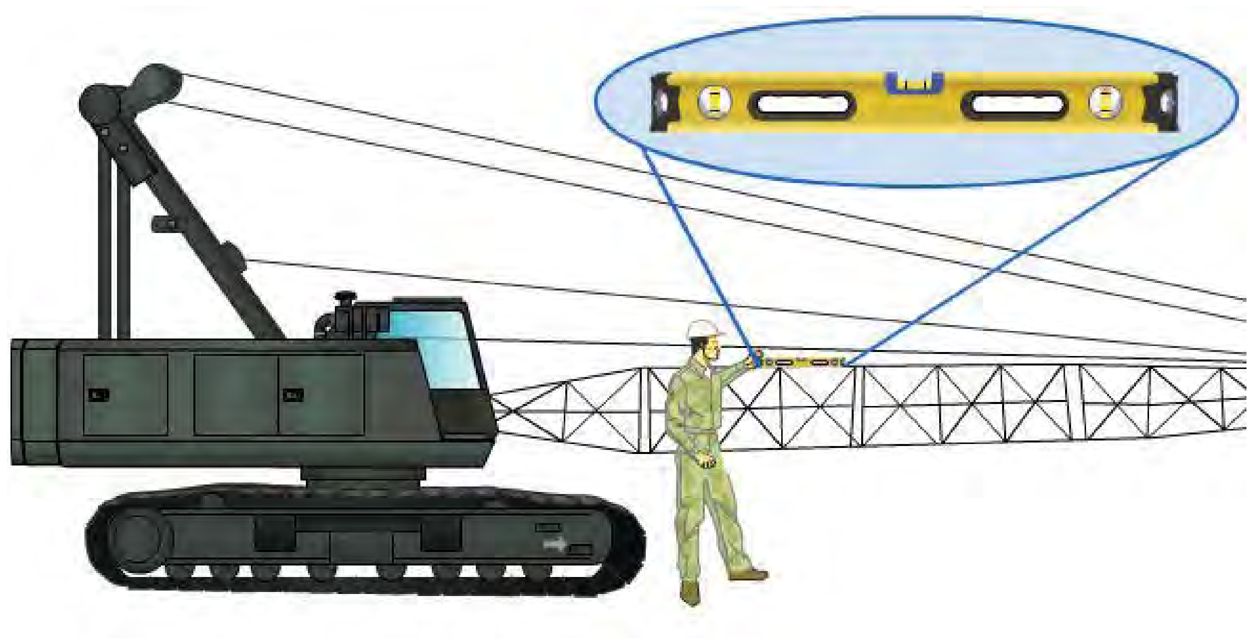

Figure 21-13 – Checking accuracy of boom angle indicator.

Although the boom angle indicator is a quick reference for the operator to know what angle the boom is at, do not rely on the boom angle indicator for radius accuracy especially when the lift exceeds 75 percent of the rated capacity. Use the radius measurement to determine the capacity of the crane from the load rating charts and to avoid any possibility of error.

3.1.8 Sheaves

Sheaves are located in the gantry, boom mast, bridle, and hook block. An arrangement of sheaves located at the very top of the boom tip section is referred to as the head machinery. Sheaves rotate on either bearings, or bushings, and are installed basically anywhere wire rope must turn or bend.

3.1.9 Boom Pendants

A pendant is a fixed-length of wire rope forming part of the boom suspension system. Each section of boom has two pendants. Both pendants must stay with the section of the boom they came with. When storing a boom section, secure the two pendants to the boom section with tie wire or rope. If one pendant is bad, always replace both. If you only replace the one bad pendant, the new or replaced pendant could be different in length or manufacture. This difference will cause an uneven pull or twist on the boom when the boom is put under a load or strain.

3.1.10 Gantry

The gantry, or A-frame, is a structural frame, extending above the revolving superstructure. The gantry supports the sheaves in which the boom hoist lines are reeved. The height of the gantry provides an angle between the pendants and boom that reduces the compression forces placed on the boom during raising and lifting operations; therefore, always raise the gantry before raising the boom or lifting a load. On some models of cranes, the gantry is adjustable, allowing it to be lowered so the crane can travel under bridges.

WARNING

A trial-and-error method of lowering or raising the gantry can cause serious injury or death; therefore, 1NCD has established AEPs for raising and lowering the gantry with and without a crane helper.

3.1.11 Boom Mast

Some models of cranes are equipped with a boom mast instead of a gantry, as shown in *Figure 21-14*. The boom mast, sometimes called live mast, consists of a structural frame hinged at or near the bottom of the boom base section that is lowered by gravity solely under the control of the boom hoist drum brake.

The tip of the boom mast supports the boom hoist sheaves and pendants. The boom mast works like the gantry, as it increases the angle between the pendants and boom, decreasing the compression forces placed on the boom.

Figure 21-14 – Boom mast.

3.1.12 Bridle Assembly

The bridle assembly is part of the boom suspension system. It may be connected to the boom mast or serve as a floating harness on a crane equipped with a gantry. The bridle assembly is the connection point between the pendants and is an assembly of sheaves in which the boom hoist wire rope reeves though.

3.1.13 Boom Hoist Reeving

Rigged to the rear winch drum, the boom hoist ***reeving*** is part of the boom suspension system used to raise and lower the boom.

3.1.14 Boom Stops

Boom stops are designed to prevent the boom from going over backwards if a load line breaks. They will not stop the boom if the operator forgets to disengage the boom hoist control lever. However, some models of cranes are equipped with a boom upper limit switch that prevents the operator from raising the boom past a preset boom angle. This switch also prevents operators from raising the boom into the boom stops. Most cranes that are equipped with the upper limit switch also have a bypass switch that allows the operator to raise the boom past the preset boom angle. One type of boom stop was shown earlier in *Figure 21-7*, another is shown in *Figure 21-15.*

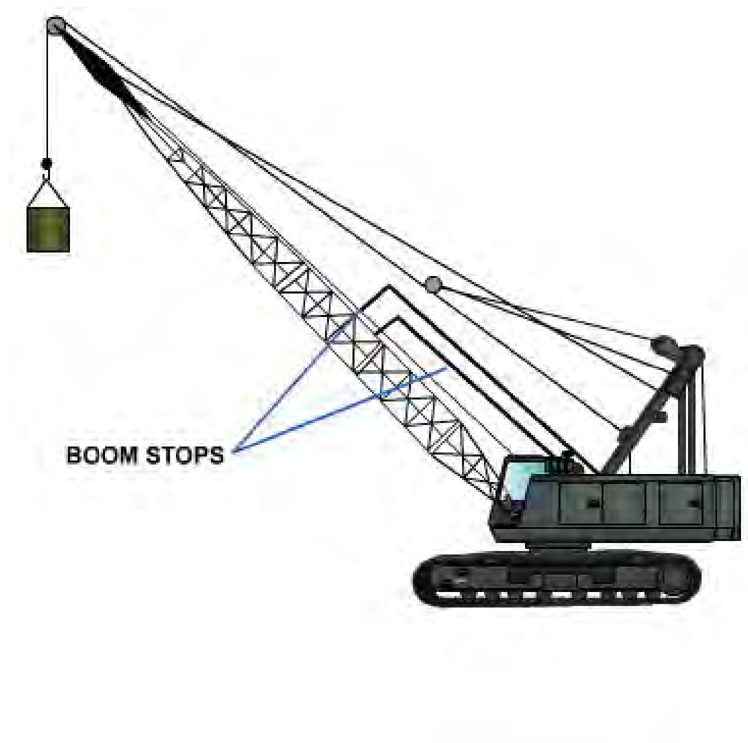

Figure 21-15 – Boom stops.

3.2.0 Controls on a Lattice Boom Crawler-Mounted Crane

Figure 21-16 shows controls on a Link-Belt LS-108H II related to crane operation.

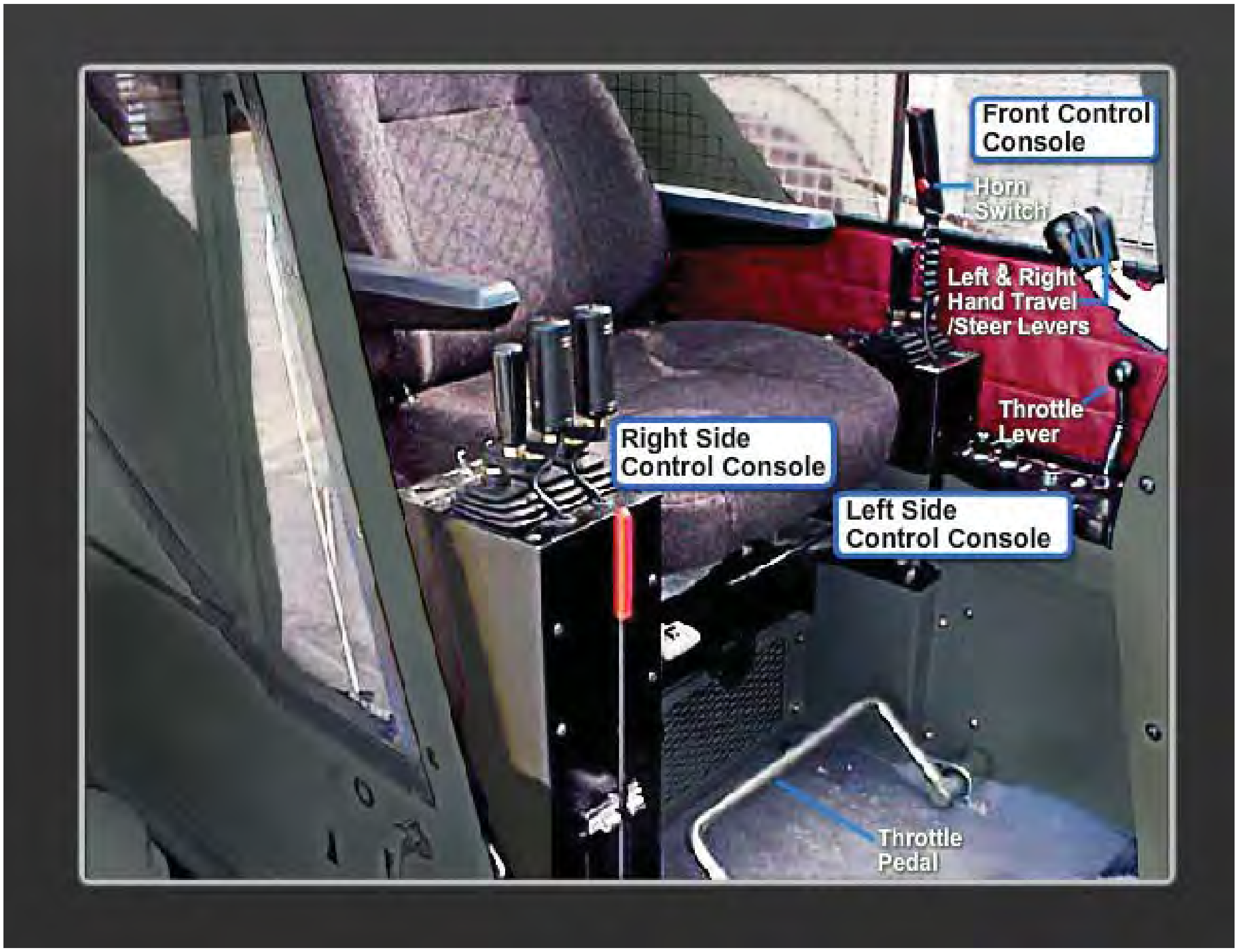

Figure 21-16 – Controls on a crawler-mounted lattice boom crane.

3.2.1 Engine Throttle Controls

The Link-Belt LS-108H II has two engine throttle controls, a pedal and a hand lever.

Throttle Pedal – Located on the cab floor, the throttle pedal provides the operator the flexibility means of controlling engine speed.

- To increase engine speed, press down on the throttle pedal.
- To decrease speed, release the pedal.

Engine speed is registered on a tachometer located on the control console.

Throttle Lever – Located on the left side control console, the throttle lever provides the operator the ability to set and hold a specific engine speed.

- To increase engine speed, pull the hand throttle lever back.
- To decrease speed, push the lever forward.

Once the hand throttle lever is set to a desired engine speed it will remain in that position until it is manually moved to a new setting. However, the engine speed may be increase by using the pedal without disturbing the lever.

3.2.2 Boom Hoist Operations

Raising and lowering of the boom is controlled by the boom hoist control lever and a pump control switch. An automatic brake is also incorporated in the system which remains applied anytime the boom hoist control lever is in the neutral position.

- To raise the boom, move the pump control switch on the left side control console to the desired position (high or low speed) and pull the boom hoist control lever back. If desired, increase the engine throttle to speed up the boom. After reaching the desired boom angle, move the boom hoist control lever to the neutral position to stop the boom.
- To lower the boom, move the pump control switch to the desired position and push the boom hoist control lever forward. If desired, increase the engine throttle to speed up the boom. After reaching the desired boom angle, throttle down and slowly move the boom hoist control lever to the neutral position to stop the boom.

Boom Hoist Limit System – The boom hoist limit system prevents over hoisting the boom. As the boom contact the boom backstops, it trips a limit switch at the very end of the boom base section, which disables the boom hoist function and prevents it from being raised any further. An audible alarm and light on the front control console will activate.

You must lower the boom to silence the alarm; however, to release the boom, hoist the boom hoist drum lock, and lower the boom, it may be necessary to raise the boom slightly to disengage the boom hoist drum ***pawl***. Then use the boom hoist override switch on the front control console to reactivate the boom hoist function to raise the boom enough to release the drum lock and lower the boom, The indicator light will continue to flash and the audible alarm to sound even after you have pushed this switch. To reset the boom hoist limit system, lower the boom until the boom hoist limit indicator light goes off and the audible alarm is silent.

3.2.3 Front and Rear Drum Operation

Raising and lowered a load is controlled by the front and rear drum control levers, drum lock switches, pump control switch, and drum brake mode switches. The front and rear drum brake pedals control the load and operate either automatically or manually.

The brake system for the front and rear drums have two modes of operations; automatic and manual. When the drum brake mode switch, located right behind the control lever, is moved down into the “Auto Brake” mode, the drum brake applies automatically anytime the control lever is in the neutral position. When it is moved up into the “Free” mode position, the drum brake must be manually applied using the brake pedal(s) on the cab floor.

Operating in “Auto Brake” Mode – The following instructions are for raising, holding, and lower a load while the drum brake mode switch is in the “Auto Brake” position. Prior to performing these operations ensure that the free mode indicator light on the front control console panel is off, the drum brake pedal is unlatched and releases, the position of the boom’s head machinery is directly above the load and the hook block is securely connect to the load. In addition, ensure that the pump control switch on the left side control console is moved to the desired position (high or low speed).

- To raise a load, slowly pull the control lever back. If desired, increase the engine throttle to speed up the winch once the load begins to move. After the load reaches the desired height, throttle down and slowly move the control lever to the neutral position to stop the load.

- To hold the load for an extended period of time, with the control lever in the neutral position, fully apply and latch the drum brake foot pedal. Check to see that the drum lock switch on the front control console is in the "on" position.
- To lower a load, unlatch and fully release the drum brake foot pedal. Move the drum lock switch to the "off" position and slowly move the control lever forward. If desired, increase the engine throttle. After the load reaches the desire height, throttle down and slowly move the control lever to the neural position to stop the load.

Operating in "Free" Mode – The following instructions are for raising, holding, and lowering a load while the drum brake mode switch is in the "Free" position. Prior to performing these operations, ensure that the free mode indicator light on front control console is illuminated, the boom's head machinery is directly above the load, and the hook block is securely connected to the load. In addition, ensure that the pump control switch is moved to the desired position (high or low speed).

- To raise a load, pull back on the control lever while releasing the drum brake foot pedal. If desired, increase the engine throttle. After the load reaches the desired height, throttle down and slowly apply the drum brake pedal while moving the control over to the neutral position.
- To hold the load, with the control lever in the neutral position, fully apply and latch the drum brake foot pedal. Check to see that the drum lock switch is in the "on" position.
- To lower a load, move the drum lock switch to the "off" position. With the control lever in neutral, slowly release the drum brake foot pedal and allow the load to lower slowly. The speed at which the load falls is regulated by the pressure applied to the drum brake pedal. After the load reaches the desired height, slowly apply the drum brake pedal and bring the load to a complete stop. Engage the drum pawl by moving the drum lock switch to the "on" position.

3.2.4 Swing Operations

Rotation of the superstructure of the crawler-mounted crane is controlled by the swing control lever, swing (park) brake rocker switch, and travel swing lock control lever located under the operator's seat on the right-hand side. The system also incorporates a swing alarm which sounds anytime the swing control lever is moved out of the neutral position.

- To swing the superstructure, check that the travel swing lock control lever is down in the "engaged" position, then move the swing (park) brake rock switch, which is located on the swing control lever, to the "off" position. Check to see that the swing (park) brake indicator light on the service monitor is off and then disengage the travel switch lock. Push the swing control lever forward to swing left or pull it back to swing right. Release the control lever to neutral and allow the superstructure to coast as the crane approaches the desired position. Slowly engage the swing control lever in the opposition direction to that which started the swing in order to slow and then stop the superstructure. After coming to a complete stop, apply the swing (park) brake and travel swing lock as desired.

3.2.5 Steering and Traveling the Crane

Crane movement is controlled by a left- and right-hand travel/steer lever.

- To travel forward or in reverse, simultaneously, move both the travel/steer levers in the desired direction. The travel brakes are automatically applied when you return these levers to the neutral position.
- To steer the crane right, push the left travel/steer lever forward while leaving the right travel/steer lever in the neutral position.
- To steer the crane left, push the right travel/steer lever forward while leaving the left travel/steer lever in the neutral position.
- To spin turn (counter-rotate), push one travel/steer lever forward while pulling the other lever back. The direction of rotation will depend on the direction you push the travel/steer levers.
- To stop, release the travel/steer levers.

3.3.0 Disassembly and Assembly

When assembling or disassembling a lattice boom always observe the following points:

- Obtain, read, and understand the step-by-step instructions outlined in the approved AEP specific to the type of crane.
- Do not stand inside, on, or under the boom at any time while assembling or disassembling the boom.
- Do not climb, stand, or walk on the boom. Use a ladder or similar device to reach necessary areas.
- When removing or installing the boom section, drive the connection pins from the outside of the boom toward the inside, as shown in *Figure 21-17.*

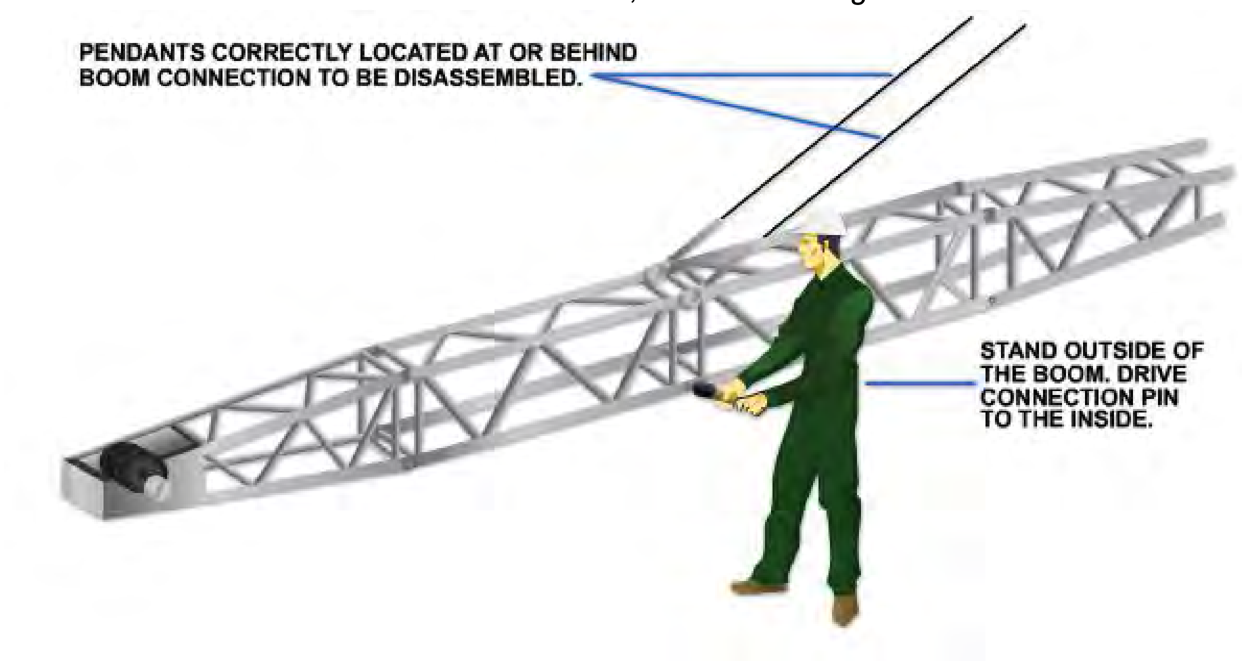

Figure 21-17 – Drive connection pins from outside in.

- When removing the boom section, be sure the pendants are tight and located at or behind the boom connection. Only the lower pins located behind the pendants may be removed; the boom must be straight, and head machinery rested on blocking, all of which are shown in *Figure 21-18.*

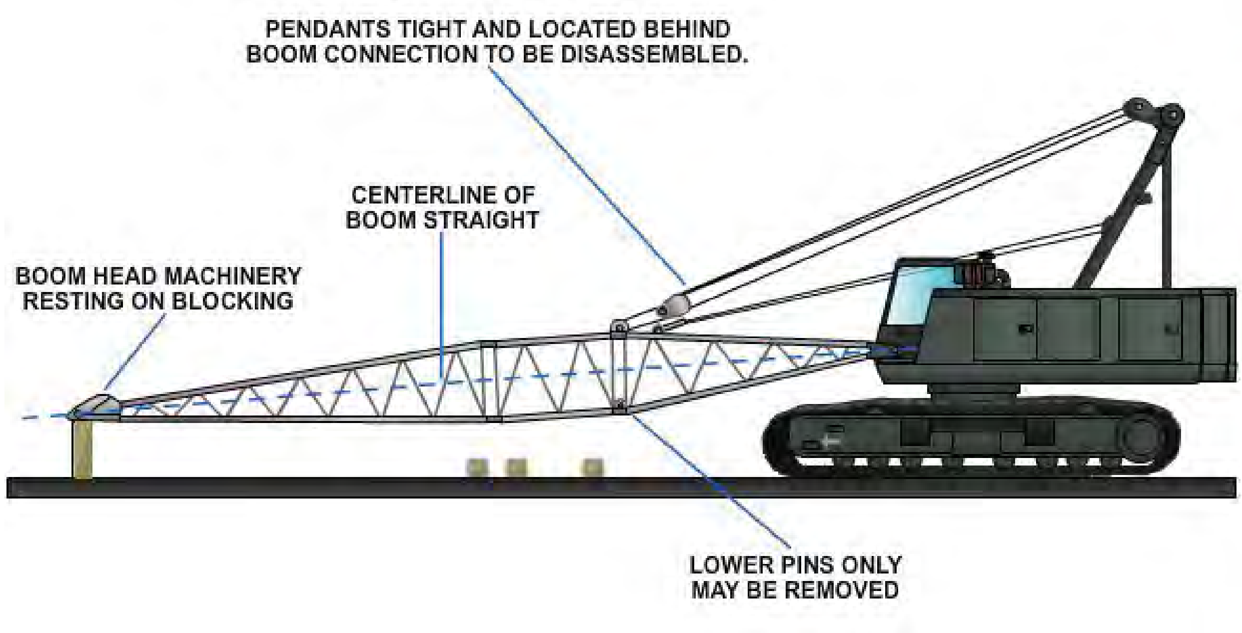

Figure 21-18 – Correct way of removing lattice boom section.

- Always wear proper eye protection, hard hat, safety glasses or goggles and safety shoes when removing or installing the boom section.
- Stay clear of pinch points when aligning boom section connection lugs. Never place your fingers in connection pin holes.
- Use caution when disconnecting the ***dead end*** of wire ropes. Reeve ropes can become twisted on the sheaves. When the dead end pin or socket is removed, the rope may spin.

3.3.1 Disassembly

When disassembling a lattice boom, take the opportunity to inspect thoroughly items such as the connection pins, cotter keys, and inside the connection lugs for wear, rust, and surface cracks.

The following are general steps for disassembling a boom section on a lattice boom that is equipped with either a gantry or boom mast, mounted on either a crawler or truck carrier.

Step 1. If the crane is mounted on a truck carrier, set outriggers and swing the superstructure over the rear or side, depending on the make and model of the crane.

Step 2. Lower the hook block(s) to the ground and provide slack in the hoist line(s). Next, lower the boom and set the head machinery on blocking.

Step 3. Engage the boom hoist control lever to lower the bridle assembly or boom mast to slacken the pendants.

Step 4. To prevent the pendants from falling to the ground, use tie wire or rope to secure them to the boom. Then, remove the cotter pins and drive out the main pins from the bridle assembly connections in the pendants.

Step 5. Position the bridle assembly on top of the boom base (*Figure 21-19*). The operator does this by engaging the boom hoist control lever to tighten the boom hoist lines until the bridle is positioned on top of the boom base. To align the pinholes, manually position the bridle assembly using a crowbar. The pins that are used for the pendant line connections are normally the pins used to connect the bridle assembly to the boom base. If the crane is equipped with a boom mast, the boom mast normally has a short set of pendants that connect to the boom base pinholes (*Figure 21-20*).

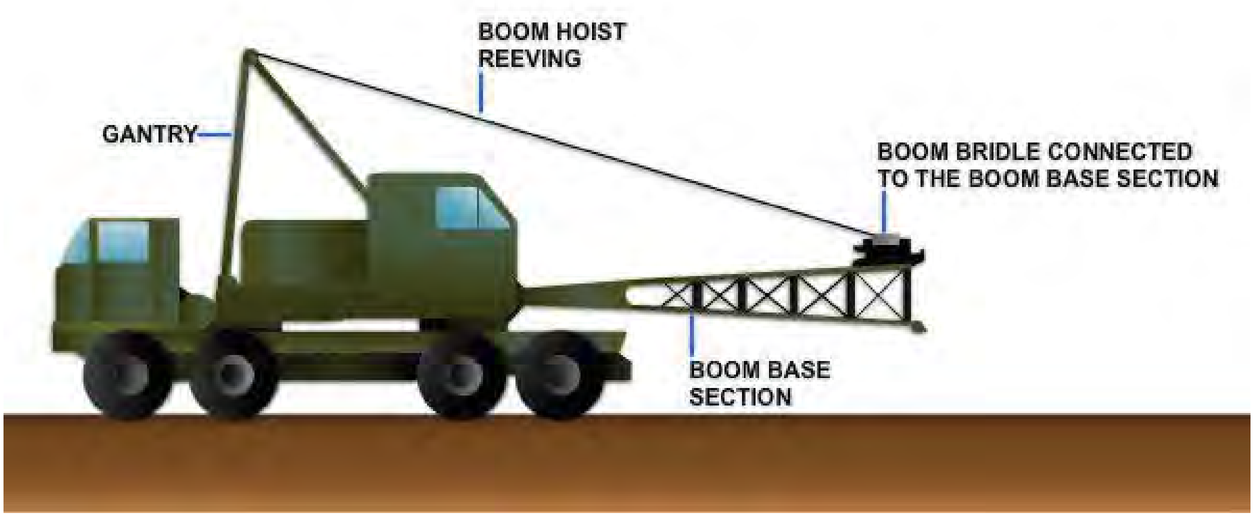

Figure 21-19 – Bridle connection.

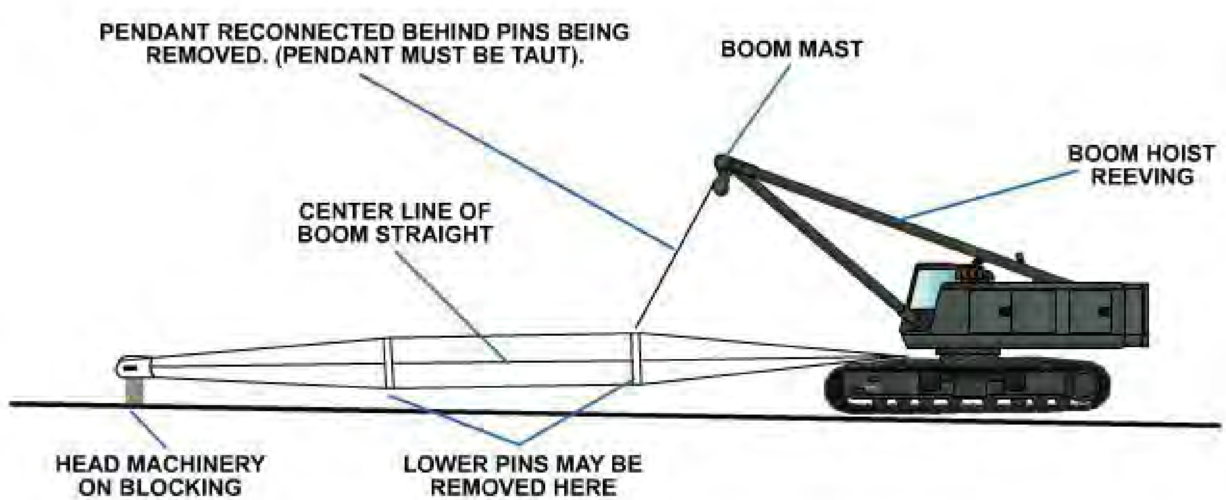

Figure 21-20 – Boom mast connection.

NOTE

Visually check the boom hoist drum to ensure the boom hoist wire rope does not loosen and cross wind on the hoist drum, resulting in crushing or kinking the wire rope.

Step 6. Tighten the boom hoist lines to support the weight of the boom, but not so tight that the head machinery is lifted off the blocking.

Step 7. Remove the cotter pins from the boom connecting pins and drive out the lower boom connection pins.

Step 8. After removing the lower pins, engage the boom hoist control lever and lower the bridle assembly or mast, allowing the boom to separate at the bottom by hinging on the top pins. Then, lower the boom on blocking

Step 9. Remove the top connection pins. Once they are removed, engage the boom hoist enough to separate the boom connection lugs.

When performing the boom breakdown over the rear of the crane, separate the boom by raising the outriggers enough to move forward with the carrier and by releasing the brakes on the hoist line(s) to slacken the hoist wire rope, as the carrier moves forward to allow space to add a section(s).

When performing the boom breakdown over the side of the crane, separate the boom by releasing the brakes on the hoist line(s) to slacken the hoist wire rope and using a forklift to pick up the boom tip carefully and maneuver it enough to provide adequate space to insert a boom section(s).

3.3.2 Assembly

The following are general steps for assembling a boom section on a lattice boom that is equipped with either a gantry or boom mast, mounted on either a crawler or truck carrier:

Step 1. Have a forklift align the boom section with the boom base section.

Step 2. Reverse the crane until the boom base top pin connection lugs are connected with the top pin connection lugs on the boom section. The boom breakdown performed over the side requires a forklift to maneuver the boom section until the pins are aligned.

Step 3. Once the top lugs are aligned, drive the boom connection pins into the top lugs from the inside out and insert the cotter pins.

Step 4. Engage the boom hoist control lever to raise the boom base section. This allows the top pins to perform as a hinge that draws the bottom pin connection lugs together.

Step 5. Once the bottom lugs are aligned, drive the boom connection pins into the bottom lugs from the inside out and insert the cotter pins.

Step 6. Raise both the boom base and section several inches to clear the ground. Reverse the crane until the top connection lugs of the boom section align with the top connection lugs of the boom tip. Final alignment of the lugs might require the use of a crowbar.

Step 7. Once the lugs are aligned, drive the boom connection pins into the top lugs and insert the cotter pins.

Step 8. Engage the boom hoist control lever to raise the boom section and tip. This results in the top pins performing as a hinge, drawing the bottom pin connection lugs together.

Step 9. Once the bottom lugs are aligned, drive the boom connection pins into the bottom lugs from the inside out and insert the cotter pins.

Step 10. If the crane is mounted on a truck carrier, reset the outriggers.

The procedures for connecting the bridle to the pendants are as follows:

Step 1. Engage the boom hoist control lever to lower the bridle or boom mast to produce slack in the boom hoist wire rope.

Step 2. The next step is to connect the bridle assembly to the boom section pendant lines. To do this, disconnect the bridle assembly from the boom base section and manually maneuver the bridle assembly to connect with the pendants of the boom section. Producing slack in the bridle assembly may require manually feeding the boom hoist wire rope through the sheaves.

NOTE

If the crane is equipped with a boom mast, lower the boom mast to connect the pendants.

Step 3. When the pendants are connected to the bridle, it is a good practice to insert the pins from the inside out. This practice allows for an easier visual inspection of the cotter pins inserted in the pendant line pins when the boom is in the air.

Step 4. The next step is to connect the boom section pendants to the boom tip pendants. This usually requires manual labor to align the boom section pendants to the boom tip pendants. You may also have to engage the boom hoist control lever to provide slack in the boom hoist reeving to align the pendants. Once the pendants are aligned, insert the pendant connection pins and cotter pins.

Step 5. Next, engage the boom hoist control lever to raise the bridle assembly and pendants. Before doing this, go back through and visually inspect all boom and pendant pin connections and cotter pins. Have someone watch the boom hoist drum to ensure the wire rope does not cross wind, causing it to be crushed or kinked. Additionally, ensure all of the boom hoist wire rope is properly running on all of the sheaves. Once everything checks out, engage the boom hoist control lever and raise the bridle and pendants until they are tight.

Step 6. Visually check the boom’s suspension system before raising it off the ground. As the boom is being raised, visually check the boom hoist wire rope.

Step 7. Once the boom is erected, check the hoist wire rope reeving. You want to ensure the wire rope is correctly flowing through the head machinery and hook block sheaves and winding properly on the hoist drum.

Test your Knowledge (Select the Correct Response)

3. **(True or False)** The rule of thumb used when mixing short boom sections with long sections is to install the longer sections closest to the boom base section.

   A. True
   B. False

4. **(True or False)** When removing or installing the boom section, drive the connection pins from the inside of the boom toward the outside.

   A. True
   B. False

4.0.0 TELESCOPIC BOOM

Telescopic boom cranes are typically called hydraulic cranes. Such cranes are highly maneuverable and easy to transport to jobsites.

4.1.0 Major Components of a Telescopic Boom Truck-Mounted Crane

As previously mentioned, major components and controls on cranes vary depending on type of carrier, boom, and manufacturer. You are responsible for reading the operator's manual for specific information. *Figure 21-21* shows the major components of the Link-Belt HTC-8640 telescopic boom truck-mounted crane. This particular crane has the rated capacity of 40 tons.

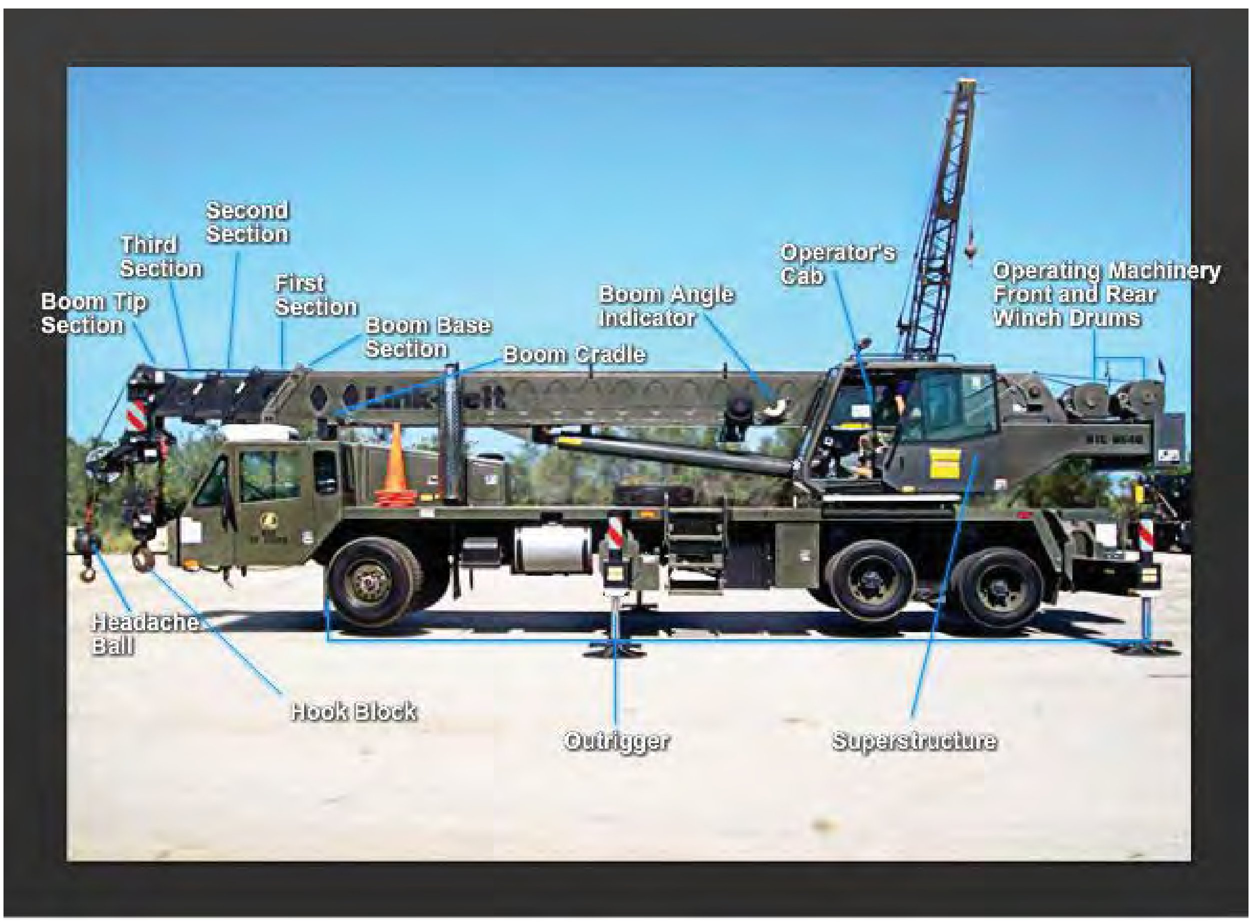

Figure 21-21 – Major components of a telescopic boom truck-mounted crane.

4.1.1 Superstructure

The superstructure on a truck-mounted crane includes an operator's cab, counterweight, operating machinery, and a hydraulic boom.

4.1.2 Operator's Cab

On a truck-mounted crane, the carrier cab houses various controls, such as a steering wheel, transmission shifter, and the throttle pedal used to drive the crane.

Whereas the operator's cab that makes up the superstructure, houses the gauges, switches, and controls used to operate the boom.

4.1.3 Counterweight

Mounted at the rear, beneath the winch drums, the counterweight provides greater stability when lifting loads (*Figure 21-22*). When you are performing near-capacity lifts at high boom angles using a telescopic crane, about 60 percent of load weight is placed on the outriggers away from the load. When you are performing the same lift with a lattice boom crane, about 60 percent of the load is placed on outriggers close to the load.

Figure 21-22 – Counterweight on a truck-mounted telescopic boom.

4.1.4 Operating Machinery

Similar to the lattice boom, the operating machinery on the telescopic boom consists a front and a rear winch drum, mounted one behind the other and located behind the boom.

4.1.5 Power Source

The power for a telescopic crane comes from hydraulic fluid. In most cases, the main carrier engine drives the hydraulic pump that supplies the hydraulic fluid to hydraulically controlled components. The valve body at the operator's control station diverts power to hydraulic motors or cylinders. The hydraulic power provides positive control of all crane functions.

4.1.6 Boom Sections

The telescopic boom is composed of a series of rectangular, trapezoidal, or other shaped symmetrically cross-sectional segments, fitting into each other as shown in *Figure 21-23*. The boom base section is the largest segment while the boom tip section is the smallest. In between there can be one or more sections called the first, second, and so forth, sections.

Figure 21-23 – Telescopic boom sections.

Telescopic booms may be pinned boom, full-powered boom, or a combination of both. A “pinned boom” means sections are pinned in the extended or retracted position. A “full-powered boom,” as shown earlier in *Figure 21-23*, extends or retracts hydraulically. Some models have a full-powered main boom with a pinned boom tip section. Read the operator’s manual for the proper operation of the type of boom on the crane you are assigned to operate.

On a full-powered boom, the sections are extended and retracted (except for the boom base section) by hydraulic cylinders, called extension cylinders. The cylinders are mounted parallel to the boom center line within each section. The boom extension cylinders on most telescopic booms have sequencing valves that allow the sections to extend (telescope) by equal amounts. These cranes usually have a single telescope control lever in the cab. However, on cranes not equipped with sequencing valves, the operator will have to extend each section equally. (The crane will have two or three boom telescope control levers in the cab, each controlling only a single boom section.) If the boom sections are extended unequally, the most fully extended section of boom could bend to uneven stresses. Additionally, the load rating chart will be invalidated for determining the rated capacity of the crane. Boom sections that are marked off in equal increments make it easier for the operator or signalman to make sure each section is extended equally.

When a load is placed on a telescopic boom, the load weight on the boom causes the hydraulic rams within the boom to stiffen and slightly curve. As the load is removed from the boom, the rams return the straight position. Because of this, do not extend the boom while it is under load. Read the operator's manual for boom extension information.

4.1.7 Outriggers

Truck-mounted cranes have an outrigger located beneath the front of the carrier as well as two other outriggers located on each side of the carrier, behind the front and rear tires.

4.1.8 Boom Cradle

Like other types of telescopic cranes, the Link-Belt HTC-8640 is equipped with a boom cradle for supporting the boom while it is in the lowered position.

4.1.9 Boom Angle Indicator

The boom angle indicator is located on the boom base section, on same side as the superstructure operator's cab. The boom angle on a telescopic boom crane is between the boom base section and the horizontal while the boom is under load (*Figure 21-24*).

Checking the accuracy of a boom angle indicator on a telescopic boom is similar to doing so on a lattice boom.

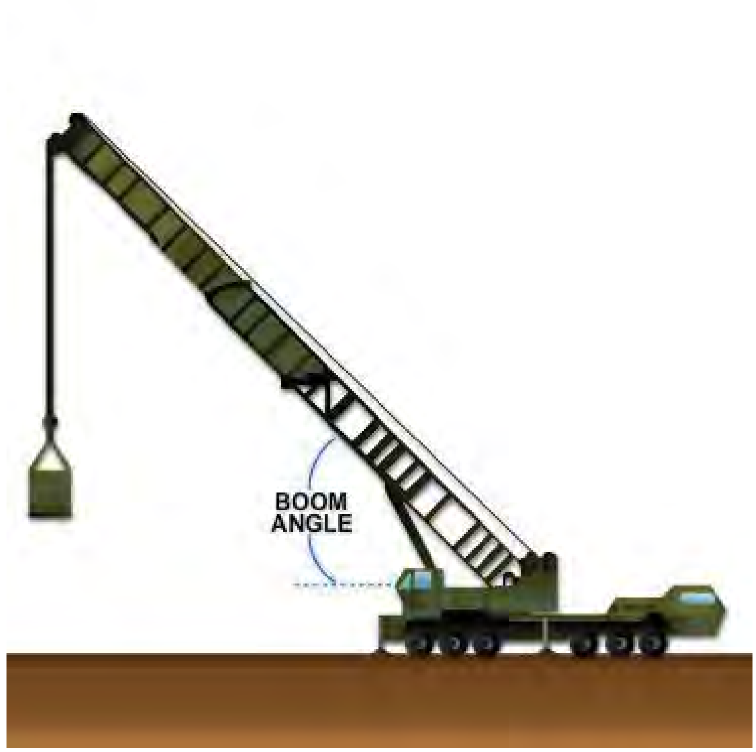

Figure 21-24 – Boom angle for a telescopic boom crane.

4.2.0 Controls on a Telescopic Boom Truck-Mounted Crane

Figure 21-25 shows the controls system controls on a Link-Belt HTC-8640.

Figure 21-25 – Controls on a telescopic boom truck-mounted crane.

4.2.1 Engine Throttle Controls

The engine throttle controls include a foot pedal and a lock system.

Throttle Pedal – The throttle pedal controls engine speed.

- To increase speed, press down on the throttle pedal.
- To decrease speed, release the pedal.

Throttle Lock System – The throttle lock system gives the operator the ability to set and hold a specific engine speed. This provides the operator with more flexibility for certain job requirements.

- To lock the throttle, press the throttle pedal until the desired engine speed is reached and press and release the adjustment switch to the "SET/ACCEL" side. The engine should continue to run at a constant speed when the throttle pedal is released.
- To increase the throttle lock setting, either press and hold the adjustment switch to the "SET/ACCEL" side until desired engine speed is reached and release switch, or press the throttle pedal until the desired engine speed is reached and press and release the adjustment switch to the "SET/ACCEL" side. The throttle

lock setting can also be increased incrementally by pressing and releasing (tap up) the “SET/ACCEL” side.

- To decrease the throttle lock setting, press and hold the adjustment switch to the “RESUME/DECEL” side until desired engine speed is reached and release switch. The throttle lock setting can also be decreased incrementally by pressing and releasing (tap down) the “RESUME/ DECEL” side.
- To return to idle, press and release the bottom part of the disengage switch.
- To resume a previous throttle lock setting, press and release the adjustment switch to the “RESUME/DECEL” side.

4.2.2 Swing System

The swing system rotates the superstructure over the truck carrier. Controls such as the swing brake pedal, left hand-side hydraulic control lever, travel swing lock, and swing park brake operate the swing function of the crane.

Swing Brake Pedal – The swing brake pedal is used to stop the rotate of the superstructure.

- To apply the swing brake, push down on the swing brake pedal.
- To release the swing brake, release the pedal.

Swing Control Lever – The left hand-side hydraulic control lever serves as the swing control lever for moving the superstructure left or right.

- To swing the superstructure left or right, fully apply the swing brake pedal and release the swing park brake and/or swing lock(s). Release the swing brake pedal as you begin to move the swing control lever to the desired direction.
- To stop the superstructure swing, ease the swing control lever into the neutral position. Apply the swing brake to bring the superstructure to a complete stop. Engage the swing park brake as required. Check engagement of the swing park brake by trying to swing right, then left. The superstructure should not swing.

Travel Swing Lock – Use the travel swing lock to lock the superstructure directly over either the front or rear of the carrier. The travel swing lock will engage in these two positions only. Use of the travel swing lock is mandatory when traveling or transporting the crane and during pick and carry operations.

- To release the travel swing lock, fully apply the swing brake pedal. Press the button in the center of the travel swing lock knob and pull the knob up. Release the button and knob. The knob should remain in the released position.
- To engage the travel swing lock, position the superstructure directly over either the front or rear of the carrier. Fully apply swing brake pedal. Press the button in the center of the travel swing lock knob and push the knob down. Check the engagement of the travel swing lock by trying to swing the superstructure right, then left. The superstructure should not swing.

Swing Park Brake – The swing park brake is a multiple disc type brake and is used for holding the superstructure, in any position, over the carrier during normal stationary crane operations. Engage the travel swing lock and release the swing park brake anytime the crane is traveled or transported. An indicator light on the control panel will illuminate when the swing park brake is applied.

- To release the swing park brake, fully apply the swing brake pedal. Push the top part of the swing park brake rocker switch on the gauge and control panel to release the park brake. The indicator light will go out.
- To apply the swing park brake, rotate the superstructure to the desired position over the carrier. Apply the swing brake pedal to bring the superstructure to a complete stop. Push the bottom part of the swing park brake rocker switch on the gauge and control panel to apply the park brake. The indicator light will illuminate. Check engagement of swing park brake by trying to swing the superstructure right, then left. The superstructure should not swing.

4.2.3 Wire Rope Winch System

The wire rope winch system raises and lowers the winch lines. It is equipped with a two speed motor that, when activated, will double the speed of the winch lines. Controls such as both hydraulic control levers and winch control switches operate the front and rear winches while raising and lowering loads.

The left hand-side hydraulic control lever controls the front winch, while the right hand-side lever controls the rear winch.

- To raise either the front or rear winch, pull its respective hydraulic control lever back.
- To lower either the front or rear winch, push its lever forward.

Provided is a brief description of basic procedures for operating the winch lines during the lifting and lowering of a load.

- To lift a load, attach the hook block or ball to the load. Position the head machinery directly above the load. Pull either the front or rear winch control lever back, toward the operator.
- To hold a load, return the control lever to the neutral position. The automatic brake in the winch system will hold the load in position.
- To lower a load, push the control lever forward. Return the control lever to neutral to stop the load.

Winch Control Switches – Both winch control switches located behind the right hand-side hydraulic control lever have three rocker positions. These switches control the speed hoist and disable the front and rear winch.

- To increase hoist speed of either the front or rear winch, center its corresponding winch control switch.
- To decrease speed, press the bottom half of the switch.
- To disable either the front or rear winch, press the top half of the switch.

4.2.4 Boom Hoist System

The boom hoist system raises and lowers the boom. Controls such as the right-hand side hydraulic hoist control lever, a boom telescope pedal and override switch operate the boom.

The right hand-side hydraulic control lever serves as the boom hoist control lever for raising and lowering the boom.

- To raise the boom, move the boom hoist control lever left.

- To lower the boom, move the lever right.
- To stop the boom, ease the lever into the neutral position.

Boom Telescope System – The telescoping feature of the boom sections is operated through the use of two hydraulic cylinders and a cable/sheave mechanism which are an integral part of the boom assembly. The boom can be extended or retracted to any desired length using the control pedal in the operator's cab. The telescope feature has two modes of operation: “A” and “B”.

Boom Mode “A” – In boom mode “A” only the inner mid boom section extends/retracts. This mode offers increased strength capacities. Select this mode through the Rated Capacity Limiter system.

Boom Mode “B” – In boom mode “B” all boom sections extend/retract simultaneously. This mode offers increased stability capacities. Select this mode through the Rated Capacity Limiter system.

Boom Telescope Control Pedal – The boom telescope control pedal extends and retracts the boom.

- To extend the boom, press down on the toe-end of the boom telescope control pedal.
- To retract the boom, press down on the heel-end

Use the telescope mode in conjunction with the telescope control pedal to extend the boom sections to the desired length.

Boom Telescope Override Switch – The boom telescope override switch is provided to manually override the telescope system when the boom is not extending/retracting proportionally. Use this switch for that purpose only. While in boom mode “B”, the switch will stop one of the boom sections so the boom can be extended/retracted proportionally.

- To extend the boom sections, park the crane on a firm level surface, engage the park brake, and shift the transmission to neutral. Press down on the toe-end of the telescope control pedal. Stop the boom sections by releasing the pedal.
- To retract the boom sections, press down on the heel-end of the telescope control pedal. Stop the boom sections by releasing the pedal.

Test your Knowledge (Select the Correct Response)

5. **(True or False)** A “full-powered boom” extends and retracts hydraulically.

   A. True
   B. False

6. **(True or False)** On a telescopic boom crane, the boom angle is between the center line of the boom and the horizontal while the boom is under load.

   A. True
   B. False

5.0.0 ATTACHMENTS

The crane is a versatile piece of equipment that can be equipped with various attachments to perform a number of different operations. These attachments include a jib, hook block, headache ball, clamshell, dragline, and pile driver.

5.1.0 Jib

A jib is a lattice structure used to extend either a hydraulic or lattice boom, as shown in *Figure 21-26*. A jib is equipped with its own forestay pendants connected from the jib head sheave to the jib mast by means of equalizer sheaves. Its backstay pendants connect the jib mast to the boom tip section using the same equalizer sheaves. The backstay pendants and are normally manually adjustable to change the angle of the jib.

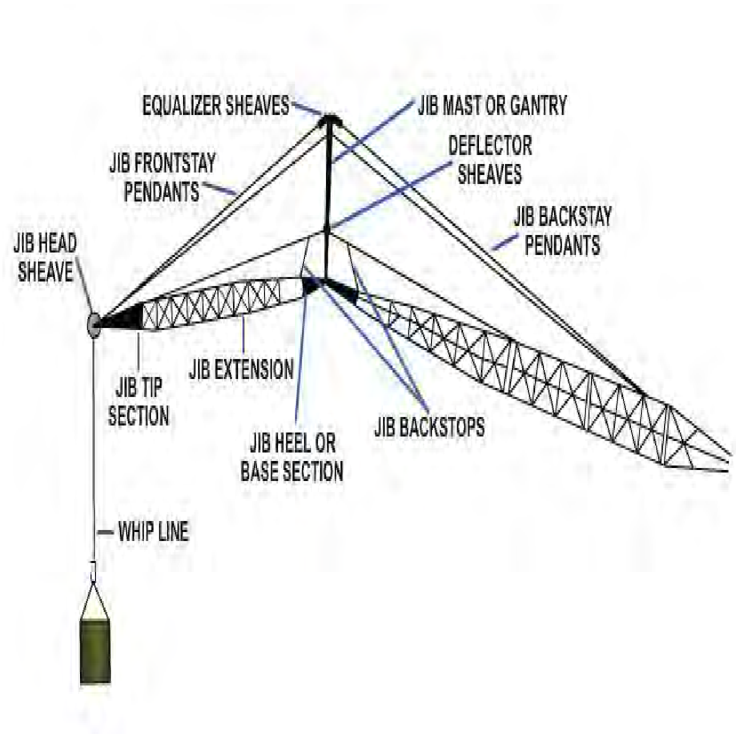

Figure 21-26 – Jib on a lattice boom.

On most cranes the function of the jib is to increase the lift height and to aid in increasing load radius. When assembling or disassembling a jib it is critical to follow the AEP specific to the type of crane. In addition, remember if lifts are made with the main hook block, the weight of the jib assembly will reduce the lifting capacity of the crane; therefore, you must deduct the effective weight of the jib assembly from the gross capacity of the crane.

5.2.0 Hook Block

The hook block is essentially a block with a hook attached with a single sheave for a two or three part line, or multiple sheaves for four or more lines. *Figure 21-27* shows an eight-part rigged hook block.

The number of parts of a line rigged on the hook block is important for figuring the capacity of the crane. Most crane load rating charts show the rated capacity of the crane for different parts of the line; for example, a crane that is capable of being rigged with an eight-part line may be rigged with a six-part line; however, the eight-part line gives the crane a greater lifting capacity; therefore, you must check the load rating chart for the six-part line capacity to avoid overloading the crane.

Figure 21-27 – Hook block.

Such an attachment is primarily used for hoisting, transferring, traveling, and placing loads. When operating a crane rigged with a hook block, operators must avoid two blocking. Two blocking is when the hook block comes in contact with the boom's head machinery during hoisting of the hook or lowering of the boom. This is dangerous because it could result in damage to the crane, parting of the hoist lines, and dropping of the load.

Some cranes are equipped with a hoist limit switch to prevent over travel of the hook block and the possibility of two blocking; however, operators should not rely solely on such a device to prevent potential hazard. Crane crew members must work together to monitor the movement of the hook block and boom, to ensure two blocking does not occur.

An SOP has been established to prevent two blocking. It outlines crane crew member's responsibilities in preventing that hazard as well as procedures for operating cranes with and without hoist limit switches.

5.3.0 Headache Ball

The headache ball, as shown in *Figure 21-28*, is a heavyweight ball with a hook attached. Because it only has a single part line, known as a whip line, it is used to lift lighter loads quickly compared a hook block.

Figure 21-29 shows a headache ball in operation.

Figure 21-28 – Headache ball.

Figure 21-29 – Headache ball in operation.

5.4.0 Clamshell

The clamshell, shown in *Figure 21-30*, consists of a bucket with two scoops hinged together in the center with counterweights bolted around the hinge. The counterweights help the bucket penetrate the material. Each scoop includes a back bottom plate, side plates, lip, teeth, hinge, and arm brackets.

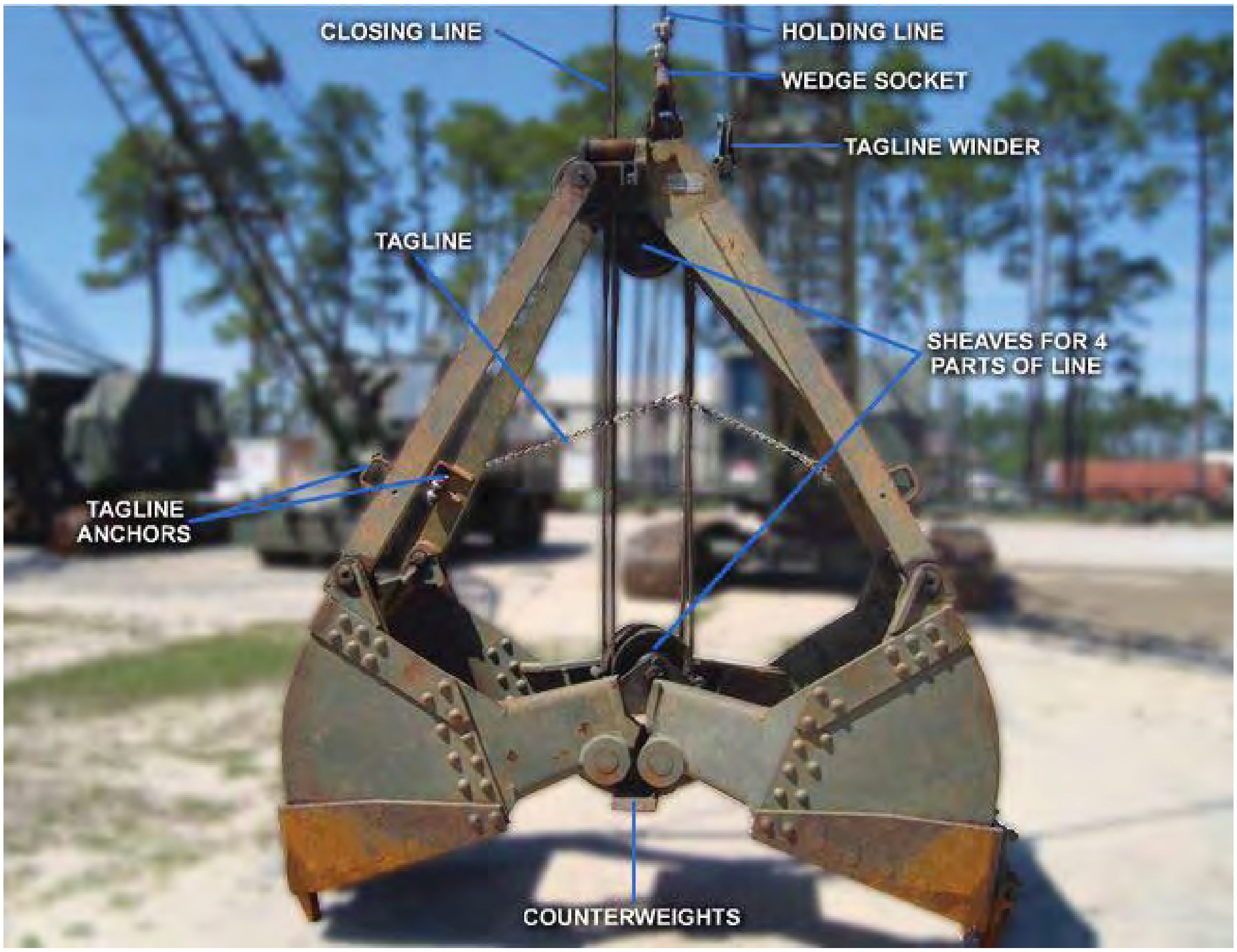

Figure 21-30 – Clamshell.

Rigged to the front drum, a holding line holds the bucket while dumping, lowers the bucket when it is open, and controls the depth of the cut (*Figure 21-31*). Rigged to the rear drum, a closing line closes the bucket using sheaves and hoists the bucket when it is completely filled. The clamshell bucket is equipped with anchors for securing a tagline from a tagline winder, which is mounted on the boom base section. Requiring no operator control, the tagline helps prevent the clamshell bucket from swinging and twisting during operations. The spring loaded tagline winder controls the tagline's tension. Like the clamshell bucket, it is interchangeable with most crane makes or models in the same-size range.

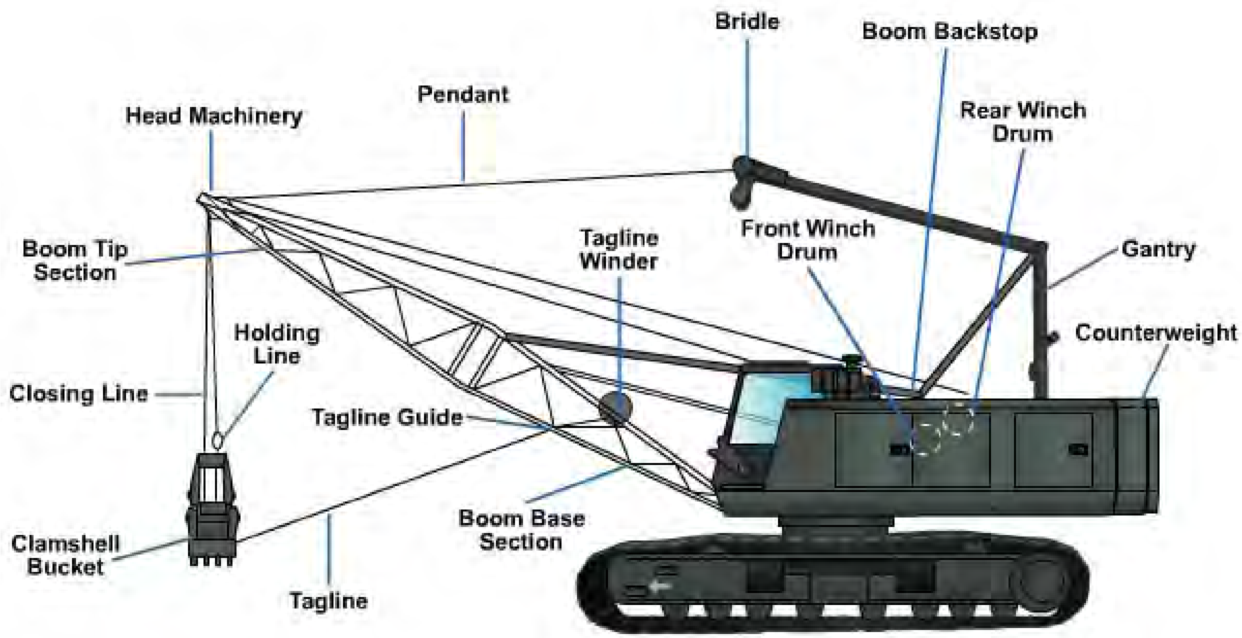

Figure 21-31 – Rigged clamshell.

As shown in *Figure 21-32*, the clamshell is used for vertical digging of loose to medium compacted soil. It is also used for placing materials at considerable height, depth or distance and for moving bulk materials from stockpile to plant bins, loading hoppers, and conveyors; however, can not be operated off of a jib.

Figure 21-32 – Clamshell in operation.

When changing attachments from a hook block to a clamshell, check the operator's manual for the correct length of wire rope reeving; for example, some crane models require more wire rope for hook block operations than for clamshell operations. Too much wire rope on the winch drum during clamshell operations will cause the wraps of wire rope to loosen on the winch drum and crosswind, resulting in crushed wires and kink spots in the wire rope. This is very expensive, because the wire rope is usually no longer useful for hook block operations.

Changing the length of rope requires unreeving the hook block wire rope and reeving the correct length of wire rope for the clamshell. This may be a time-consuming effort, but saves you from having to replace many feet of wire rope when the crane is rigged for hook block operations.

5.5.0 Dragline

The dragline, shown in *Figure 12-33*, consists of dump block that connects a dump sheave, hoist line, and hoist chains. Spread by a spread bar, the hoist chains are attached to each side of a bucket. Rigged to the rear winch drum, the hoist line operates over the boom's head machinery to raise and lower the bucket.

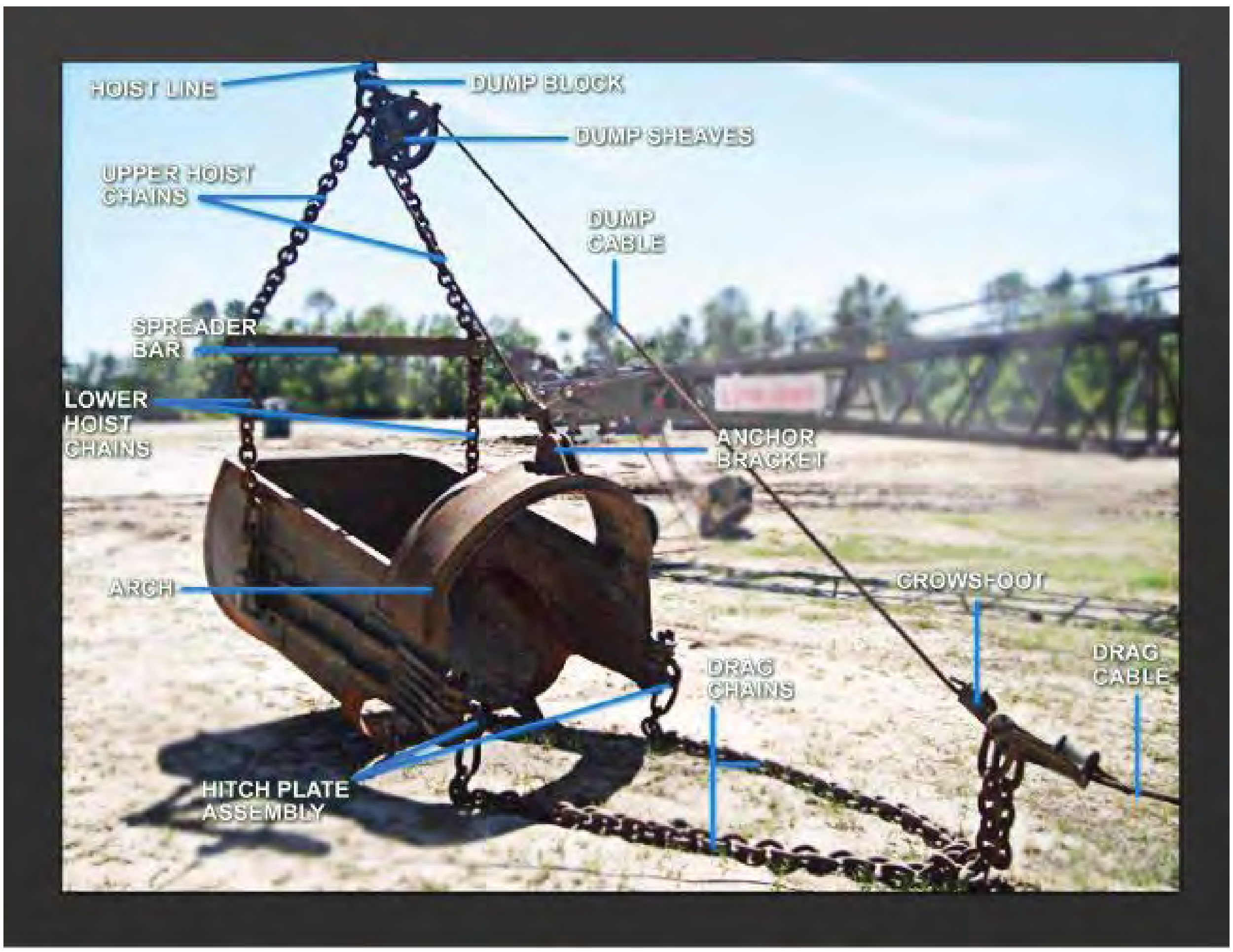

Figure 21-33 – Dragline.

A three-way drag hitch, known as a crowfoot, intercepts two drag chains, a dump cable, and a drag cable. The drag chains are attached to the bucket's hitch plate assembly. The dump cable operates over the dump sheave and is attached to the bucket by an anchor bracket. It can be adjusted for operating conditions. For dry shallow excavation, it can be lengthened and for wet or deep excavation it can be shortened. Rigged to the front winch drum, the drag cable pulls the bucket through the material (*Figure 21-34*). When the bucket is being loaded, the drag cable is smoothly guided into the drum by a fairlead mounted at front of the crane. The fairlead is capable of rotating 360° and swinging side to side.

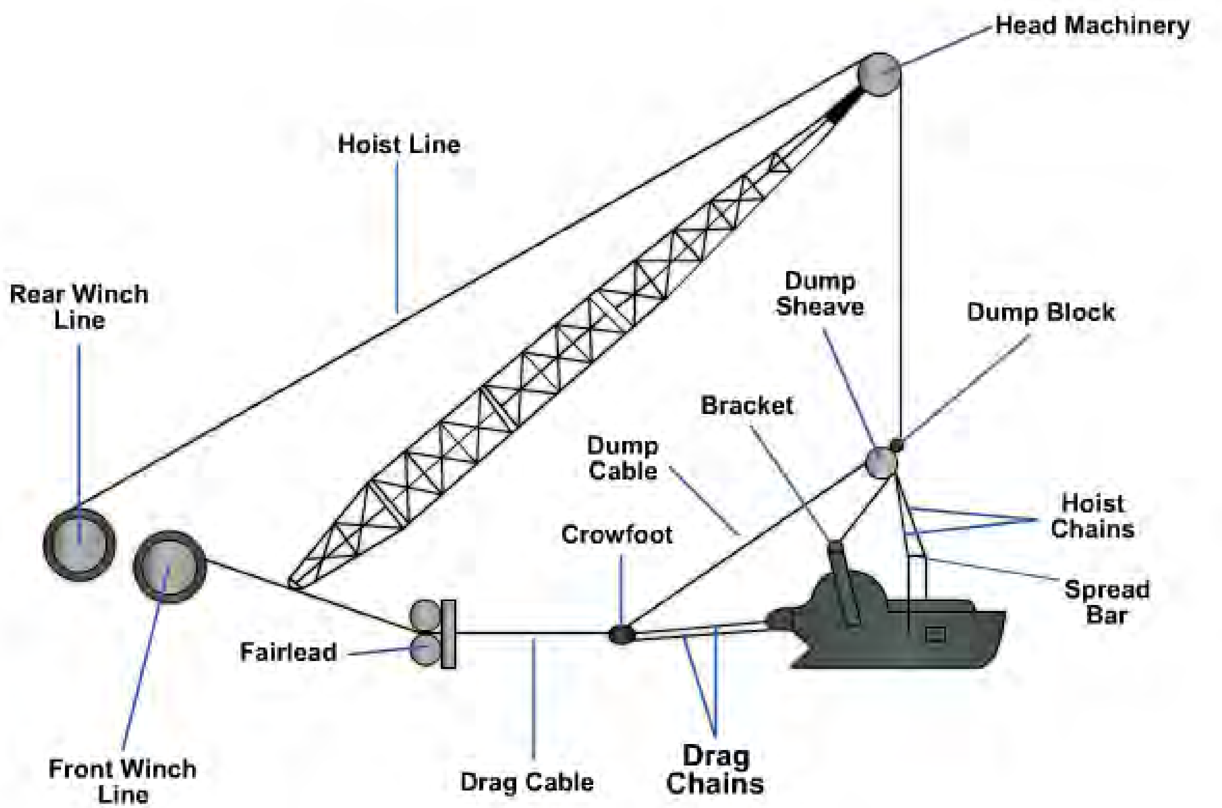

Figure 21-34 – Rigged dragline.

WARNING

On some crane models, you must make sure the fairlead is in a vertical position when lowering the boom to avoid bending the cords of the boom base section.

The dragline is capable of a wide range of operations at and below ground level. The dragline can dig through loose to medium compacted soil. The biggest advantage of the dragline over other machines is its long reach for both digging and dumping. Another advantage is its high cycle speed. The dragline does not have the positive digging force of the backhoe. The bucket is not weighted or held in alignment by rigid structures; therefore, it can bounce, tip over, or drift sideways when digging through hard materials. This weakness increases with digging depth.

The construction industry rates dragline buckets in different types and classes. The types and classes are as follows:

- Type I (light duty)
- Type II (medium duty)
- Type III (heavy duty)
- Class P (perforated plate)
- Class S (solid plate)

The most common buckets used by the Navy are the type II, class S buckets. Class P buckets are available for dredging operations.

NOTE

Do not lubricate the drag cable. If the drag Class P (perforated plate) cable is lubricated and pulled through the dirt, it retains the dirt, which causes damage to the wire rope.

When changing attachments from hook block or clamshell to dragline, check the operator's manual for the lengths and diameter size of wire rope required for dragline operations. The pulling force of the dragline normally requires a larger diameter drag cable. The length of the hoist line is also shorter than normal to avoid cross winding on the winch drum.

5.6.0 Pile Driver

Categorized under the 36-00000 USN number registration series, the pile driver attachment shown operating in *Figure 21-35* is a mechanical device used to drive piles into soil. It consists of leads and a hammer used with either on a crawler- or truck-mounted crane.

Figure 21-35 – Pile driver in operation.

5.6.1 Piles

A pile is a load-bearing member driven into soil for the support of bridges, building, wharves, docks, and other structures and in temporary construction. They are usually forced into the ground to transfer the load to underlying soil or rock layers when the surface soils at a proposed site are too weak or compressible to provide enough support.

Piles are identified by how they are driven, what type of soil they are driven into, and by what purpose they serve.

- Bearing Piles - Piles that are driven vertically and used for the direct support of vertical loads are called bearing piles. Bearing piles transfer the load through a soft soil to an underlying firm stratum. They also distribute the load through relatively soft soils that are not capable of supporting concentrated loads. There are distinct types of bearing piles: end bearing piles, friction piles, and combination piles, as shown in *Figure 21-36*.

Figure 21-36 – Types of bearing piles.

  - Typical end-bearing piles are driven through very soft soil, such as a loose silt-bearing stratum underlain by compressible strata. Remember this factor when determining the load the piles can support safely.
  - When a pile is driven into soil of fairly uniform consistency and the tip is not seated in a hard layer, the load-carrying capacity of the pile is developed by skin friction. The load is transferred downward and laterally to the adjoining soil by friction between the pile and the surrounding soil.
  - Many piles carry loads by a combination of friction and end bearing. For example, a pile may pass through a fairly soft soil that provides frictional resistance and then into a form layer which develops a load-carrying capacity by both end bearing and friction over a rather short length of embedment.

- Anchor Piles – As shown in *Figure 21-37* anchor piles may be used to anchor bulkheads, retaining walls, and guy wires. They resist tension or uplift loads.

- Dolphin Piles – As shown in *Figure 21-37*, dolphin piles are a group of piles driven close together in water and tied together so that the group will withstand lateral forces, such as boats and other floating objects.
- Fender Piles – As shown in *Figure 21-37*, fender piles are driven in front of a structure to protect it from damage.

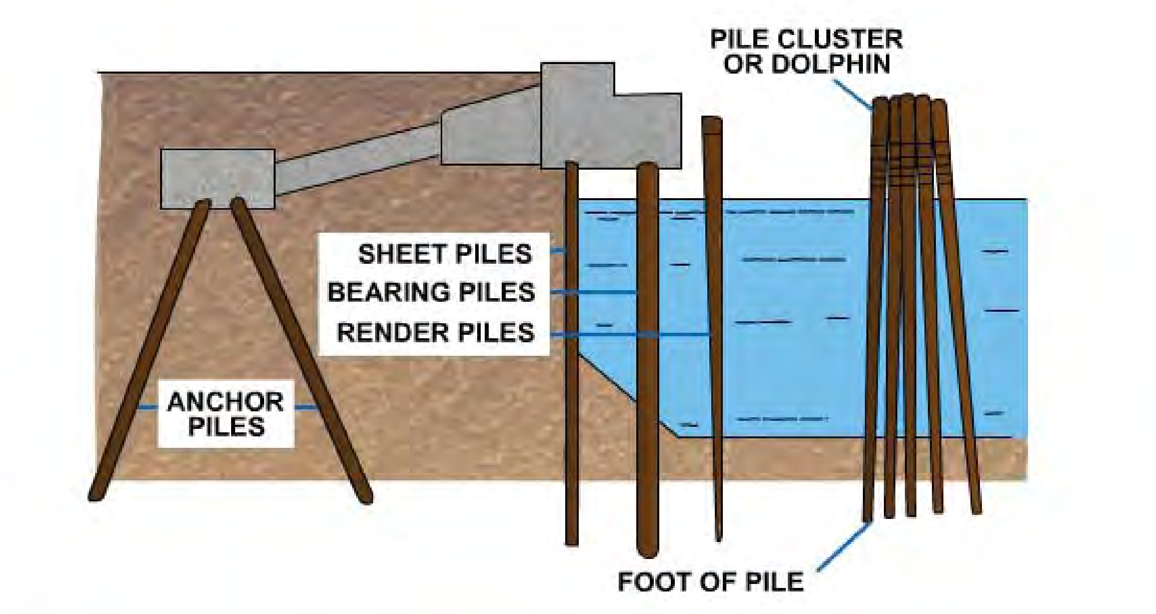

Figure 21-37 – Typical uses of piles driven in a waterfront structure.

- Compaction Piles – Compaction piles are driven into loose, cohesion-less soils with the objective to increase density. They are also used where a pier or wharf had sagged.
- Guide Piles – Guide piles are used as guides for driving other piles. They also used as guides and support for wale, when driving sheet piles.
- Batter Piles – Piles driven at an angle to the vertical are called batter piles. They resist lateral or incline loads when such loads are huge or when the foundation material immediately beneath the structure fails to resist the lateral movement of vertical piles. They also may be used if piles are driven into a compressible soil to spread vertical loads over a large area thereby reducing final settlement. They may be used alone (battered in opposite directions) or with vertical piles.

The following are terminology commonly uses during pile-driving operations.

- Foot of Pile – As shown earlier in *Figure 21-37*, the term foot of a pile refers to the lower end of a driven pile, which is the smaller end.
- Pile Bent – Pile bent is a terms used to refer to two or more piles driven in a row, transverse to the long dimension of a structure and fastened together by capping or in some cases by bracing.
- Pile Foundation – Pile foundation is a term used to refer to a group of piles used to support column or piers, a row of piles under a wall, or a number of piles distributed over a large area to support a mat foundation.
- Pile Group – Pile group is a term used to refer to a number of bearing piles driven together to form a pile foundation.

- Test Pile – Test pile is a term used to refer to a pile driven to learn driving conditions and probable required lengths, one on which a loading test may also be made to find its load settlement properties and the carrying capacity of the soil and as a guide in designing pile foundations.
- Springing – "Springing" is a term used to describe a pile vibrating too much laterally from the blow of the hammer. Springing may occur when a pile is crooked, when the butt has not been squared off properly, or when the pile is not in line with the fall of the hammer. In all pile-driving operations, ensure the fall of the hammer is in line with the pile axis; otherwise, the head of the pile and the hammer may be damaged and much of the energy of the hammer blow lost.

  Excessive bouncing may come from a hammer which is too light. However, it usually occurs when the butt of the pile has been crushed or ***broomed***, when the pile has met an obstruction, or when the pile has penetrated to a solid footing. When a double-acting hammer is being used, bouncing may result from too much screw or air pressure. With a diesel hammer, if the hammer lifts on the upstroke of the ram piston, the throttle setting is probably too high. Back off on the throttle control just enough to avoid this lifting. If the butt of the timber pile has been crushed or broomed more than an inch or so, it should be cut back to sound wood before driving operations continue.

Piles are made of timber, concrete, steel or a combination of these materials.

- Timber Piles – Common timber piles are usually straight tree trunks cut off above ground swell, trimmed of branches, and the bark removed. A good timber pile has the following characteristics:
  - It is free of sharp bends, large or loose knots, splits, or decay.
  - It has a straight line between centers of the butt and tip and lies within the body of the pile.
  - It has a uniform taper from butt to tip.
- Concrete Piles – Two types of concrete piles are precast and cast-in-place. Factors contributing to their use are the availability of the material form which concrete is made.
  - Precast concrete sections that are steel reinforced section that are square or octagonal in shape except near the tip. They vary in length up to 50-60 feet. Because of their eight, greater lengths are generally not feasible. They require time for setting and curing and storage space. Precast concrete piles are frequently driven with the aid of water jetting, as shown in *Figure 21-38.* Water is forced through and out the pile tip through and out the pile tip through jetting pipes constructed into the piles while the pile is driven.

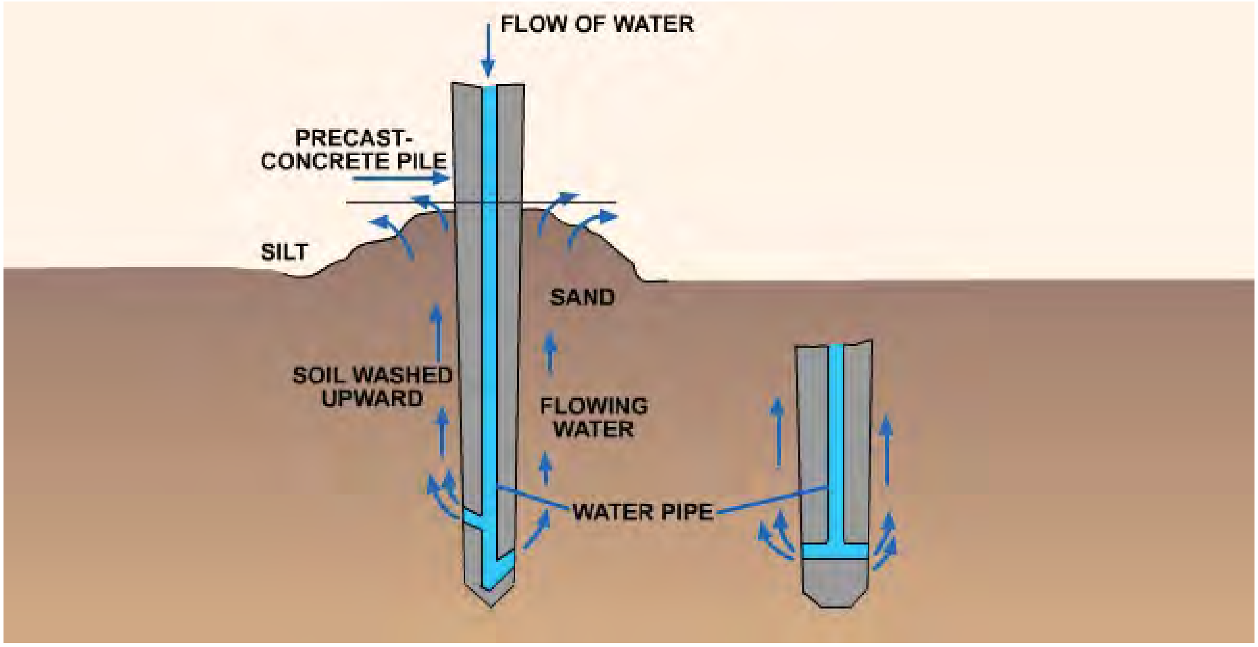

Figure 21-38 – Water jetting precast concrete pile.

- Cast-in-place concrete piles may be used when conditions are favorable. They are made by pouring concrete into a tapered hole or cylindrical form previously driven into the ground or into a hole in the ground from which a driven mandrel has been withdrawn. The left-in-place form may be a steel shell heavy enough to be driven without a mandrel, or it may be a steel form designed for driving with a mandrel that is removed on completion of driving, as shown in *Figure 21-39.*

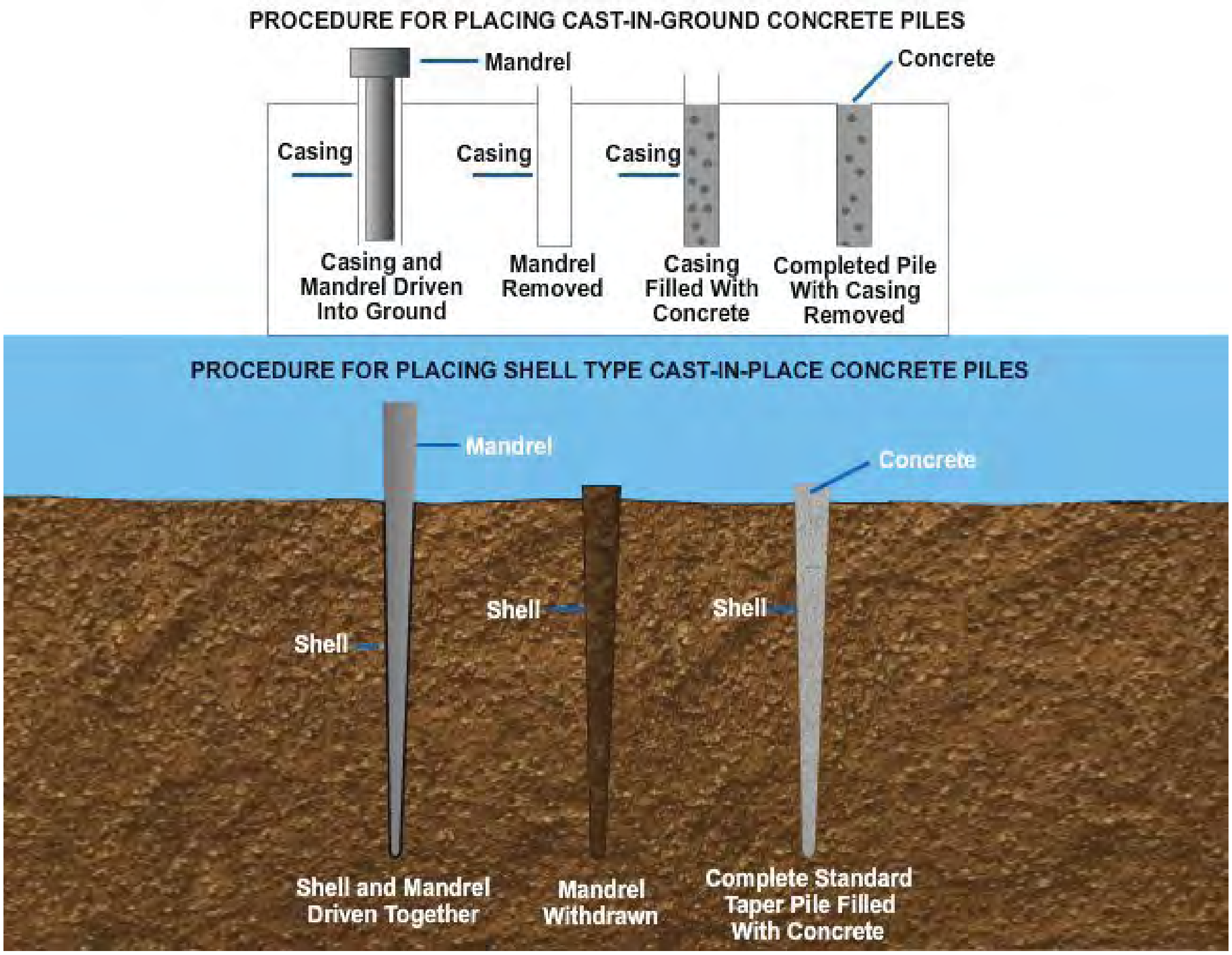

Figure 21-39 – Cast-in-pace concrete piles.

- Composite Piles – Composite piles are formed of one material in the lower section and another material in the upper section, as shown in *Figure 21-40.* A composite pile that is constructed of wood and concrete is used to support loads of 20 to 30 tons. A composite pile that is constructed of steel and concrete is used to support loads up to 50 tons. In *Figure 21-40*, the first section of wood or steel is driven first, and then a mandrel and steel ***casing*** are driven on top of the first section. The mandrel is removed and the casing is filled with concrete.

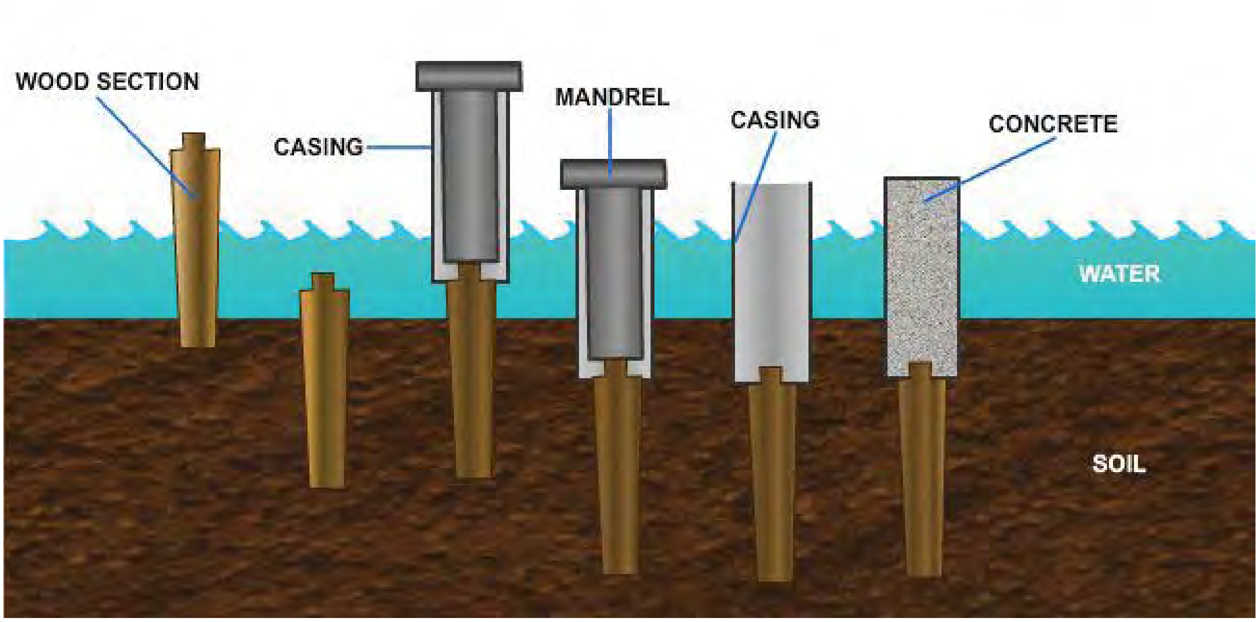

Figure 21-40 – Composite piles.

- Sheet piles – Sheet piles are special shapes of interlocking piles made of steel, wood, or formed concrete which form a continuous wall to resist horizontal pressures resulting from earth or water loads.

  The most common types of sheet piles are straight-web, shallow-arch, and deep-arch, shown in *Figure 21-41*.

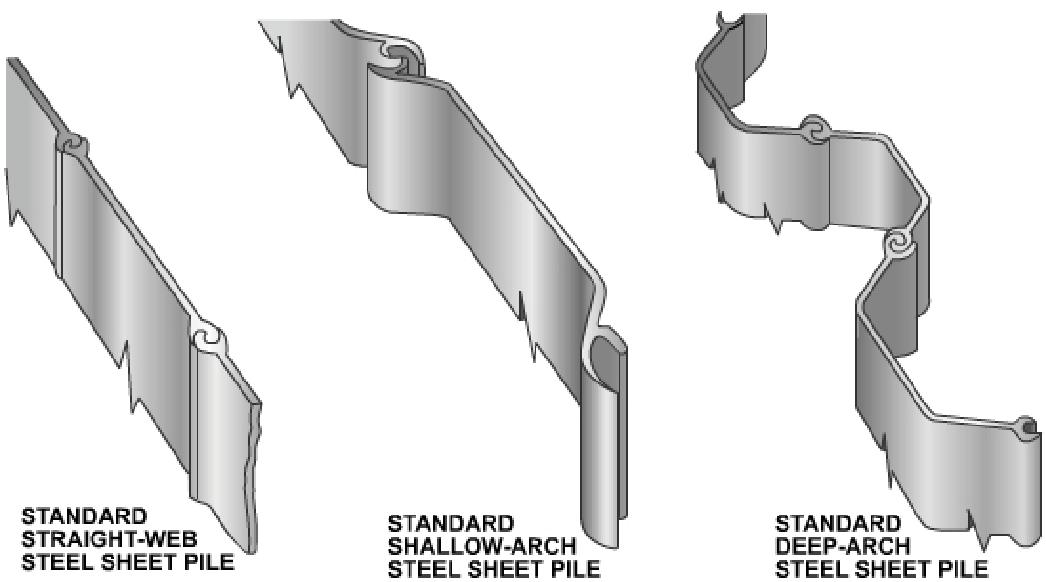

Figure 21-41 – Types of steel sheet piles.

The straight-web section is designed for maximum flexibility and tensile straight; it is particularly adapted to cellular cofferdam and retraining wall construction. The shallow-arch and deep-arch sections are multipurpose sections having some resistance to bending.

5.6.2 Leads

Pile-driving leads serve as tracks along which the pile-driving hammer runs and as guides for positioning and steadying the pile during driving operations. The leads come in 10-, 15-, and 20-foot sections bolted together to form various lengths and run along the sides and back of the hammer as shown in *Figure 21-42.*

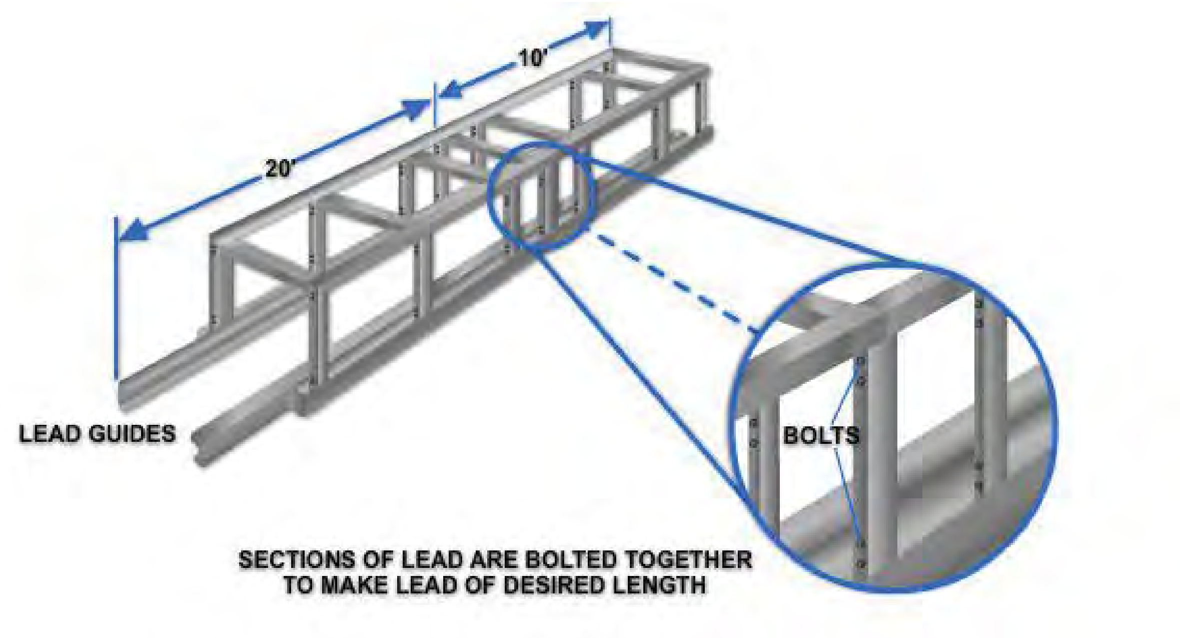

Figure 21-42 – Assembly of 10- and 20 foot lead section.

NOTE

Because of the vibrations created during pile-driving operations, you must check all the lead section bolts for tightness at the beginning of each pile-driving shift.

The types of leads used by the NCF are swinging, underhung, extended four-way, and spud leads.

Swinging Leads – Swinging leads are assembled face down on the ground by bolting the 15-foot tapered section to the selected intermediate sections. Swing leads require a crane equipped with three drums; however, under certain conditions, a crane with only two drums can be used. One single line from the front drum holds the pile, while another single line from the rear drum holds the pile-driving hammer. The hammer is slipped into, and guided by, the rails of the swing leads. The third drum provides the line that supports the lead when raised in a vertical position by a combination of booming, swinging, and/or traveling and is secured in the ground, normally with stabbing points attached to the bottom of the leads, and held plumb or at the desired position as shown in *Figure 21-43*. Short swinging leads are often used to assist in driving steel sheet piles. The boom's head machinery accommodates the drum wire ropes that support the pile, hammer, and leads.

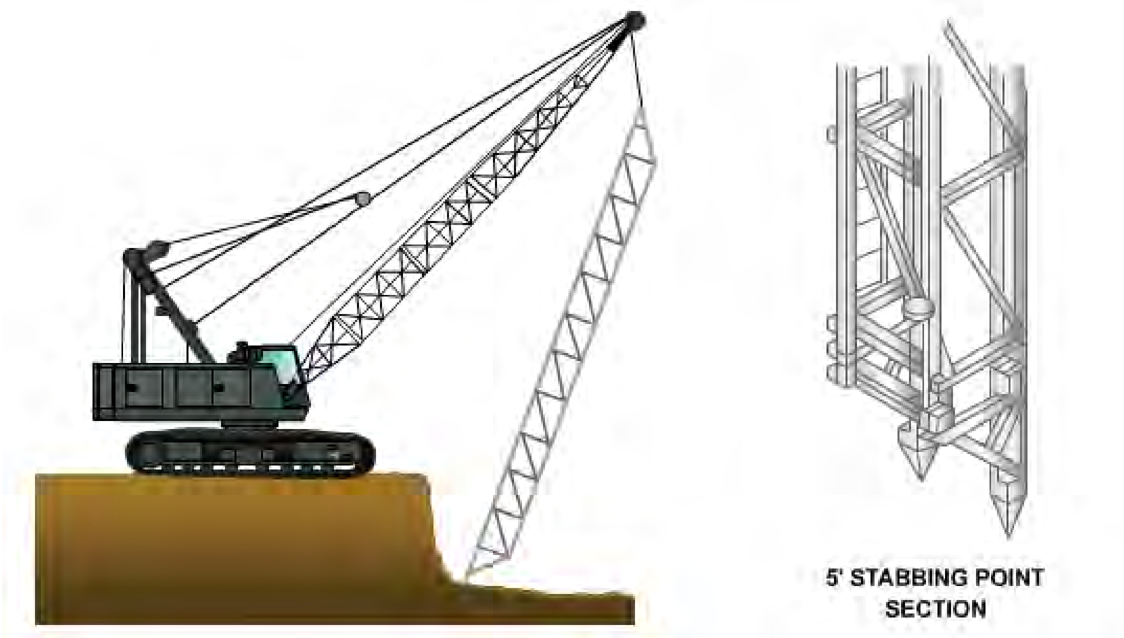

Figure 21-43 – Swing leads.

Some advantages of using a swinging lead over other types of leads are as follows:

- They are the lightest, simplest, and least expensive.
- With stabbing points secured in the ground, these leads are free to rotate sufficiently to align the pile-driving hammer with the pile without precise alignment of the crane with the pile.
- Because these leads are generally 15 to 20 feet shorter than the boom, the crane can reach out farther if it has sufficient capacity.
- They can be used to drive piles in a hole, ditch, or over the edge of an excavation.
- For long lead and boom requirements, the weight of the leads can be supported on the ground and the pile is lifted into place without excessively increasing the working weight.

Some disadvantages of using a swinging lead are as follows:

- It requires a three-drum crane (main line for the pile, secondary for the pile-driving hammer, and third for the leads) or a two-drum crane with the lead hung on the sling from the boom head machinery.
- Because the leads are supported by the hoist wire rope, precise positioning of the leads with the top of the pile is difficult and slow.
- If stabbing points are not secured to the ground, it is difficult to control the increasing the working load weight.

NOTE

The tagline winder may be used to control the twisting of the leads.

- Because these leads are not rigid, it is more difficult to position the crane to set up for pile-driving operations.

Underhung Leads –
Underhung leads are composed of exactly the same sections used for swinging leads. Underhung leads are bolted together on the ground, like swinging leads, and connected to the head machinery through the use of lead adapters shown in *Figure 21-44.* The head machinery is used to accommodate the pile and the pile-driving hammer. All underhung leads have a standard bolt hole layout for bolting the lead adapters to the leads; however, the dimensions of the boom tip end of the adapters vary according to the make and model of the crane.

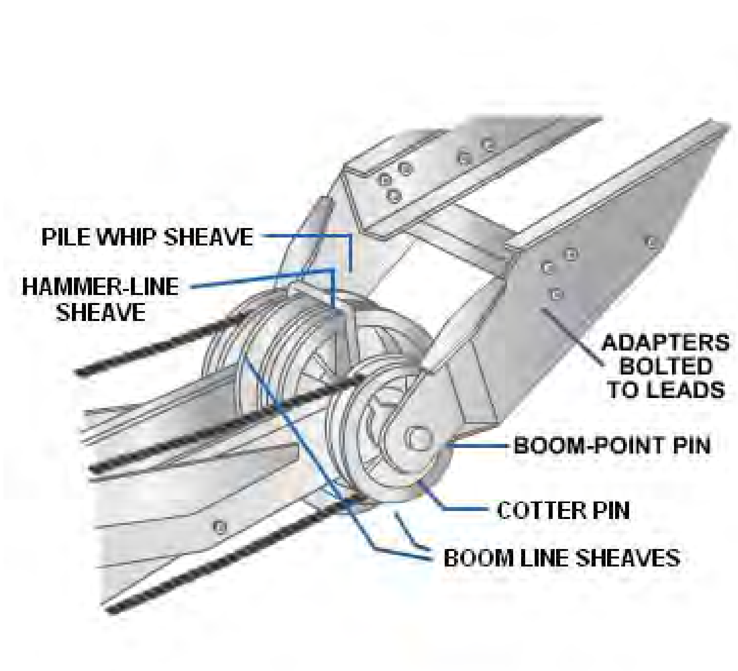

Figure 21-44 – Leads adapters connected to the boom tip.

After the adapters are connected to the boom, the boom is raised to bring the leads to a vertical position as shown in *Figure 21-45.* Long lead sections may require the use of support equipment to raise them to a vertical position.

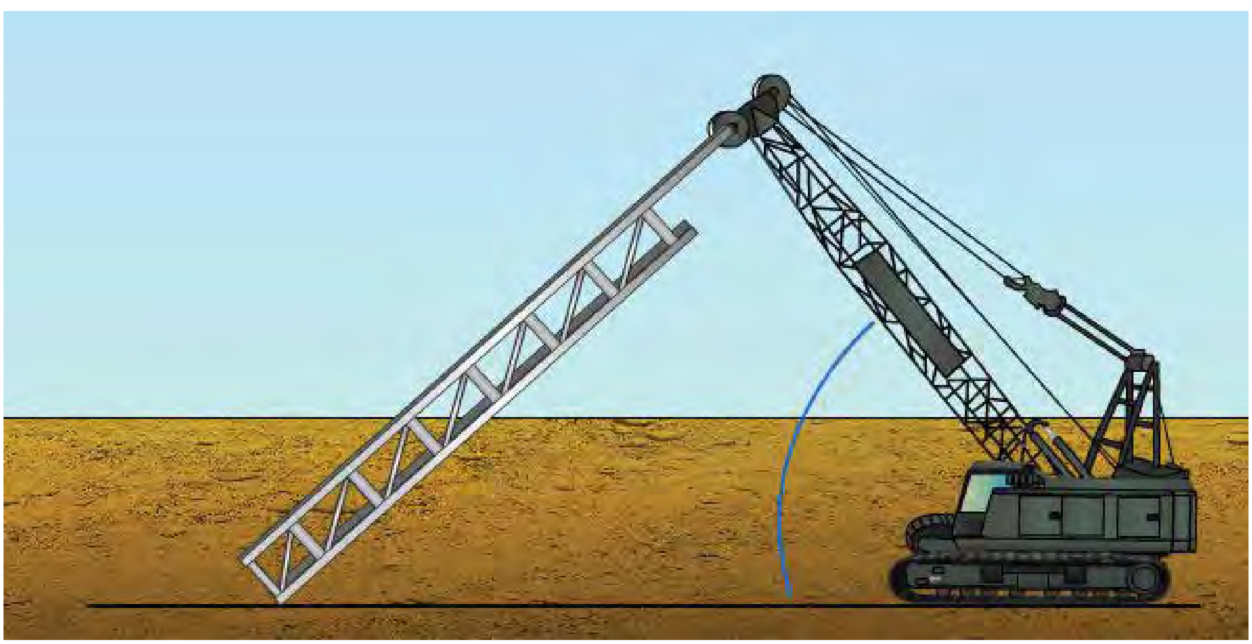

Figure 21-45 – Underhung leads being raised by boom.

NOTE

Check the adapter bolts for tightness at the beginning of each pile-driving shift.

Adapter plates are mounted to the boom base section or crane cab and on the bottom lead section for connection of a fore-and-aft bottom brace, commonly known as a catwalk, shown in *Figure 21-46*. The catwalk can be extended or telescoped to various lengths. It can be set to hold the leads vertical for driving bearing piles or to hold them at an angle for driving batter piles. In use, an underhung lead is held by the boom at a fixed radius.

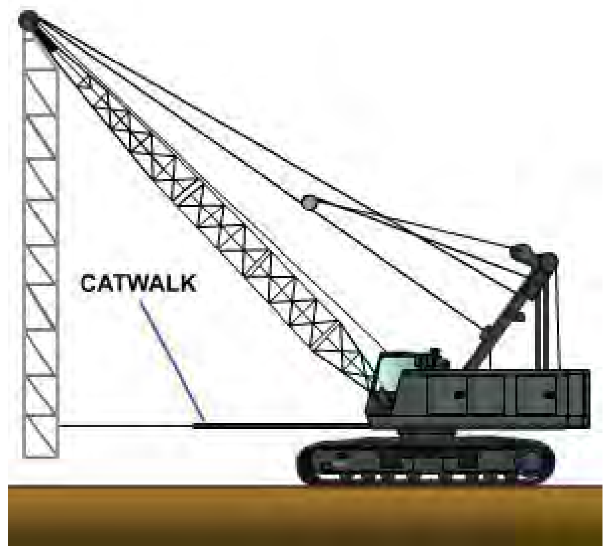

Figure 21-46 – Underhung leads.

Some advantages of using underhung leads over other types of leads areas follows:

- They are lighter and generally less expensive than the extended four-way type of lead.
- They require only a two-hoist drum crane.
- They provide accuracy in positioning leads in vertical and fore-and-aft batter positions.
- They provide precise control of the leads during positioning operation.
- They reduce rigging time in setting up and breaking down.
- They use boom tip sheaves.

Some disadvantages of using underhung leads are as follows:

- They cannot be used for side-to-side batter driving.
- The length of pile is limited by boom length, since this type of lead cannot be extended above the head machinery.
- When long leads require the use of long boom lengths, the working radius that results may exceed the capacity of the crane.
- They do not allow the use of a boom shorter than the lead.

Extended Four-Way Leads – Commonly used by the NCF, extended four-way leads use the same intermediate lead sections as swinging leads and a 30-foot slide section with a sheave head assembly. A universal sliding boom tip connector, slipped into the 30-foot slide section, connects to the boom tip as shown in *Figure 21-47.* The sliding boom tip connector swivels, allowing for driving batter piles in all directions. The boom is lowered over the leads for connecting the boom tip to the sliding boom connector. The connector is bolted into the 30-foot slide section at the location dictated by the amount of lead extension desired above the boom tip.

Figure 21-47 – Sliding boom tip connector.

NOTE

Extension of the lead over the boom tip must not exceed one third of the total lead length or up to 25 feet maximum.

The boom is raised to raise the leads. The type of catwalk used is a hydraulic or mechanical parallelogram bottom brace. This type of brace allows for a fixed radius or side-to-side batter by swinging the linked parallelogram in the desired position. The parallelogram allows for pile driving in all directions at the bottom. *Figure 21-48* shows an extended four-way lead.

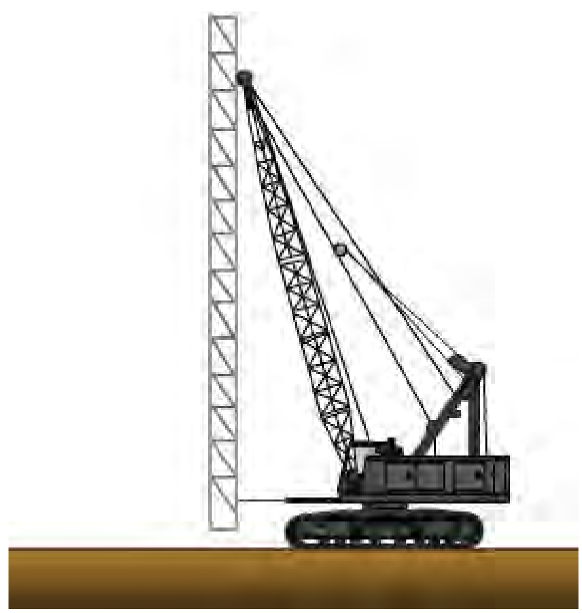

Figure 21-48 – Extended four-way leads

The boom’s head machinery is not used to accommodate the pile-driving hammer and the piles; instead, extended four-way leads are equipped with a special sheave head assembly, shown in *Figure 21-49*, that the two-hoist drum wire rope reeves through to support the pile-driving hammer and the piles.

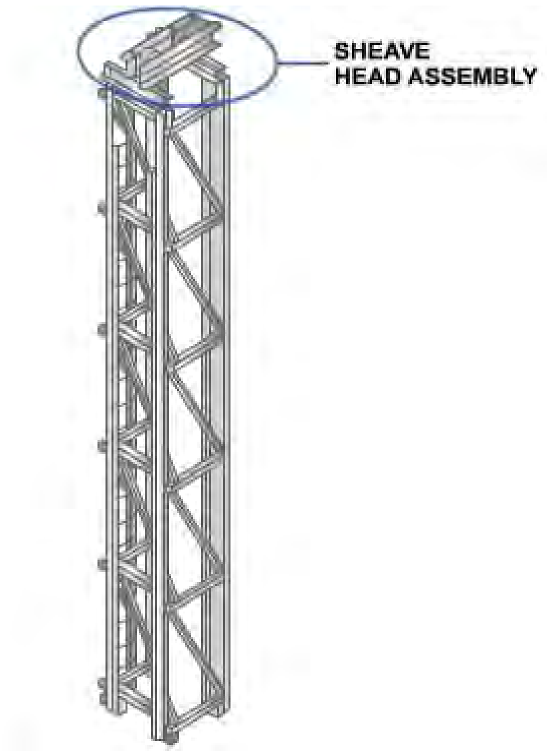

Figure 21-49 – Sheave head assembly.

Some advantages of using an extended four-way lead are as follows:

- It requires only a two-winch drum crane.
- It provides accuracy in locating leads in all batter positions.
- It provides rigid control of the leads during positioning operation.
- It allows batter angles to be set and accurately maintained.
- It allows for the use of short boom angles that increase the crane’s capacity.
- The boom can be lowered and leads folded under for short hauls over the road when a crane with adequate capacity is used. This operation depends on the length of the lead and boom and the configuration of the crane.

Some disadvantages of using an extended four-way lead are as follows:

- It is the heaviest and most expensive of the three basic lead types.
- It is more troublesome to assemble.

Spud Leads –
A spud lead is a steel wide flange or H-beam used in place of pile-driving hammer leads. The pile-driving hammer rides on the flange of the beam through spud clips bolted to one side of the pile-driving hammer, as shown in *Figure 21-50*

Depending on the design of the spud lead, the spud can be used as a swinging and underhung lead or equipped with a sheave head assembly as an extended four-way lead. An advantage of this type of lead is that it bears the whole bottom of the pile cap to the piling especially when sheet piles are being driven *Figure 21-51.*

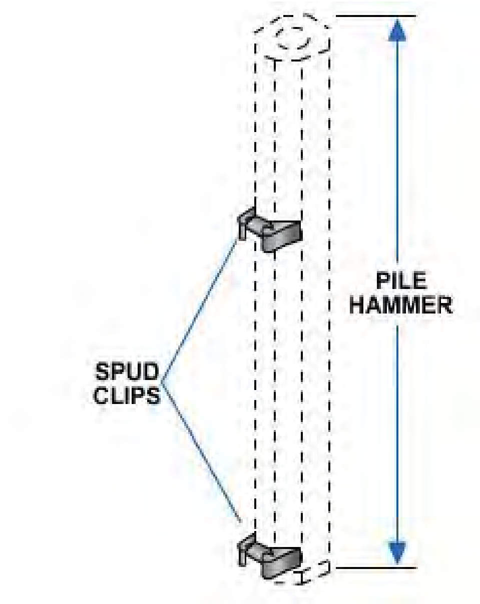

Figure 21-50 – Spud clips mounted to one side of the pile-driving hammer.

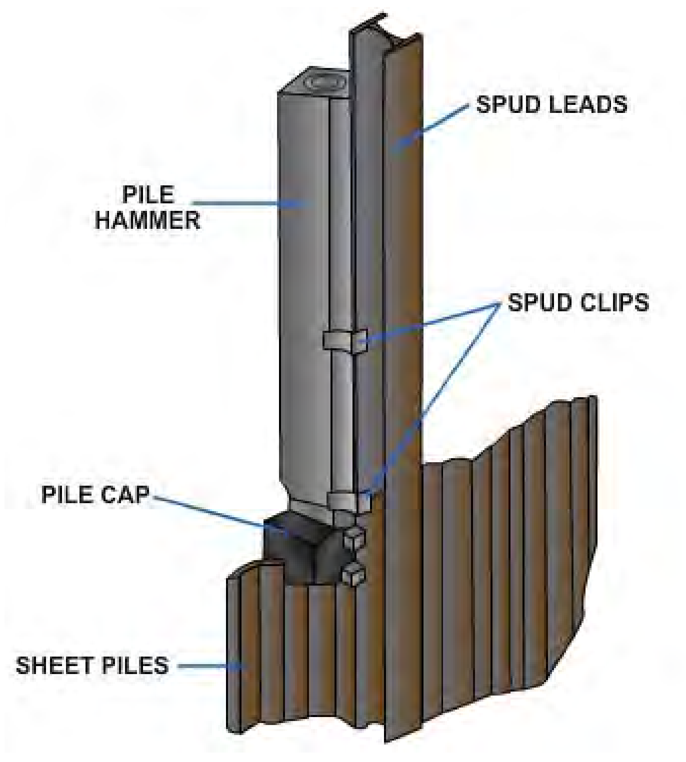

Figure 21-51 – Sheet pile driving with spud leads.

5.6.3 Pile-Driving Hammers

The three principal types of pile-driving hammers are the drop hammer, the screw, or pneumatic hammer, and the diesel hammer.

Drop Hammer – A drop hammer is a block of metal hoisted to a specific height and then dropped on a cap paced on the butt or head of the pile. Drop hammers weigh from 1,200 to 3,000 pounds.

WARNING

The noise generated by a pile driving operation can cause hearing loss. Personnel must wear hearing protection in the vicinity of pile driving operations.

Screw or Pneumatic Hammer – The screw, or pneumatic hammer like the ones shown in *Figure 21-52* has replaced the drop hammer. This hammer consists of a cylinder that contains a screw-driven or air-driven ram. The ram consists of a piston equipped with a striking head. The hammer is rested on the butt or head of the pile for driving.

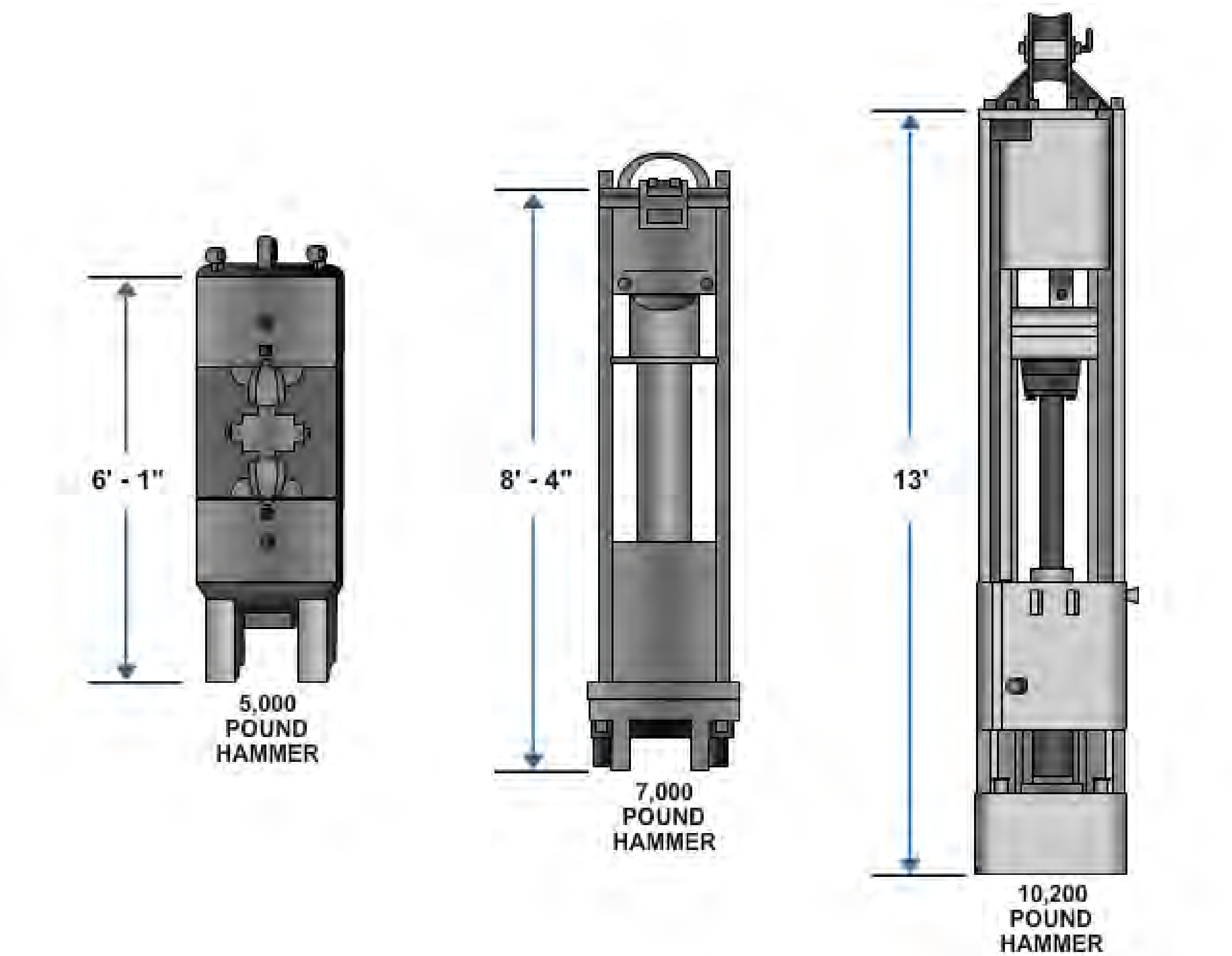

Figure 21-52 – Steam, or pneumatic hammers.

With a single-action screw hammer, the power drive serves only to lift the ram; the downward blow of the ram results from the force of gravity only. In a double-action hammer, the ram is both lifted and driven downward by the power drive. A double-action hammer weighs from 5,000 to 14,000 pounds, and a single-action hammer weighs about 10,000 pounds.

The blows of the double-action hammer are lighter but more rapid than those of the single-action hammer. The double-action hammer generally drives lightweight or average weight piles into soils of average density. The rapid blows tend to keep the pile in motion, thereby reducing the resistance of inertia and friction. However, when you are driving heavy piles in hard or dense soil, the resistance from inertia and friction, together with the rapid, high-velocity blows of the double-action hammer, tends to damage the butt or head of the pile.

The single-action hammer is best for driving heavy piles into hard or dense soil. The heavy ram, striking at low velocity, allows more energy to be transferred into the motion of the pile, thereby reducing impact and damage to the butt or head of the pile.

A conventional pneumatic hammer requires a 600-cubic-foot-per-minute compressor to operate, and the diesel is a self-contained unit constructed in sizes that deliver up to 43,000 foot-pounds of energy per blow. The diesel pile hammer is about twice as fast as a conventional screw hammer of like size and weight.

Diesel Hammer – The diesel hammer is the most common type of hammer in the NCF. *Figure 21-53* shows the components of the Delmag 12-32 diesel hammer. By temporary use of the side lifting ears, rigged to the whip line, such a hammer is inserted into extended four-way leads by following a specific SOP titled Assembly and Disassembly for Pile Driving Operations. Inserting the hammer into leads is by far the most dangerous of all types of pile driving operations and should be attempted only by experienced operators.

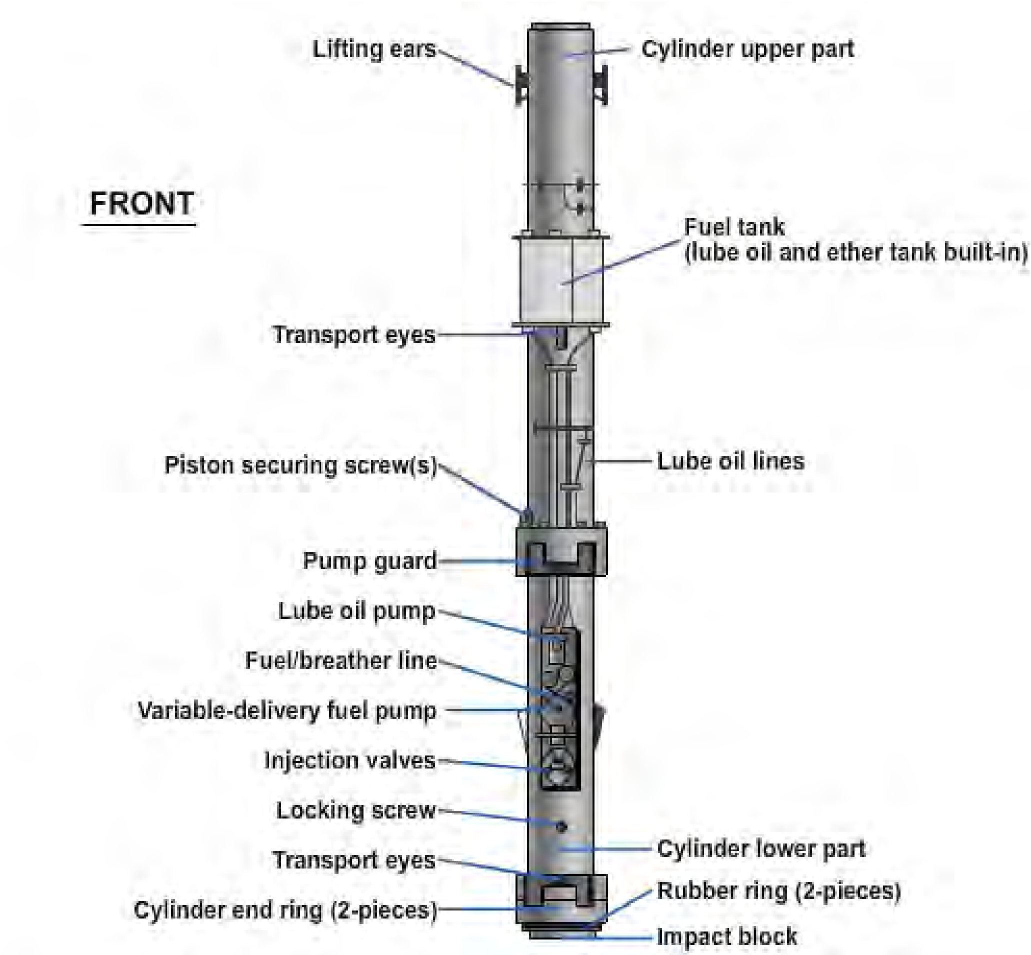

Figure 21-53 – Diesel hammer.

Rigged to the main drum by a single line, a trip device, located at the rear hammer, raises and lowers the hammer and piston.

As shown in *Figure 21-54*, the trip device consists of a retractable pawl and a turntable carrier with rotating arms, all of which operate in conjunction with of a pawl lever and a turntable carrier lever, which an operator positioned behind the hammer uses a tagline to pull down.

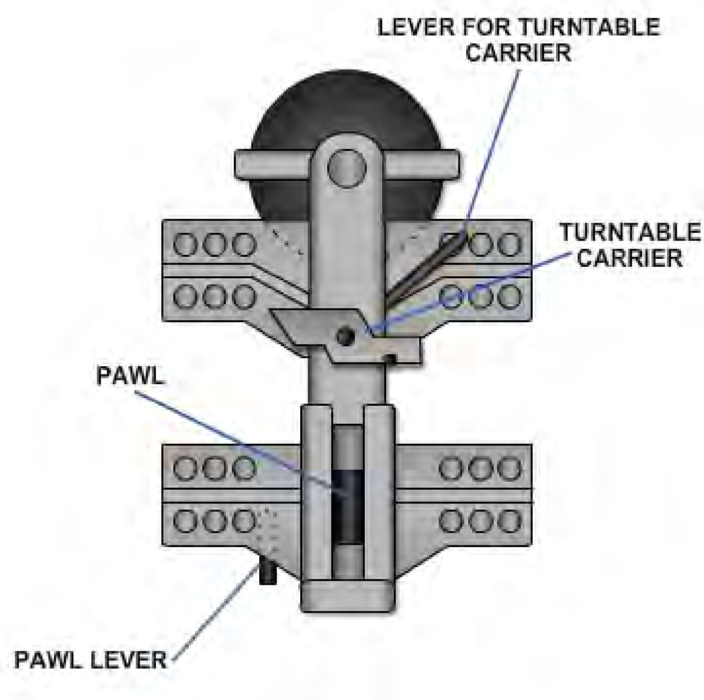

Figure 21-54 – Trip device.

The working principle of the trip device includes lowering the trip device, raising and lowering the hammer, and raising the piston for starting.

Lowering the trip device engages the piston. Lower the trip device by pulling and holding the turntable carrier lever, which causes the pawl to retract, the pawl lever to lower, and the turntable carrier arms to rotate counterclockwise and position themselves vertically so that the trip device can pass the hammer supports. As soon as the pawl lever hits the lower stop, it is pushed upwards, causing the pawl to extend and engage into the piston's lifting groove and the turntable carrier arms to rotate clockwise and position themselves horizontally.

When raising the trip device and subsequently the hammer, the turntable carrier arms should be in firm contact with both hammer supports. During this time, do not pull the turntable carrier lever.

To raise the piston, pull and hold the turntable carrier lever. Lower the trip device to engage the piston. After the trip device is past the hammer supports, the turntable carrier lever can be released. The engaged pawl raises the piston up to its starting position where the upper stop allows the piston to fall.

Figure 21-55 shows the working principle of the trip device.

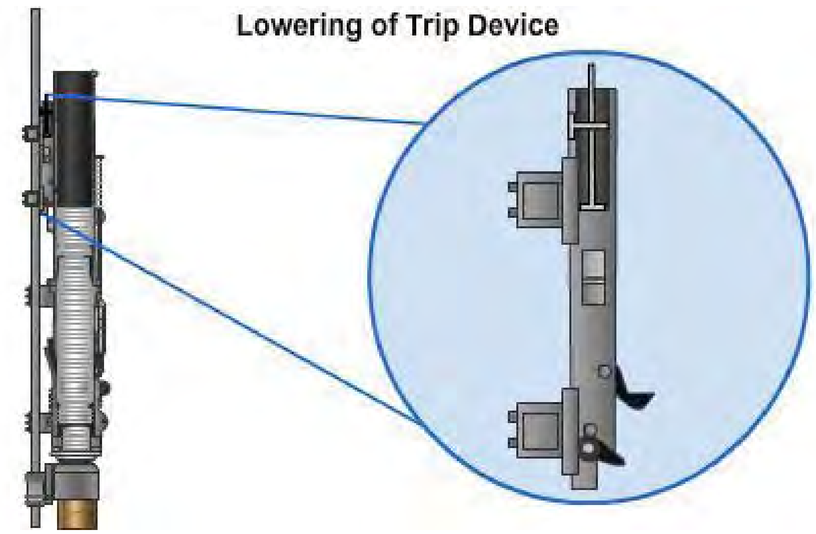

Figure 21-55 – Trip device working principle in action.

The diesel hammer has four operating cycles: injection of diesel oil and compression, impact and explosion, exhaust, and scavenging.

- Injection of the Diesel Oil and Compression: The falling piston actuates the pump lever, injecting a certain amount of diesel oil onto the surface of the impact block. As soon as the falling piston passes the exhaust ports, compression of the air trapped in the cylinder commences. The increasing compression presses the impact block and the pile helmet firmly onto the pile head.
- Impact and Explosion: When the piston end hits the impact block, the diesel oil in the combustion chamber is atomized and the pile driven downward into the ground. The atomized fuel ignites in the highly compressed air and the resulting explosion energy drives the pile further into the ground and simultaneously drives the piston upwards.
- Exhaust: The ascending piston opens the exhaust ports, releasing the exhaust gases, and the pressure in the cylinder returns to normal.

- Scavenging: As the piston continues to ascend, fresh air is sucked in through the exhaust ports, thoroughly scavenging the cylinder and thereby releasing the pump lever. The pump lever returns to its original position, again sucking diesel oil into the fuel pump.

Figure 21-56 shows these operating cycles.

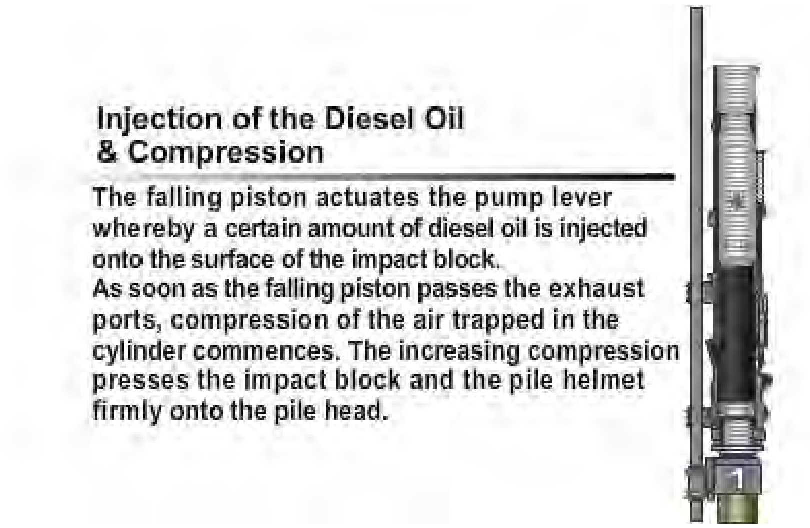

Figure 21-56 – Diesel hammer operating cycle.

As shown in *Figure 21-57*, the Delmag 12-32 has a front-mounted, variable delivery fuel pump. When pulled, the longer fuel line stops the fuel injection. It is connected to a rope so that is can be pulled for the ground. The shorter fuel lines increases and decreases the amount of diesel oil injected onto the surface of the impact block. As shown in *Figure 21-58*, an operator must climb the leads to the pump in order to pull either one of these fuel lines.

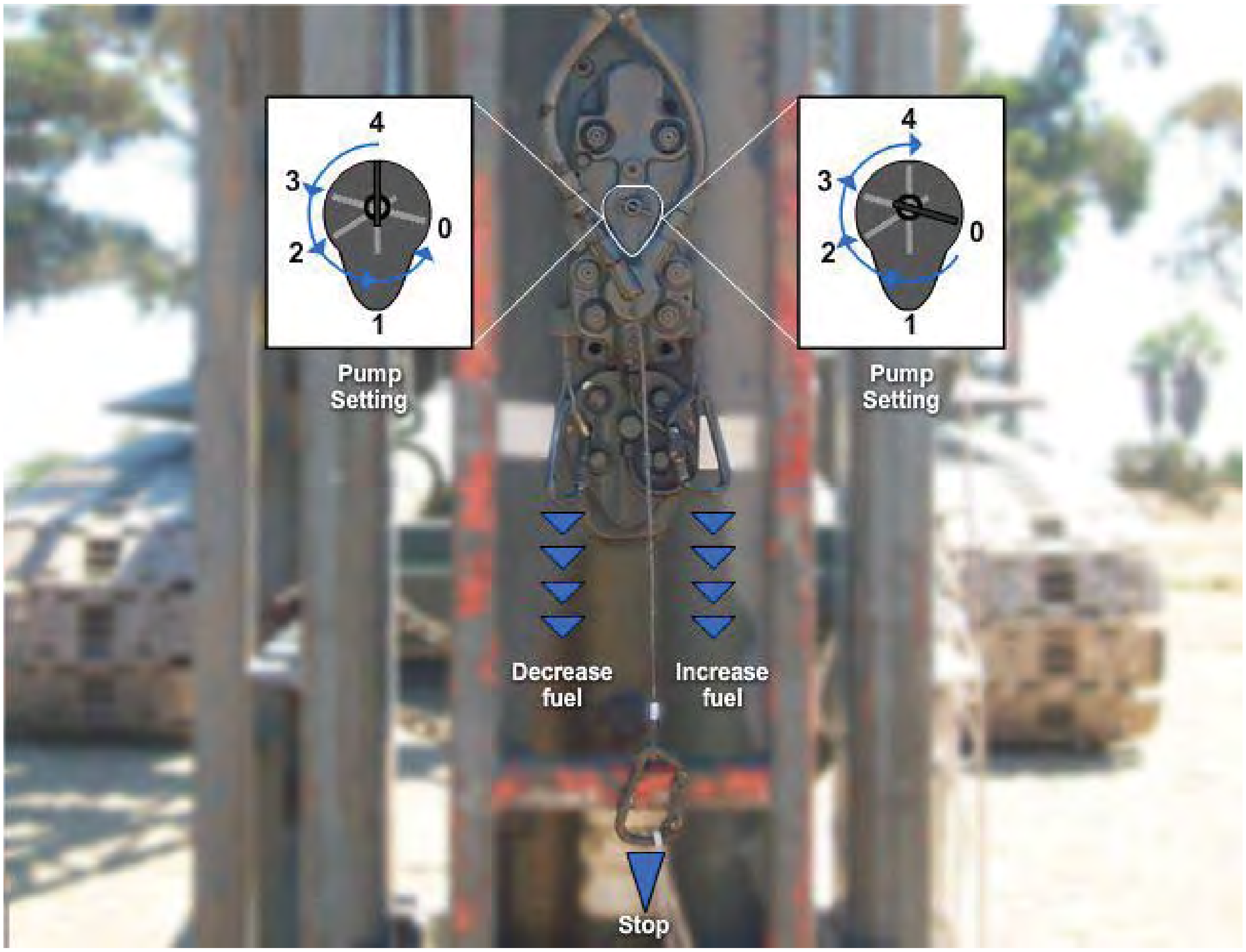

Figure 21-57 – Variable-delivery fuel pump (hammer in lowered position).

Figure 21-58 –Increasing fuel delivery (hammer in operating position).

During pile driving operations, the lube oil pump automatically lubricates the upper cylinder part. However, addition lube oil additives are recommended. Refer to the hammer's operator's manual.

After every 4 hours of operating, replenish the lube oil tank. Do this by disconnecting the lube oil pressure lines from the pump and filling the lube oil pressure lines from below using a force-feed oil can until oil runs from each pipe socket. Then reconnect the lines and the pump. Always check the tank's oil level to ensure it is full.

A pile-driving cap is a block (usually a steel block) that rests on the butt or head of the pile and protects it against damage by receiving and transmitting the blows of the hammer or ram. In the screw hammer, the cap is a part of the hammer. The cap with a drop or diesel hammer is a separate casting with the lower part recessed to fit the head or butt of the pile and the upper part recessed to contain a hard cushion block that receives the blows of the hammer. The cap is fitted with a wire rope sling so that the cap, as well as the hammer, may be raised to the top of the leads when positioning a pile in the leads.

NOTE

Keep the top of the cushion block high enough to prevent the hammer shroud from fouling on the rim of the drive cap pocket.

Pile-driving caps are available for driving timber, concrete, sheet, and H-beam piles. *Figure 21-59* shows a pile cap designed for driving an H-beam pile.

Figure 21-59 – H-beam pile driving cap.

Test your Knowledge (Select the Correct Response)

7. What is the name of the single part line that the headache ball is rigged to?

   A. Headache whip
   B. Whip line
   C. Ball line
   D. One line

8. What attachment is used for vertical digging of loose to medium compacted soil?

A. Hook Block
B. Clamshell
C. Dragline
D. Pile-driver

6.0.0 CRANE CREW

The skills and safety standards demanded for efficient crane operations require that only mature professionals be assigned as crane operators and riggers. The supervisor of the crane crew is normally the best crane operator available within the battalion-wide assets and is assigned and designated in writing by the commanding officer. The equipment officer, the crane test director, and the crane crew supervisor share the responsibility of ensuring that any personnel that prepare, assemble, operate, or work with or around cranes are well trained in both safety and operating procedures.

Before you receive a license to operate a crane, you are required to attend the General Crane Safety course, as outlined in NAVFAC P-307. After attending such course, you must pass a written and performance test for the type of crane for which a license is to be issued. The crane certifying officer may be assisted in administering the performance test by the crane test director. The equipment officer is normally responsible for the duties of the crane certifying officer and is designated in writing by the commanding officer. The crane certifying officer designates in writing the crane test director and all crane test personnel. Crane license is issued on the Construction Equipment Operator License, NAVFAC 11260/2, and will indicate the make, model, capacity, and the attachments the operator is qualified to operate.

Additionally, operators who need to renew their license must complete the online General Crane Safety Refresher course at Navy Knowledge Online (www.nko.navy.mil).

Crane accidents take a heavy and tragic toll each year in lives, serious injury, and/or property damage. The vast majority of crane accidents results from personnel error and can be avoided. Crane operation safety is the result of effective crew work among operators, riggers, and crane walkers. In most accidents, a crane crew member either performs an unsafe action or fails to perform a required safe action. In a vast majority of cases where crew members are at fault, the problem is inattention, poor judgment, overconfidence, or haste to get the job done. This section describes the responsibilities of each crane member as outlined in NAVFAC P-307.

A crane crew consists of a crane operator, rigger-in-charge, crane riggers, and crane walkers, as required. A crane crew supervisor also referred to as rigger supervisor designates the rigger-in-charge, crane riggers, and crane walkers. The size of the crew will vary to suit the job as determined by the rigger supervisor.

6.1.0 Crane Crew Supervisor

Although not a crane crew member, the crane crew supervisor responsibilities are as follows:

- Designate crane crew members
- Review on-site conditions for complex lifts

- Perform a pre-job briefing before each complex lift to ensure all crane crew members understand the required procedures for the lift
- Supervise lifts exceeding 80 percent of the certified capacity of the crane's hoist used for the lift

6.1.1 Crane Lift Checklist

The Crane Lift Checklist shown in *Figure 21-60* is outlined in the COMFIRSTNCDINST 11200.2. It must be filled out by the crane crew supervisor or the crane test director before the crane can proceed to any project or make any crane lift. After the Crane List Checklist list is complete, the crew supervisor briefs the operator and riggers on specifics of the lift and travel conditions.

CRANE LIFT CHECKLIST

DATE ________

1. Location of lift: ____
2. Supervisor responsible for lift: ____________________________________
3. Crane Operator: ____
4. Rigger(s)/Helper(s): ____
5. Lift: ____
   a. Description of lift: ____
   b. Weight of load to be lifted (in lbs.): ______________________________
   c. Is weight estimated? Yes ________ No ________ By Whom: ________
   d. Can weight be verified? Yes _______ No ________ If no, contact Crane Certifying Officer for further instructions.
   e. Is the load non-symmetrical? Yes _______ No ________ If yes, follow the procedures in the NCC crane rigging course manual (show calculations on the reverse side of the checklist).
6. Crane(s) assigned to lift: ____
   a. USN#: ____
   b. Certified capacity (in lbs.): ____________________________________
   c. Rated capacity (in lbs.) _____________ at _____________ FT. boom
7. Is travel route safe and free of obstacles? Yes _______ No ________
8. Has travel permits been obtained (if required)? Yes _______ No ________
9. Have operators and riggers been briefed on the operation/lift sequence? Yes _______ No ________
10. Has the crane been inspected for stability? Yes _______ No ________ If no, explain. ____
11. Has the crane operating area been inspected? Yes _______ No ________ If no, explain. ____
12. Have slings and other hardware being used been inspected? Yes _______ No ________ If no, explain. _______________________________________
    a. List the type, size and capacity with ID number of the rigging gear and hardware. ____
13. Is the capacity of slings based upon the sling angle at which the sling will be used? Yes _______ No ________

Figure 21-60 – Crane lift checklist.

Crane Stability – Setting up for a crane lift is the most critical portion of the crane operation. The most common causes of crane mishaps are as follows:

- Failure to block/crib under the outrigger pads when poor ground conditions cannot support the total weight of the crane and load. Proper and improper cribbing is shown in *Figure 21-61.*

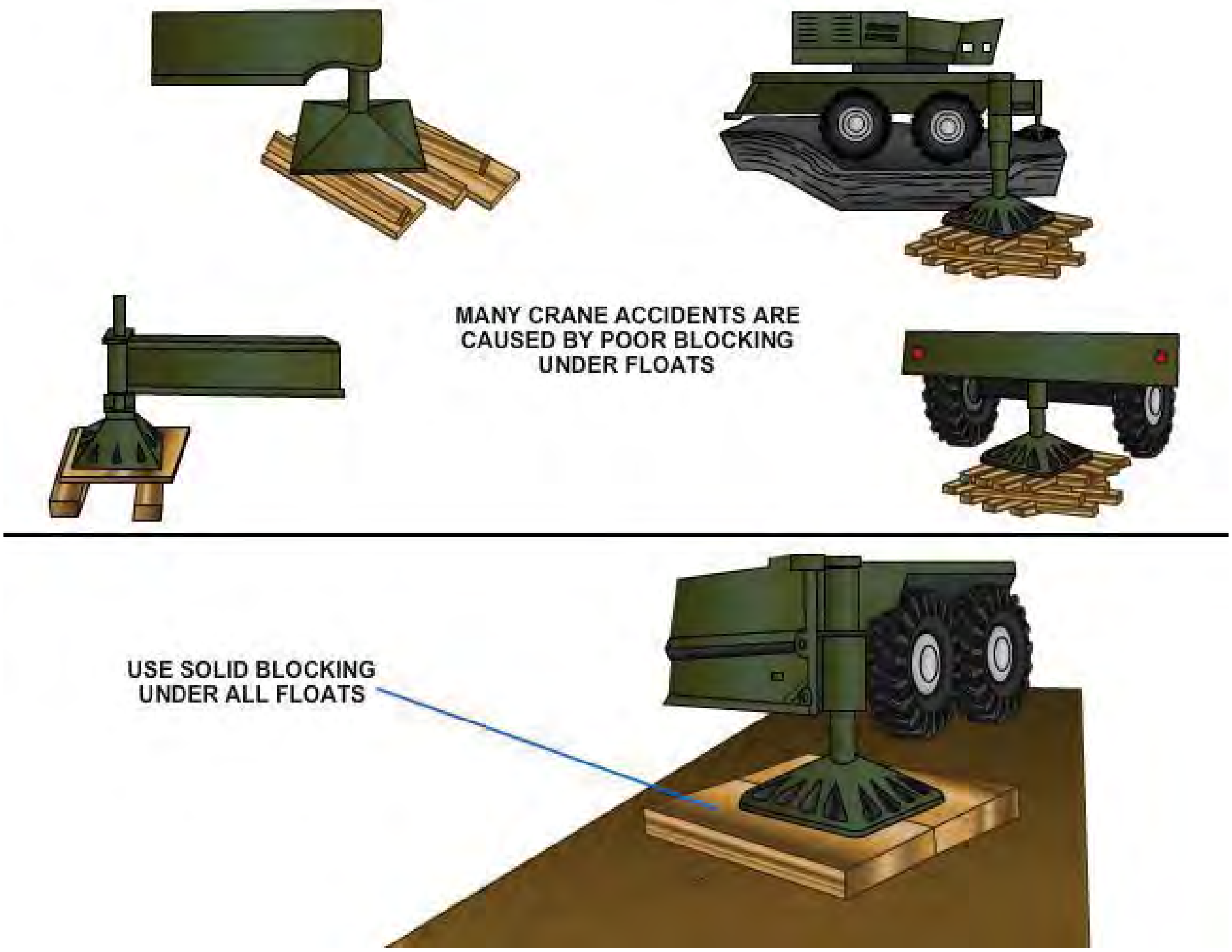

Figure 21-61 – Proper and improper cribbing.

- Failure to extend the outriggers fully and use them following the manufacturer's instruction
- Failure to note overhead obstructions, such as overpasses and power lines
- Failure to level the crane. Leveling the crane cannot be overemphasized. Cranes must be set up per manufacturer's instruction with all outriggers fully extended and the crane leveled. Crane capacity is lost when the crane is out of level by only a few degrees, as shown in *Table 21-1.*

Table 21-1 – Crane capacity lost by crane out of level.

BOOM LENGTH and LIFT RADIUS	Chart Capacity Lost When Crane Out of Level By		
	1°	2°	3°
Short Boom, Minimum Radius	10%	20%	30%
Short Boom, Maximum Radius	8%	15%	20%
Long Boom, Minimum Radius	30%	41%	50%
Long Boom, Maximum Radius	5%	19%	15%

For some cranes, being out of level just 3 degrees can reduce listed capacity by as much as 50%. Most cranes have levels mounted on them, but the levels are not always accurate. Use a 3-foot builder's level to check the level of the crane over the front or rear and over the sides as shown in *Figure 21-62*. Another quick way to check for level is to sight along hoist wire rope. It should hang in line with boom centerline in all quadrants.

Figure 21-62 – Leveling procedures using a builder level.

Load Capacity – The rated capacities of mobile cranes are based on both strength and stability. Manufacturers of cranes will normally denote on the load rating charts a shaded area or a bold line across the chart dividing the lifting capacities based on strength or stability of the crane. It is extremely important to know the difference for, in one case, one of the structural components of the crane will break and, in the other case, the crane will tip over.

Additionally, you must recognize the following factors and adjust the capacity accordingly:

- Do not use stability to determine lifting capacity. Use the load rating chart provided by the crane manufacturer. The load rating chart is securely attached in the operator's cab.
- The number of parts of line on the hoist and the size and type of wire rope for various crane loads
- Length of boom
- Boom angle
- Boom pendant angle (when the telescopic/ folding gantry is down, the angle decreases and the stress increases)
- Gantry and/or live mast in the highest position
- Quadrant of operation (that is, over the side, over the rear capacities).

Load Rating Chart – *Figure 21-63* shows the load rating chart for the Link-Belt HTC-8640. To determine the capacity of the crane by using the load rating chart, the operator must know the length of boom, the load radius, the boom angle, and if the lift is to be performed over the side or over the rear. When performing lifts using the boom angle indicator that indicates an angle not noted on the load rating chart, use the next lower boom angle noted on the load rating chart for determining the capacity of the crane. For example, using chart in *Figure 21-63*, the crane is rigged with 33 feet of boom, and the boom angle indicator indicates a boom angle of 67 degrees. A 67-degree boom angle load capacity is not noted on the load rating chart, so you must use the next lower noted boom angle of 66 degrees for determining the capacity of the crane.

Rated Lifting Capacities In Pounds
Fully Extended Outriggers
See Set Up Note 2

6,700 lbs.
FULL EXTENSION
MAIN BOOM "A"

Load Radius (Ft.)	33Ft.			40Ft.			Load Radius (Ft.)
	∡°	360°	Over Rear	∡°	360°	Over Rear	
9	68.0	80,000	80,000				9
10	66.0	72,300	72,300	70.5	72,300	72,300	10
12	62.0	65,800	65,800	67.5	65,500	65,500	12
15	55.5	55,800	55,800	62.5	55,600	55,600	15
20	43.5	40,700	40,800	54.0	40,200	40,200	20
25	26.5	27,200	27,200	44.0	27,000	27,000	25
30				31.0	19,400	19,400	30
Min.Bm Ang./Cap	0 (27.5)	18,400	18,400	0 (34.5)	14,100	14,100	Min.Bm Ang./Cap
Load Radius (Ft.)	50 Ft.			57 Ft.			Load Radius (Ft.)
	∡°	360°	Over Rear	∡°	360°	Over Rear	
10	75.0	67,500	67,500	77.0	43,800	43,800	10
12	73.0	61,200	61,200	75.0	43,800	43,800	12
15	69.0	53,400	53,400	72.0	42,100	42,100	15
20	62.5	39,600	39,600	66.5	34,300	34,300	20
25	55.5	26,600	26,600	60.5	26,300	26,300	25
30	48.0	19,100	19,100	54.5	18,900	18,900	30
35	39.0	14,300	14,300	47.5	14,200	14,200	35
40	27.5	10,900	10,900	40.0	10,800	10,800	40
45				30.5	8,200	8,300	45
50				16.0	6,100	6,400	50
Min.Bm Ang./Cap	0 (44.5)	8,400	8,600	0 (51.5)	5,500	5,900	Min.Bm Ang./Cap

Note: Refer To Page 5 For "Capacity Deductions For Auxiliary Load handling Equipment".
∡° Loaded Boom Angle In Degrees
( ) Reference Radius For Min. Boom Angle Capacities (Shown in Parenthesis) Are In Feet.

Figure 21-63 – Link-belt HTC-8640 load rating chart.

NOTE

Do not rely on the boom angle indicator for radius accuracy when lifts exceed 75 percent of the rated capacity. Measure the radius to avoid the possibility of error.

When using a radius measurement not noted on the load rating charts, use the next longer radius measurement noted on the chart for determining the capacity of the crane. For example, using the load rating charts in *Figure 21-63*, the crane is rigged with 50 feet of boom, and the radius measurement is 18 feet. An 18-foot radius measurement is not noted on the load rating charts, so you must use the next longer radius measurement of 20 feet noted on the chart for determining the capacity of the crane.

The number of part lines reeved on the main hoist block can affect the capacity of the crane. If the crane is capable of being reeved with an eight-part line and the reeving is changed to a six-part line, the capacity of the crane changes. On newer models of cranes, the capacity for different parts of line configurations is noted on the load rating charts. On older models, you must refer to the manufacturer's manual.

The load rating chart provides the capacity of the crane with outriggers set and without outriggers. "Outriggers Set" means the outriggers are fully extended and the weight of the crane is off of the suspension system or the tires are off the ground. If a situation arises where the outriggers cannot be fully extended, you must use the without outriggers load capacity ratings.

NOTE

Load capacities change when swinging from each quadrant of operation, such as from over the rear to over the side.

Safe Lifting – The following factors are basic guidelines to perform safe daily crane operations:

- Determine the weight to be lifted and the crane required to make the lift safely.
- Travel the proposed route the crane will follow to and from the project site, and complete the Crane Lift Checklist.
- Obtain travel permits if required.
- Brief operators and riggers on the specifics of the lift and travel conditions.
- Inspect the crane area setup for stability and safe operating area.
- Fully extend the outriggers and use them according to the manufacturer's instruction.
- Check the crane for levelness.
- Inspect all rigging hardware.
- Select the proper sling, one with sufficient capacity rating.
- Center the sling in the base (bowl) of the hook to avoid hook point loading, and ensure the hook block is always placed over the center of the load to eliminate shock loading of the slings or cranes from load shifts when making a lift.
- Make ample safety allowances for unknown factors.
- Stand clear of and do not walk under suspended loads.

- Boom deflection – All crane booms have deflection. When the load is lifted off the ground, the boom will deflect, causing the radius to increase. Increased radius may cause overloading of the crane.
- An uncontrolled swinging load can cause the radius to increase.
- Clean the operating area. Water coolers, excess tools, grease, soda cans, and other unnecessary items should be kept outside of the operating area of the crane. Water coolers must be kept off the crane to prevent people from congregating around the crane when in operation.

NOTE

Safe lifting is paramount! Project completion must not interfere with safe crane operation.

6.2.0 Rigger-in-Charge

The rigger-in-charge serves as crewleader and has overall control of the operation including the following:

- Planning all aspects of the lift
- Determining the weight of the load to be lifted
- Establishing the appropriate method of communication such as hand signals, radios, or relayed signals
- Ensuring the load is properly rigged
- Ensuring the crane operating envelope, or working area, remains clear of all obstructions
- Providing signals to the operator or assigning another rigger or signal person to provide the signals
- Conducting the operation in a safe manner
- Coordinating the activities of other crane crew members

6.3.0 Crane Rigger

The crane rigger is responsible for carrying out the assignments from the rigger-in-charge or the rigger supervisor including the following:

- Assisting the crane operator in performing his pre-use check of the crane
- Proper gear selection and inspection prior to use
- Safe rigging of the load
- Keeping the rigger-in-charge informed of questionable conditions associated with the operation

6.4.0 Crane Walker

Crane walker responsibilities are as follows:

- Assisting the rigger and operator in the pre-use check of the crane
- Ensuring the safe travel of the crane by observing for potential obstructions,
- Properly aligning crane rail switches

- Being in a position to immediately notify the operator to stop operations should a potential problem arise

6.5.0 Operator

The primary responsibility of the operator is the safe operation of the crane. Operator responsibilities include the following:

- Performing a pre-use check of the crane at the start of the shift
- Fully understanding the lift, prior to starting
- Participating in pre-lift briefings
- Maintaining communication with the rigger-in-charge or designated rigger throughout the operation
- Making movements only when given the direction to do so
- Refusing to operate the crane when there are concerns about the safety of the operation

6.5.1 Crane Operator’s Daily Checklist

Every day, prior to operating a crane, an operator must complete a prestart inspection using a Crane Operator’s Daily Checklist (ODCL) shown in *Figure 21-64*. The ODCL indentifies components common on most types of cranes that are critical to safe crane operation; however, it can be customized for cranes equipped with ***load bearing*** or ***load controlling parts*** or ***safety devices*** not identified.

CRANE OPERATOR'S DAILY CHECK LIST

CRANE NO.	TYPE/CAPACITY	LOCATION	CERTIFICATION EXPIRATION DATE	SHIFT			HOUR METER		HRS OPERATED	DATE
				1	2	3	START	STOP		

OPERATORS

LEGEND: S = SATISFACTORY U = UNSATISFACTORY NA = NOT APPLICABLE

	1 WALK AROUND CHECK	S	U	NA		2 MACHINERY HOUSE CHECK	S	U	NA		3 OPERATOR CAB CHECK	S	U	NA		4 OPERATIONAL CHECK	S	U	NA
a	Safety Guards and Plates				a	Housekeeping				a	Gauges				a	Area Safety *			
b	Carrier Frame and Rotate Base *				b	Diesel Engine and Generator *				b	Indicator and Warning Lights				b	Outriggers and Stabilizers *			
c	General Hardware				c	Leaks				c	Visibility *				c	Unusual Noises			
d	Wire Rope *				d	Lubrication				d	Load Rating Charts *				d	Control Action *			
e	Reeving *				e	Battery				e	List/Trim Indicator (Floating Cranes) *				e	Wire Rope or Chain *			
f	Block *				f	Lights				f	Boom Angle/Radius Indicator *				f	Brakes and Clutches *			
g	Hook *				g	Glass				g	Fire Extinguisher				g	Boom Angle/Radius Indicator *			
h	Sheaves or Sprockets *				h	Clutches and Brakes *				h	Level Indicator (Mobile Cranes) *				h	Limit Switches *			
i	Boom and Jib *				i	Electric Motors *				i	Danger/Caution Tags *				i	Emergency Stop *			
j	Gantry, Pendants, and Boom Stops *				j	Auxiliary Engine and Compressor									j	Other Operational Safety Devices *			
k	Walkways, Ladders, and Handrails				k	Danger/Caution Tags *									k	General Safety Devices			
l	Windlocks, Stops, and Bumpers				l	Fire Extinguishers									l	Fleeting Sheaves			
m	Tires, Wheels and Tracks				m	Hoist Drum Pawls and Rachets *													
n	Leaks																		
o	Outriggers and Stabilizers *																		
p	Load Chain *																		
q	Area Safety *																		

INSTRUCTIONS - Check all applicable items indicated, each shift. Suspend all operations immediately when observing an unsatisfactory condition of any item indicated with an asterisk (*) unless the condition has been reviewed and continued operation has been authorized by the activity engineering organization. In addition, suspend operation when any unsafe condition is observed and immediately notify supervisor. For any unsatisfactory item, identify the specific component and describe the deficiency in the "Remarks" block.

SUPERVISOR'S SIGNATURE

DATE

FIRST OPERATOR'S SIGNATURE	OPERATOR'S SIGNATURE	OPERATOR'S SIGNATURE	OPERATOR'S SIGNATURE
DATE	DATE	DATE	DATE

REMARKS

Figure 21-64 – Crane operator's daily checklist.

As shown, items are grouped in four major areas: a walk around check, a machinery house check, an operator cab check, and an operational check. They may be inspected in any sequence. Items with an asterisk are either load bearing or load controlling parts or safety devices, which must be thoroughly inspected for deficiency. Depending on the condition of the item, the operator reports his or her observation by checking the appropriate column on the ODCL; "S" for satisfactory and "U" for unsatisfactory and "NA" for not applicable. For any unsatisfactory item, the operator must describe the deficiency in the "Remarks" block on the ODCL. If that item has an asterisk, the operation of that particular crane must be suspended and the supervisor notified, unless the item has previously been identified and reviewed and continued operation has been authorized by activity engineering organization.

After inspecting all items, the operator signs the ODCL. Subsequent operators review the initial ODCL, perform the operational checks and sign the checklist. At the end of day, the last operator turns in the ODCL to the supervisor.

1. Walk Around Check – Conduct the walk around check while the boom remains in normal operating range. For cranes equipped with a safe access means, such a check can be conducted "on the crane"; however, do not climb the boom or gantry. For all other cranes, conduct it on the ground.

   During this time, the operator must ensure that the crane is currently certified and its expiration date entered on the ODCL. If you discover that the crane is not currently certified, report it to the supervisor. At a minimum, observe and report the condition of the following:

   a. Safety Guards and Plates – Check for missing safety guards and plates.

   b. Carrier Frame and Rotate Base – Check the carrier frame and rotate base thoroughly for obvious physical damage, such as cracking, bending, or deformation of plates or welds. Check for cracking or flaking of paint that may indicate a crack or damage in the structure beneath. Check hook rollers, bull gear, and rotate pinion.

   c. General Hardware – Check for missing and loose hardware (bolts, nuts, brackets, etc.).

   d. Wire Rope – Check wire rope for unusual wear, fraying, birdcaging, corrosion, and kinking. These defects are shown in *Figure 21-65.*

Figure 21-65 – Common wire rope defects.

Other areas to inspect are swage fittings, swivels, pendants, and securing hardware for wear. Hoist drum end fittings need only be disconnected or disassembled when experience or visible indications show it necessary.

The exact time for replacement of wire rope cannot be given because many variables are involved; however, safety depends upon the use of good judgment in evaluating wire rope.

The following conditions are reasons for wire rope replacement:

- Running Ropes – Replace the rope when there are six or more broken wires randomly distributed, broken or torn wires in one lay, or three broken wires in one strand in one lay. Replace the end connecting when there are any broken wires adjacent to the end connecting.
- Boom Pendant Wire Ropes – More than two broken wires in one lay in sections beyond the end connecting or one or more broken wires at an end connecting
- Kinks or Crushed Sections – Severe kinks or crushed rope in straight runs where the wire rope core is forced through the outer strands
- Flattened Section – Flat sections where the diameter across the flat section is less than five sixths of the original diameter
- Wire Rope Wear – Measure wire rope with wire rope calipers (*Figure 21-66*) to check for wear accurately. Replace wire rope that has wear of one third of the

original diameter of outside individual wires. A crescent wrench can be used as an expedient means to measure wire rope.

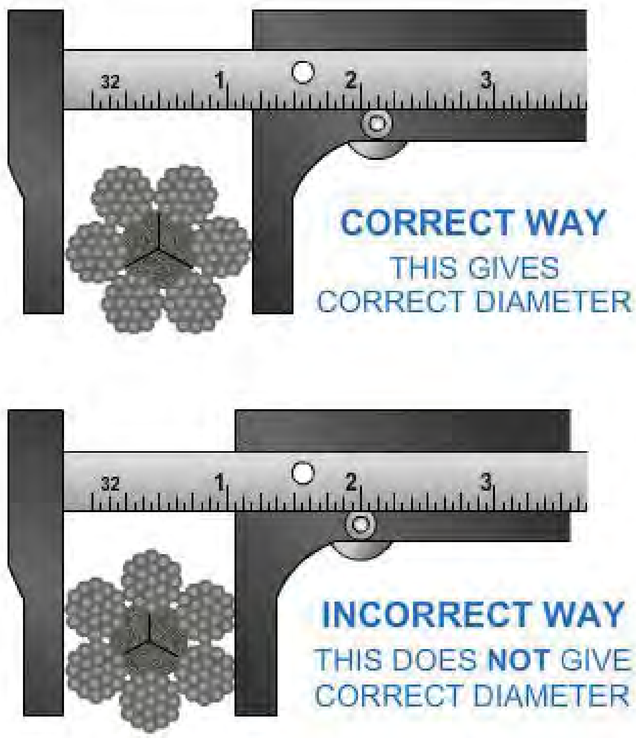

Figure 21-66 – Measuring wire rope.

Check end connection where visible, particularly wedge sockets like the one shown in *Figure 21-67* for proper configuration, seating, and condition of wire rope. Check chafing blocks for adequate guidance of lines and excessive wear.

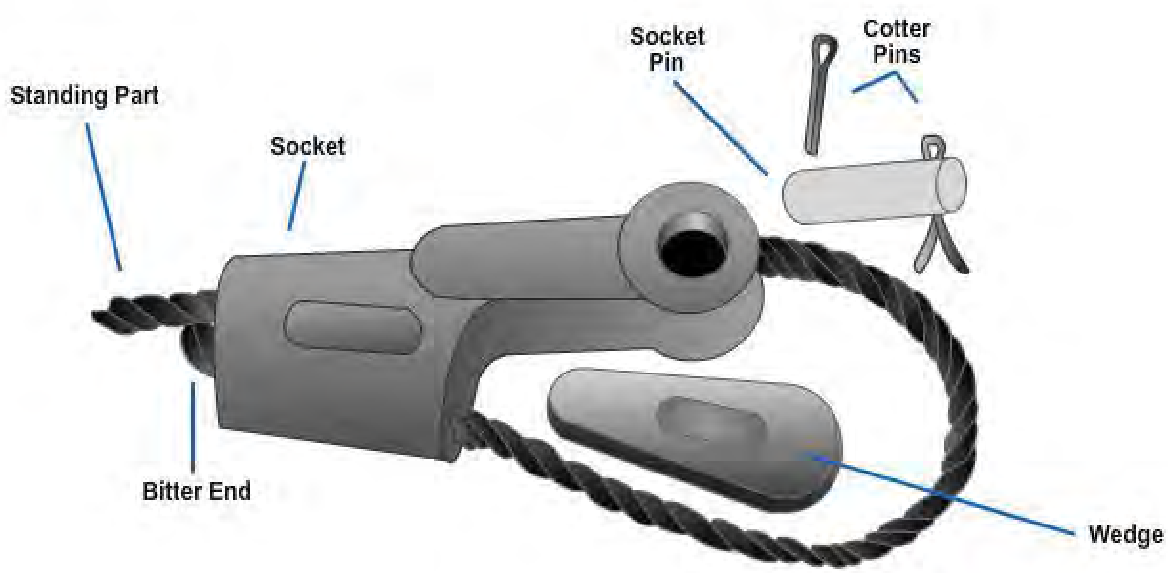

Figure 21-67 – Wedge socket.

Wedge sockets develop only 70 to 80 percent of the breaking strength of the wire rope due to the crushing action of the wedge. Exercise extreme caution when using wedge socket connections in making rated capacity lifts.

Wedge sockets are particularly subject to wear, faulty component fit, and damage from frequent change outs. They are also highly vulnerable to inadvertent wedge release and disassembly in two-blocking situations. When using wedge sockets, take care to avoid accidental slackening of the wire rope releasing the wedge inside the socket.

Single saddle wire rope clips that clamp both the dead end and live rope shall not be used in conjunction with a wedge socket. Such connectors are hazardous because they restrain the wedge from seating properly in the socket and may damage the rope. Use only approved double saddle clips specifically designed for wedge sockets and wedge socket proprietary clip designs.

1NCD has established an AEP for the assembly and disassembly of wedge sockets on the Link-Belt HTC-8640. The following procedure is in accordance with this AEP:

Step 1. Because the section of the wire rope used in the prior socket has been subject to sharp bending and crushing, cut and remove it prior to re-socketing. Follow wire rope original equipment manufacturer's (OEM's) requirements for seizing the rope prior to cutting and for securing the cut end prior to inserting in the socket. This is particularly important for rotation resistant wire rope to prevent core slippage or loss of rope lay.

Step 2. Exercise caution in installing the wedge socket properly to ensure that the wire rope carrying the load is in direct alignment with the eye of the socket clevis pin so the load pull is direct (*Figure 21-68)*.

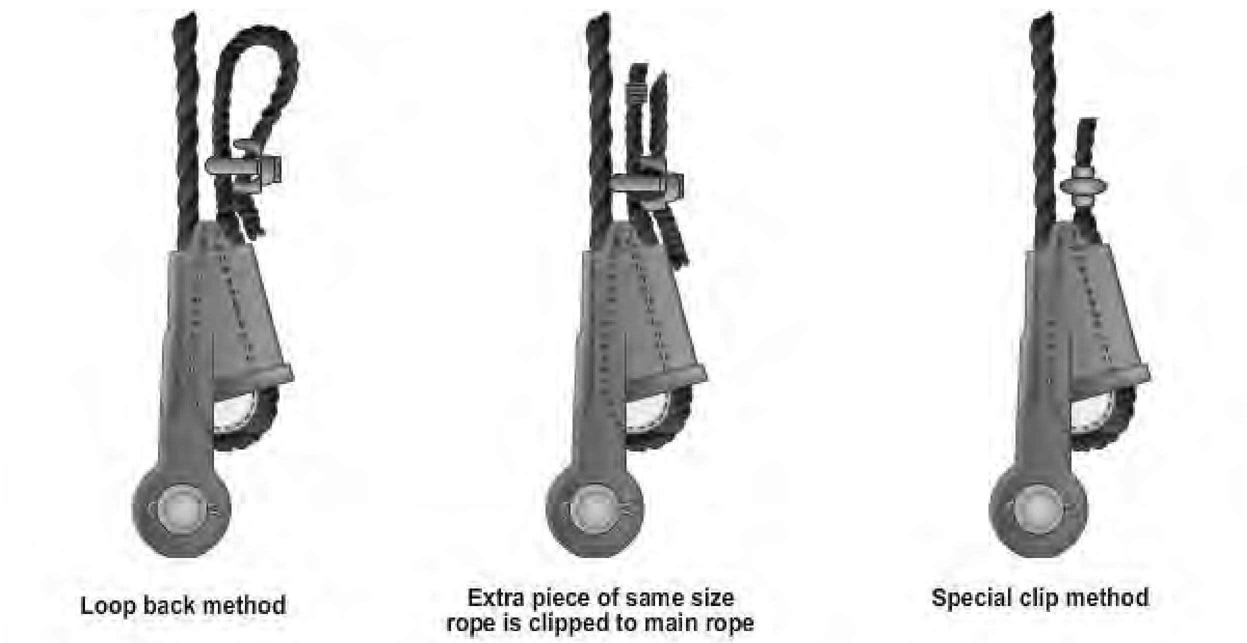

Figure 21-68 – Wedge socket methods.

Step 3. Place the socket in upright position and bring the rope around in a large, easy to handle hoop. Extend the dead end of the wire rope from the socket a sufficient distance to secure the dead end in either of the ways shown earlier in *Figure 21-68*. Be sure the minimum tail length extending from the wedge socket is in accordance with the socket OEM's guidelines. (Note: Tail lengths for rotation resistant wire rope are normally greater than for standard 6 to 8 strand wire rope.) Insert the wedge into the socket permitting the rope to adjust around the wedge.

Step 4. Secure the socket to a support and carefully take a strain on the live side of the rope to ensure proper initial seating of the wedge. Increase the load gradually until wedge is fully seated. Avoid applying any sudden shock loads.

Step 5. Secure the dead end as shown earlier in *Figure 21-68*. Alternatively, you may use approved double saddle clips specifically designed for wedge sockets and special wedge sockets specifically designed for use with single saddle clips.

e. Reeving – Check for condition of wire rope or load chain reeving. Ensure the wire rope fleet angle has not caused overriding of the drum flange. Check to ensure the wire rope or load chain is running true in the hook block and head machinery. Check to ensure the wire rope or load chain is laying correctly on the drum or sprockets.

f. Block – Check condition of the block and ensure all swivels rotate freely.

g. Hook – Check condition of the hook for cracks, excessive throat opening, or twist.

   In addition, inspect the hook block for cleanliness, binding sheaves, damaged or worn sheaves, worn or distorted sheave pins, broken bolts, and worn cheek weights. Inspect the hook for damage, excessive wear to the hook safety latch, hook swivel trunnions, thrust collar, and securing nut. Also inspect the hook for damaged or missing lubrication fittings and proper lubrication.

h. Sheaves or Sprockets – Check, where practical, the condition of sheaves or sprockets to be sure that they are free to rotate and are not cracked or chipped.

   In addition, inspect the sheaves for wear in the wire rope sheave groove, loose or damaged sheave guards, and worn bearings and pins (*Figure 21-69*). Sheaves rotate on either bearings or bushings that are inspected for discoloration (due to excessive heat), metallic particles, chips or displaced metal, broken or distorted bearing retainer or seals, adequate lubrication, and tight bearing caps.

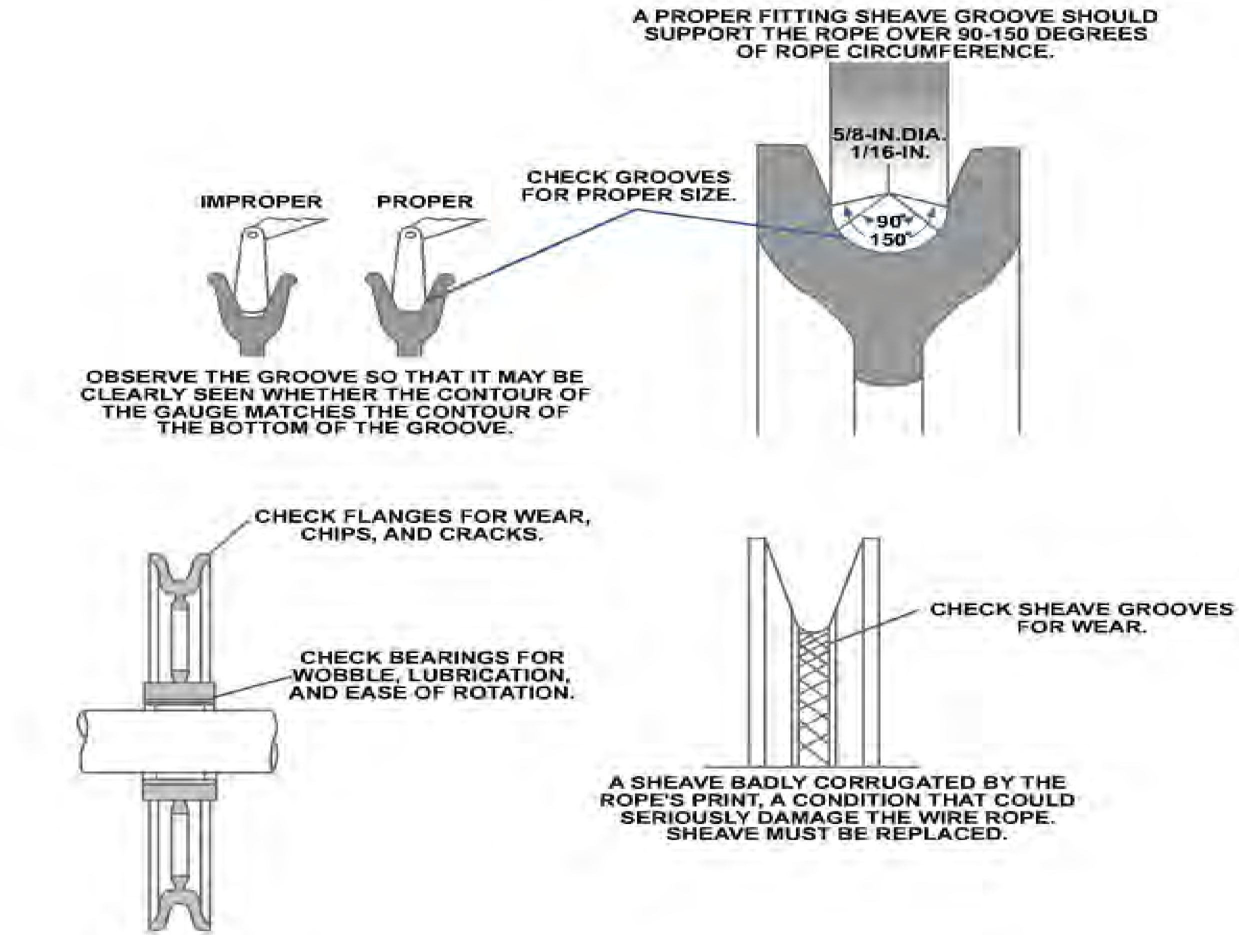

Figure 21-69 – Sheave (pulley) inspection.

i. Boom and Jib – Check condition of the boom and jib for straightness and any evidence of physical damage, such as cracking, bending, or other deformation of the steel elements or welds. When checking lattice booms, be especially watchful for bent lattices and dents in the main chords.

j. Gantry, Pendants, and Boom Stops – Check the condition of the gantry, pendants, and boom stops. Check the gantry for distortion or other damage. Check the pendants for sags or other evidence of unequal length and that the anchor pins are set. Check the boom stops to ensure they are not damaged and the telescoping struts are not jammed.

k. Walkways, Ladders, and Handrails – Check the condition of walkways, ladders, and handrails. Look for loose mountings, cracks, excessive rust, loose rungs, or any other signs of unsafe conditions.

l. Windlocks, Stops, and Bumpers – Check for free action of windlocks. Check the stops and bumpers on the crane for cracks or other damage.

m. Tires, Wheels, and Tracks – Check the condition of tires for inflation, serious cuts, or excessive wear. If lifts on rubber are planned, check the tire with a guage for proper inflation pressure per OEM load rating chart. Check the wheels to ensure they are not loose or damaged. On track machines, look for excessive slack, broken or loose pads, or any other obvious defects.

n. Leaks – Check for evidence on the machine frame and the ground beneath machine, of any leakage of fuel, lubricating oil, hydraulic fluid, or engine coolant.

o. Outriggers and Stabilizers – Check outriggers and stabilizers for damage. If floats or pads are not permanently installed on the outrigger, ensure they are on the carrier and that they are not damaged.

p. Load Chain – Check for damaged or deteriorated links.

q. Area Safety – Check work area and ensure that exact locations of obstacles or hazards are known. Ensure ground conditions are sufficiently firm to support a loaded crane. Verify temporary connections are removed or cleared for operation (e.g., temporary shore power or hotel power).

2. Machinery House Check – To conduct a machinery house check, enter the machinery house and/or remove the machinery inspection panels or covers and observe the following:

   a. Housekeeping – Check to ensure the machinery house and accesses are clean. Ensure tools and authorized materials are properly stored and that waste and debris are removed.

   b. Diesel Engine and Generator – Check diesel engine lube oil, radiator coolant, hydraulic oil, and fuel levels. Check the fan and drive belts for damage. Check for evidence of loose fasteners, oil or grease splashes, and any indications of overheating.

   c. Leaks – Check for leaks of lubricating oil, fuel, coolant, hydraulic oil, or grease.

   d. Lubrication – Check gear cases for lubricant level and evidence of over or under lubrication of crane components.

   e. Battery – Check for excessive corrosion and leakage.

   f. Lights – Check that the machinery house lights are working.

   g. Glass – Check for broken or missing glass in the machinery house doors or windows.

   h. Clutches and Brakes – Check accessible portions of clutches and brakes for evidence of excessive heat, wear, or grease and oil on the linings. Check for evidence of loose fasteners and for missing or broken parts. If a brake is equipped with a manual release mechanism, check to ensure the mechanism is not in the released position.

   i. Electric Motors – Check all motors for evidence of loose fasteners, oil or grease splashes, and any indications of overheating.

   j. Auxiliary Engine and Compressor – Check lube oil level, radiator coolant level, hydraulic oil level, and fuel level. Check fan and drive belts for damage. Check for evidence of loose fasteners, oil or grease splashes, and any indication of overheating.

   k. Danger/Caution Tags – If danger or caution tags are posted, read, understand, and follow the directions on the tags. Check the appropriate ODCL column as follows: “S” – all tags are properly hung; “U” – tags improperly hung or otherwise deficient; “NA” – no tags.

   l. Fire Extinguishers – Ensure fire extinguishers are in place, seals are unbroken, and inspection tags are up to date.

   m. Hoist Drum Pawls and Ratchets – Check locking pawls and ratchets, where visible, for damage, alignment and proper engagement.

3 Operator Cab Check. To conduct an operator cab check, enter cab and ensure all controls are in the neutral or off position before starting engine. Start engine and check the following:

(Note: Specific sequence will vary with the type of crane.)

a. Gauges – Check gauges to ensure none are broken or missing and that they are operating normally.

b. Indicator and Warning Lights – Check indicator and warning lights to ensure none are broken or missing and that applicable indicator and warning lights are lit.

c. Visibility – Check visibility to ensure that all windows and mirrors are clean, unbroken and that any vandal guards have been removed from windows.

d. Load Rating Charts – Ensure that load rating charts are posted in the operator's cab and that they are legible.

e. List/Trim Indicator (Floating Cranes) – Check list and trim indicator to ensure crane is level within tolerances. Ensure both list and trim bubble tubes are in their respective holders and not broken.

f. Boom Angle/Radius Indicator – Check indicator(s) for damage and ensure linkages are connected. When electronic indicators are used, ensure power is supplied.

g. Fire Extinguisher – Ensure fire extinguishers are in place, seals are unbroken, and inspection tags are up to date.

h. Level Indicator (Mobile Cranes) – Check level indicator for damage.

i. Danger/Caution Tags – If danger or caution tags are posted, read, understand, and follow the directions on the tags. Check the appropriate ODCL column as follows: “S” – all tags are properly hung; “U” – tags improperly hung or otherwise deficient; “NA” – no tags.

4 Operational Check – To conduct an operational check, warm up the engine. When ready, alert the rigger and perform the following:

a. Area Safety – Check the work area and ensure that exact locations of obstacles or hazards are known. Ensure ground conditions are sufficiently firm to support a loaded crane.

b. Outriggers and Stabilizers – Prior to the initial set up, check the outriggers and stabilizers to ensure they function freely.

c. Unusual Noises – After starting the engine, be alert for unusual noises, fluid leaks, improper functioning, incorrect readings of gauges, and loss of power or bad response to control of the engines or motors.

d. Control Action – Check controls through a range sufficient to ensure that they operate freely and that the corresponding component actuates properly when a control is activated. Check the hoist controls through the full speed range.

e. Wire Rope or Chain – Check for proper paying-out of the wire rope or chain, that the wire rope or chain and hook blocks do not twist/spin, and that the wire rope or chain is running freely through the sheaves or sprockets and blocks. If the boom and hoist drums or load sprocket are visible from the operator's station, check for proper spooling of the wire rope on/off the drum or chain on/off the load sprocket. After lowering the hooks and the boom for limit switch tests and hook inspections, observe sections of wire rope or chain that may not be visible during the walk around check.

f. Brakes and Clutches – Check brake and clutch actions and ensure they are functioning normally and that there is no slippage, excessive play, or binding. Exercise brakes and clutches to ensure they are dry.

g. Boom Angle/Radius Indicator – Check operation of the boom angle and/or radius indicator.

h. Limit Switches – Checking of limit switches shall include each upper hook hoist primary limit switch and the upper and lower boom hoist primary limit switches. (Verifying the operation of the upper and lower boom hoist limit switches is required only during the initial check of the crane each day.) Checking of hook hoist lower limit switches is not required if the hook can be lowered to its lowest possible position (e.g., bottom of drydock being worked at minimum radius) while still maintaining a minimum of two wraps of rope on the hoist drum (three wraps for ungrooved drums). For cranes that do not have the requisite number of wraps, check the hook hoist lower limit switch where operationally possible, i.e., if the crane is at a location where the limit switch can be checked (where the lower limit switch is not checked during the pre-use check, check it if the crane is subsequently relocated to a position where it can be checked). For cranes without hoist upper limit switches, do not check hoist overload clutches if so equipped. (See section 10 for specific precautions for these hoists.) Checking of secondary limit switches is not required unless a specific operation is planned where the primary limit switch will be bypassed. (See section 10 for controlling the bypassing of safety devices.)

i. Emergency Stop (e.g., Power-Off Button) – Check the emergency stop. Know its location and ensure it is working properly. (Not applicable to diesel engine shutdowns on portal and floating cranes.)

j. Other Operational Safety Devices – Check any other operational safety devices as directed by the activity engineering organization.

k. General Safety Devices – Check general safety devices and ensure they are functioning.

l. Fleeting Sheaves – Check operation of fleeting sheaves, where visible, to ensure they travel freely on the shaft.

Test your Knowledge (Select the Correct Response)

9. **(True or False)** Crane capacity is lost when the crane is out of level by only a few degrees.

   A. True
   B. False

10. Which of the following form is used when performing a crane prestart inspection?

   A. ODCL
   B. Hard card
   C. Operator's Inspection Guide
   D. Operator's Daily PM report

7.0.0 OPERATIONS

Prior to performing crane operations such as clamshell, dragline, and pile driving operations, operators and those on the crane crew must be familiar with standard hand signals.

7.1.0 Hand Signals

During crane operation, hand signals such as the ones shown in *Figure 21-70* are used to prevent misunderstandings and help ensure safe operations. These signals are posted in all cranes and in clear view of operator.

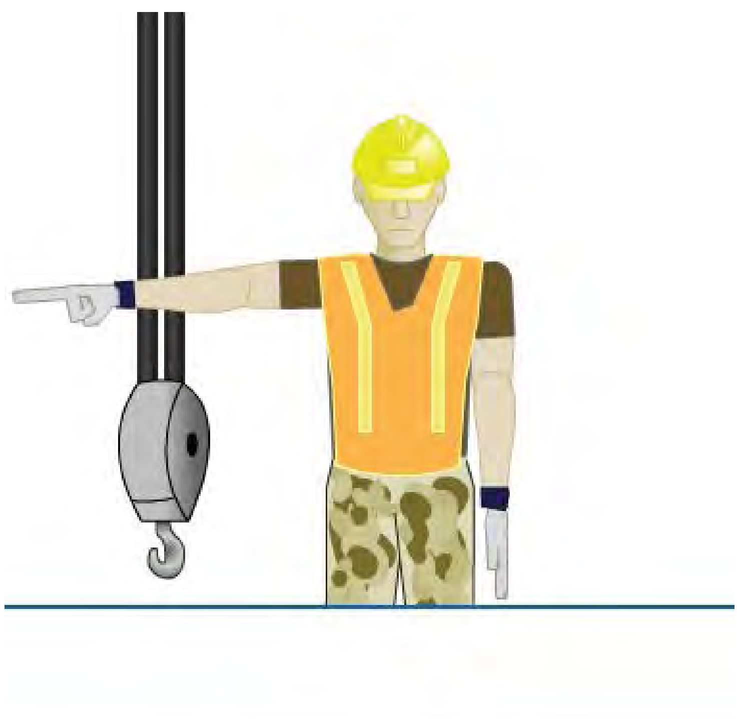

Figure 21-70 – Standard hand signals for crane operations.

As crane operator, make movements only when given the signal to do so. Additionally, take signals from only one designated signaler and stop when signals are not clear or if you cannot see the signaler.

As signaler, remain in clear view of the crane operator; make all signals as clear as possible, and keep arms/hands away from your body while making signals. The operator may not recognize signals given with arms and hands close to the body or worse yet, may misunderstand them. Because dirty gloves can make signals difficult to see, use bare hands or clean white gloves to signal cranes.

7.2.0 Traveling

Before any crane travels to a jobsite, the crane crew supervisor must visually review the planned travel route to determine if low wires, low overpasses, narrow bridges, or other unsafe obstacles exist. When operating or traveling near electrical transmission lines, operators must avoid the area referred to as the danger zones, as shown in *Figure 21-71*. The required clearance for normal voltage is shown in *Table 21-2*.

Figure 21-71 – Danger zone area.

Table 21-2 – Clearance of electrical transmission lines.

NORMAL VOLTAGE, KV (PHASE TO PHASE)	MINIMUM REQUIRED CLEARANCE, FT
Operation Near High Voltage Power Lines	
0 to 50	10
Over 50 to 200	15
Over 200 to 350	20
Over 350 to 500	25
Over 500 to 750	35
Over 750 to 1000	45
Operation in Transit with No Load and Boom or Mast Lowered	
0 to 0.75	4
Over 0.75 to 50	6
Over 50 to 345	10
Over 345 to 750	16
Over 750 to 1000	20

When traveling with a truck-mounted crane equipped with a lattice boom, do NOT rest the boom on the cradle, as the lower cords of the boom can be dented if the boom bounces while traveling. Position the boom 2 to 4 inches above the cradle.

7.3.0 Clamshell Operations

The following are general instructions for performing clamshell operations. In addition, it is recommended to review the instructions featured in the crane's operator's manual.

Step 1. Position and level the crane, ensuring the digging operation is as close to the radius as the dumping operation. This prevents you from having to boom up and down, resulting in a loss of production.

Step 2. Select the correct size and type of bucket for the crane.

Step 3. In lowering the clamshell bucket, if too much pressure is applied to the closing line brake, the bucket will close and an excess amount of wire rope will unwind from the holding line hoist drum. To avoid this, release the holding line and closing line brakes simultaneously when lowering the open clamshell into the material for the initial bite. Engage the closing line control lever to close the bucket. Control the digging depth by using the holding line control lever and brake.

Step 4. If, during hoisting, the hoist line gets ahead of the closing line, the bucket will open and spill the material. This could also be caused by having too much wire rope on the hoist drum. The operator must hoist both the closing and holding lines at the same speed to keep the bucket from opening and spilling material.

Step 5. When the clamshell bucket is raised enough to clear all obstacles, start the swing by engaging the swing control lever. The bucket can be hoisted as it is swung to the dumping site. The spring-loaded tagline will retard the twisting motion of the bucket if the swing is performed smoothly.

Step 6. Dump and unload the clamshell by keeping the holding line brake applied while the closing line brake is released. Apply the closing line brake quickly after dumping the load to prevent the closing line from unwinding more wire rope than is needed to dump the material. After the bucket is emptied, swing the open clamshell back to the digging site. Then lower the open bucket and repeat the cycle.

The clamshell operating cycle has four steps: filling (closing) the bucket, raising the loaded bucket, swinging, and dumping. Refer to the operator's manual for the correct boom angle for clamshell operations. Be careful when working with higher boom angles, as the bucket could hit the boom. A clamshell attachment is not a positive digging tool.

The height reached by the clamshell depends on the length of the boom used. The depth reached by the clamshell is limited by the length of wire rope that the hoist drum can handle. For the safe lifting capacity of the clamshell, refer to the operator's manual and the crane capacity load rating chart.

7.4.0 Dragline Operations

The following are general instructions for performing clamshell operations. In addition, it is recommended to review the instructions featured in the crane's operator's manual.

Step 1. Keep the teeth of the dragline bucket sharp and built up to proper size.

Step 2. Keep the dump rope short, so the load can be picked up at a proper distance from the crane.

Step 3. Excavate the working area in layers, not in trenches, and sloped upward toward the crane.

Step 4. Do not drag the bucket in so close to the crane that it builds piles and ridges of material in front of the crane.

Step 5. Do not guide the bucket by swinging the crane while digging. This puts unnecessary side stresses on the boom. Start the swing only after the bucket has been raised clear of the ground.

Step 6. A pair of drag chains is attached to the front of the bucket through brackets by which the pull point may be adjusted up or down. The upper position is used for deep or hard digging, as it pulls the teeth into a steeper angle.

Step 7. The drag cable can be reversed end for end to prolong the life of the wire rope, reduce early wire rope replacement, and keep wire rope cost down. Remember, do not lubricate the drag cable.

Step 8. When lowering the dragline bucket into the area to be worked, release the drag brake to tip the cutting edge down and then release the hoist brake. You do not have to drop the bucket to force the teeth into the material. The bucket is filled as it is dragged toward the crane by engaging the drag control lever. The cutting depth is controlled by releasing tension from the hoist brake. The dragline is NOT a positive digging tool.

Step 9. The dragline cycle is filling the bucket, lifting the bucket, swinging the loaded bucket, and dumping the load.

Step 10. Since the dragline is not a rigid attachment, it will not dump materials as accurately as do other excavators. When a load is dumped into a haul unit or hopper, you need more time to position the bucket before dumping it.

NOTE

When you are dumping into a haul unit, NEVER load over the cab. Additionally, make sure the operator is out of the cab and clear of the dragline or clamshell bucket.

Step 11. Refer to the operator's manual for the correct boom angle. However, check the crane load rating chart to ensure this low boom angle does not exceed the capacity of the crane. At this relatively low boom angle, be careful when excavating and dumping wet, sticky materials as the chance of tipping the crane increases because the material tends to hang in the bucket.

7.4.1 Dragline Employment

The dragline can be used in dredging where the material handled is wet and sticky. It can dig trenches, strip overburden, clean and dig roadside ditches, and slope embankments. The dragline is the most practical attachment for handling mud. Its reach enables it to handle a wide area of excavation while sitting in one position, and the sliding action of the bucket eliminates trouble with suction. Other uses of the dragline include the following:

- In-Line Approach – When excavating a trench with the dragline, ensure the dragline carriage is in line with the trench center line as shown in *Figure 21-72.* The dragline cuts or digs to the front and dumps on either side of the trench. The crane moves away from the face as the work progresses.

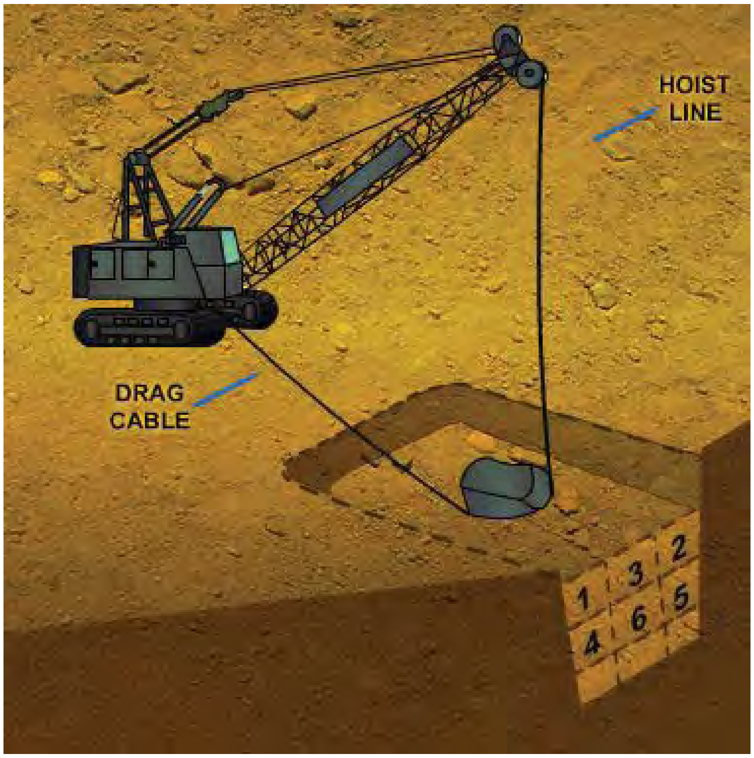

Figure 21-72 – In-line approach.

- Parallel Approach – The dragline can slope an embankment better by working it from the bottom to the top. The crane is positioned on the top of the embankment with the carrier parallel to the working face as shown in *Figure 21-73*. This position enables the crane to move the full length of the job without excessive turning.

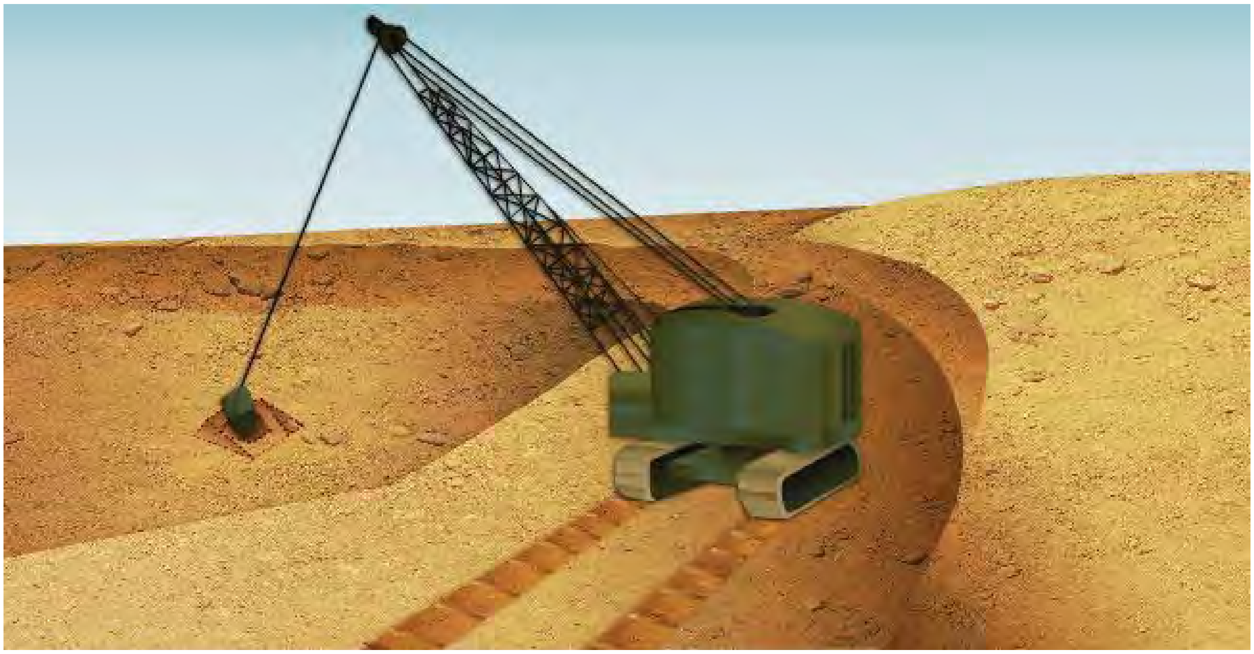

Figure 21-73 – Parallel approach.

- Drainage – A dragline is ideal if earthwork materials have to be removed from a trench, canal, gravel pit, and so forth, containing water. Plan the work to begin at the lowest grade point, so drainage will be provided as the dragline progresses towards higher levels.

NOTE

Digging underwater or in wet materials increases the weight of the materials and frequently prevents carrying heaped bucket loads.

Ditching the excavation through swamps or soft terrain is common. Under these conditions the excavated material is normally cast onto a levee or spoils bank.

- Loading Haul Units – When the job requires excavated material to be loaded into hauling units, the excavation should be opened up so loaded hauling equipment can travel on high, dry ground or on better grades. The spotting of trucks and dragline should be planned for minimum boom swing with the truck bed under the boom point and the long axis of the bed parallel with the long axis of the boom or at right angles to the boom. More spillage is to be expected from a dragline than from a front-end loader.

7.4.2 Efficient Dragline Operations

Requirements for efficient dragline operations are as follows:

- Although the dragline bucket can be readily cast beyond the length of the boom, the machine should be positioned to eliminate casting.
- Use heavy timber mats for work on soft ground. The mats should be kept level and clean.
- When setting up for a dragline operation, you should have access for maintenance, operating personnel, and hauling equipment.
- Excavate the working area in layers, not in trenches, and keep the slope upward toward the crane.

- Do not drag the bucket in so close to the crane that it builds piles and ridges of material in front of the crane.
- Salvage pieces of hoist wire rope for use as the dump rope.

7.5.0 Pile-Driving Operations

Take care during pile driving to avoid damaging the pile, the hammer, or both. The pile driver must be securely anchored as shown in *Figure 21-74* to avoid a shift of position. If the hammer shifts while driving, the blow of the hammer will be out of line with the axis of the pile and both the pile and hammer may be damaged.

Carefully watch the piles for any indication of a split or brake below the ground. If driving suddenly becomes easier or if the pile suddenly changes direction, a break or split has probably occurred. When this happens, the pile must be pulled.

Figure 21-74 – Pile securely anchored.

7.5.1 Driving Bearing Piles in Groups

Bearing piles are frequently driven in groups, as in a pile group which will support a column footing for a building or in closely spaced rows, as beneath a wall. When piles must be driven in closely spaced groups, observe these principles:

- When a pile is driven into sand or gravel deposits, the soil must be compacted or displaced an amount equal to the volume of the pile. If the deposit is quite loose, the vibration of pile driving frequently results in considerable compaction of the soil. The surface of the ground between and around the piles then may subside or shrink. This action may result in damage to the foundation of nearby structures. If piles are driven into dense sand and gravel deposits, the ground may heave.
- Clay soils are hard to compress in pile driving; hence, a volume of soil equal to that of the pile will usually be displaced, as shown in *Figure 21-75.* The ground will heave between and around the piles. Driving a pile alongside those previously driven will frequently cause those already in place to heave upward. If the piles are driven through a clay stratum to firm bearing beneath, the heave

may destroy the contact between the tip of the pile and the firm stratum. Such cases maybe detected by taking a level reading on the top of the piles previously placed. Piles which are raised appreciably should be re-driven to a firm bearing. Soil displaced by the pile may cause enough lateral force to move previously driven piles out of line.

Figure 21-75 – Displacement of clay soil caused by driving solid piles.

The sequence of driving piles in groups is as follows:

Step 1. Driving progresses from an area of high resistance to one of low resistance, toward a stream, or downslope to reduce the shoving of previous driven piles that are out of place when succeeding piles are driven.

Step 2. Drive outer rows in the group first if the piles derive their main support from friction. Drive inner rows first if the piles are supported from a point bearing.

7.5.2 Obstruction and Refusal

The condition reached when a pile being driven by a hammer has a 1-inch penetration per blow or zero penetration per blow (as when the point of the pile reaches an impenetrable bottom such as rock) or when the effective energy of the hammer is no longer sufficient to cause penetration (hammer is too light or velocity at impact too little), under which circumstances the pile may cease to penetrate before it has reached the desired depth is known as refusal. Further driving after refusal is likely to break or split the pile, as shown in *Figure 21-76.*

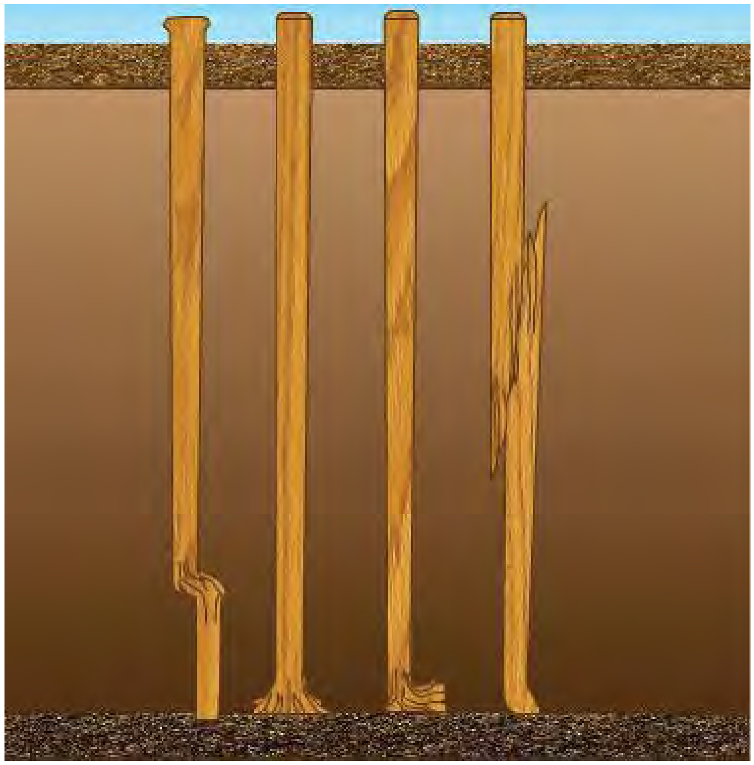

Figure 21-76 – Pile damage caused by overdriving timber piles.

When a pile has been driven to a depth where deeper penetration is prevented by friction, the pile has been driven to refusal. A pile supported by skin friction alone is called a friction pile. A pile supported by bedrock or an extra dense layer of soil at the tip is called an end-bearing pile. A pile supported partly by skin friction and partly by a substratum of extra dense soil at the tip is called a combination end-bearing and friction pile.

It is not always necessary to drive a friction pile to refusal; such a pile needs to be driven only to the depth where friction develops the required load-bearing capacity.

7.5.3 Straightening and Realigning Piles

Straighten piles when there is any misalignment during pile driving. The accuracy of alignment necessary for the finished job depends on various factors, but if a pile is more than a few inches out of its plumb line, make an effort to bring it back into alignment. The greater the penetration along the wrong line, the more difficult it will be to straighten, so early detection and correction is the best policy.

One method of realignment is to use pull from a block and tackle with the impact of the hammer jarring the pile back into line as shown in *Figure 21-77*. The straightening of steel bearing piles must include twisting of the individual piles to bring the webs of the piles parallel to the center line of the bent.

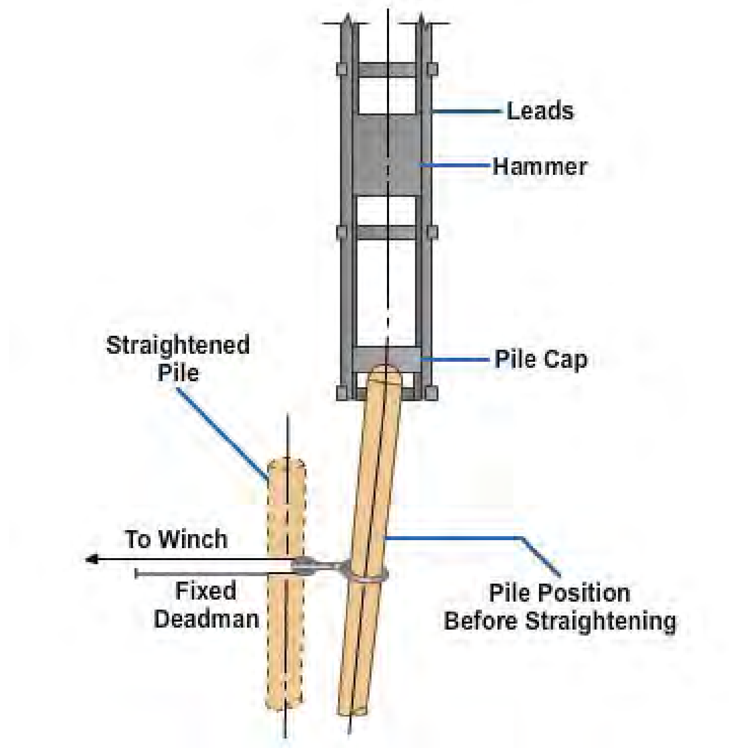

Figure 21-77 – Realigning pile using block and tackle.

Another method of realignment is shown in *Figure 21-78.* It involves using a jet to realign piles driven in a bent. This method may be used in conjunction with the block-and-tackle method.

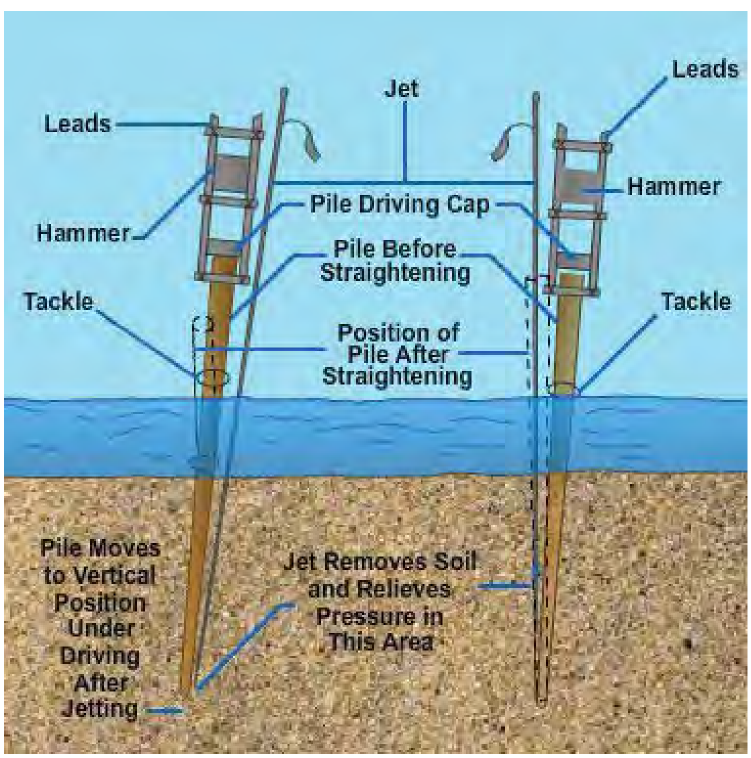

Figure 21-78 – Realigning pile by jetting.

A third method is shown in *Figures 21-79* and *21-80.* It involves using a frame to realign piles driven in a bent. The frame is constructed using 6 by 8 timber on each side of the bent with threaded rod and bolts to pull piles into realignment. This method can also be used in conjunction with the block and tackle method.

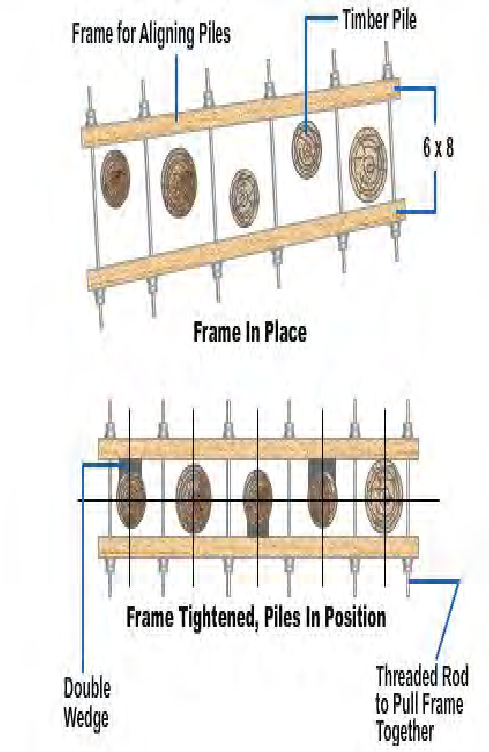

Figure 21-79 – Realigning frame used for timber pile bent.

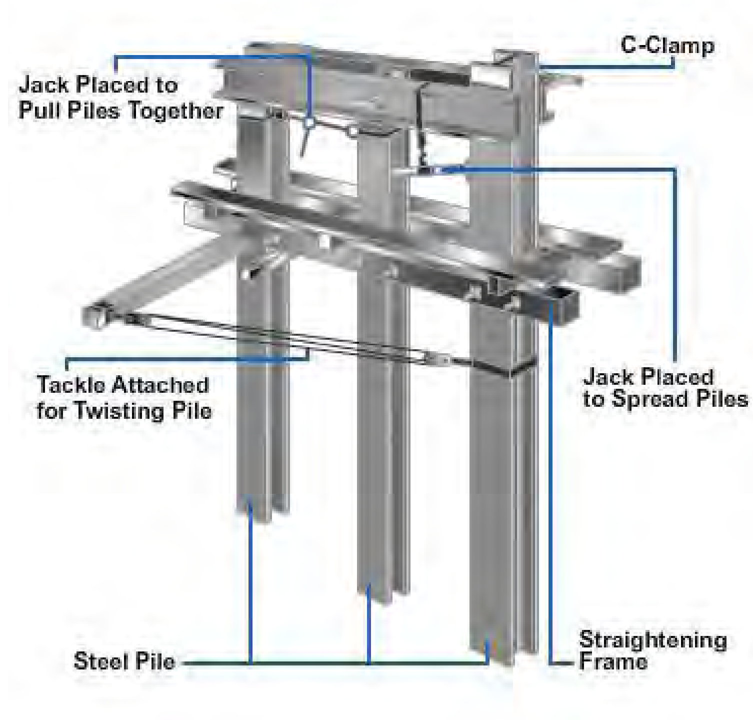

Figure 21-80 – Realigning and capping steel pile bents.

7.5.4 Pulling Piles

A pile that has met an obstruction, which has been driven in the wrong place, that has split or broken in driving, or that is to be salvaged (steel sheet piles are frequently salvaged for reuse) is usually extracted (pulled). Pulling should be done as soon as possible after driving. The longer the pile stays in the soil, the more compact the soil becomes, causing greater resistance. Methods of pulling piles are as follows:

- In a direct lift method, use a crane to pull the pile. Rig the crane hoist line to the pile with wire rope rigging, and gradually apply an increase in pull to the pile. Give lateral blows from a skull cracker, a heavy steel ball swung on a crane line, to demolish walls or a few light blows on the butt or head with the pile-driving hammer to break the skin friction, then increase the crane pull. If the pile still refuses to extract, loosen it by jetting, air extractors, or beam pullers.
- Using a screw hammer in an inverted position to pull piles. Turn the hammer over and attach the wire rope rigging to it and extract the pile. A pneumatic extractor may also be used. The crane line holding the hammer or extractor is hoisted taut, and the upward blows of the hammer ram on the sling, plus the pull of the crane hoist, are usually enough to pull the pile.
- In tidewater, use tidal lift to pull piles. Wrap rigging around the piles and attach it to barges or pontoons at low tide; the rising tide pulls the piles as it lifts the barges or pontoons.

Test your Knowledge (Select the Correct Response)

11. **(True or False)** The in-line approach with the dragline involves positioning the crane on the top with the embankment with the carrier parallel to the working face.

    A. True
    B. False

Summary

This chapter introduced two types of crane configurations: the crawler-mounted lattice boom crane and the truck-mounted telescopic boom crane. You were introduced to their major components, controls, and attachments. You were introduced to the responsibilities of all those on the crane crew including the rigger-in-charge, crane rigger, crane walker, and operator. Lastly, you were introduced to crane operations, such as clamshell, dragline, and pile-driving operations.

Review Questions (Select the Correct Response)

1. **(True or False)** Ancillary Equipment Procedures incorporate instructions from the original equipment manufacture, 1NCD Crane Program, and NAVFAV P-307.

   A. True
   B. False

2. Crawler-mounted cranes are categorized under what USN number registration series?

   A. 37-00000
   B. 42-00000
   C. 60-00000
   D. 82-00000

3. It is NOT productive to travel a crawler-mounted crane for more than what distance, in miles?

   A. 1
   B. 2
   C. 3
   D. 4

4. Crawler-mounted cranes having tracks that extend are rated at what percentage of the maximum load chart capacity?

   A. 90%
   B. 85%
   C. 80%
   D. 75%

5. Crane radius is measured from what two points?

   A. Boom base section to the center of the hook
   B. Center of rotation to the boom tip section
   C. Center of rotation to the center of the hook block
   D. Boom base section to the boom tip section

6. Which of the following is NOT a quadrant of operation for a crawler-mounted crane?

   A. Over the side
   B. Over the drive end
   C. Over the idler end
   D. Over the rear-end

7. **(True or False)** The capacity of a crane may change when rotating a load from one quadrant to another.

A. True
B. False

8. Where can you find information concerning a crane's capacity in each quadrant of operations?

A. On the equipment status board
B. In the rigging loft
C. On the crane's load rating chart
D. In the dispatch office

9. Truck-mounted cranes are categorized under what USN number registration series?

A. 37-00000
B. 42-00000
C. 60-00000
D. 82-00000

10. Which of the following components is also called the machinery deck?

A. Superstructure
B. Operator's cab
C. Operating machinery
D. Engine

11. Which of the following types of crane operations would require the use of two hoist drums?

A. Clamshell
B. Dragline
C. Pile-driving
D. All of the above

12. Manufacturers recommend not using a crane if it has what type of defect(s) or damage?

A. Rust
B. Bent lacings or cords
C. Cracked welds
D. All of the above

13. An operator of a crane should NOT rely on the boom angle indicator for radius accuracy especially when lifts exceed what percentage of the rated capacity?

A. 60%
B. 65%
C. 70%
D. 75%

14. **(True or False)** If one boom pendant is bad, both pendants must be replaced.

    A. True
    B. False

15. Which of the following components is the connection point between the pendants and boom hoist wire rope?

    A. Fairlead
    B. Pile driver hammer
    C. Bridle assembly
    D. Master clutch

16. Boom stops are designed to prevent the boom from going-over backwards in the event what problem occurs?

    A. The boom bounces out of the cradle during transport
    B. A load line breaks
    C. The operator leaves the boom hoist lever engaged
    D. The operator swings the crane too fast

17. **(True or False)** On the Link-Belt LS-108H II, raising and lowering the boom is controlled by the boom hoist control lever and pump toggle control switches.

    A. True
    B. False

18. **(True or False)** When the brake system on the Link-Belt LS-108H II is in the "Free" mode, the drum brake must be manually applied using the brake pedal(s) on the cab floor.

    A. True
    B. False

19. Which of the following provides step-by-step instructions for assembling and disassembling a lattice boom?

    A. NAVFAC P-307
    B. COMFIRSTINCD
    C. SOP
    D. AEP

20. **(True or False)** When removing a boom section, the boom's head machinery should set on blocking.

    A. True
    B. False

21. When performing near-capacity lifts at high boom angles using a telescopic crane, what percentage of the load weight is placed on the outriggers?

A. 80
B. 60
C. 40
D. 20

22. **(True or False)** When telescopic boom sections are extended unequally, uneven stresses are placed on the most retracted section.

A. True
B. False

23. On the Link-Belt HTC-8640 telescopic boom truck-mounted boom, which of the following stops the rotate of the superstructure?

A. Swing control lever
B. Travel swing lock
C. Swing brake pedal
D. Swing park brake

24. **(True or False)** On the Link-Belt HTC-8640 telescopic boom truck-mounted boom, the left hand-side hydraulic control lever controls the rear winch.

A. True
B. False

25. **(True or False)** On most cranes, the function of the jib is to increase the lift height.

A. True
B. False

26. **(True or False)** The number of part lines rigged on a hook block is NOT a factor when figuring the capacity of a crane.

A. True
B. False

27. **(True or False)** Two blocking is when the hook block comes in contact with the boom's head machinery during hoisting of the hook or lowering the boom.

A. True
B. False

28. Which of the following attachment consists of a bucket with two scoops hinged together in the center with counterweights bolted around the hinge?

A. Concrete bucket
B. Clamshell
C. Dragline
D. Pile hammer

29. Which of the following components helps prevent the clamshell from twisting during clamshell operations?

A. Fairlead
B. Closing line
C. Tagline winder
D. Bridle assembly

30. A fairlead performs what function during crane operations?

A. Keeps the clamshell from twisting
B. Guides the drag cable onto the winch drum
C. Guides the boom hoist cable through the gantry
D. Supports the pile hammer during pile–driving operations

31. **(True or False)** A drag cable should be lubricated each time operator maintenance is performed on a crane.

A. True
B. False

32. What term is used to describe a group of piles driven close together in water and tied together so that the group will withstand lateral forces?

A. Batter
B. Anchor
C. Dolphin
D. Fender

33. What term is used to describe when a pile vibrates too much laterally from the blow of the hammer?

A. Springing
B. Bouncing
C. Refusal
D. Bearing

34. What type of pile is made by pouring concrete into a tapered hole or cylindrical form previously driven into the ground?

A. Precast concrete
B. Cast-in–place concrete
C. Composite
D. Sheet

35. Which of the following is a commonly used type of sheet pile?

A. Straight web
B. Shallow arch
C. Deep arch
D. All of the above

36. Which of the following types of sheet piles are designed for maximum flexibility and tensile strength?

A. Straight web
B. Shallow arch
C. Deep arch
D. Z web

37. What type of lead is connected to the head machinery through the use of lead adapters?

A. Swinging
B. Underhung
C. Extended four-way
D. Overhead

38. During what time period should lead adapter bolts be checked for tightness?

A. At the beginning of each day
B. At the beginning of each week
C. At the beginning of each month
D. At the beginning of each shift

39. What component is used to hold leads at a vertical for driving bearing piles or to hold the leads at an angle for driving batter piles?

A. A tagline winder
B. A bridle assembly
C. A catwalk
D. A boom mast

40. What type of lead uses a sliding boom tip connector for connecting the boom tip of the crane to the leads?

A. Swinging
B. Underhung
C. Extended four-way
D. Overhead

41. What type of lead has an advantage over other leads because it bears the entire bottom of the pile cap to the piling?

A. Swinging
B. Spud
C. Extended four-way
D. Underhung

42. **(True or False)** The noise generated by a pile–driving operation can cause hearing loss.

A. True
B. False

43. Which of the following component raises and lowers the diesel hammer and piston?

A. Fuel pump assembly
B. Belleville spring assembly
C. Trip device
D. Thrust bearing

44. **(True or False)** The top of the cushion block should be high enough to prevent the hammer shroud from fouling on the rim of the drive cap.

A. True
B. False

45. Who fills out the crane lift checklist before a crane can proceed to any project or make any lift?

A. Operator
B. Rigger-in-charge
C. Crane Crew Operator
D. Signalman

46. Who is responsible for establishing the appropriate method of communication?

A. Operator
B. Rigger-in-charge
C. Crane Crew Operator
D. Signalman

47. Wire rope should be replaced when wear has destroyed what fraction of the original diameter of the outside individual wires?

A. 1/8
B. 1/3
C. 1/2
D. 2/3

48. Which of the following sockets can develop only 70 percent of the breaking strength of the wire rope?

A. Swage socket
B. Cappel socket
C. Spelter socket
D. Wedge socket

49. What is the minimum required clearance when operating near electrical transmission lines with voltage between 350 and 500?

A. 15 feet
B. 20 feet
C. 25 feet
D. 35 feet

50. **(True or False)** A boom should rest in the cradle when traveling with a truck-mounted crane equipped with a lattice boom.

A. True
B. False

51. What term is used to describe the condition reached when a pile being driven by a hammer has a 1-inch penetration per blow?

A. Springing
B. Bouncing
C. Refusal
D. Bearing

52. What term is used to describe a pile supported by skin friction alone?

A. Bearing
B. Batter
C. Lateral
D. Friction

53. **(True or False)** The longer the pile stays in the soil, the more compact the soil becomes causing greater resistance.

A. True
B. False

Terms Introduced in this Chapter

Superstructure	The rotating frame, gantry and boom, or other operating equipment.
Broomed	The straightening of the wires at the end of a wire rope in preparation for pouring a speltered or resin socket.
Casing	A pipe lining for a drilled hole.
Power plant	Includes the prime power source (which may be an internal combustion engine or electric motor) and the power takeoff.
Lagging	Removable and interchangeable drum spool shells for changing the hoist drum diameter to provide variation in rope speeds and line pulls.
Reeving	The path that a rope takes in adapting itself to all sheaves and drums of a piece of equipment.
Dead end	The fixed end of a rope or cable on a crane, derrick, or hoist.
Pawl	Also known as "dog". It is a gear locking device for positively holding the gears against movement.
Load controlling	Those parts of a crane that position, restrain, or control the movement of the load (e.g., rotate and travel brakes, clutches) a malfunction of which could cause dropping, uncontrolled shifting, or uncontrolled movement of the load. Crane mounted diesel engines, generators, electrical power distribution systems, and electrical control circuits, associated with the movement of the load, shall be treated as load controlling parts.
Load bearing	Those parts of a crane that support the load and upon failure could cause dropping, uncontrolled shifting, or uncontrolled movement of the load.
Safety devices	(1) Operational Safety Devices. Safety devices that affect the safe load lifting and handling capability of the equipment, such as interlocks, limit switches, load/load moment and overload indicators with shutdown capability, emergency stop switches, radius indicating devices, and locking devices. (2) General Safety Devices. Safety devices, such as bells, horns, warning lights, and bumpers, which provide protection for operation and maintenance personnel and equipment on or in the operating path of, cranes.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Cranes and Attachments Gulfport, *1,* SCBT 540.1, Naval Construction Training Center, Gulfport, MS 1988.

Crane and Attachments 2, SCBT 540.2, Information Sheet (Piledriver), Naval Construction Training Center, Gulfport, MS, 1980.

Crane Handbook, Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Ontario, Canada, 1982.*Earthmoving Operations*, FM 5-434, Headquarters Department of the Army, Washington, DC, 2000.

Naval Construction Force (NCF) Equipment Management Instruction, COMFIRSTNCDINST 11200.2, Department of Navy, First Naval Construction Division, 2006.

Delmag Operating Instructions: Diesel Pile Hammers D5-32 up to 100-13. Pileco, Inc.

Management of Weight Handling Equipment, NAVFAC P-307, Naval Facilities Engineering Command, Navy Crane Center, 2006.

Mobile Crane Manual, Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Ontario, Canada, 1982.

Operator's Manual: LS-108H II, Book No. 939, Link-Belt Construction Equipment Company.

Operator's Manual: HTC-8640, Link-Belt Construction Equipment Company.

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Chapter 22

Rigging Operations

Topics

1.0.0 Basic Engineering Principles

2.0.0 NAVFAC P-307

3.0.0 Wire Rope

4.0.0 Fiber Rope

5.0.0 Chains

6.0.0 Slings

7.0.0 Mechanical Advantage

8.0.0 Safe Rigging Operations

To hear audio, click on the box.

Overview

Rigging is one of the most important safety and risk exposure considerations on any construction project. It is one of the techniques used in handling equipment and is used to handle a wide range of material using weight handling equipment (WHE). This equipment includes wire rope, fiber rope, chains, and slings. Rigging operations are a vital part of your job as a Equipment Operator (EO).

The Naval Construction Force (NCF) requires an in-depth program for maintenance and use of all rigging gear to ensure that all weight-handling operations are performed safely and professionally.

This chapter will cover the mechanical advantages of safe rigging operations and characteristics.

Objectives

When you have completed this chapter, you will be able to:

1. Understand basic engineering principles associated with rigging operations.
2. Describe the purpose and contents of NAVFAC P-307.
3. Identify the characteristics, maintenance, and attachments of wire rope.
4. Identify types, handling, and inspection of fiber line.
5. Understand chain grades, strength, and maintenance.
6. Identify the types and uses of slings.
7. Identify types and use of mechanical advantages.
8. Understand how to perform rigging operations.

9. Understand rigging safety.

Prerequisites

None

This course map shows all of the chapters in Equipment Operator Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Miscellaneous Equipment	↑	E
Paving Operations and Equipment		Q
Rigging Operations		U
Cranes		I
Rollers		P
Dozers		M
Scrapers		E
Graders		N
Ditchers		T
Excavators		
Backhoe Loaders		O
Front-End Loaders		P
Rough Terrain Forklifts		E
Truck Driving Safety		R
Truck-Tractors and Trailers		A
Tank Trucks		T
Dump Trucks		O
Medium Tactical Vehicle Replacements		R
Earthwork Operations		
Electrical and Hydraulic Systems		B
Chassis Systems		A
Power Train		S
Engine Systems		I
Transportation Operations		C

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The Figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 BASIC ENGINEERING PRINCIPLES

For any rigging operation, the first order of business is to determine forces (loads) and their direction, magnitude, load-bearing surfaces, method of connection, required support, and effects of motion. After determining these factors, select equipment for safe handling and installation of the load.

To determine the above factors, the rigger must know something about fundamental engineering principles such as determination of sling angle stress, load weight, weight distribution, center of gravity, and D/d ratio.

1.1.0 Load Weight Determination

Determination of load weight will provide you the capacity of gear and the crane. Remember, you must know the weight to prevent overloads. You must know the load weight and what load weight will excedd 50% of the crane's hook capacity.

1.1.1 Methods of Determining Load Weight

The following is a list of acceptable methods used for determining load weight:

- Load indicating device
- Label plates
- Documentation
- Engineer evaluation
- Approved calculations

NOTE: NEVER take word of mouth weight estimations to establish load weight.

The following is a list of basic rules to be followed when calculating weights:

- Round up on all dimensions
- Never mix feet and inches
- Round up on calculated weights
- Always double check your weight estimates

1.1.2 Using Area to Calculate Weights

The value of area for any given object can be used to calculate weights. Multiply square feet by material weight per square foot based on a specified thickness. In order to do this, you must first calculate the area of a given object.

1.1.2.1 Area of Rectangle or Square

Formula:

A = L x W (Rectangle) or A = B x H (Square). Refer to *Figure 22-1*.

A = Area

L = Length

W= Width

B = Base

H = Height

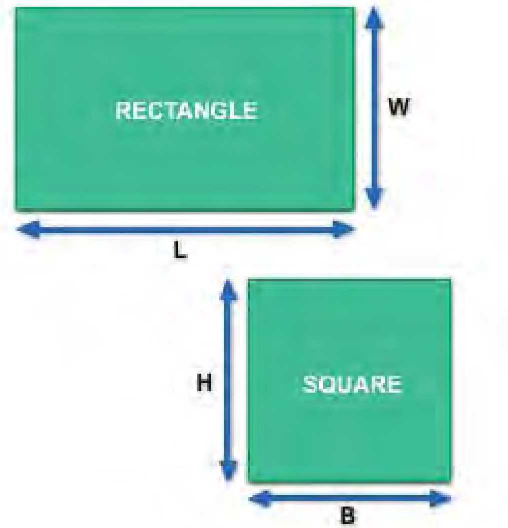


Figure 22-1 — Area of rectangle and square.

1.1.2.2 Area of a Triangle

Formula:

A = $\frac{B x H}{2}$

A = Area

B = Base

H = Height

Refer to *Figure 22-2*.

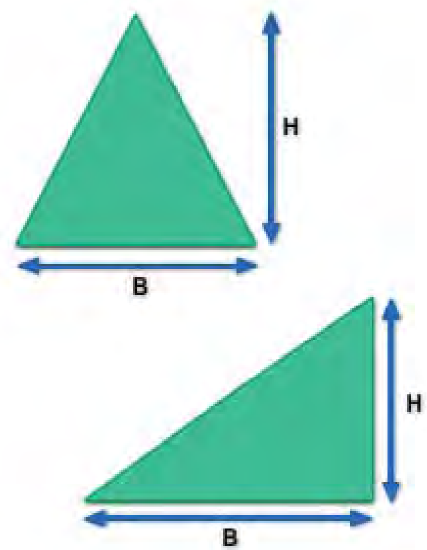


Figure 22-2 — Area of a triangle.

1.1.2.3 Area of a Circle

Formula:

A= $\pi x R^2$

A = Area

π = 3.14

R = Radius

Refer to *Figure 22-3*.

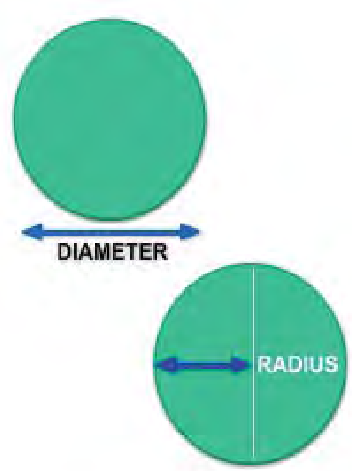


Figure 22-3 — Area of a circle.

1.1.2.4 Area of Complex Shapes

When encountering complex shapes, the first thing to do is to split the shapes into more common shapes (See *Figure 22-4*). In this case, the complex shape is split into a square and triangular shape.

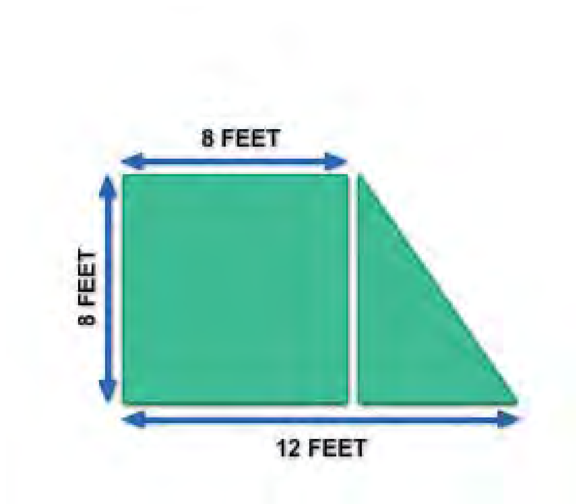


Figure 22-4 — Complex shape breakdown.

The first step is to figure out the area of the square shape, using the formula previously discussed.

A = B x H

A = 8 x 8

A = 64 square feet (ft^2)

Now, calculate the area of the triangle, using formula previously discussed.

$$A = \frac{B x H}{2}$$

$$A = \frac{4 x 8}{2}$$

$$A = \frac{32}{2}$$

A = 16 ft^2

Finally, add the area of the square and triangle together to get the total area of the complex shape.

A = 64 + 16

A = 80 ft^2

1.1.2.5 Calculating Weight Using the Area of Complex Shapes

Let us continue with the example demonstrated above. We know that the total area of this complex shape is 80 ft^2, and the object is manufactured out of steel. The next step in determining load weight is to obtain the thickness of the shape. Determine this by using any standard distance measuring device (i.e. ruler, measuring tape, or laser). In this case the thickness is 1 inch. Since you know the material is manufactured out of 1 inch thick steel, reference *Table 2-1* to determine weight per square foot of material. In this case, the weight is 40.8 lbs/ft^2, but remember the basic rule to round up, so the answer is 41 lbs/ft^2.

Table 22-1 — Material Weights.

Material	Weight per cubic foot	Material	Weight per square foot per inch of thickness
Pine (white)	25	Aluminum	14.5
Fir	34	Zinc	36.7
Oak	50	Tin (cast)	38.3
Maple	53	Steel	40.8
Water (salt)	64	Stainless Steel	41.7
Sand (dry)	105	Brass/Nickel	44.8
Reinforced Concrete	150	Monel/Copper/ Phosphor/Bronze	46.4
Aluminum	165	Silver	54.7
Zinc	440	Lead	59.2
Steel	490		
Stainless Steel	500		
Brass/Nickel	537		
Monel/Copper/ Phosphor/Bronze	556		
Lead	710		
Plutonium	1211		

Now you have all the values needed to calculate the load weight. Use the following formula: W = A x MW

W = Weight

A = Area

MW = Material Weight

W = A x MW

W = 80 ft^2 x 41 lbs/ft^2

W = 3,280 pounds

1.1.2.6 Calculating Weight Using Area of Triangle

First, calculate the area of the triangle.

Given:

Base = 12 feet — Material: Brass

Height = 5 feet — Thickness: 3 inches

Solution:

$$A = \frac{B x H}{2}$$

$$A = \frac{12 x 5}{2}$$

A = 30 ft^2

Now refer to *Table 2-1* to determine weight per square foot for brass. In this case you find a value of 44.8 lbs; after rounding up, the true value is 45 lbs/ft^2. Since the material is 3 inches thick, we must multiply the weight by 3.

3 x 45 lbs/ft^2 = 135 lbs/ft^2

Now calculate the weight of the object.

W = A x MW

W = 30 ft^2 x 135 lbs/ft^2

W = 4,050 pounds

1.1.2.7 Calculating Weight Using Area of an Circle

First, calculate the area of the circle.

Given:

Radius = 2 feet Material: Steel

Thickness: 1 1/2 inches

Solution:

A= $\pi \, x \, R^2$

A = 3.14 x 2 x 2

A = 12.56 ft^2; after rounding up you get 13 ft^2.

Now refer to *Table 2-1* to determine weight per square foot for steel. In this case you find a value of 40.8 lbs; after rounding up, the true value is 41 lbs/ft^2. Since the material is 1 1/2 inches thick, multiply the weight by 1.5.

1.5 x 41 lbs/ft^2 = 61.5 lbs/ft^2; after rounding up you get 62 lbs/ft^2.

Now calculate the weight of the object.

W = A x MW

W = 13 ft^2 x 62 lbs/ft^2

W = 806 pounds

1.1.3 Volume Calculatons

1.1.3.1 Volume of Cubes and Rectangular Prisms

Formula: V = L x W x H

V = Volume L = Length

W = Width H = Height

Now lets try an example of volume calaculation for a rectangular prism. Refer to *Figure 22-5.*

Figure 22-5 — Volume of rectangular prism.

Given:

Length = 10 feet Width = 4 feet Height = 2 feet

V = L x W x H

V = 10 x 4 x 2

V = 80 cubic feet (ft^3)

Now calculate load weight for this object. Refer to *Table 2-1* for material weight. Be sure to reference the correct column; remember this is volume, which is in cubic feet. The material weight for fir material is 34 lbs/ft^3. Now calculate the load weight. Note the formula for load weight now reflects volume in cubic feet.

W = V x MW

W = 80 ft^3 x 34 lbs/ ft^3

W = 2,720 pounds

1.1.3.2 Volume of Cylinders

Formula: V = $\pi \, x \, R^2$ x H

π = 3.14 R = Radius H = Height

Now lets try an example of volume calaculation for a cylinder. Refer to *Figure 22-6.*

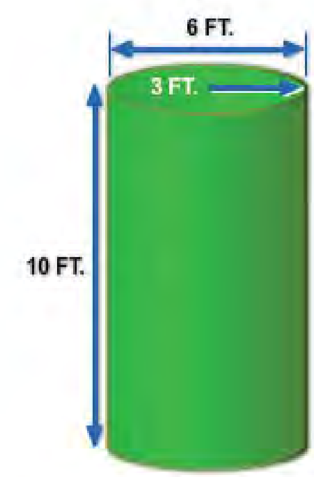


Figure 22-6 — Volume of a cylinder.

Given:

R = 3 feet H = 10 feet

V = $\pi \, x \, R^2$ x H

V = 3.14 x 3^2 x 10

V = 3.14 x 3 x 3 x10

V = 282.6 ft^3

Now calculate a steel cylinder that is 1 inch thick and full of saltwater.

Given:

Volume of cylinder = 282.6 ft^3

Material Weight of saltwater = 64 lbs/ ft^3 Material Weight of steel = 40.8lbs/ ft^3

First, calculate the weight of a cylinder (CW) full of saltwater.

CW = V x MW = 282.6 ft^3 x 64 lbs/ ft^3 = 18,086 lbs (18,087 rounded up)

But this is not the load weight, remember the weight of the container needs to be taken into account.

Now calculate the cylinder bottom plate weight (BWP).

BWP = $\pi \, x \, R^2$ x CW 3.14 x (3 x 3) x 40.8lbs/ ft^3 = 1154 lbs

Next calculate the cylinder wall weight (CWW).

CWW = π x Circumference x H x MW 3.14 x 6 x 10 x40.8lbs/ ft^3 = 7687 lbs

Now total up all weight calculations to receive load weight

BWP + CWW + CW 1154 + 7687 + 18087 = 26928 lbs

1.2.0 Center of Gravity/Center of Balance

Jobsite accidents are often caused by lack of understanding that whenever a load is lifted, the center of gravity of the load will place itself vertically below the hook, regardless of the arrangement of the slings, lift beams, or other attachments. The reason is that the sum of the forces and moments needs to be zero for a body in equilibrium.

The center of gravity of a body is that point on the body through which the weight of the body could be considered to be concentrated for all orientations of the body. For a body whose weight per net volume is uniform, the center of gravity lies at its centroid. The center of gravity is the location where the center of the object's entire weight is theoretically concentrated and where the object will balance when it is lifted. Center of gravity is always a fixed point and does not change unless the object is altered. For a balanced lift, the object's center of gravity is always in line below the hook. If you have a high center of gravity and the attachment points are below the center of gravity, the load is more prone to tip over. If you have a low center of gravity and the attachment points are above the center of gravity, the load is NOT likely to tip over when lifted.

The manufacturers normally provide the center of gravity locations of equipment. However, manufacturers' drawings typically have more information than just the center of gravity location, and as the EO, you need to sift through all of the information and identify what is relevant. In some cases, unfortunately, there is not enough information. When this occurs, you must make conservative assumptions to proceed. You are responsible for contacting the appropriate rates and supervisors for lift validations.

Center of balance is point where an object is balanced, this point can be located anywhere on the object. Two points to remember, center of balance is always perpendicular to the center of gravity and directly below the center of gravity.

1.2.1 Process to Find the Center of Gravity

Follow the process below to determine an object's center of gravity:

1. Separate objects into known sections or components.
2. Determine section weights.
3. Measure distance from a reference end to center of balance for each section.
4. Mutiply weight by distance.
5. Add together and divide by total weight.

Use this process on all three dimensions.

Refer to *Figure 22-7* to see an example of finding the center of gravity.

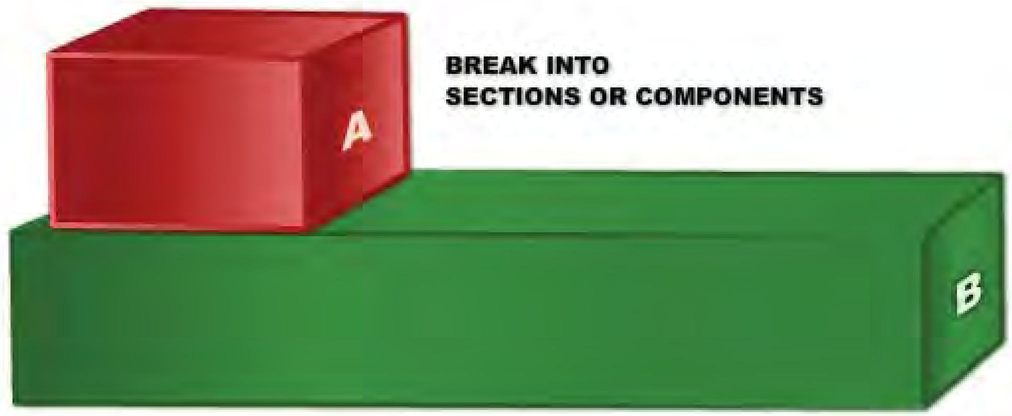


Figure 22-7 — Finding the center of gravity.

If you recall, you now must find the center of gravity for height and width. This is conducted in the same manner as described above, but along the height and width axis. Only then will you kow the true center of gravity.

1.3.0 Slings

One of the main components of any rigging arrangement is the sling or “choker.” Slings come in any number of shapes, sizes, capacities, and types. The main types are wire rope, nylon, polyester round, chain, and wire mesh. These components will be discussed in more detail later in this chapter. Wire rope used in rigging is typically 6 x 19 or 6 x 37 class, and all types must meet ASME B30.9 criteria. All slings, regardless of type, must have a legible tag stating, among other things, its safe working load (SWL) when in a straight pull. The SWL does not account for how the sling is to be used, whether in a choke or basket hitch or on an angle. When placed in a choker configuration, the sling could be derated as much as 30 percent, while a true basket hitch (where both legs are vertical) will have twice the rated capacity.

1.3.1 Basket Hitches and D/d Ratio

One catch to the basket hitch that is often missed is what is called the D/d ratio. When a sling is bent around something with a large diameter, the outer pieces of the wire rope stretch very little. However, when the sling is bent around a small diameter, the outer pieces will stretch greatly, thus requiring a reduction in capacity. To determine this reduction, calculate the D/d ratio and then look it up in a table such as Figure 22-8. The D is the diameter of the item around which the sling is bent, and the d is the diameter of the sling. For example, a 1.5 inch sling has an SWL of 21 tons and will bend around something that is 6 inches in diameter weighing 37 tons. If the D/d ratio is ignored, the capacity appears to be twice the SWL of 21 tons for a basket SWL of 42 tons. However, the D/d must be factored. Thus, 6 inches/1.5 inches = 4 inches. Now, as *Figure 22-8* indicates, the efficiency is actually 75 percent of 42 tons or 31.5 tons. Thus, calculating the D/d ratio before the lift determines that the proposed sling would be overloaded by 17.5 percent, and a larger sling can be recommended.

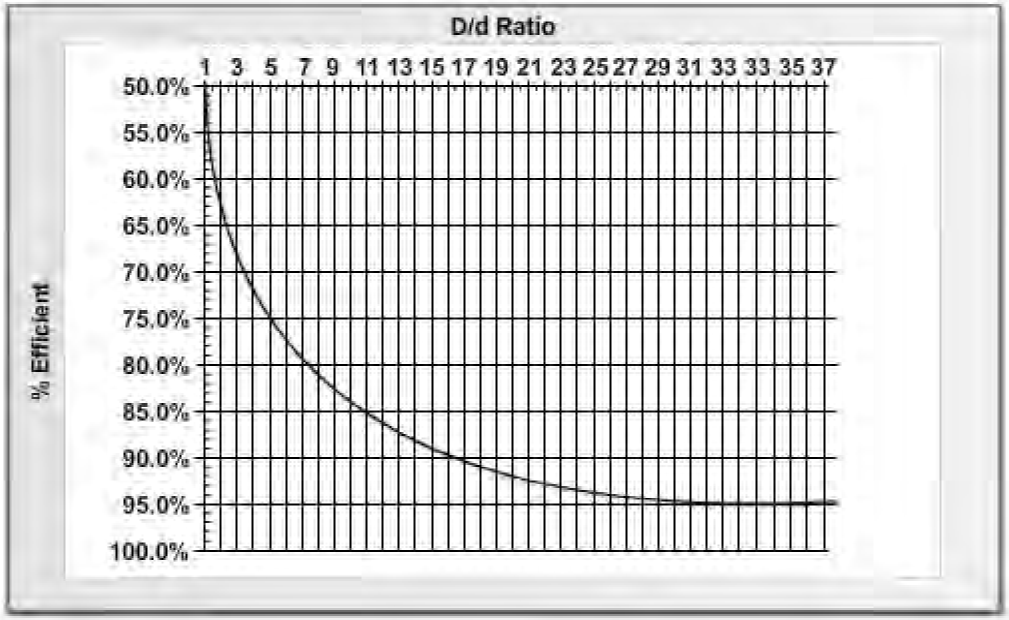


Figure 22-8 — D/d ratio chart.

1.3.2 Sling Angle

Sling angle is another area where a sling may need to be larger than thought. Note that the SWL is in straight pull. When the forces on a sling act on an angle, the forces that affect the sling will actually be greater. Refer to *Figure 22-9*.

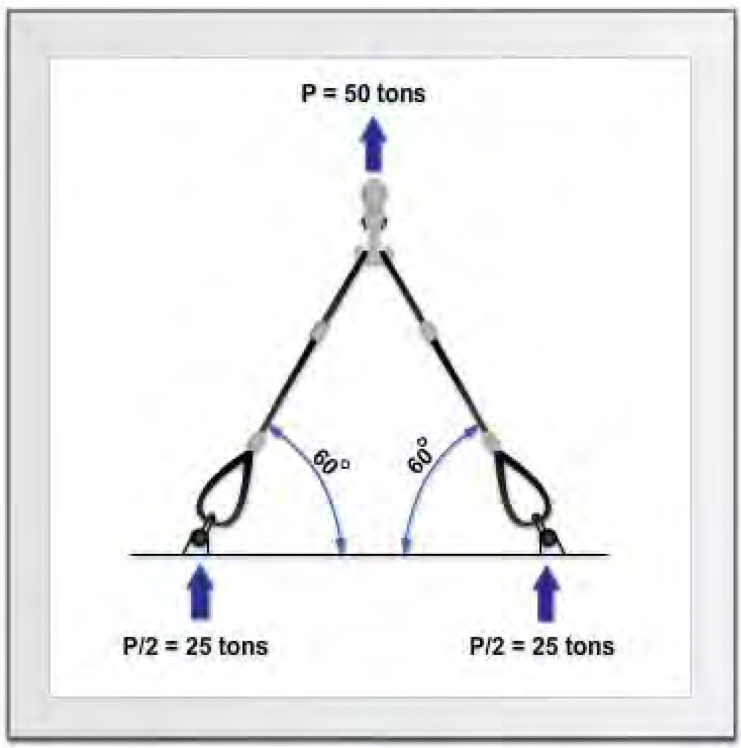


Figure 22-9 — Sling angle.

1.3.3 Bridles and Center of Gravity

Most jobsites use bridles of three or more legs on a regular basis. These items, while very useful and versatile, can be easily overloaded if not sized properly. The most common reason stems from the following logic: There are four pick points; therefore, each leg gets 25 percent of the load. However, assuming that the center of gravity is symmetrical to the lift points and that four or more pick points go to a single point, it is "statically indeterminate." Statically indeterminate means that the true load in each sling cannot be mathematically determined. In reality, only two opposite slings actually take any load, while the other two slings just help balance. Other factors contribute to this as well such as one leg being longer/shorter than the other or lugs not at the same elevation. To solve this problem, size the bridle so that only two legs can handle the load or use a spreader.

2.0.0 NAVFAC P-307

One of the most important publications, you will reference as an EO is the Management of Weight Handling Equipment, NAVFAC P-307.

This publication provides requirements for the maintenance, inspection, test, certification, repair, alteration, operation, and/or use of weight handling equipment under the technical cognizance of the Naval Facilities Engineering Command (NAVFAC). Activities covered include Navy shore activities, the Naval Construction Force (NCF), Naval Special Operating Units (SOU), and the Naval Construction Training Center (NCTC). These are the minimum requirements for all applicable equipment. This publication meets or exceeds all applicable OSHA requirements for maintenance, inspection, testing, certification, repair, alteration, and operation of equipment covered herein.

2.1.0 Purpose

The purposes of this publication are:

a. To maintain the level of safety and reliability built into each unit of applicable equipment by the original equipment manufacturer (OEM).
b. To ensure optimum service life.
c. To provide training and qualification standards for all personnel involved with maintenance, inspection, test, certification, engineering, rigging and operation of WHE.
d. To ensure the safe lifting and controlling capability of WHE and promote safe operating practices through the engineering, inspection, test, certification, qualification, operation, and rigging requirements prescribed herein.

This publication is broken down into 14 sections. The section we will cover is Section 14 – Rigging Gear and Miscellaneous Equipment.

2.2.0 Section 14

Section 14 applies to the following equipment used in weight handling operations:

- Rigging gear (slings, shackles, eye bolts, swivel hoist rings, links, rings, turnbuckles, insulated links, etc.)
- Portable manual and powered hoists. These are manual and powered hoists that are mounted by means of an upper hook (the source of power—air, electric, or manual— is irrelevant).
- Portable load indicators (dynamometers, load cells, crane scales, etc.)
- Below the hook lifting devices as identified in ASME B30.20
- Portable A-frames, portable floor cranes, and portable gantries used for general lifting
- Cranes and hoists procured with, integral to, and used solely in support of larger machine systems (milling machines, press brakes, shore power booms, etc.).

2.2.1 Test and Inspection Program

Each activity shall establish a program for applicable equipment, including a documented initial inspection and load test followed by pre-use and documented periodic inspections (and periodic tests as noted).

Remove unsatisfactory equipment and gear from service and disposed of or repair it.

Segregate equipment and gear that is not yet in a test and inspection program or is currently out of service from gear that is in service.

The goals of a effective test and inspection program are as follows:

- Prevent personnel injury
- Identify sub-standard equipment
- Remove unsafe equipment
- Prevent damage to items handled

2.2.1.1 Load Test

Except as noted, give each piece of applicable equipment an initial load test. A certificate of load (proof) test from the supplier of purchased equipment will satisfy this requirement, provided the proof loads used meet or exceed the loads specified in NAVFAC P-307 Table 14-1. Frequencies for periodic load testing of applicable equipment are also shown in Table 14-1. For equipment where the OEM does not permit testing at the percentages shown, reduce the rated load such that the OEM's allowed test load will serve as the load test value.

For each test, the equipment shall withstand the load test for a minimum of two minutes (10 minutes for hoist, cranes, and crane structures) with no permanent deformation. For hoists, trolleys, and other moving machinery, lift (travel) through at least one revolution of all moving parts.

When testing wire rope and synthetic rope slings, ensure the slings are prevented from unlaying. (See discussion in following section). Where it is not practical to test locally fabricated special rigging gear (e.g., non-standard eye bolts made specifically for a particular application), the activity engineering organization shall approve the use of such gear.

2.2.1.2 Pre Use Inspection (Frequent Inspection)

The user shall visually inspect applicable equipment prior to each use to verify rated load, marking, inspection status, serial number, and condition. No documentation of pre-use inspection is required.

2.2.1.3 Periodic Inspection

NAVFAC P-307, Table 14-1 specifies periodic documented inspections for covered equipment. Rigging gear used exclusively for lifts of 100 pounds or less and gear with a safety factor of 10 with respect to the yield point of the material are excluded from these periodic inspection requirements.

2.2.2 Equipment Markings

Markings on each piece of equipment are the most apparent way for you, the user, to know P-307 requirements have been met.

Each piece of equipment must be clearly marked, whether tagged or engraved, with:

- Rated load of the equipment
- Date the next test or inspection cycle is due

- A unique serial number that will allow it to be retraced to its test and inspection record
- Manufacturer's name or logo

Markings indicate that equipment is acceptable for use. Markings must be done in a manner that will not affect strength of component. Vibra-etch methods and low stress dot faced stamps are generally acceptable ways of marking equipment.

Contact Original Equipment Manufacturer (OEM) as necessary if you have any questions concerning where and how to mark. Refer to *Figure 22-10* for examples of equipment markings.

Figure 22-10 — Equipment markings.

Sometimes markings become hard to read due to wear, or they may even be removed during a repair process. Re-apply all markings that are hard to read or have been removed. Remember, all rigging equipment must be marked for you to use it in a weight handling operation.

3.0.0 WIRE ROPE

3.1.0 Fabrication

Wire rope is a highly specialized precision product adaptable to many uses and conditions of operation. To meet the exacting requirements of different types of service, it is designed and manufactured in a number of constructions and grades.

Wire rope is like a complex machine, composed of a number of precise, moving parts designed and manufactured to bear a very definite relationship to one another. In fact, many wire ropes contain more moving parts than most mechanisms that fall within the broad general term “machine.” For example a six-strand rope, consisting of approximately 46 wires per strand, contains a total of 276 individual wires, all of which must be able to move with respect to one another if the rope is to have the necessary flexibility during operation.

Wire rope may be manufactured by one of two methods. If the strands, or wires, are shaped to conform to the curvature of the finished rope before laying up, the rope is termed ***preformed wire rope***. If they are not shaped before fabrication, the wire rope is termed ***non-preformed wire rope***.

The most common type of manufactured wire rope is preformed. When cut, the wire rope tends not to unlay and is more flexible than non-preformed wire rope. Twisting non-preformed wire produces a stress in the wire which causes the strands to unlay when the wire is cut or broken.

3.2.0 Parts of Wire Rope

Wire rope is composed of three parts: ***wires***, ***strands***, and ***core*** (*Figure 22-11*). A predetermined number of wires of the same or different size are fabricated in a uniform arrangement of definite lay to form a strand. The required number of strands are then laid together symmetrically around the core to form the wire rope.

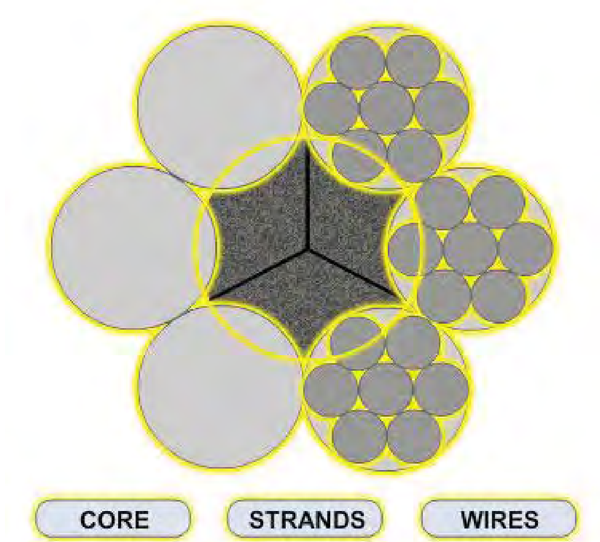


Figure 22-11 – Parts of a wire rope.

3.2.1 Wire

Wire rope varies in size and can consist of steel, iron, or other metals. The number of wires to a strand varies, depending on the intended purpose of the rope. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus a one-half inch, 6 x 19 rope has six strands with 19 wires per strand. It has the same outside diameter as a one-half inch, 6 x 37 rope that has six strands with 37 wires (of smaller size) per strand.

3.2.2 Strand

The design arrangement of a strand is called the construction. The wires in the strand may be all the same size or a combination of different sizes. *Figure 22-12* show some of the more typical wire rope constructions. The most common strand constructions you may encounter are as follows:

- Ordinary construction: Wires are all the same size.
- Seale construction: Each strand consists of three rings of wire. The first ring of wires around the center wire of the strand is of smaller diameter than the center and outer layers. Large diameter wires resist abrasion while smaller diameter wires provide flexibility.

- Warrington construction: Each strand has two layers of wire about a center wire. The outer layer consists of wires that are alternately large and small. This alternating wire size combines flexibility with abrasion resistance.
- Filler construction: Filler wire has small wires filling the voids between the rings of wire in the strand. These small wires are not counted when designating the number of wires in the strand. This construction type provides abrasion and fatigue resistance.
- Flattened construction: Strands are somewhat triangular in shape, and sometimes formed around a triangular center wire.

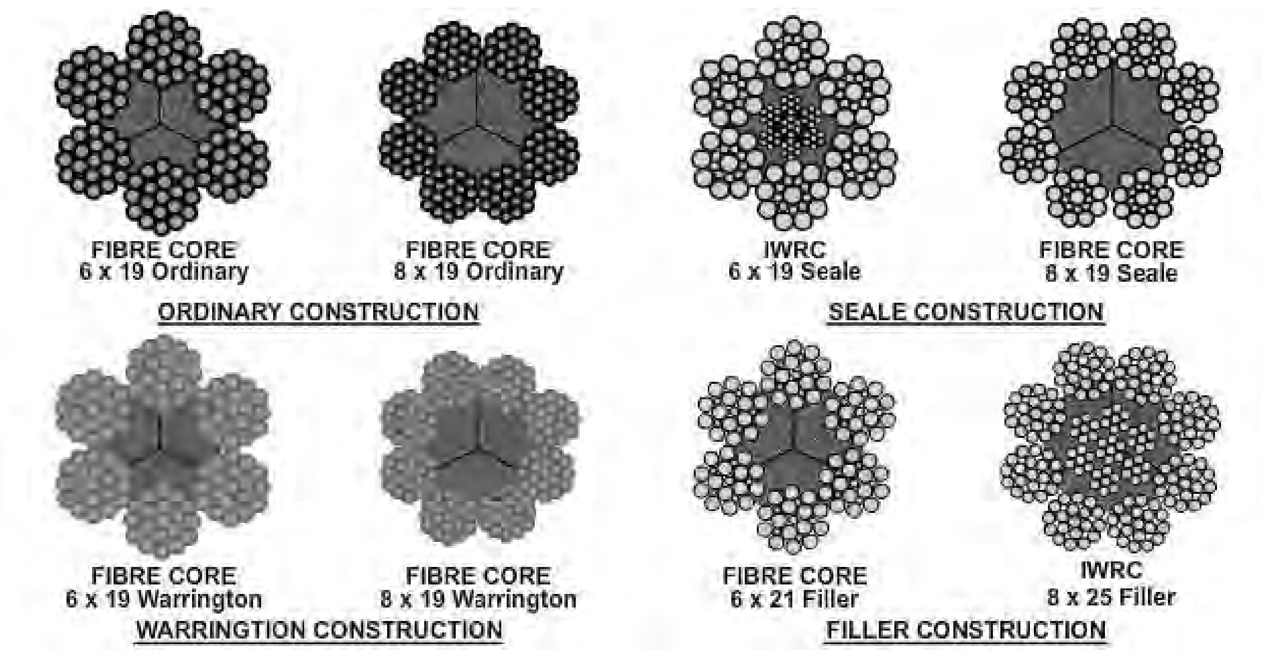


Figure 22-12 — Common strand construction.

3.2.3 Core

The wire rope core supports the strands laid around it. There are three types of wire rope core:

- **Fiber core** consists of a hard fiber, such as manila, hemp, plastic, paper, or sisal. The fiber core offers the advantage of increased flexibility. It also serves as a cushion to reduce the effects of sudden strain and acts as an oil reservoir to lubricate the wire and strands (to reduce friction). Wire rope with a fiber core is used when flexibility of the rope is especially important.
- **Wire strand core** resists more heat than a fiber core and also adds about 15 percent to the strength of the rope. However, the wire strand core makes the wire less flexible than a rope with a fiber core.

- **Independent wire rope core** (IWRC) is a separate wire rope over which the main strands of the rope are laid. This core strengthens the rope, provides support against crushing, and supplies maximum resistance to heat. Refer to *Figure 22-13.*

3.3.0 Grades of Wire Rope

There are four primary grades of wire rope:

- Mild plow steel
- Plow steel
- Improved plow steel
- Extra improved plow steel

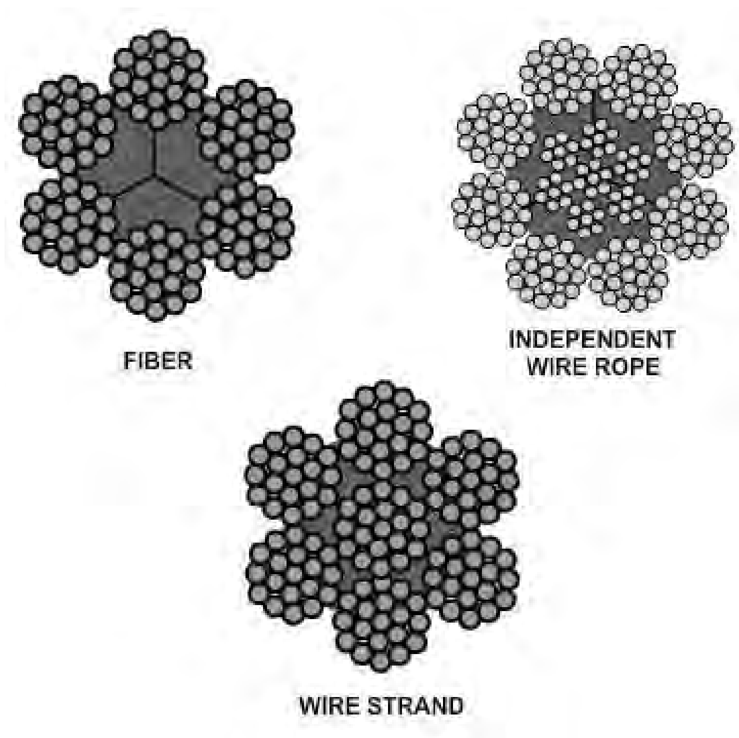


Figure 22-13 — Core construction.

3.3.1 Mild Plow Steel Wire Rope

Mild plow steel wire rope is tough and pliable. It can stand repeated strain and stress and has a tensile strength (resistance to lengthwise stress) of from 200,000 to 220,000 pounds per square inch (psi). These characteristics make it desirable for cable tool drilling and other uses in which abrasion occurs.

3.3.2 Plow Steel Wire Rope

Plow steel wire rope is unusually tough and strong. This steel, which got its name from the original high-carbon crucible furnace steel used to produce plowshares, has a tensile strength of 220,000 to 240,000 psi. Plow steel wire rope is suitable for hauling, hoisting, and logging.

3.3.3 Improved Plow Steel Wire Rope

Improved plow steel (IPS) wire rope is one of the best grades of rope available and is the wire rope most commonly used in the NCF. This type of rope is stronger, tougher, and more resistant to wear than either mild plow steel or plow steel. Each square inch of IPS can stand a strain of 240,000 to 260,000 pounds. This makes it especially useful for heavy-duty service, such as on cranes with excavating and weight-handling attachments.

3.3.4 Extra Improved Plow Steel Wire Rope

Extra Improved Plow Steel (EIP) is 15% stronger than IPS. Various manufacturers have their own name for this grade. It was developed for applications, such as rotary oil-well drilling, needing greater safety factors without a diameter increase and for maximum resistance to abrasive wear, such as that resulting from draglines in strip mining through rocky terrain. This premium grade has tensile strength ranging from 280,000 to 340,000 psi.

3.4.0 Lay of Wire Rope

Lay refers to the direction of the twist of the wires in a strand and to the direction that the strands are laid in the rope. In some instances, both the wires in the strand and the strands in the rope are laid in the same direction; in other instances, the wires are laid in one direction and the strands are laid in the opposite direction. The lay of a particular rope depends on its intended use. Most manufacturers specify the types and lays of wire rope to be used on their piece of equipment. Always consult the operator's manual for proper application.

There are five types of lays used in wire rope (*Figure 22-14*).

3.4.1 Right Regular Lay

The wires in the strands are laid to the left, while the strands are laid to the right to form the wire rope.

3.4.2 Left Regular Lay

The wires in the strands are laid to the right, while the strands are laid to the left to form the wire rope. In this lay, each step of fabrication is exactly opposite from the right regular lay.

3.4.3 Right Lang Lay

The wires in the strands and the strands in the rope are laid in the same direction; in this instance the lay is to the right.

3.4.4 Left Lang Lay

The wires in the strands and the strands in the rope are are also laid in the same direction; in this instance the lay is to the left.

3.4.5 Reverse Lay

The wires in one strand are laid to the right, the wires in the nearby strand are laid to the left, the wires in the next strand are to the right, and so forth, with alternate directions from one strand to the other. Then all the strands are laid to the right.

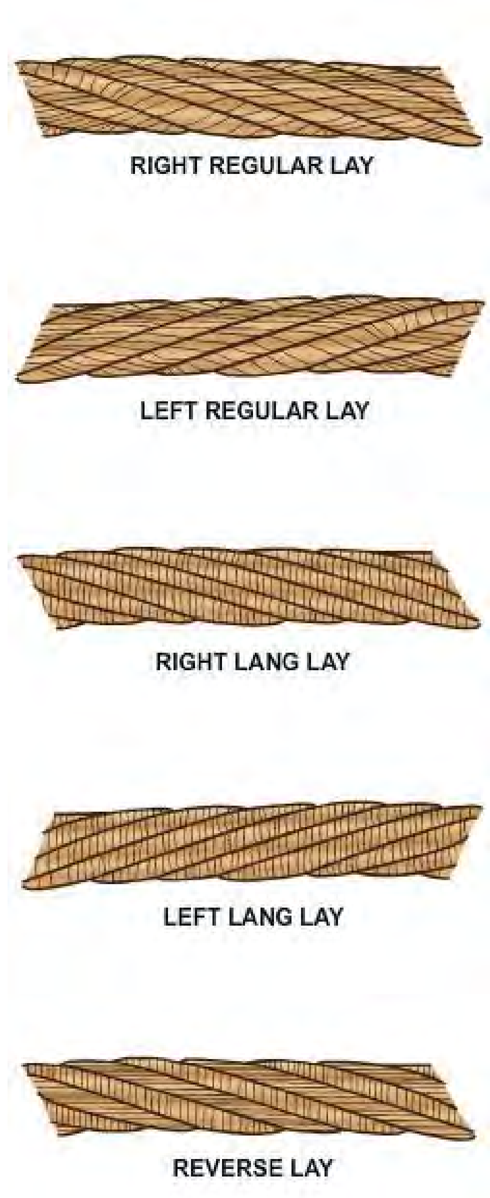


Figure 22-14 — Lay of wire rope.

3.5.0 Lay Length of Wire Rope

The length of a rope lay is the distance measured parallel to the center line of a wire rope in which a strand makes one complete spiral (or turn) around the rope. The length of a strand lay is the distance measured parallel to the center line of the strand in which one wire makes one complete spiral turn around the strand. Lay length measurement is shown in *Figure 22-15*.

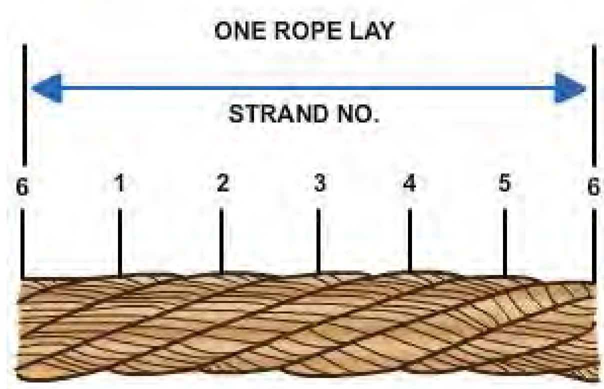


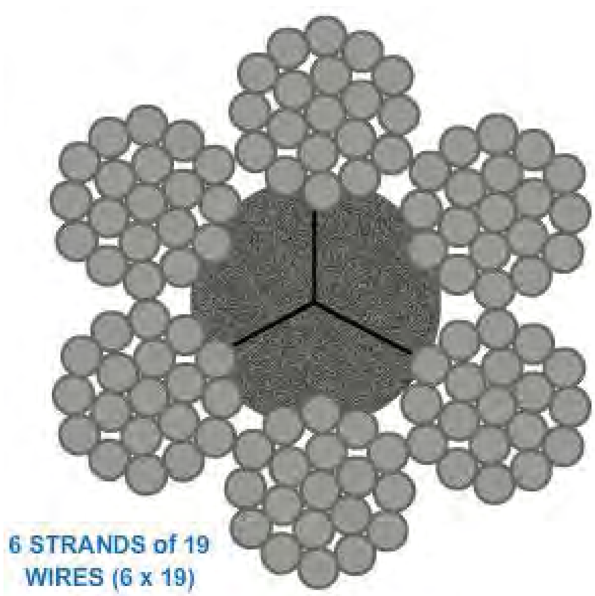
Figure 22-15 – Lay length of wire rope.

3.6.0 Characteristics of Wire Rope

The NCF use several types of wire, typically those with 6, 7, 12, 19, 24, or 37 wires in each strand. Usually the wire rope has six strands laid around the core.

The two most common types of wire rope are 6 x 19 and 6 x 37 (*Figures 22-16, and 22-17*). The 6 x 19 type, which has 6 strands with 19 wires in each strand, is the stiffest and strongest construction of the wire rope and the most suitable for general hoisting operations. The 6 x 37 wire rope, six strands with 37 wires in each strand, is very flexible, making it most suitable for cranes and other pieces of equipment in which sheaves are smaller than usual. The wires in the 6 x 37 are smaller than the wires in the 6 x 19 and, consequently, do not stand as much abrasive wear.

Consider several factors when selecting a wire rope for use in a particular kind of operation. There is not a wire rope in existence that equally withstands all kind of wear and stress. Because of this, selecting a rope is often a matter of compromise, sacrificing one quality to have another more critical characteristic.



Figures 22-16 – 6 x 19 wire ropes.

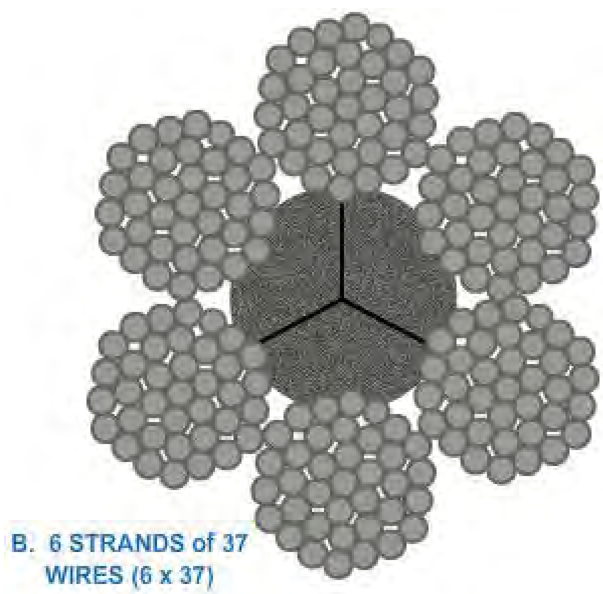


Figure 22-17 – 6 x 37 wire rope.

3.6.1 Tensile Strength

Tensile strength is the strength necessary to withstand a certain maximum load applied to the rope. It includes a reserve of strength measured in a so-called factor of safety.

3.6.2 Crushing Strength

Crushing strength is the strength necessary to resist the compressive and squeezing forces that distort the cross section of a wire rope as it runs over sheaves, rollers, and hoist drums when under a heavy load. Regular lay rope distorts less in these situations than lang lay.

3.6.3 Fatigue Resistance

Fatigue resistance is the ability to withstand the constant bending and flexing of wire rope that runs continuously on sheaves and hoist drums. Fatigue resistance is important when the wire rope must run at high speeds. Such constant and rapid bending of the rope can break individual wires in the strands. Lang lay ropes are best for service requiring high fatigue resistance. Ropes with smaller wires around the outside of their strands also have greater fatigue resistance, since these strands are more flexible.

3.6.4 Abrasion Resistance

Abrasion resistance is the ability to withstand the gradual wearing away of the outer metal as the rope runs across sheaves and hoist drums. The rate of abrasion depends mainly on the load carried by the rope and its running speed. Generally, abrasion resistance in a rope depends on the type of metal of which the rope is made and the size of the individual outer wires. Wire rope made of the harder steels, such as improved plow steel, have considerable resistance to abrasion. Ropes that have larger wires forming the outside of their strands are more resistant to wear than ropes having smaller wires which wear away more quickly.

3.6.5 Corrosion Resistance

Corrosion resistance is the ability to withstand the dissolution of the wire metal that results from chemical attack by moisture in the atmosphere or elsewhere in the working environment. Ropes, such as guy wires, that are put to static work may be protected from corrosive elements by paint or other special dressings. Wire rope may also be galvanized for corrosion protection. Most wire ropes used in crane operations must rely on their lubricating dressing to double as a corrosion preventative.

3.7.0 Measuring Wire Rope

Wire rope is designated by its diameter in inches, as shown in *Figure 22-18*. The correct method of measuring the wire rope is to measure from the top of one strand to the top of the strand directly opposite it. Measuring across two side by side strands is not correct.

To ensure an accurate measurement of the wire rope's diameter, always measure the rope at three places, at least five feet apart. Use the average of the three measurements as the diameter of the rope.

NOTE

A crescent wrench provides an expedient means to measure wire rope.

3.8.0 Wire Rope Safe Working Load

The safe working load (SWL) of wire rope is the load that can be applied and still obtain the most efficient service and prolong the life of the rope.

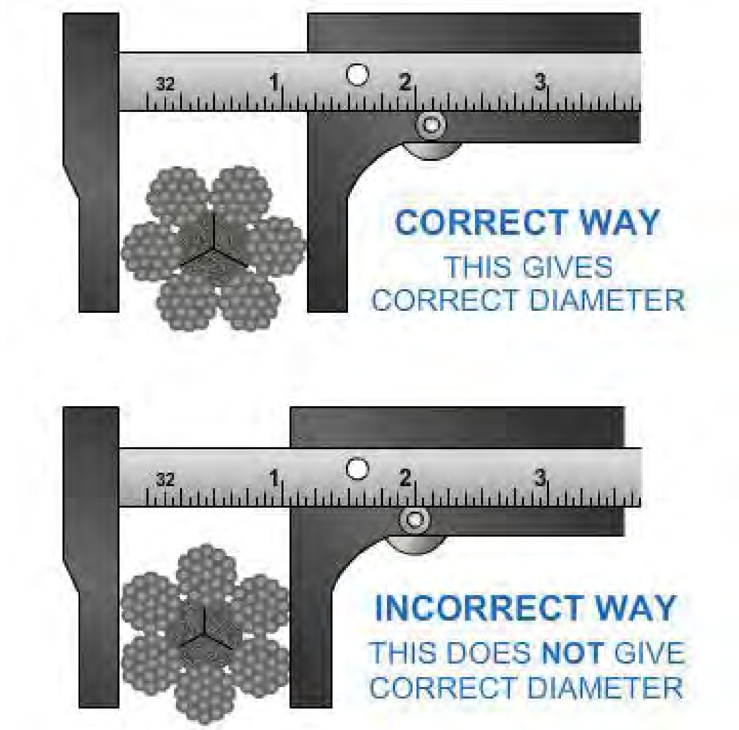


Figure 22-18 — Correct and incorrect methods of measuring wire rope.

The formula for computing the SWL of a wire rope is the diameter of the rope squared, multiplied by 8 (D x D x 8 = SWL in tons).

Example: The wire rope is 1/2 inch in diameter. Compute the SWL for the rope.

The first step is to convert the 1/2 into a decimal number by dividing the bottom number of the fraction into the top number of the fraction: (1 divided by 2 = .5). Next, compute the SWL formula: (.5 x .5 x 8 = 2 tons). The SWL of the 1/2 inch wire rope is 2 tons.

NOTE

Do NOT downgrade the SWL of wire rope if it is old, worn, or in poor condition. Cut up and discard wire rope in these conditions.

3.9.0 Wire Rope Failure

Common causes of wire rope failure include:

- Using an incorrect size, construction, or grade of rope
- Dragging rope over obstacles
- Lubricating improperly
- Operating over sheaves and drums of inadequate size
- Overriding or cross winding on drums
- Operating over sheaves and drums with improperly fitted grooves or broken flanges
- The rope jumping off sheaves
- Exposing ropes to acid and/or other corrosive liquids/gases
- Using an improperly attached fitting
- Allowing grit to penetrate between the strands, promoting internal wear
- Subjecting the rope to severe or repetitive overload
- Using an excessive ***fleet angle***

3.10.0 Handling and Care of Wire Rope

To maximize the safe, dependable service of wire rope, take care to perform the maintenance necessary to keep the wire rope in good condition. Various ways of caring for and handling wire rope are discussed below.

3.10.1 Coiling and Uncoiling

Once a new reel is open, it may be coiled or faked down (laid in a coil or series of long loops to allow the rope to run freely without kinking) like line. For left lay wire rope, coil counterclockwise. For right lay wire rope, coil clockwise. Because of the resilience of the wire, it can be resistant to being coiled down. When this occurs, it is not useful to force the wire down the turn because it will just spring up again. Instead, throw the wire in a back turn (*Figure 22-19)*, and it will lie down properly. A wire rope, when faked down, runs right off. But when wire rope is wound in a coil, it has to be unwound manually.

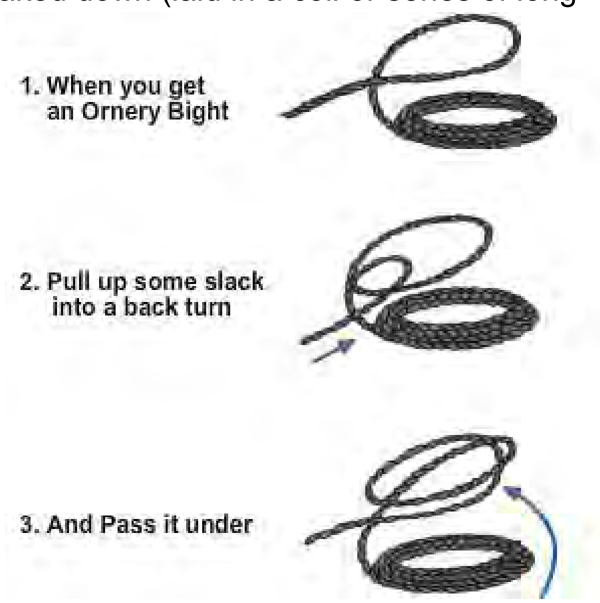


Figure 22-19 – Throwing a back turn.

Wire rope tends to kink during uncoiling or unreeling, especially if it has been in use for a long time. A kink can cause a weak spot in the rope that wears out more quickly than the rest of the rope.

A good method for unreeling wire rope is to run a pipe or rod through the center and mount the reel on drum jacks or other supports so the reel is off the ground. In this position, the reel turns as the rope unwinds, and the rotation of the reel helps keep the rope strait. During unreeling, pull the rope strait forward and try not to rush. To avoid kinking, NEVER unreel wire rope from a stationary reel. Refer to *Figure 22-20*.

To uncoil a small twist of wire rope, simply stand the coil on edge and roll it along the ground like a wheel or hoop. Do not lay the coil flat on the floor/ground and uncoil it by pulling on the end- such practice can kink and/or twist the rope.


Figure 22-20 — Unreeling wire rope and uncoiling wire rope.

3.10.2 Kinks

One of the most common forms of damage resulting from improper handling of wire rope is kink development. A kink starts with the formation of a loop. A loop that is not pulled tight enough to set the wires or strands of the rope into a kink can be removed by turning the rope at either end in the direction appropriate to restore the lay (Figure 22-21).

If you attempt to remove a loop simply by pulling it tight, a kink will result, and the rope will be irreparably damaged. Kinking is preventable through proper uncoiling and unreeling methods and by handling the rope correctly at all times.

3.10.3 Drum Winding

Spooling wire rope on a crane hoist drum causes a slight rotating tendency due to the spiral lay of the strands. Two types of hoist drums are used for spooling wire rope:

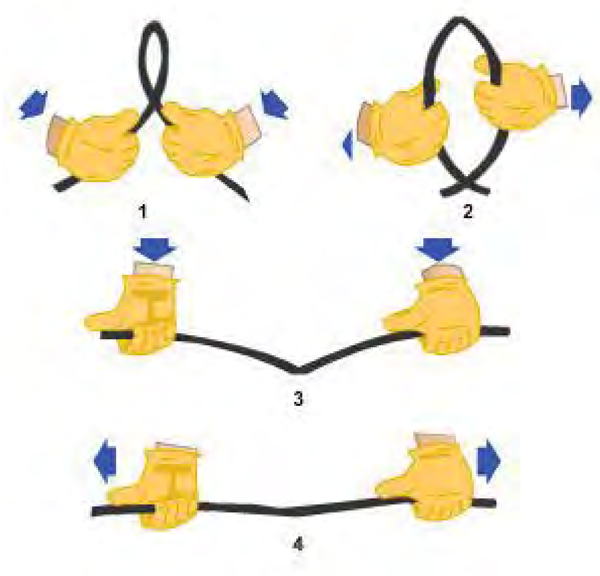


Figure 22-21 – Removing a loop.

- Grooved drum: On grooved drums, the grooves generally give sufficient control to wind the wire rope properly, whether it is right or left lay rope.
- Smooth-Faced Drum: On smooth-faced drums, the only influence on the wire rope in winding the first layer is the fleet angle. The slight rotational tendency of the rope can be used as an advantage in keeping the winding tight and uniform.

NOTE

Using the wrong type of wire rope lay causes the rotational tendency of the rope to be a disadvantage because it results in loose and non-uniform rope winding on the hoist drum.

Figure 22-22 shows drum winding diagrams for selection of the proper lay of rope. Standing behind the hoist drum and looking toward an oncoming overwind rope, the rotating tendency of right lay rope is toward the left; whereas, the rotating tendency of a left lay rope is toward the right.

Refer to *Figure 22-22*. With overwind reeving and a right lay rope on a smooth-faced drum, the wire rope bitter end attachment to the drum flange should be at the left flange. With underwind reeving and a right lay rope, the wire rope bitter end attachment should be at the right flange.

When wire rope is run off one reel onto another or onto a winch or drum, it should be run from TOP TO TOP or from BOTTOM TO BOTTOM**,** as shown in *Figure 22-23*.

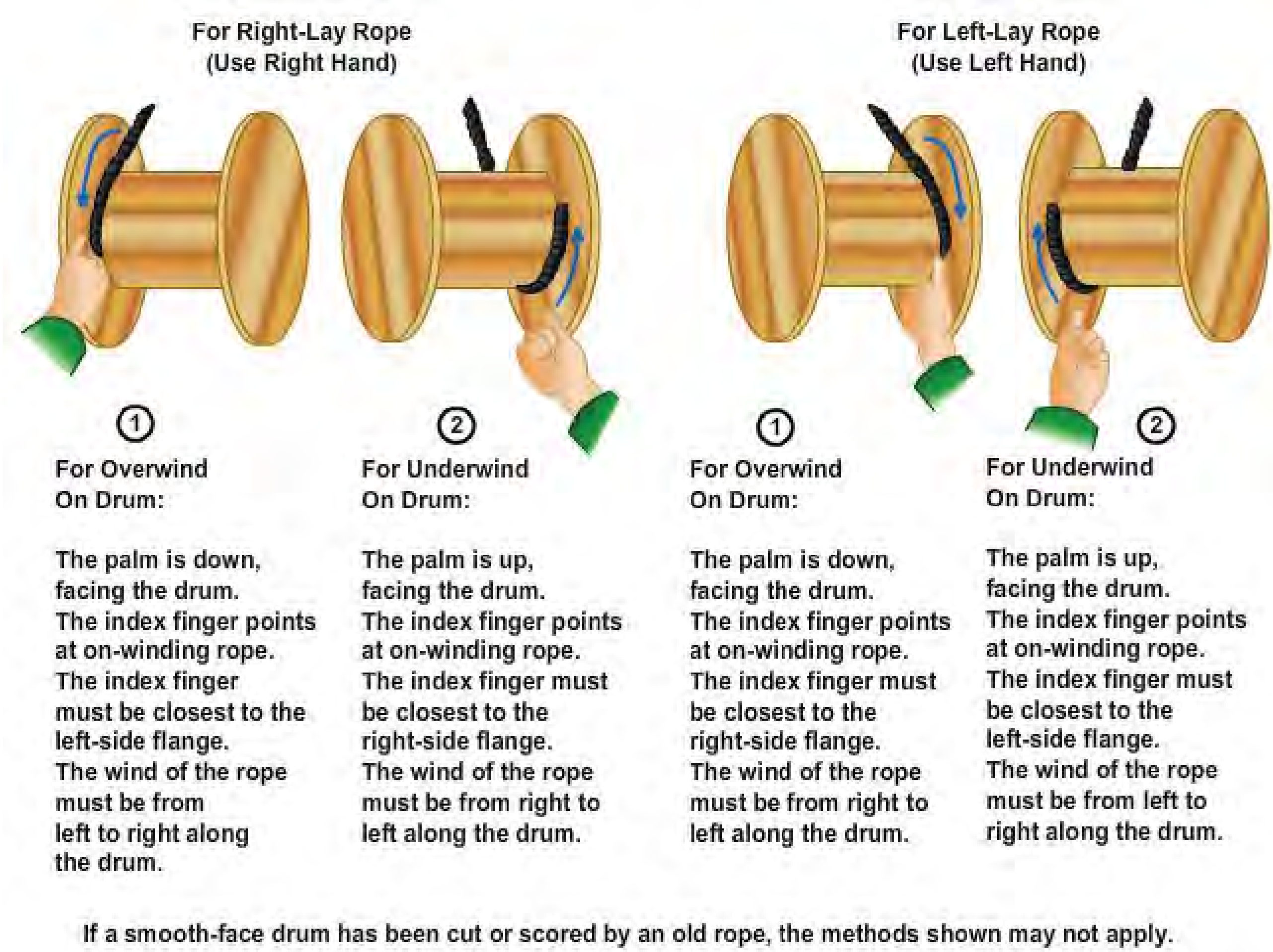


Figure 22-22 — Different lays of wire rope winding on hoist drums.

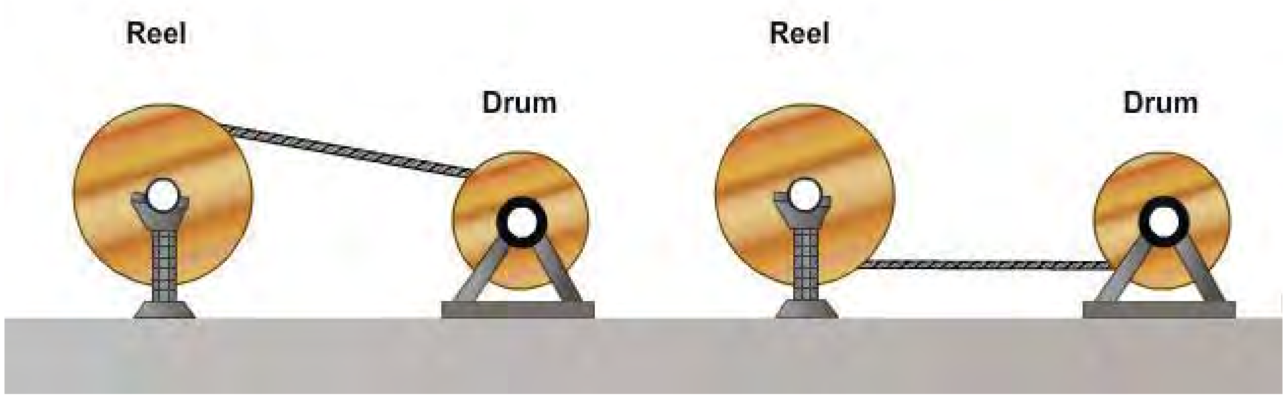


Figure 22-23 — Transferring wire rope from reel to drum.

3.10.4 Fleet Angle

The fleet angle is formed by running wire rope between a sheave and a hoist drum whose axles are parallel to each other, as shown in *Figure 22-24*. Too large a fleet angle can cause the wire rope to climb the flange of the sheave and can also cause the wire rope to climb over itself on the hoist drum.

3.10.5 Sizes of Sheaves

The diameter of a sheave should never be less than 20 times the diameter of the wire rope. An exception is 6 x 37 wire for which a smaller sheave can be used, because this wire rope is more flexible.

Use the chart shown in *Table 22-2* to determine the minimum sheave diameter for wire rope of various diameters and construction.

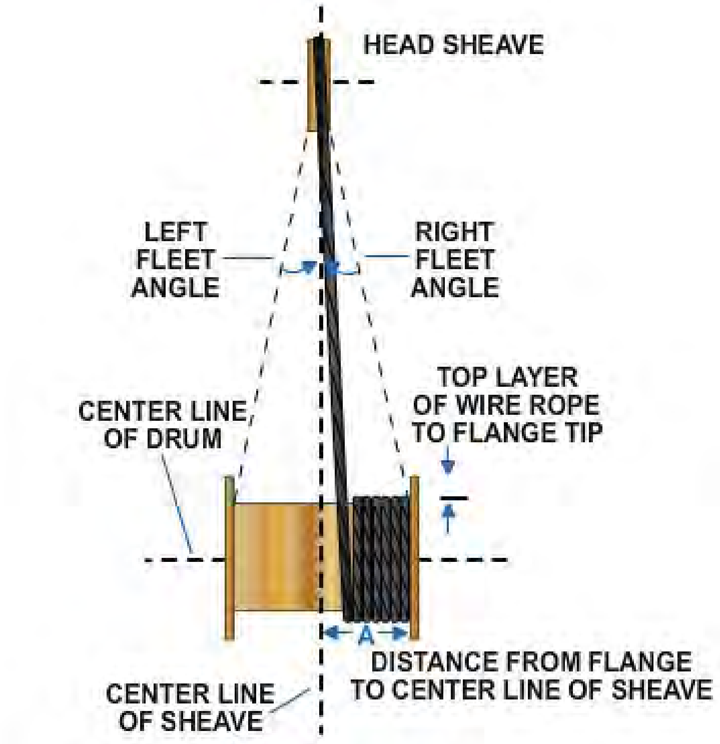


Figure 22-24 Fleet angle relationship.

Table 22-2 — Suggested minimum tread diameter of sheaves and drums.

Rope diameter in inches	**Minimum tread diameter in inches for given rope construction ***			
	6 x 7	6 x 19	6 x 37	8 x19
1/4	10 1/2	8 1/2		6 1/2
3/8	15 3/4	12 3/4	6 3/4	9 3/4
1/2	21	17	9	13
5/8	26 1/4	21 1/4	11 1/4	16 1/4
3/4	31 1/2	25 1/2	13 1/2	19 1/2
7/8	36 3/4	29 3/4	15 3/4	22 3/4
1	42	34	18	26
1 1/8	47 1/2	38 1/4	20 1/2	29 1/4
1 1/4	52 1/2	42 1/2	22 1/2	32 1/2
1 1/2	63	51	27	39
*** Rope construction is in strands times wires per strand**.				

3.10.6 Reverse Bends

Whenever possible, place drums, sheaves, and blocks used with wire rope to avoid reverse or S-shaped bends. Reverse bends cause the individual wires or strands to shift too much and increase wear and fatigue. For a reverse bend, the drums and blocks affecting the reversal should be of a larger diameter than ordinarily used and should be spaced as far apart as possible.

3.10.7 Seizing and Cutting

Wire rope makers are careful to lay each wire in the strand and each strand in the rope under uniform tension. If the ends of the rope are not secured properly, the original balance of tension is disturbed and maximum service is not possible because the load weight ends up being unevenly distributed. Before cutting steel wire rope, place seizing on each side of the cutting point (*Figure 22-25*).

Determining the size and number of seizings and the distance between them depends on several rules of thumb:

- The number of seizings applied is equal to approximately three times the rope's diameter.
- The width of each seizing is between one and one and a half times as long as the diameter of the rope.
- Space seizing a distance equal to twice the wire rope's diameter.

A common method used to make a temporary wire rope seizing involves winding the seizing wire uniformly, using tension on the wire. After taking the required number of turns, twist the ends of the wires counterclockwise by hand so that the twisted portion of the wires are near the middle of the seizing. Grasp the ends with end-cutting nippers. Cut the ends and pound them down on the rope, then use a serving bar (or iron) to increase tension on the seizing wire when putting on the turns.

A wire rope can be cut in a number of ways. One effective and simple method is to use a hydraulic wire rope cutter.

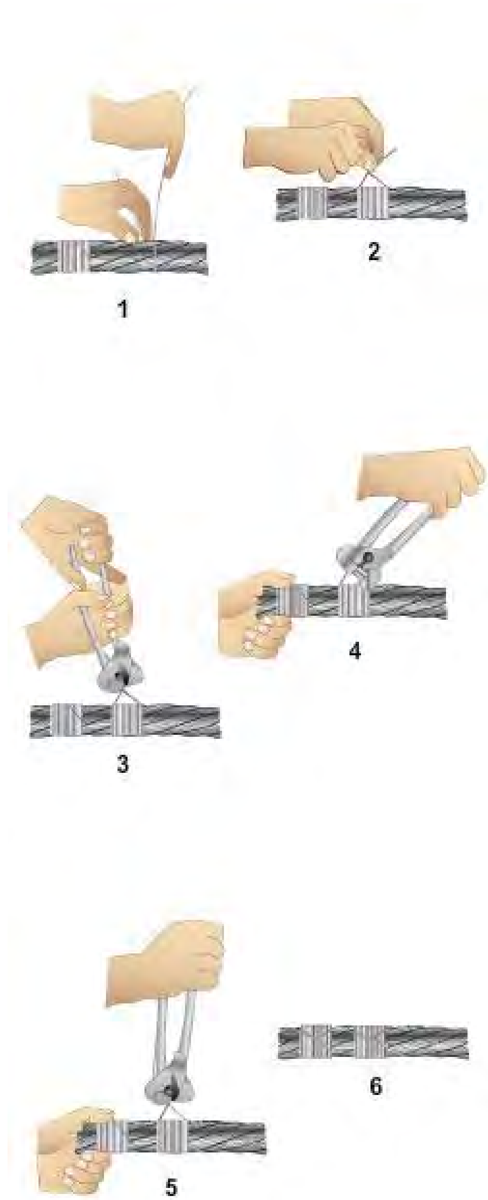


Figure 22-25 — Seizing wire rope.

Seize all wire before cutting it, then place the rope in the cutter so that the blade comes between the two central seizings. With the release valve closed, jack the blade against the rope at the location of the cut and continue to operate the cutter until the cut is complete.

3.11.0 Wire Rope Maintenance

Wire rope bending around hoist drums and sheaves will wear like any other metal article, so lubrication is just as important to an operating wire rope as it is to any other piece of working machinery. For a wire rope to operate correctly, its wires and strands must be free to move. Friction from corrosion or lack of lubrication shortens the service life of wire rope.

Deterioration from corrosion is more dangerous than that from wear, because corrosion ruins the inside wires, a process hard to detect by inspection. Deterioration caused by wear can be detected by conducting internal and external inspections.

3.11.1 Inspections

Unless experience with specific operating conditions indicates that more frequent inspections are required, visually inspect all running wire rope in service quarterly to determine whether deterioration has resulted in appreciable loss of original strength and constitutes a safety hazard.

3.11.1.1 External Inspection

The external inspection criteria for general usage running wire rope is as follows:

A. Reduction of nominal rope diameter due to loss of core support or internal or external corrosion or wear of individual outside wires. The diameter shall be measured in a circumscribing circle in six or more places on the wire rope, as shown in *Figure 22-18*.
B. Number of broken outside wires and degree of distribution or concentration of broken wires.
C. Corroded, pitted, or broken wires at the end connections.
D. Corroded, cracked, bent, worn, or improperly applied end connections.
E. Severe kinking, crushing, or distortion of rope structure.
F. Evidence of heat damage from any cause.

3.11.1.2 Internal Inspection

A wire rope can be opened for internal inspection only when completely relaxed. Using care to avoid damaging the strands or core, open the wire rope in six or more places, by working a marlin spike beneath two strands. Carefully rotate the spike to expose the core and underside of the strands. Inspect for evidence of internal corrosion, broken wires, or core failure. Give particular attention to the wire rope in areas close to end fittings, those lengths that pass over sheaves, onto drums, or that remain exposed to or immersed in seawater. If a wire rope has been opened properly and carefully, and internal condition does not show cause for removal, the strands can be returned to their original working positions without distorting the wire rope or impairing future usefulness. Only qualified personnel shall be authorized to inspect wire rope.

3.11.1.3 Rejection Criteria

The following is a list of conditions that indicate a wire rope should be removed from service:

A. The nominal rope diameter is reduced by more than the amount shown in *Table 22-3* for the applicable size rope, or there is an unexpected increase in lay length as compared to previous lay length measurements

Table 22-3 — Wire rope allowable diameter reduction.

Rope Diameter (Inches)	Maximum Allowable Nominal Diameter Reduction (Inches)
5/16 and smaller	1/64
3-8 to 1/2	1/32
9/16 to 3/4	3/64
7/8 to 1 1/8	1/16
1 1/4 to 1 1/2	3/32
1 9/16 to 2	1/8
2 1/8 to 2 1/2	5/32

B. Six broken wires in one rope lay length, or three broken wires in one strand lay length

C. One broken wire within one rope lay length of any end fitting

D. Wear of 1/3 the original diameter of outside individual wires, evidenced by flat spots almost the full width of the individual wire, extending one lay length or more

E. Pitting due to corrosion, or nicks, extending one lay length or more

F. Severe kinking, crushing, or any other damage resulting in distortion of the rope structure

G. Evidence of internal corrosion, broken wires on the underside of strands or in the core

3.11.2 Lubrication

Both internal and external lubrication protect a wire rope against wear and corrosion. Internal lubrication can be properly applied only when the wire rope is being manufactured, and manufacturers customarily coat every wire with a rust-inhibiting lubricant and lay it into the strand. The core is also lubricated in manufacturing.

Lubrication applied in the field is designed not only to maintain surface lubrication but also to prevent the loss of the internal lubrication provided by the manufacturer. The Navy issues an asphaltic petroleum oil that must be heated before using. This lubricant is known as Lubricating Oil for Chain, Wire Rope, and Exposed Gear and comes in two types:

- Type I, Regular: This type of lubricant does not prevent rust and is used where rust prevention is unnecessary. For example, elevator wires used inside structures that are not exposed to the weather, but still require lubrication.
- Type II, Protective: A lubricant and an anti-corrosive, it comes in three grades:
  - Grade A: For cold weather (60°F and below)
  - Grade B: For warm weather (between 60°F and 80°F)
  - Grade C: For hot weather (80°F and above)

Apply the oil, issued in 25-pound or 35-pound buckets and also in 100-pound drums, with a stiff brush, or draw the wire rope through a trough of hot lubricant (Refer to *Figure 22-26*). The frequency of application depends upon service conditions; as soon as the last coating has appreciably deteriorated, renew it.

CAUTION

Avoid prolonged skin contact with oils and lubricants. Consult the Materials Safety Data Sheet (MSDS) on each item before use for precautions and hazards.

A good lubricant to use when working in the field, as recommended by *Naval Ships Technical Manual Chapter 613*, is Mil-Spec lubricant (MIL-G-18458).

Figure 22-26 — Trough method of lubricating wire rope.

Do not lubricate wire rope that works a dragline or other attachments that normally bring the wire rope in contact with soils. The lubricant will pick up fine particles of material, and the resulting abrasive action will be detrimental to both the wire rope and sheave.

As a safety precaution, always wipe off any excess oil when lubricating wire rope, especially with hoisting equipment. Too much lubricant can get into brakes or clutches and cause them to fail. When machinery is in use, its motion may sling excess oil around and over crane cabs and onto catwalks, making them unsafe.

NOTE

Properly dispose of wiping rags and used or excess lubricant as hazardous waste. See your supervisor for details on local disposal requirements.

3.12.0 Wire Rope Attachments

Many attachments can be fitted to the ends of wire rope, so the rope can be connected to other wire ropes, pad eyes, or equipment.

3.12.1 Wedge Socket

The wedge socket is the most often used attachment for connecting ends of wire rope to pad eyes or like fittings on cranes and earthmoving equipment (*Figure 22-27*). The socket is always applied to the bitter end (the end of a rope that is tied off) of the wire rope.

NOTE

The wedge socket has only 70 percent of the breaking strength of the wire rope due to the crushing action of the wedge.

Figure 22-27 – Wedge socket.

3.12.2 Speltered Socket

Speltering is the best way to attach a closed or opened socket in the field. Speltering is the process of attaching the socket to the wire rope by pouring hot zinc or an exopy resin compound around it, as shown in *Figure 22-28*. Only qualified personnel should perform speltering.

Forged steel speltered sockets are as strong as the wire rope itself; they are required on all cranes used to lift personnel, ammunition, acids, and other dangerous materials.

NOTE

Spelter sockets develop 100 percent of the breaking strength of the wire rope.

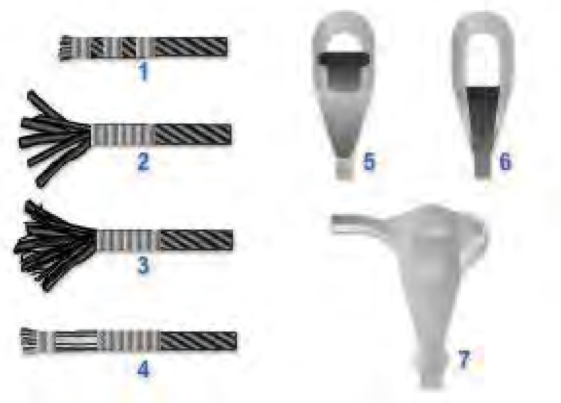


Figure 22-28 — Speltering a socket.

3.12.3 Wire Rope Clips

Wire rope clips make eyes in wire rope, as shown in *Figure 22-29*. The U-shaped part of the clip with the threaded ends is the U-bolt; the other part is the saddle. The saddle is stamped with the diameter of the wire rope that the clip will fit. Always place a clip with the U-bolt on the bitter end, not on the standing part of the wire rope. If clips are attached incorrectly, the standing part of the wire rope will be distorted or have mashed spots. A rule of thumb when attaching a wire rope clip is NEVER to saddle a dead horse.

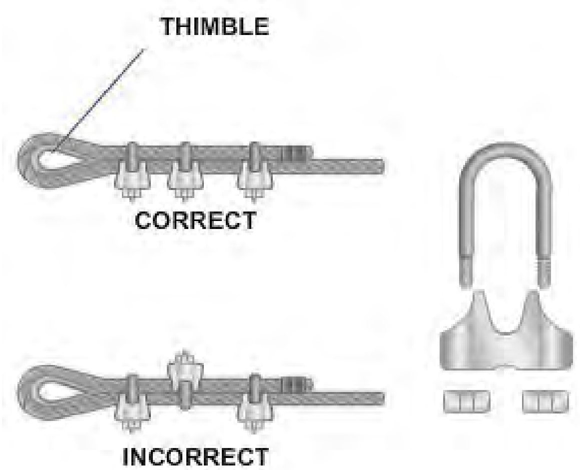


Figure 22-29 — Wire rope clips.

Two simple formulas for figuring the number of wire rope clips needed are as follows:

- 3 x the wire rope diameter + 1 = Number of clips
- 6 x the wire rope diameter = Spacing between clips.

Another type of wire rope clip is called the twin-base clip, often referred to as the universal or two clamp (*Figure 22-30*). Both parts of this clip are shaped to fit the wire rope so that the clip cannot be attached incorrectly. The twin-base clip allows for a clear 360-degree swing with the wrench when tightening the nuts.

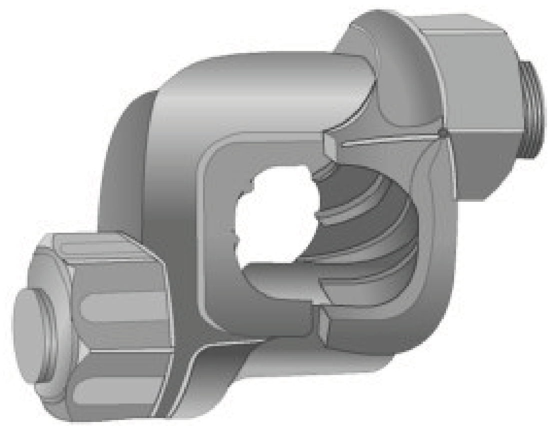


Figure 22-30 – Twin-base wire rope clip.

3.12.4 Thimble

When an eye is made in a wire rope, a metal fitting called a thimble is usually placed in the eye, as shown in *Figure 22-29*. The thimble protects the eye against wear. Wire rope eyes with thimbles and wire rope clips can hold approximately 80 percent of the wire rope strength.

After the eye made with clips has been strained, retighten the clip nuts. Check now and then for tightness or damage to the rope caused by the clips.

3.12.5 Swaged Connections

Swaging makes an efficient and permanent attachment for wire rope, as shown in *Figure 22-31*. A swaged connection is made by compressing a steel sleeve over the rope by using a hydraulic press. When the connection is made correctly, it provides 100 percent of the capacity of the wire rope.

Carefully inspecting the wires leading into these connections is important because of the pressure put upon the wires in this section. If there is one broken wire at the swaged connection, or there is a crack in the swage, replace the fitting.

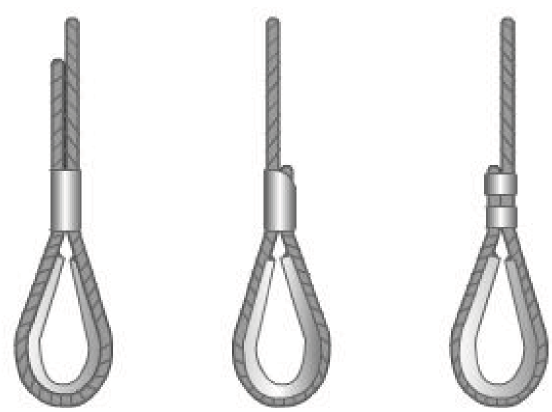


Figure 22-31 — Swaged connections.

3.12.6 Hooks and Shackles

Hooks and shackles are handy for hauling or lifting loads without tying them directly to the object with a line, wire rope, or chain. They can be attached to wire rope, fiber line, blocks, or chains. Shackles should be used for loads too heavy for hooks to handle.

When hooks fail due to overloading, they usually straighten out and lose or drop their load. When a hook is bent, DO NOT straighten it and put it back into service. Instead, cut it in half (with a cutting torch) and discard it.

Inspect hooks at the beginning of each work day and before lifting a full-rated load. If it is unclear whether the hook will bear the intended load, use a shackle. Use hooks that close and lock where there is danger of catching on an obstruction, particularly in hoisting buckets, cages, or skips, and especially during shaft work. Hooks and rings used with a chain should have about the same length as the chain.

Follow the manufacturers' recommendations in determining the SWL's of various sizes and types of specific and identifiable hooks. Test all hooks for which no applicable manufacturers' recommendations are available to twice the intended SWL before initially putting them into use.

Mousing is a technique often used to close the open section of a hook to keep slings, straps, and similar attachments from slipping off the hook, as shown in *Figure 22-32*.

Mouse hooks with rope yarn, seizing wire, or a shackle. When using rope yarn or wire, make 8 or 10 wraps around both sides of the hook. To finish off, make several turns with the yarn or wire around the sides of the mousing, and then tie the ends securely.

Two types of shackles used in rigging are the anchor (*Figure 22-33*) and the Chain (*Figure 22-34*). Both are available with screw pins or round pins.

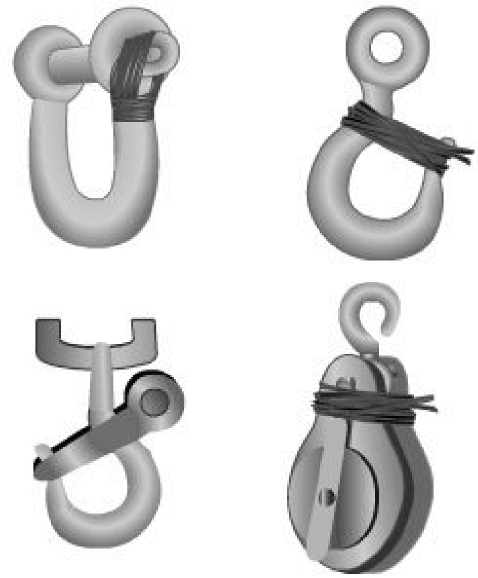


Figure 22-32 — Mousing.

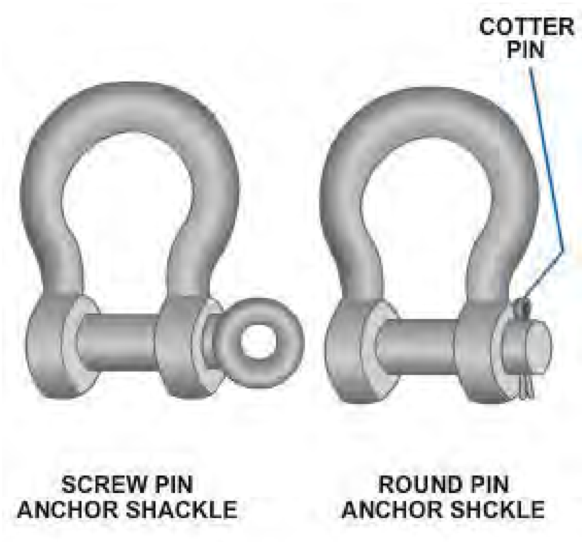


Figure 22-33 — Anchor shackles.

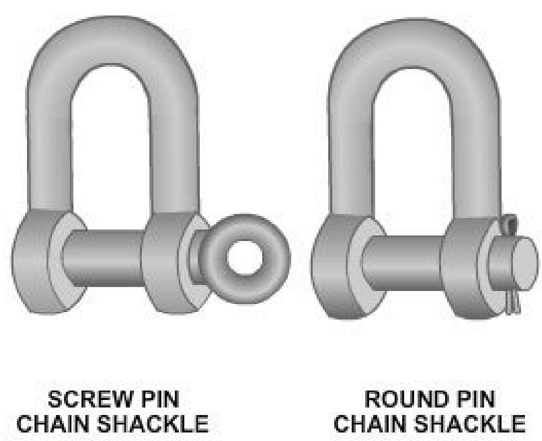


Figure 22-34 — Chain shackles.

Use shackles in the same configuration as they were manufactured. NEVER replace the shackle pin with a bolt. When the original pin is lost or does not fit properly, do not use the shackle. All pins must be straight and cotter pins must be used or all screw pins must be seated.

Never pull a shackle from the side, because this causes it to bend, which reduces the capacity tremendously. Always attach a screw pin shackle with the screw pin on the dead end of the rope. If you place it on the running end, the movement of the rope may loosen the pin.

Shackles are moused whenever there is a chance of the shackle pin working loose and coming out because of vibration. To mouse a shackle, simply take several turns with seizing wire through the eye of the pin and around the bow of the shackle. *Figure 22-32* shows what a properly moused shackle looks like.

3.12.7 Eyebolts

Eyebolts are often attached to a heavy load by a manufacturer in order to aid in hoisting the load. One type of eyebolt, called a ringbolt, is equipped with an additional movable lifting ring. Eyebolts and ringbolts can be either shoulderless or shoulder type.

The shoulder type is recommended for use in hoisting applications because it can be used with angular lifting pulls, whereas the shoulderless type is designed only for lifting a load vertically. Angular loading reduces the SWL of eyebolts and ringbolts. Always apply loads to the plane of the eye to reduce bending. This procedure is particularly important for using bridle slings.

3.12.8 Lifting Lugs

Lifting lugs are typically attached to the object being lifted by a manufacturer. They are designed and located to balance a load and support it safely. Use lifting lugs for straight, vertical lifts only.

3.12.9 Turnbuckle

Turnbuckles are used to adjust the length of rigging connections and are available in a variety of sizes. Three common types of turnbuckles are the eye, jaw, and hook ends. They can be used in any combination. The SWL for turnbuckles is based on the diameter of the threaded rods. The SWL can be found in the manufacturer’s catalog. The SWL of turnbuckles with hook ends is less than the same size turnbuckle with other types of ends.

3.12.10 Beam Clamps

Beam clamps connect hoisting devices to beams so that the beams can be lifted and positioned properly.

3.12.11 Plate Clamps

Plate clamps attach to structural steel plates to allow for easier rigging attachment and handling of the plate. There are two basic types of plate clamps: the serrated jaw type, and the screw type.

Serrated clamps are designed to grip a single plate for hoisting and are available with a locking device. Screw clamps are considered the safest and rely on the clamping action of a screw against the plate to secure them. Serrated clamps are for vertical lifting; whereas, screw clamps can be used from a horizontal position through 180 degrees. Plate clamps are designed to lift only one plate at a time.

3.12.12 Spreader and Equalizer Beams

Spreader beams are used to support long loads during lifting operations. They eliminate the hazard of load tipping, sliding, or bending. They reduce low sling angles and the tendency of the slings to crush the load.

Equalizer beams are used to balance the load on sling legs and to maintain equal loads on dual hoist lines when making tandem lifts.

Test your Knowledge (Select the Correct Response)

1. What term is used to describe a wire rope that has strands or wires shaped to conform to the curvature of the finished rope?

   A. Non-preformed wire rope
   B. Preformed wire rope
   C. Non-conform wire rope
   D. Conform wire rope

2. Which part of the following components is part of the construction of a wire rope?

   A. Wires
   B. Strands
   C. Core
   D. All of the above

3. Wire rope is designated by the number of strands per rope and what other factor?

   A. The length of the strand
   B. The diameter of the strand
   C. The number of wires in each strand
   D. The number of strands in each wire

4. Because it is very flexible, which of the following types of wire rope is acceptable for use on cranes?

   A. 6 x 12
   B. 6 x 19
   C. 6 x 24
   D. 6 x 37

4.0.0 FIBER ROPE

Fiber ropes are complicated, precision products that are adaptable to many uses under a variety of operating conditions. To meet the requirements which are imposed upon them, ropes are designed and manufactured using a number of different construction techniques and several types of fibers, either natural or synthetic. Large fiber ropes used by the Navy for working operation include those made of manila, nylon, polyester (Dacron), polypropylene, and aramid (Kevlar). Other small cordage used for seizing and lashing consists of sisal, cotton, jute, and hemp.

4.1.0 Fiber Rope Identification

4.1.1 Fibers

Natural fiber ropes are readily distinguishable from the synthetics by their drier, harsher feel, and their shorter fiber length (24 to 36 inches). Synthetic fibers are usually continuous throughout the length of the rope. Nylon, polyester, multifilament polypropylene, and aramid fibers are very soft and fine, while monofilament and fibrillated film polypropylene fibers are coarse, stiff, and usually brightly colored.

4.1.2 Large Ropes

Large ropes are identified by a water-resistant marker inserted into the center of one strand of the rope. When untwisted and flattened, the marker indicates the manufacturer, the date of manufacture, and the fiber type. If these markers are not present, it is necessary to identify the rope fiber content before use. Methods of identification are discussed in the following sections.

4.1.3 Manila and Sisal Ropes

Sisal is used in 2-1/2 inch circumference and smaller ropes when the strength of manila is not required. To differentiate between manila and sisal, remove and observe a few fibers from a strand center. Manila fibers will be a light yellow to cream color, with occasional reddish brown tones, whereas sisal will be a lustrous white. If the condition of the rope makes color identification difficult, burn sample fibers on a metal surface. Manila ash will powder during burning, while sisal ash will retain the fiber form. When available, use a known similar fiber as a control.

4.1.4 Synthetic Rope

Polypropylene fibers will float in water because the specific gravity of polypropylene is less than the specific gravity of water, which is 1.00. Nylon, polyester, and aramid fibers will sink in water because their specific gravities are greater than 1.00. Nylon and polyester are white; aramid is yellow. To differentiate between nylon and polyester, test burn a sample of the unidentified fiber. A slow-burning blue flame is indicative of nylon, and a fast-burning yellow flame indicates polyester. When available, use a known similar fiber as a control.

4.2.0 Fiber Rope Construction

4.2.1 Twisted Fiber Ropes

Twisted fiber ropes are constructed of natural or synthetic fibers that are twisted into yarns. In the case of synthetics, three yarns are plied together to prevent the fibers from untwisting. These yarns are then grouped together to form strands, with the size and number of yarns in each strand varying according to the strand size required to make the particular rope size.

4.2.2 Large Laid Ropes

All fiber ropes 1-3/4 inch in circumference or larger that the Navy uses are required to be right-laid ropes. This requirement averts hazards of attaching a left-laid rope to a right-laid rope. Under strain, ropes in a left-right combination would unlay each other, resulting in sudden rupture with a load far lighter than the normal maximum limit. Large fiber rope specifications are given in *Table 22-4*.

Table 22-4 — Fiber Rope Specifications.

TYPE OF ROPE	CIRCUMFERENCE (Inches)	SPECIFICATION
Aramid 4 – Strand	3 3/8 to 8 3/16	CID A-A-50435
Polyester Double Braided	3/4 to 16	MIL–R-24677
Polyester 12 – Strand	1 1/8 to 15	MIL–R-24750
Polyester 8 – Strand Plaited	3/4 to 16	MIL–R-24730
Polyester 3 – Strand	5/8 to 12	MIL–R-30500
Polyester Double Braided (Staple Wrap)	3/4 to 5	MIL–R-24536
Polyester Plaited (Staple Wrap)	3/4 to 4 1/2	MIL–R-24537
Nylon Double Braided	3/4 to 16	MIL–R-24050
Nylon 8 – Strand Plaited	3/4 to 16	MIL–R-24337
Nylon 3 – Strand	5/18 to 12	MIL–R-17343
Polypropylene 3 – Strand	5/18 to 12	MIL–R-24049
Manila and Sisal	5/18 to 12	Fed Spec T-R-605

4.2.3 Plain Laid Ropes

Plain laid ropes are normally constructed of three strands twisted in an alternate pattern. Natural fiber ropes have a ZSZ twist pattern; the yarn has a right (Z) twist, the strand has a left (S) twist, and the rope has a right (Z) turn. Synthetic fiber ropes have a plied yarn construction with an SZSZ pattern; the single yarns have a left (S) twist, the ply a right (Z) twist, the strand a left (S) twist, and the rope a right (Z) lay. (See *Figure 22-35*). Four strand aramid fiber rope is constructed of parallel yarns in each strand, left laid helically around a strand core. The four parallel laid strands are twisted together in the opposite direction around a center core.

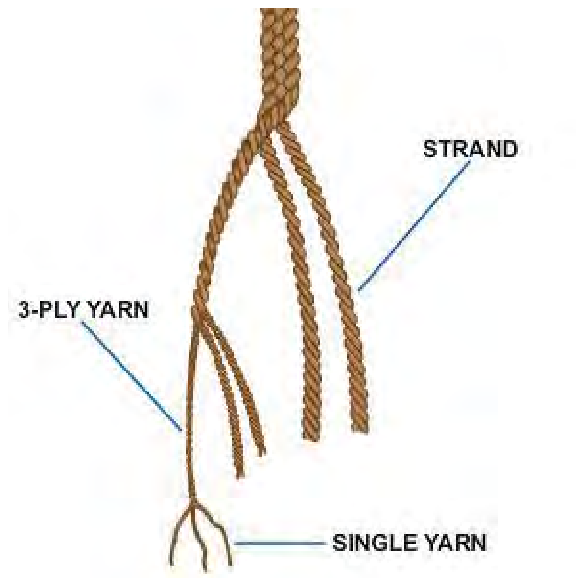


Figure 22-35 — Synthetic fiber plain laid rope.

4.2.4 Cable Laid Ropes

Cable laid ropes consist of three right plain laid ropes twisted together in the opposite direction (*Figure 22-36*). The final turn in the cable laid rope is always to the left.

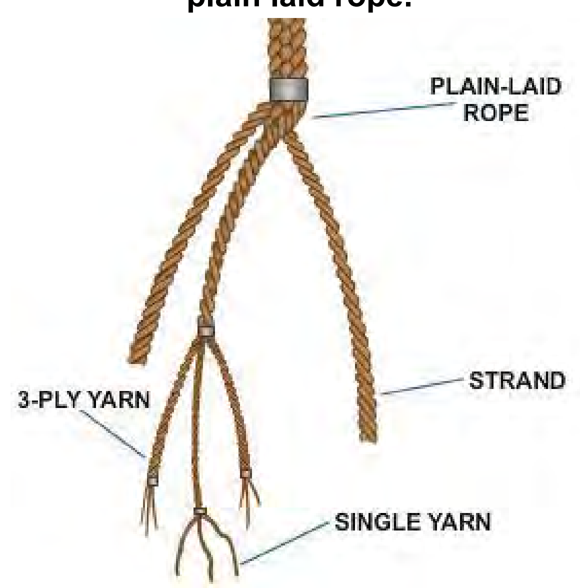


Figure 22-36 — Synthetic fiber cable laid rope.

4.2.5 Plaited Ropes

Plaited ropes are available with synthetic fibers. The construction of the strands is similar to three strand synthetic plain laid rope, except there are four right (Z) and four left (S) twist strands. These strands are plaited together in pairs, two parallel strands of left turn going to the right and two parallel strands of right turn going to the left (see *Figure 22-37*). These ropes are available in sizes from 3/4 inch to 16 inches in circumference and are spliceable by cross-braiding of the strands.

Figure 22-37 — Plaited rope.

4.2.6 Braided Ropes

Braided ropes have been reclassified from special to general purpose use. There are several different types of braided ropes: namely, hollow braid, stuffer braid, solid braid, and double braid. With the exception of double braid, braided ropes range in sizes up to 1 inch circumference. Double braided ropes are available up to 16 inches in circumference. The chief advantage of double braided rope is that it can be made in long continuous lengths (up to 20,000 feet) without noticeable splice bulge, and it will not kink or twist in a single part operation while under load.

4.3.0 Precautions and Techniques for the Use of Ropes

4.3.1 Uncoiling Natural Fiber Laid Ropes

If natural fiber ropes are furnished in coils, uncoil them by drawing the rope up from the eye in a counterclockwise direction to avoid rope kinking. Should kinks develop as a result of improper uncoiling, DO NOT pull them out as they develop into permanent strand cockles and reduce the rope strength by 1/3. When kinks develop, lay the rope out straight and remove the unbalanced turn before use. Fake down ropes that are to be used in blocks and falls and allow them to relax for at least 24 hours before reeving. After reeving, tension the completed tackle under a load equal to 1/10 of the total strength of the number of parts making up the falls.

4.3.2 Uncoiling Synthetic Fiber Laid Ropes

If synthetic fiber ropes are furnished in coils, uncoil them by rolling or by drawing from a turntable. DO NOT attempt to draw up through the eye or from the outer flakes of the coil. Should a coil of synthetic fiber rope collapse, causing kinking and tangling, DO NOT try to pull the rope free as it will form permanent cockles.

4.3.3 Unreeling Synthetic Fiber Ropes

When synthetic fiber ropes are unreeled, insert a pipe mandrel through the center holes of the reel heads to hold the reel clear of the deck. The rope may then be drawn from the lower reel surface with no danger and without rope damage. DO NOT throw twisted synthetic fiber ropes off reel heads, as tangles and kinks will develop. It is also recommended that new, twisted synthetic fiber ropes be faked down on the deck and allowed to relax for 24 hours. Lengths of new twisted synthetic fiber ropes less than 50 feet long will relax within 1 hour when laid out straight. Fake down double braided rope in a figure-eight pattern. If double braided rope is faked down in the same fashion as described for twisted rope, it will develop twists.

4.4.0 Recoiling and Rereeling

Recoil or Flemish all twisted ropes in the clockwise direction. Rereeling may be done in either direction, but take care that the turns are laid closely together to prevent binding in the underturns.

4.5.0 Elongation and Permanent Stretch

4.5.1 Natural Fiber Ropes

Load stretching is permanent and irreversible in natural fiber ropes such as manila and sisal. With each successive load increase, an additional amount of permanent stretch occurs until the stretch limit is reached and the rope fails. The stretch limit for a natural fiber rope is approximately 20 percent of its original length; for example, a 10 foot length of rope will break when it reaches its stretch limit at 12 feet.

4.5.2 Synthetic Fiber Ropes

A portion of the load-stretch in synthetic fiber ropes is permanent and irreversible. However, this permanent stretch is small and not progressive with successive loadings, provided those loadings do not exceed SWLs. Under safe load conditions, the permanent stretch of nylon and polyester ropes is usually no greater than 7 percent of the original length; aramid is much less. After a synthetic fiber rope has reached its maximum stretch point (usually at the fifth loading), it will stretch and recover repeatedly without serious damage. The approximate stretch limits (at breaking strength) for synthetic fiber ropes vary widely: only 6 percent for aramid 4-strand; 30 percent for polyester double braid and polyester 12-strand; 35 percent for polyester 3-strand; 40 percent for nylon double braid; 45 percent for polyester 8-strand plaited and polypropylene 3-strand; 55 percent for nylon 3-strand; and 65 percent for nylon 8-strand plaited.

4.6.0 Shrinkage and Swelling

Most natural and synthetic fiber ropes, when wet, will shrink in length and swell in diameter to some extent. The shrinking and swelling do not seriously affect rope strength, but stiffness which occurs after drying out will cause some difficulty in splicing.

4.6.1 Natural Fiber Ropes

Wet conditions cause natural fiber ropes to shrink and swell. Shrinkage varies with rope size, ranging from 5 to 8 percent, with a corresponding amount of swelling and stiffening. After drying, natural fiber ropes remain in the shrunken state. Rope in this condition is not weakened, but does kink more easily; therefore, rouse out the rope from lockers or coils with care.

4.6.2 Synthetic Fiber Ropes

Synthetic ropes shrink slightly when wet, and minimal swelling may occur. The only noticeable effect of wet conditions is a slight increase in weight, with the exception of nylon which has approximately 15 percent strength loss from water being absorbed by the nylon molecules. (Nylon regains most of this strength loss if dried out.) Absorbed water will be squeezed out when the ropes are tensioned. Under working loads, the expelled water will appear as a steamlike water vapor. This vapor is beneficial because it cools the fibers when friction develops under repeated stretching conditions, as in towing.

4.7.0 Whipping and Sealing

4.7.1 Whipping

Whipping natural fiber rope ends is similar to seizing, but is done to prevent rope ends from fraying and unlaying.

4.7.2 Sealing

Heat-sealing the ends of synthetic rope is especially effective and will prevent sewed whippings from slipping off. This procedure consists of placing whipping around the rope, cutting off excess yarns, and then sealing the rope ends by pressing them against a hot metal surface or by applying heat from a torch.

4.8.0 Extending Rope's Service Life

The safety of personnel and equipment and the performance of many important construction projects depend upon correct use and maintenance of ropes. All personnel are held responsible for protecting ropes from damage and for a thorough knowledge of the effects of age and working conditions on rope selection and performance.

4.8.1 Damaging Conditions

4.8.1.1 Excessive Pull

Avoiding excessive tension (overloading of the rope) requires knowledge of the recommended SWL, the minimum breaking strength, and the elongation (stretch) of the rope. Apply the load slowly and carefully using a tattle-tale while noting the reduction in circumference and increase in length to avoid excessive tension. Tattle-tales cannot be used with aramid lines, because aramid lines have low stretch (comparable to wire rope); also, they do not neck-down (reduce circumference) appreciably when put under load. Carefully control the load to avoid excessive tension (overloading of the line).

4.8.1.2 Surface Abrasion

Rope surface abrasion and chafing are serious concerns, particularly for polypropylene and manila ropes, which have a high coefficient of friction with structural materials. Nylon and polyester ropes are less affected by abrasion and chafing, as is aramid rope, which has a braided cover on each strand, but each should be protected to ensure longer service life.

4.8.1.3 Gritty Material

A variety of gritty materials, ranging from hard crystalline sands to flaky graphite, can seriously damage fiber rope when they become lodged between the rope yarns and strands while the rope is in a relaxed state. When loads are later applied to the ropes, the grit works progressively outward, cutting the inner fibers and destroying the rope structure.

4.8.1.4 Effects of a Freezing Environment

Although not always recognized as such, frozen water (ice) is another abrasive that can cut fibers under tension. Wet natural and synthetic fiber ropes that are allowed to freeze are therefore reduced in strength. Although bending will cause the external ice coating to fall away, ice crystals that remain within the rope yarns and strands will fracture the inner fibers and result in rope failure when tension is applied to the rope. Allow frozen ropes to thaw thoroughly and drain before use. Store fiber ropes under cover to prevent ice crystal formation. Nylon, polyester and aramid ropes should be wound tightly on reels and covered when dry.

4.8.1.5 Sharp Edges and Shearing

To prevent rope damage, use padding or fairleads on sharp metal edges of parts such as coamings, fairwater guides, metal block cheeks, and padeyes, or, if practical, relocate or modify the parts.

Another type of mechanical damage is the shearing action caused by crushing or pinching. Such damage often occurs when a kink in the rope is permitted to run into a block and bind against the cheeks. Other crushing effects are caused by knots in the rope or by hauling heavy loads over the rope. Shearing can be readily avoided by careful attention to receiving and handling procedures.

4.9.0 Effect of Aging on Fiber Ropes

4.9.1 Natural Fiber Ropes

Natural rope fibers (manila and sisal) consist mainly of cellulose and have the same aging properties as paper. They become yellow or brownish and brittle with time, even under the best storage conditions. This color change indicates some loss of strength, usually from 1 to 2 percent loss per year of storage. However, strength loss alone is not a true index of rope deterioration because the rope fibers become so stiff and brittle with age that when ropes are bent over sheaves or other holding devices, the fibers rupture easily and break down further with each successive bend, even under light loading conditions. Rope bending strength loss is more significant than rope breaking strength loss because the bending strength decreases five times more rapidly. Because of this, it is important to determine the age of unused natural fiber ropes from the identification marker tape within the rope strand. Should the marker indicate the age to be 5 years or more, do not use the rope for critical operations or those involving the lives of personnel.

4.9.2 Synthetic Fiber Ropes

Although synthetic fiber ropes also show color change with aging, this color change does not indicate a change in strength. White nylon ropes develop a lemon-yellow or pink color and become stiff when stored in a warm, humid area. At first the stiffness will present some handling difficulty, but when tensioned, white nylon ropes will become flexible with no breaking or bending strength loss. Polyester ropes lose very little strength due to exposure and tend to take on a gray cast. Unstabilized polyethylene and polypropylene ropes will deteriorate very rapidly when exposed to sunlight on a continuing basis and could easily lose 40 percent of their strength over a 3 month exposure period. Avoid the use of polyolefin ropes (polyethylene or polypropylene) where prolonged exposure to sunlight is required.

4.10.0 Rope Stowage

4.10.1 Natural Fiber Rope Stowage

Ropes of manila, sisal, and other natural fibers are subject to deterioration from heat, sunlight, and mildew rot. They are also damaged by chemicals, acids, alkalies, paints, soaps, and vegetable oils such as linseed or cottonseed. It is therefore mandatory that natural fiber ropes be stored away from any of these damaging materials or conditions. The best storage for natural fiber ropes is a dry, cool, dark, well-ventilated area, far removed from any source of chemicals or gaseous fumes. If natural fiber ropes are stowed outside, hang them on reels or pegs and cover them with weatherproof materials.

4.10.2 Synthetic Fiber Rope Stowage

Synthetic fiber ropes are usually packaged on reels and covered with waterproof paper to prevent damage in transit or storage. If covers or reels are damaged during prolonged storage, repair the reels and promptly replace the paper covering to prevent exposure, because most synthetic fiber ropes are affected by sunlight, fluorescent light, and chemicals. Nylon ropes are sensitive to all light radiations and acid chemicals; polyester ropes are sensitive to sunlight and caustic (alkaline) chemicals.

4.11.0 Inspection Criteria

When inspecting natural or synthetic fiber ropes, look for indications of rope damage as follows:

1. When inspection reveals fiber rupture and powdering between strands, the rope has been overloaded and rendered unfit for service.
2. If there are dark red, brown, or black spots between the strands or if it has a sour, musty, or acidic odor, the rope has suffered considerable damage from rot and shall be destroyed. Storage of rotting rope adjacent to new rope will promote rapid infection of the new rope. Remove both ropes so stored; dry and air the area before restorage of the new rope.
3. Cut out distorted strand areas because they reduce rope strength by as much as 60 percent. These defects are the result of improper coiling and bending operations and can be avoided by strictly observing approved rope coiling, bending, and unkinking procedures.
4. Internal wear is detected as a powdery appearance between the natural fiber rope strands and by a fuzzed or fused condition between synthetic rope strands.
5. Frequently examine ropes in service in areas where chemicals (acids or akalies) are used for evidence of chemical damage such as brittle or ruptured fibers, dark red or brown spots, salt incrustation, and swollen areas. Remove from service any rope showing signs of such damage.
6. Inspect ropes used in tackle operations for localized rust spots; pay particular attention to ropes used in exterior marine areas where iron rusting promotes rope deterioration.
7. Do NOT use natural fiber ropes of indeterminate age in any critical application.
8. A harsh, dry, dead feel in manila or sisal rope indicates doubtful quality and precludes rope use.

9. Hand pull tests of single or small rope fiber bundles can indicate the quality of the rope from which they were removed. A strong fiber will usually cut into the flesh, leaving a red mark, and will emit a sharp cracking noise upon breaking. Weakened fiber will not mark the flesh and will break with a soft popping sound.
10. Accumulation of heavy, greasy materials adversely affects rope strength and reduces holding power. Remove greasy materials by rinsing with light petroleum fuels such as diesel oil or kerosene.
11. Measure ropes that are to be end for ended for sheave fit to ensure that the unworked end has not swollen to the point that it will chafe on the block cheeks. If the end does not fit into the sheave, cut away the swollen section before reeving.
12. When 30 percent of the yarns in a rope cross section have been worn through, remove the rope from working operations.

4.12.0 Synthetic Ropes

4.12.1 Advantages

Numerous laboratory and service tests have determined that synthetic fiber ropes are 1-1/2 to over 4 times as strong as manila ropes of equal size. Their superior strength and durability, with good working elongations (except for aramid), make these ropes very desirable for many applications involving heavy loads. Synthetic rope resistance to rot and mildew contributes to longer rope life. Reduced bulk and weight are other advantages offered by synthetic fiber ropes. The increasing use of synthetic ropes makes it essential that all rope handling personnel be familiar with the properties of this type of rope, since these properties differ from those of manila rope. Pay particular attention to the precautions for using synthetic fiber ropes.

4.12.2 Maintenance

Synthetic fiber ropes soon fluff or nap as a result of small surface filament abrasion. The strength loss is negligible, except in the case of monofilament polypropylene ropes, which behave in the same manner as natural fiber ropes. In fact, most synthetic ropes will hold a load despite extensive yarn abrasion. If a localized, badly chafed section develops, cut out that section and splice the ends together for satisfactory continued use. Surface abrasion and stretching are not necessarily indicative of reduced rope load-carrying ability, because synthetics have little internal abrasion and little permanent stretch.

Rusting can cause a 40 percent loss of nylon rope breaking strength in only 1 month. Accordingly, avoid prolonged rope contact with rust-prone bare iron surfaces unless such surfaces have protective rust-proof coatings, such as anti-corrosive epoxy or silicone alkyd or latex-base paints. Wood, aluminum, and bronze surfaces have no effect on synthetic fiber ropes.

5.0.0 CHAINS

In the NCF, never use a chain when it is possible to use wire rope. The reason for this is that unlike wire rope, chain does not have reserve strength and does not give any warning that it is about to fail; therefore, you will not be alerted of a potentially hazardous condition.

Chain is better suited than wire rope for some jobs because it is more resistant to abrasion, corrosion, and heat. When chain is used as a sling, it has no flexibility and grips the load well.

5.1.0 Chain Grades

It is difficult to determine the grade of some types of chains by looking at them. Most chains used by the NCF are class A, alloy steel chain grade 80 or grade 100. If you are uncertain of the class or size of a chain, ask your supervisor.

5.2.0 Chain Strength

Before lifting with a chain, make sure the chain is free from twists and kinks. A twisted or kinked chain placed under stress could fail even when handling a light load. Additionally, ensure that the load is properly seated in the hook (not on the point) and that the chain is free from nicks or other damage. Avoid sudden jerks in lifting and lowering the load, and always consider the angle of lift with a sling chain bridle.

The strength of any chain will be affected when it has been knotted, overloaded, or heated to temperatures above 500°F.

5.3.0 Chain Handling and Care

When hoisting heavy metal objects using chain for slings, insert padding around the sharp corners of the load to protect the chain links from cuts.

Store chains in a clean, dry place, protected from weather. Before storing, apply a light coat of lubricant to prevent rust.

Do NOT perform makeshift repairs, such as fastening links of a chain together with bolts or wire. When links become worn or damaged, cut them out of the chain, then fasten the two nearby links together with a connecting link. For cutting small sized chain links, use bolt cutters. To cut large sized links, use a hacksaw.

Inspect the chain to ensure a safe operating condition. Frequently inspect chains used continuously for heavy loading. Chains are less reliable than manila or wire rope slings because the links have the potential to crystallize and snap without warning.

Before lifting with a chain, first place dunnage between the chain and the load to provide a gripping surface. For hoisting heavy metal objects with a chain, always use chafing gear around the sharp corners on the load to protect the chain links from being cut. As chafing gear, use either planks or heavy fabric. In handling rails or a number of lengths of pipe, make a round turn and place the hook around the chain (*Figure 22-38*).

Examine the chain closely link by link and look for stretch, wear, distortion, cracks, nicks, and gouges. Wear typically appears at the ends of the links where joining links rub together. If you find wear, lift each link

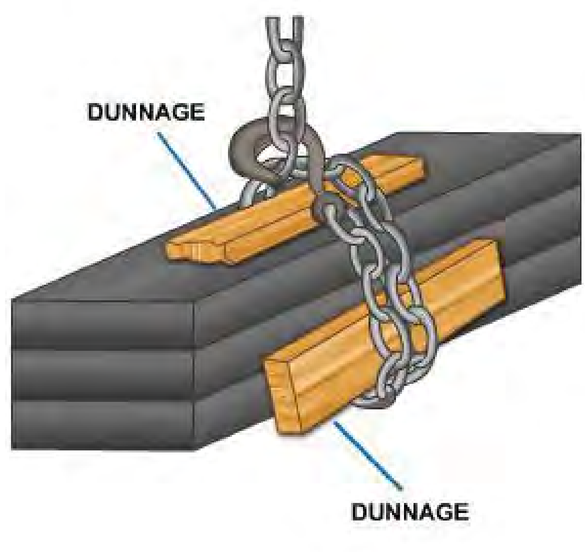


Figure 22-38 — Chain sling with chafing gear.

and measure its cross section. Refer to *Table 22-5.*

Table 22-5 — Minimum Allowable Thickness of Chain Sling Link

Nominal Size of Link (Inches)	Minimum Allowable Thickness (Inches)
7/32	0.189
9/32	0.239
5/16	0.273
3/8	0.342
1/2	0.443
5/8	0.546
3/4	0.687
7/8	0.750
1	0.887
1 1/4	1.091
1 3/8	1.187
1 1/2	1.261

5.4.0 Chain Sling Rejection Criteria

Remove the sling from service if inspection reveals any of the following:

- Reduction of link size below the values specified in *Table 22-5* or as limited by the OEM if more restrictive. For sizes not shown consult the OEM.
- Missing or illegible sling identification
- Cracks or breaks
- Excessive wear, nicks, or gouges
- Stretched chain links or components
- Bent, twisted, or deformed chain links or components
- Evidence of heat damage
- Excessive pitting or corrosion
- Weld splatter
- Knots in any part of sling

Before lifting with a chain, first place dunnage between the chain and the load to provide a gripping surface. For hoisting heavy metal objects with a chain, always use chafing gear around the sharp corners on the load to protect the chain links from being cut. As chafing gear, use either planks or heavy fabric. In handling rails or a number of lengths of pipe, make a round turn and place the hook around the chain (*Figure 22-11*).

Test your Knowledge (Select the Correct Response)

5. For some jobs, which of the following properties make chain more suited for use than wire rope?

   A. Resistant to abrasion
   B. Resistant to corrosion
   C. Resistant to heat
   D. All of the above

6.0.0 SLINGS

Slings are widely used for hoisting and moving heavy loads. Some types of slings come already made. Slings may be made of wire rope, fiber line, or chain.

6.1.0 Slings and Rigging Gear Types

The Naval Construction Force (NCF) has slings and rigging gear in the battalion Table of Allowance (TOA) to support the rigging operations and CESE lifting. Kit types 80098B, 80104B, 80104, 84003, and 84004 remain in the custody of the supply officer in the Central Tool Room (CTR). The designated embarkation staff and the crane test director monitor the condition of all rigging gear. The crane crew supervisor normally has the responsibility of inventorying the kit contents. The rigging kits must be stored under cover.

6.1.1 Wire Rope Slings

Wire rope slings offer the advantages of both strength and flexibility. These qualities make wire rope adequate to meet the requirements of most crane hoisting jobs; therefore, wire rope slings are used more often than fiber line or chain slings.

6.1.2 Fiber Line Slings

Fiber line slings are flexible and protect finished material better than wire rope slings. However, fiber line slings are not as strong as wire rope or chain slings and are more likely to be damaged by sharp edges.

6.1.3 Chain Slings

Chain slings are most often used for hoisting heavy steel items, such as rails, pipes, beams, and angles. Chain slings are the most appropriate type of sling for hot loads and loads that have sharp edges that might otherwise sever the sling components.

6.2.0 Using Wire Rope and Fiber Line Slings

There are three types of wire rope and fiber line slings: endless, single leg, and bridle.

An endless sling, usually referred to as a sling, can be made by splicing the ends of a piece of fiber line or wire rope to form an endless loop. An endless sling is easy to handle and can be used as a choker hitch (*Figure 22-39*). A single-leg sling, commonly referred to as a strap, can be made by forming a spliced eye in each end of a piece of fiber line or wire rope. Sometimes the ends of a piece of wire rope are spliced into eyes

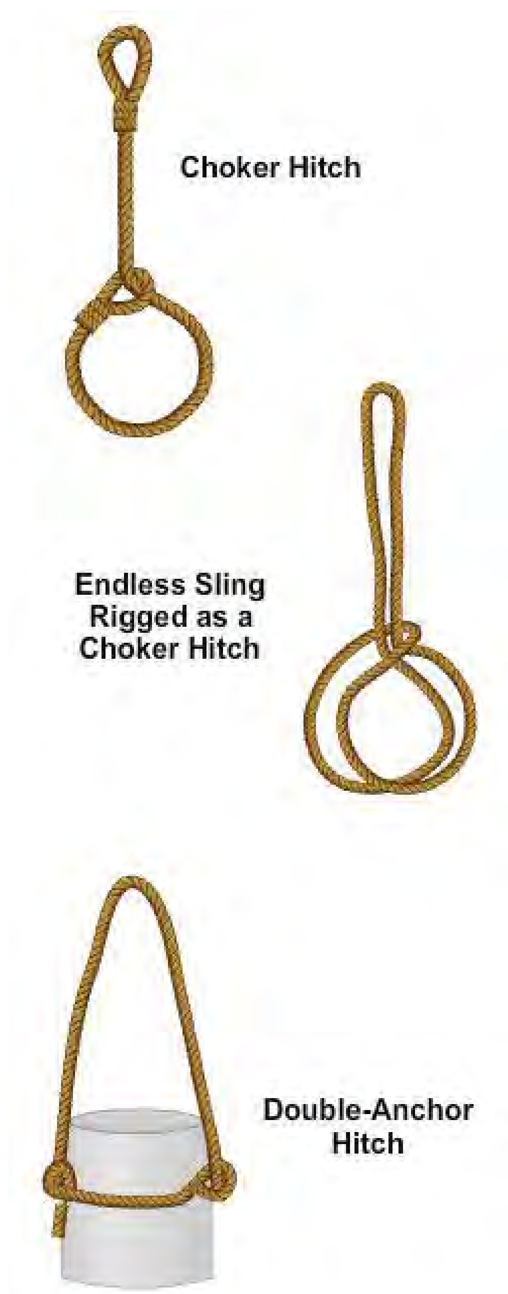


Figure 22-39 – Endless slings.

around thimbles, and one eye is fastened to a hook with a shackle. In this arrangement, the shackle and hook are both removable.

The single-leg sling may be used as a choker hitch (Refer to *Figure 22-39*) in hoisting by passing one eye through the other eye and over the hoisting hook. The singe-leg sling is also useful as a double-anchor hitch (See *Figure 22-39*), and works well for hoisting drums or other cylindrical objects where a sling must tighten itself under strain and lift by friction against the sides of the object. Single-leg slings are used to make various types of bridles.

Single-leg slings can be used to make various types of bridles. Three common uses of bridles are shown in *Figure 22-40*. Two or more single slings may be used for a given combination.

The bridle hitch provides excellent load stability when the load is distributed equally among each sling leg. The load hook is directly over the center of gravity of the load, and the load is raised level. The use of bridle slings requires that the sling angles be carefully determined to ensure that the individual legs are not overloaded.

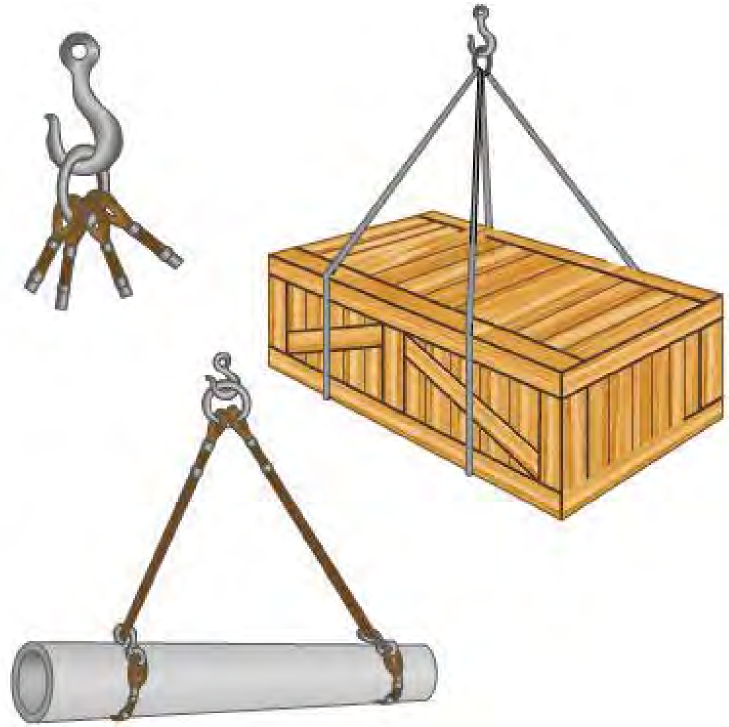


Figure 22-40 — Multi-legged bridle slings.

NOTE

It is wrong to conclude that a three or four leg bridle will safely lift a load equal to the safe load on one leg multiplied by the number of legs. This is because there is no way of knowing whether each leg is carrying its share of the load.

When a four-legged bridle sling lifts a rigid load, it is possible for two of the legs to support practically the full load, while the other two legs only balance it. NAVFAC P-307 strongly recommends that the rated capacity for two-legged bridle slings listed in the NAVFAC P-307 be used as the safe working load for three and four-legged bridle hitches.

When lifting heavy loads, ensure that the bottom of the sling legs are fastened to the load in an effort to prevent damage to the load. Many pieces of equipment have eyes fastened to them during the process of manufacture to aid in lifting. With some loads, though, fastening a hook to the eye on one end of each sling leg suffices to secure the sling to the load.

Use a protective pad to protect a fiber line or wire rope sling from exposure to sharp edges at the corner of the load. Pieces of wood or old rubber tires are often available and handy for padding.

6.2.1 Sling Angles

When using slings, bear in mind that the greater the angle from the vertical, the greater the stress on the sling legs. This point is shown in *Figure 22-41*.

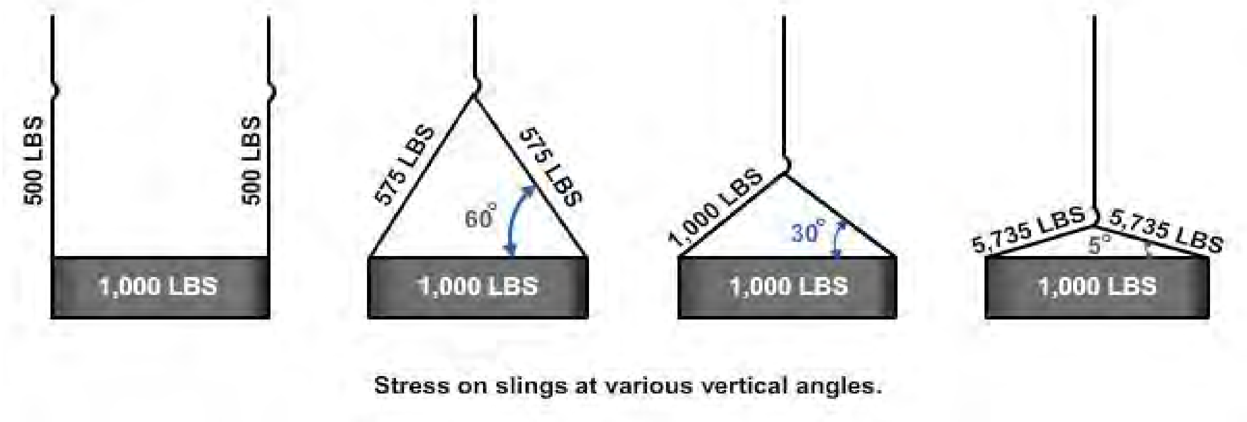


Figure 22-41 – Stress on slings at various vertical angles.

The rated capacity of any sling depends on its size, the configuration of its legs, and the angles formed by the legs and the horizontal. A sling with two legs used to lift a 1,000 pound object has 500 pounds of the load on each leg when the sling angle is 90 degrees. The load stress on each leg increases as the angle decreases; for example, if the sling angle is 30 degrees when lifting the same 1000 pound object, the load is 1000 pounds on each leg. Try to keep all sling angles greater than 45 degrees; sling angles approaching 30 degrees are considered extremely hazardous.

6.2.2 Spreader Bars

In hoisting with slings, spreader bars are used to prevent crushing and damaging the load. Spreader bars are short bars, or pipes, with eyes fastened to each end. By setting spreader bars in the sling legs above the top of the load (*Figure 22-42*), you change the angle of the sling leg and avoid crushing the load, particularly in the upper portion.

Spreader bars are also used in lifting long or oversized objects to control the sling angle. When you use spreader bars, make sure you do not overload the end connection. A spreader bar has the same rated capacity as hooks and shackles. A good rule of thumb is the thickness of the spreaders' end connection should be the same as the thickness of the shackle pin.

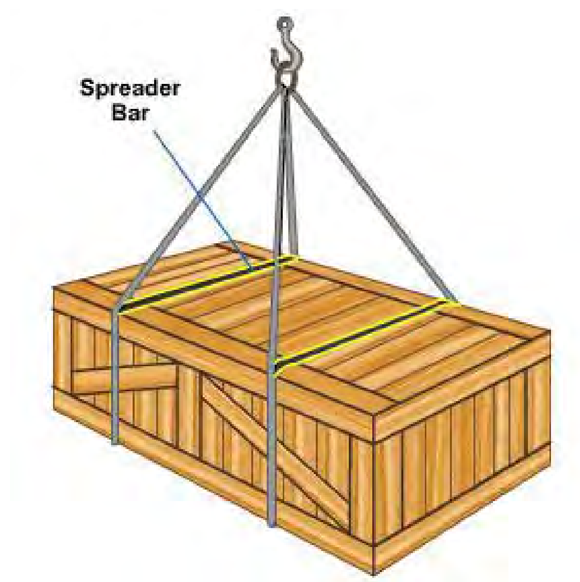


Figure 22-42 — Using spreader bars.

6.2.3 Sling Safe Working Loads

There are several formulas for estimating the loads for most sling configurations. These formulas are based on the SWLs of the single-vertical hitch of a particular sling. When determining the capacity of the combination, consider the efficiencies of the end fittings used.

The formula used to compute the SWL for a bridle hitch with two, three, or four legs (*Figure 22-43*) is: SWL (of single-vertical hitch) x Height (H) divided by Length (L) x 2. When the sling legs are not equal in length, used the smallest H/L measurement. This formula is intended for a two-leg bridle hitch, but should be used for a three or four leg hitch as well.

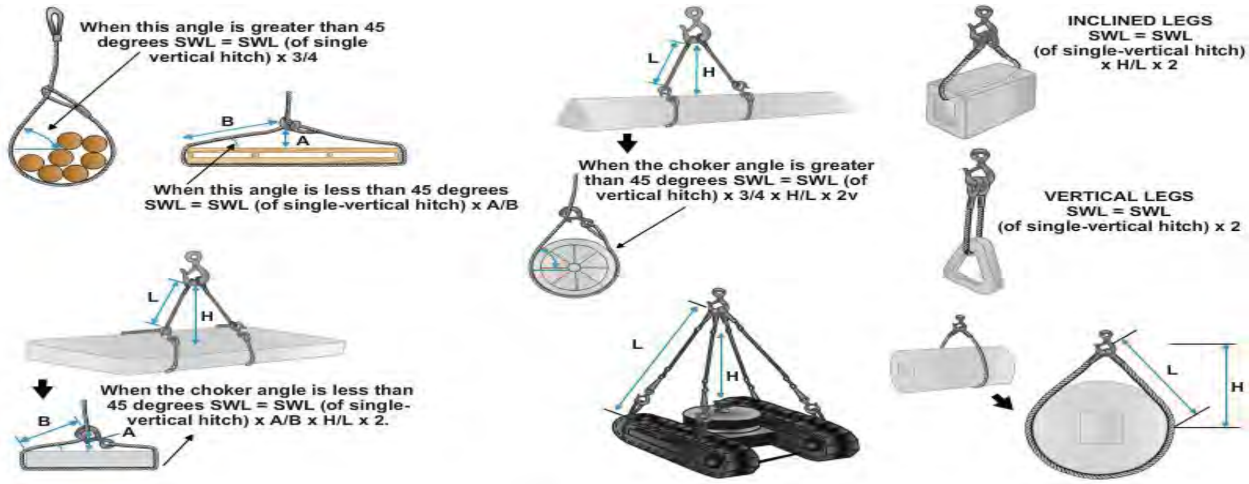


Figure 22-43 – Determination of various sling capacities.

NOTE

Remember: It is dangerous to assume that a three or four-leg hitch can safely lift a load equal to the safe load on one leg multiplied by the number of legs.

Other formulas include:

- Single-Basket Hitch (for vertical legs): SWL (of single vertical hitch) x 2
- Single-Basket Hitch (for inclined legs)**:** SWL (of single vertical hitch) x H divided by L x 4
- Double-Basket Hitch (for vertical legs): SWL (of single vertical hitch) x 4
- Double-Basket Hitch (with inclined legs): SWL (of single vertical hitch) x H divided by L x 4
- Single-Choker Hitch (for sling angles of 45 degrees or more)**:** SWL (of single vertical hitch x 3/4 or .75
- Single-Choker Hitch (for sling angles of less than 45 degrees)**:** Remember, this is not recommended, and may compromise the integrity of the load and the safety of personnel. SWL (of single vertical hitch x Adivided byB)
- Double-Choker Hitch (for a single angle of 45 degrees or more): SWL (of single vertical hitch) x 3 divided by 4 x H divided by L x 2
- Double-Choker Hitch (for a single angle of less than 45 degrees): SWL (of single vertical hitch) x A divided by B x H divided by L x 2

6.2.4 Sling Inspection

Visually inspect all slings for obvious unsafe conditions before each use. A determination to remove slings from service requires experience and good judgment, especially when evaluating the remaining strength in a sling after allowing for normal wear. The safety of the sling depends primarily upon the remaining strength. Wire rope slings must be immediately removed from service if any of these conditions are present:

- Six randomly distributed broken wires in one rope lay or three broken wires in one strand in one lay
- Wear or scraping on one third of the original diameter of the outside individual wires
- Kinking, crushing, bird caging, or any other damage resulting in distortion of the wire rope structure
- Evidence of heat damage
- End attachments that are cracked, deformed, or worn
- Hooks that have obviously abnormal (usually 15 percent from the original specification) throat opening, measured at the narrowest point or twisted more than ten degrees from the plane of the unbent hook
- Corrosion of the wire rope sling or end attachments

To avoid confusion and eliminate doubt, do not downgrade slings to a lower rate capacity. Remove a sling from service if it cannot safely lift the load capacity for which it was originally rated. Destroy slings and hooks removed from service by cutting before disposal to ensure they will not be used again.

When a leg on a multiple-leg bridle sling is unsafe, it is necessary only to destroy the damaged or unsafe leg(s). Units that have the capability may fabricate replacement legs in the field, provided the wire rope replacement is in compliance with specifications. The NCF has a hydraulic swaging and slicing kit in the battalion TOA. Before use, all slings must be proof tested in accordance with NAVFAC P-307.

Spreader bars, shackles, hooks must also be visually inspected before each use for obvious damage or deformation.

Check fiber line slings for signs of deterioration caused by weather exposure. Ensure that no fibers have been broken or cut by sharp-edged objects.

6.2.5 Proof Testing Slings

Proof load all field fabricated slings terminated by mechanical splices, sockets, and pressed and swaged terminals before they are placed into initial service. NAVFAC P-307 has the rated capacity charts that describe the diameter, rope construction, type core, grade, and splice on the wire rope sling as well as vertical rated capacity V.R.C.) for the sling. The test weight for single leg bridle slings and endless slings is the V.R.C. times two (V.R.C. x 2 = sling test weight).

Applyl the test load for multiple leg bridle slings to the individual legs. Be sure the load is two times the V.R.C. of a single leg sling of the same size, grade, and wire rope construction. When slings and rigging are broken out of the TOA for field use, proof-test and tag them before returning them to CTR for storage.

6.2.6 Records

The crane crew supervisor establishes and maintains a card file system containing a record of each sling in the unit's inventory. Proof Test/Inspection Sheets (*Figure 22-44*) are used to document tests made on all items of weight lifting slings, spreader bars, hooks, shackles.

Card ____ of ____

WIRE ROPE SLING PROOF TEST/INSPECTION RECORD

____________ DATE

____________ SLING ID NO.

Specifications: ____________

Length: ____________

Cable body diameter: ____________

Type splice: ____________

Rated capacity (lbs): ____________

* Proof test weight (lbs): ____________

* Date of proof test: ____________ Proof test director sig: ____________

Date of inspection: ____________ Crane Uspv inspector sig: ____________

Date of inspection: ____________ Crane Supv inspector sig: ____________

Date of inspection: ____________ Crane Supv inspector sig: ____________

REMARKS:

*Applies only to field fabricated slings.

SAMPLE

Figure 22-44 – Proof test/inspection sheet.

These records are permanent and contain at a minimum:

- Sling identification number (unit location and two digit number with Alpha designation for each wire rope component)
- Sling length
- Cable body diameter (inches) and specifications
- Type of splice
- Rated capacity
- Proof test weight
- Date of proof test
- Signature of proof test director

All the slings must have a permanently affixed, near the sling eye, durable identification tag containing:

- Rated capacity (in tons) (vertical SWL)
- Rated capacity (in tons) (45 degree SWL)
- Identification number

Spreader bars, shackles, and hooks must have their rated capacities and SWL permanently stenciled or stamped on them. Occupational Safety and Health Administration (OSHA) identification tags can be acquired at no cost from CONTHIRDNCB DET, Port Huenemie, CA or COMSECONDNCB DET, Gulf Port, MS. Metal dog tags are authorized, providing the required information is stamped onto the tags.

6.2.7 Storage

Wire rope slings and associated hardware must be stored in either coils or on reels, hung in the rigging loft, or laid on racks indoors to protect them from corrosive weather and other types of damage such as kinking or being backed over. Do NOT leave slings on the crane at the end of the work day.

Test your Knowledge (Select the Correct Response)

6. In the NCF, at what location are the 80104, 84003, and 84004 kits maintained?

   A. Collateral equipage
   B. Central Tool Room
   C. Mechanic shop
   D. Rigging loft

7. The bridle hitch provides excellent load stability when which of the following conditions exists?

   A. The load is distributed equally among each sling leg
   B. The load hook is directly over the center of gravity of the load
   C. The load is raised level
   D. All of the above

8. **(True or False)** A three or four leg hitch can safely lift a load equal to the safe load on one leg multiplied by the number of legs.

   A. True
   B. False

7.0.0 MECHANICAL ADVANTAGE

The push or pull a human exerts depends on the weight and strength of the individual. To move any load heavier than the amount a person can physically move, a mechanical advantage must be used to multiply human physical power. The mechanical devices most commonly used for this purpose are block and tackles, chain hoists, and winches.

7.1.0 Block and Tackle

A block consists of one or more sheaves fitted in a wood or metal frame supported by a shackle inserted in the strap of the block. A tackle is an assembly of blocks and lines used to gain a mechanical advantage in lifting and pulling.

The block(s) in a tackle assembly change(s) the direction of the pull, provide(s) mechanical advantage, or both. The name and location of the key parts of a fiber line block (*Figure 22-45*) include:

- Frame (or shell): Houses the sheaves and is made of wood or metal

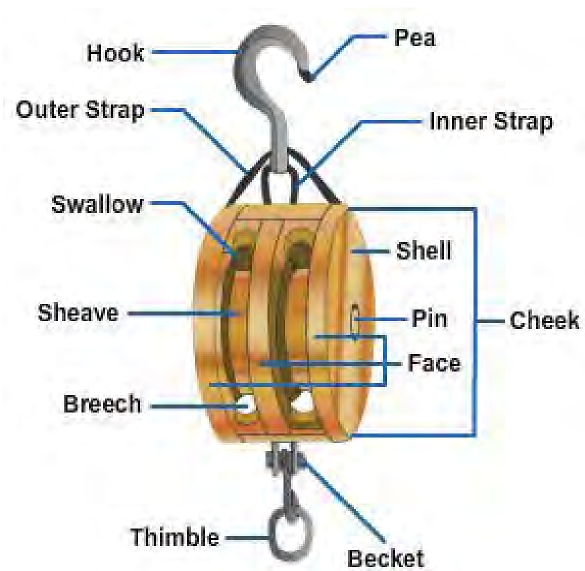


Figure 22-45 — Parts of a fiber line block.

- Sheave: A round, grooved wheel over which the line runs. Usually the blocks have anywhere from one to four sheaves. Some blocks have up to eleven sheaves.
- Cheeks: The solid sides of the frame or shell
- Pin: A metal axle on which the sheave turns. The pin runs from cheek to cheek through the middle of the sheave.
- Becket: A metal loop formed at one or both ends of a block. The standing part of the line is fastened to the becket.
- Straps: Hold the block together and support the pin on which the sheaves rotate
- Shallow: The opening in the block through which the line passes

In a tackle assembly, (*Figure 22-46*) the line is passed over the sheaves of blocks. The two types of tackle systems are simple and compound. A simple tackle system is an assembly of blocks with a single line. A compound tackle system is an assembly of blocks with more than one line.

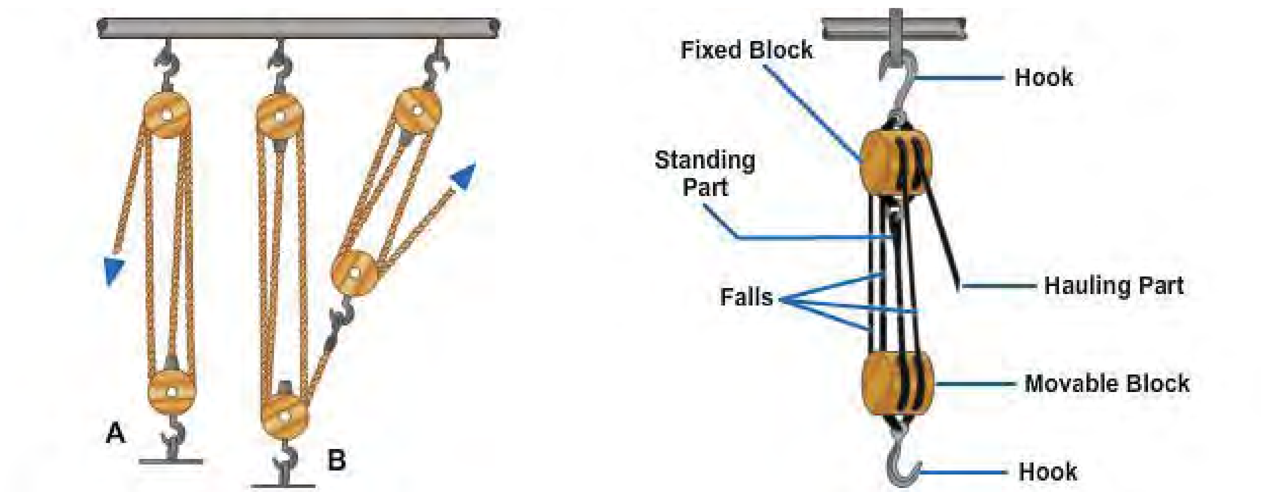


Figure 22-46 — Simple and compound tackle, as well as components of tackle.

Tackle related terminology includes:

- Fall: Either the wire rope or fiber line reeved through a pair of blocks to form a tackle
- Hauling part: Leads from the block upon which the power is exerted
- Standing: the end attached to a becket
- Movable (or running) bock: The block attached to a fixed objector support. When a tackle is being used, the movable block moves and the fixed block remains stationary
- Two blocked**:** Both blocks of a tackle are as close together as they can be. Also refered to as block and block.
- Overhaul: Lengthen a tackle by pulling two blocks apart
- Round in: Bring the blocks of a tackle toward each other, usually without a load on the tackle

Blocks are constructed for use with fiber line or wire rope. Wire rope blocks are heavily constructed and have large sheaves with deep grooves. Fiber line blocks are generally not as heavily constructed and have smaller sheaves with shallow, wide grooves. A wire rope requires a large sheave to prevent sharp bending. Fiber line is flexible and pliable, so it doesn't need sheaves as large as those required for wire rope of the same size.

Blocks fitted with one, two, three, or four sheaves are often referred to as a single, double, triple, or quadruple block. Blocks are fitted with a number of attachments, such as hooks, shackles, eyes, and rings.

7.1.1 Block to Line Ratio

The size of a fiber line block is designated by the length in inches of the shell or cheek. The size of a standard wire rope block is controlled by the diameter of the rope. With nonstandard and special-purpose wire rope blocks, the size is found by measuring the diameter of one of its sheaves in inches.

Use care in selecting the proper size line or wire for the block you are using. If a fiber line is reeved onto a tackle that has sheaves below a certain minimum diameter, the line becomes distorted, which causes unnecessary wear. A wire rope too large for a sheave tends to pinch and damage the sheave. Also, the wire suffers damage because the radius of the bend is too short. A wire rope too small for a sheave lacks the necessary bearing surface, putting strain on only a few strands and shortening the life of the wire.

With fiber line, the length of the block used should be about three times the circumference of the line. However, an inch or so either way does not matter too much; for example, a 3 inch line maybe reeved onto an 8 inch block with no ill effects. As a rule, you are more likely to know the block size than the sheave diameter. However, the sheave diameter should be about twice the size of the circumference of the line used.

Wire rope manufacturers issue tables that give the proper sheave diameters used with the various types and sizes of wire rope they manufacture. In the absence of these, a rough rule of thumb is that the sheave diameter should be about 20 times the diameter of the wire. Remember with wire rope, it is the diameter, rather than circumference, and this rule refers to the diameter of the sheave, rather than to the size of the block, as with line.

7.1.2 Block Safety

Always consider safety when using block and tackle:

- Stress safety when hoisting and moving heavy objects around personnel with block and tackle.
- Check block and sheave condition before using them on a job:
  - Ensure the blocks are properly greased.
  - Ensure that the line and sheave are the right size for the job.
- Avoid use of worn, chipped, or corrugated sheaves and drums. Sheaves and drums in such condition will injure the line. Find out whether there is enough mechanical advantage in the amount of blocks to make the load as easy to handle as possible.
- Refrain from using wire rope in sheaves and blocks designed for fiber line. Those sheaves and blocks are not strong enough, and the rope will not fit the sheave grooves. Additionally, refrain from using fiber line on sheaves and blocks built for wire rope.

7.2.0 Chain Hoists

Chain hoists provide a convenient and efficient method for hoisting by hand under specific circumstances. The chief advantages of chain hoists are that the load can remain stationary without requiring attention and one person can operate the hoist to raise loads weighing several tons. The slow lifting travel on a chain hoist permits small movements, accurate adjustment of height, and gentle handling of loads. Use a ratchet handle pull hoist for short, horizontal pulls on heavy objects. Chain hoists differ ideally in their mechanical advantage, depending upon their rated capacity.

Three general types of chain hoists for vertical operation are the spur gear hoist, the differential chain hoist, and the screw gear hoist.

The spur gear hoist (*Figure 22-47 View A*) is the most satisfactory for ordinary operations. This type of hoist (*Figure 22-47 View B*) is about 85 percent efficient. The differential chain hoist is only about 35 percent efficient and is satisfactory for occasional use and light loads. The screw gear hoist is about 50 percent efficient and is satisfactory where less frequent use of the hoist is required.

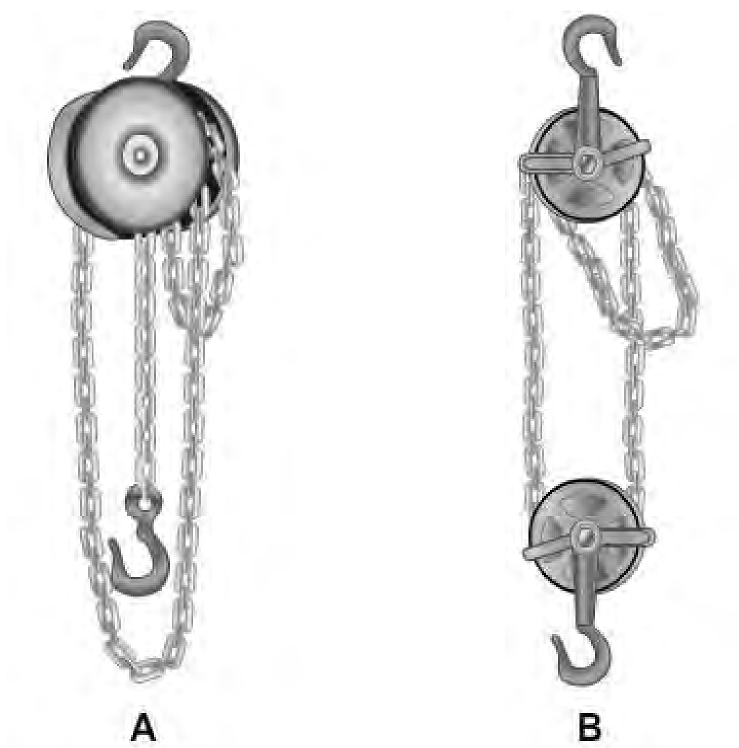


Figure 22-47 — View A: Spur gear chain hoist; View B: Differential chain hoist.

Chain hoists are usually stamped with their load capacities on the shell of the upper block. Chain hoists are constructed with their lower hook as the weakest part of the assembly. This is done as a precaution so that the lower hook is overloaded before the chain hoist is overloaded. The lower hook starts to spread under the load, indicating the approaching overload limit. Under ordinary circumstances the pull exerted on a chain hoist by one or two people will not overload the hoist.

Inspect chain hoists before each use. Any evidence of spreading of the hook or excessive wear requires hook replacement. Distorted chain links indicates that the chain hoist has been heavily overloaded and is probably unsafe for continued use. Under such conditions, condemn the chain hoist. Before using any permanently mounted chain hoists, ensure the annual certification is current.

7.3.0 Winches

Vehicular mounted winches and engine driven winches are sometimes used in conjunction with tackles for hoisting. When placing a power winch to operate hoisting equipment, consider two points:

- The angle with the ground that the hoist line makes at the drum of the hoist: This angle is sometimes referred to as the ground angle (*Figure 22-48*).
- The fleet angle of the hoisting line winding on the drum: The distance from the drum to the sheave is the controlling factor in the fleet angle.

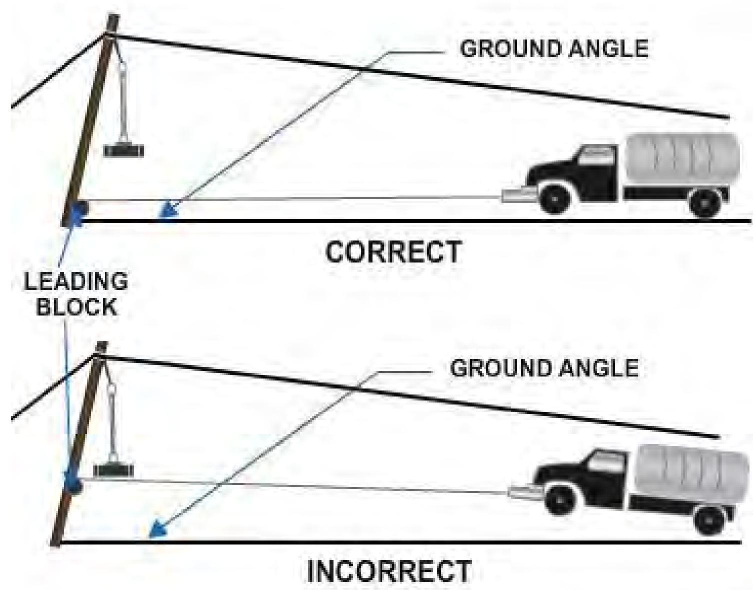


Figure 22-48 — Vehicle winch used for hoisting.

When using vehicle-mounted winches, place the vehicle in a position in which the operator can watch the load being hoisted. A winch is most effective when the pull is exerted on the bare drum of the winch. When a winch is rated at capacity, the rating applies only as the first layer of cable is wound onto the drum. The winch capacity reduces as each layer of cable is wound onto the drum because of the change in leverage resulting from the increased diameter of the drum. The capacity of the winch may decrease by as much as 50 percent when the last layer is being wound onto the drum.

7.3.1 Ground Angle

If the hoisting line leaves the drum at an angle upward from the ground, the resulting pull on the winch will tend to lift it off the ground. In such cases, place a leading block in the system at some distance from the drum to change the direction of the hoisting line to a horizontal or downward pull. The hoisting line should be overwound or underwound on the drum as may be necessary to avoid a reverse bend.

7.3.2 Fleet Angle

The drum of the winch is placed so that a line from the last block passing through the center of the drum is at right angles to the axis of the drum. The angle between this line and the hoisting line as it winds on the drum is called the fleet angle. As the hoisting line is wound in on the drum, it moves from one flange to the other, so the fleet angle changes during the hoisting process. Do not permit the fleet angle to exceed two degrees keep it below this, if possible. A 1.5 degree maximum angle is satisfactory and is obtained if the distance from the drum to the first sheave is 40 inches for each inch from the center of the drum flange. The wider the drum of the hoist, the greater the lead distance must be in placing the winch.

Test your Knowledge (Select the Correct Response)

9. What term is used to describe an assembly of blocks and lines used to gain a mechanical advantage in lifting and pulling?

   A. Two blocked
   B. Tackle
   C. Overhaul
   D. Breech

10. With fiber line, the length of the block used should be approximately what size compared to the line?

    A. Three times the circumference of the line
    B. Four times the circumference of the line
    C. Five times the circumference of the line
    D. Six times the circumference of the line

11. Which of the following chain hoists has an efficiency of 85 percent?

    A. Screw gear
    B. Differential chain
    C. Spur gear
    D. Spindle gear

8.0.0 SAFE RIGGING OPERATIONS

All personnel involved in the use of rigging gear must be thoroughly instructed and trained to comply with several safety practices:

- Do not use wire rope with loads that exceed the rate capacity outlined in NAVFAC P-307. Use slings not included in that publication ONLY according to the manufacturer's recommendation or OME documentation.
- Determine the weight of a load before attempting any lift.
- Use the proper hitch.
- Guide loads with a tag line when practical.
- When using multiple leg slings, select the longest sling practical to reduce the stress on the individual sling legs.
- Attach the sling securely to the load.
- Pad or protect any sharp corners or edges with which the sling may come in contact to prevent chaffing.
- Keep the slings free of kinks, loops, and/or twists.
- Keep hands and fingers away from the area between the sling and the load.
- Start lifts slowly to avoid placing shock on the slings.
- Keep slings well lubricated to prevent corrosion.
- Do not pull the slings from under a load when the load is resting on the slings. Block the load up to remove the slings.

- Do not shorten a sling by knotting or using wire rope clips.
- Do not inspect wire rope slings by passing bare hands over the rope. Broken wires, if present, may cause serious injuries. When practical, wear leather palmed gloves when working with wire rope slings.
- Be mindful of the center of balance. Load stability is critical to the loading process. A stable load is one that has a center of balance directly below the hook. When a load is suspended, it will always shift to that position below the hook. To rig a stable load, establish the center of balance. Once center of balance is established, swing the hook over the center and select the length of sling needed from the hook to the lifting point of the load.
- When using a multi-legged bridle sling, do not assume that a three or four-leg hitch will safely lift a load equal to the safe load on one leg multiplied by the number of legs. With a four-legged bridle sling lifting a rigid load, it is possible for two of the legs to support practically the full load while the other two only balance it.

NOTE

If not all the legs of a multi-legged sling are required, secure the remaining legs out of the way.

Test Your Knowledge (Select the Correct Response)

12. **(True or False)** To avoid placing shock on a set of slings, start a crane lift quickly and smoothly.

    A. True
    B. False

Summary

In this topic you learned the basic concepts of rigging operations, basic rigging mathematical concepts, and the use of NAVFAC P-307.

You learned the distinctions of wire rope, including grades, lay, and lay length characteristics. You were presented with the method used to measure wire rope, the circumstances under which wire ropes are prone to failure, and the proper handling and care procedures that maximize the lifetime of wire rope.

You were presented with information about fiber line, including the different varieties, what tasks are best suited for each variety, and how to handle and care for fiber line. You learned about chain grades, strength, and proper handling techniques.

A significant focus of this chapter was developing your understanding of sling use and equipment. You were presented with different types of slings, proper use techniques, as well as administrative aspects.

This chapter discussed the mechanical advantages available, chain hoists, and winches. Particular attention was devoted to formulas used to compute safe loading and lifting.

Review Questions (Select the Correct Response)

1. Which of the following factors is NOT considered during the initial phase of any rigging operation?

   A. Equipment selection
   B. Method of connection
   C. Effects of motion
   D. Magnitude

2. Which of the following methods is NOT an acceptable method used for determing load weight?

   A. Load indicating device
   B. Supervisor evaluation
   C. Label plates
   D. Engineer evaluation

3. What is the formula used to generate the area of a square?

   A. $A = \frac{B x H}{2}$
   B. $A = \pi x R^2$
   C. $A = LxW$
   D. $A = BxH$

4. What is the formula used to generate the area of a square?

   A. $A = LxW$
   B. $A = \frac{B x H}{2}$
   C. $A = BxH$
   D. $A = \pi x R^2$

5. You need to calculate the weight of an object, you know the area of the object and the material the object is manufactured out of; what is the next value needed to determine the weight?

   A. Thickness of material
   B. Capacity of lifting hoist
   C. Radius of material
   D. Volume of material

6. What is the formula for the calculation of cylinder volume?

A. $V = L\ x\ W\ x\ H$

B. $V = \pi\ x\ R^2\ x\ H$

C. $V = \frac{\pi}{R_2}$

D. $V = R^2\ x\ \pi$

7. If you have a high center of gravity and the attachment points are below the center of gravity, what will most likely occur to the load being lifted?

A. Center balanced
B. Less likely to tip over
C. More prone to tip over
D. Load shift to left

8. What is another term used for sling?

A. Clamp
B. Hoist
C. Strap
D. Choker

9. When a sling is bent around a small diameter load, the pieces will stretch, what would happen to the capacity of the sling?

A. Reduce
B. Enlarge
C. Stay the same

10. Which of the following publications provides inspection requirements for WHE?

A. COMSECONDNCBINST 11200.11
B. NAVFAC P-307
C. NSTM Chapter 613
D. NAVFAC P-300

11. (True or False) Section 14 of NAVFAC P-307 applies to rigging gear maintenance.

A. True
B. False

12. Which of the following is NOT a goal of a effective test and inspection program?

A. Prevent personnel injury
B. Remove unsafe equipment
C. Maintain crane qualifications
D. Identify sub-standard equipment

13. What is the minimum amount of time equipment shall withstand a load test?

A. 30 minutes
B. 20 minutes
C. 10 minutes
D. 2 minutes

14. **(True or False)** Not all rigging equipment has to be marked with rated load value to be eligible for use.

A. True
B. False

15. Which of the following strand constructions has alternating large and small wires that provide a combination of great flexibility with a strong resistance to abrasion?

A. Ordinary
B. Seale
C. Warrington
D. Filler

16. Each square inch of improved plow steel can withstand a strain that is within what range, in pounds, of pressure?

A. Between 100,000 and 140,000
B. Between 240,000 and 260,000
C. Between 300,000 and 340,000
D. Between 440,000 and 440,000

17. What type of wire rope damage starts with the formation of a loop?

A. Crush spots
B. Wear spots
C. Kinks
D. Broken wires

18. In wire rope rigging, the diameter of sheave should never be less than how many times the diameter of the wire rope?

A. 10
B. 20
C. 30
D. 40

19. Type II, Protective A lubricant comes in three grades, which grade would be used in temperatures of between 80°F and 110°F?

A. Grade A
B. Grade B
C. Grade C

20. What term is used to describe the technique of attaching a socket to a wire rope by pouring hot zinc around it?

A. Seizing
B. Speltering
C. Wedging
D. Swaging

21. Which of the following formulas is used to obtain the number of wire clips required for a wire rope?

A. 6 x wire rope diameter
B. 3 x wire rope diameter
C. 6 x wire rope diameter + 1
D. 3 x wire rope diameter + 1

22. Wire rope eyes with thimbles and wire rope clips can hold approximately what percentage of strength of a wire rope?

A. 60
B. 70
C. 80
D. 90

23. Which of the following pieces of equipment is used to connect hoisting devices to beams?

A. Beam clamp
B. Plate clamp
C. Eyebolt
D. Turnbuckle

24. How are large ropes identified?

A. Tag attached to bitter end
B. Water resistant marker inserted into center of one strand of rope
C. By verifying it on receipt documentation
D. Water resistant marker inserted into open end of line

25. Cable laid ropes consist of how many right plain laid ropes twised together?

A. 1
B. 2
C. 3
D. 4

26. The stretch limit of a natural fiber rope is what percentage of its original length?

A. 10
B. 20
C. 30
D. 40

27. What color indicates a loss of strength in a natural fiber rope?

A. Yellow
B. Chalk white
C. Black
D. Green

28. While inspecting synthetic fiber ropes, you notice a musty odor emitting from the rope. What does this indicate?

A. Strands are saturated with water.
B. Rope has been stored in a dark environment.
C. Strands are saturated in oil.
D. Rope has suffered from rot.

29. Which of the following alloy steel chain grades are currently in use with the Seabees?

A. 60
B. 70
C. 100
D. 120

30. Which one of the following is NOT a reason for rejection during a chain sling inspection?

A. Discoloration of hook
B. Stretched chain links
C. Weld splatter
D. Heat damage

31. How many different types of wire rope slings are there?

A. 1
B. 2
C. 3
D. 4

32. **(True or False)** With a four legged bridle sling lifting a rigid load, it is possible for two of the sling legs to support practically the full load while the other two legs only balance it.

A. True
B. False

33. Which of the following degree sling angles is considered extremely hazardous and must be avoided?

A. 55
B. 50
C. 45
D. 30

34. Which of the following is a reason for immediate removal of service of a sling inspection?

A. Three broken wires in two strands in one lay
B. Six randomly distributed broken wires in one rope lay
C. Six broken wires in one strand in one lay
D. Three randomly distributed broken wires in one rope lay

35. Which of the following postions establishes and maintains a card file system containing a record of each sling in a unit's inventory?

A. Crane crew supervisor
B. ROICC
C. Crew leader
D Safety chief

36. To which of the following parts of the block is the standing part of the line attached?

A. Sheave
B. Shallow
C. Cheeks
D. Becket

37. Which of the following terms is the process of bringing the blocks of a tackle toward each other?

A. Round in
B. Standing
C. Fall
D. Movable block

38. The capacity of a winch may be reduced by what percentage when the last layer of wire rope is being wound onto the winch drum?

A. 30
B. 40
C. 50
D. 60

39. **(True or False)** Knotting and use of wire clips is an appropriate method for shortening a sling.

A. True
B. False

Trade Terms Introduced in this Chapter

Core	Wire rope consists of strands of wire wrapped around a core. The wire rope core supports the strands laid around it. There are three types of core.
Abrasion	A scraped spot or area; the result of rubbing or abrading
Corrosion	The act or process of corroding; condition of being corroded
Fleet angle	The distance from the drum to the sheave is the controlling factor in the fleet angle.
Non-preformed wire rope	Wire rope that has strands or wires that are not shaped before fabrication.
Preformed wire rope	Wire rope that has strands or wires that are shaped to conform to the curvature of the finished rope before laying up.
Strands	Several pieces of wire are wrapped around a core that constitutes wire rope. These pieces of wire wrapped around the core are called the strands.
Tensile strength	The strength necessary to withstand a certain maximum load applied to the rope. It includes a reserve of strength measured in a so-called factor of safety.
Wire	Rope consisting of steel, iron, or other metal in various sizes. The number of wires to a strand varies, depending on the intended purpose of the rope. Wire rope is designated by the number of strands per rope and the number of wires per strand.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

COMFIRSTNCDINST 11200.2, Naval Construction Force (NCF) Equipment Management Instruction. 06 JAN 2006.

NAVFAC P-307, Management of Weight Handling Equipment. June 2006.

Rigging Manual, 1st ed., Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Ontario, Canada, 1975.

ASME B 30.9

ASME B30.20

Wire and Fiber Rope and Rigging, Naval Ship's Technical Manual, NAVSEA S9086-UU-STM-000/CH-613, Chapter 613, Commander, Naval Sea System Command, Washington, DC, 1978.

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Chapter 23

Paving Operations and Equipment

Topics

1.0.0 Asphalt-Paving Mixes

2.0.0 Asphalt Pavement Structures

3.0.0 Preparing Asphalt for Construction Operations

4.0.0 Types of Asphalt Pavement Construction

5.0.0 Defects in Flexible Pavement

6.0.0 Purposes of Surface Treatments

7.0.0 Paving Equipment

8.0.0 Safety

To hear audio, click on the box.

Overview

The use of ***asphalt*** for road and street construction began in the late 1800s and grew rapidly with the emerging automobile industry. Today, asphalt technology is complex, and the equipment and techniques used to build asphalt pavement structures are highly sophisticated. This chapter presents only the basic components, procedures, and principles of paving operations. The extensive knowledge and skills required to perform the operations must be gained through formal and on-the-job-training.

One rule that has remained constant throughout the long history of the use of asphalt in construction is that pavement is only as good as the materials and workmanship that go into it. No amount of sophisticated equipment can make up for the use of poor materials or poor construction practices.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Understand the characteristics, structure, and preparation of asphalt-paving mixes.
2. Identify types of asphalt pavement construction.
3. Identify types of paving equipment and their operations.
4. Understand how to perform paving operations.
5. Understand paving safety.

Prerequisites

None

This course map shows all of the chapters in Equipment Operator Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Miscellaneous Equipment	↑	E Q U I P M E N T O P E R A T O R B A S I C
Paving Operations and Equipment		
Rigging Operations		
Cranes		
Rollers		
Dozers		
Scrapers		
Graders		
Ditchers		
Excavators		
Backhoe Loaders		
Front-End Loaders		
Rough Terrain Forklifts		
Truck Driving Safety		
Truck-Tractors and Trailers		
Tank Trucks		
Dump Trucks		
Medium Tactical Vehicle Replacements		
Earthwork Operations		
Electrical and Hydraulic Systems		
Chassis Systems		
Power Train		
Engine Systems		
Transportation Operations		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 ASPHALT-PAVING MIXES

Asphalt-paving mixes may be produced from a wide range of ***aggregate*** combinations, each with its own characteristics and suited to specific design and construction uses. Aside from the asphalt content, relative amounts of aggregates determine the principal characteristics of the mix. The aggregate composition may vary from a coarse-textured mix to a fine-textured mix, depending on aggregate size and design specifications.

The selection of ***bituminous*** material depends upon the type of pavement, temperature extremes, rainfall, type and volume of traffic, and type and availability of equipment. In general, hard penetration grades of asphalt paving are used in warm climates and softer penetration grades in cold climates. Heavier grades of asphalt cutbacks and tars are generally used in warm regions.

Asphalt materials are produced by the refining of petroleum (*Figure 23-1*). Asphalt is produced in a variety of types and grades, ranging from hard, brittle solids to almost water-thin liquids. The semi-solid form, known as asphalt cement, is the basic material. Liquid asphaltic products are generally prepared by cutting back (blending) asphalt cements with petroleum distillates or by blending with an emulsifying agent and water known as asphalt emulsion. Refer to *Table 23-1*.

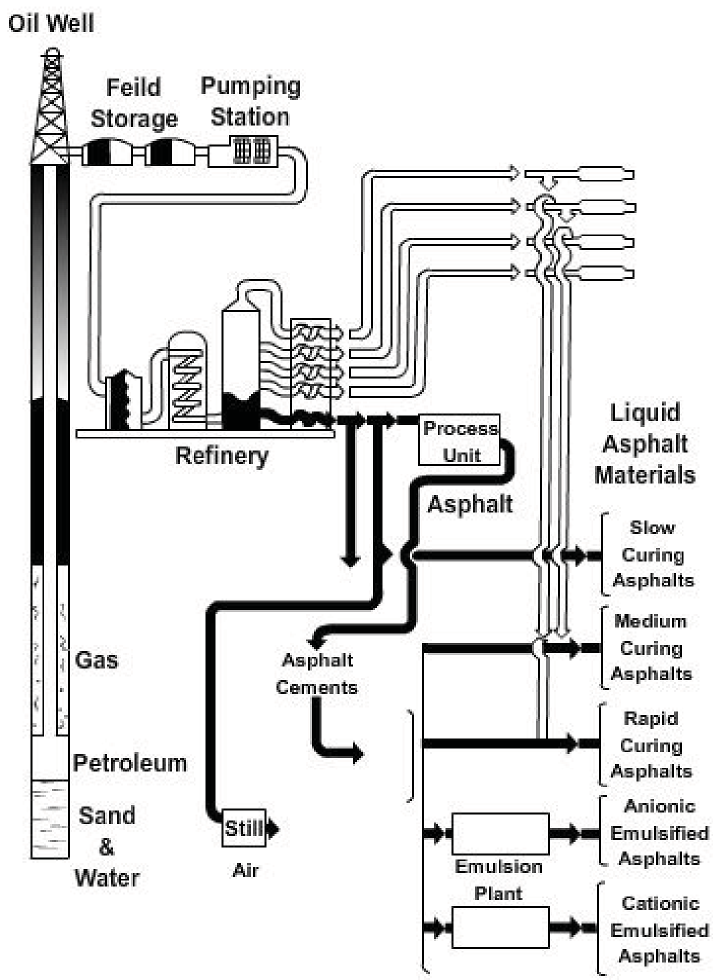


Figure 23-1 – Petroleum asphalt flow chart.

Table 23-1 – Three Basic Classifications of Low-Viscosity Liquid Asphalt

Rapid Cure	Medium Cure	Slow Cure
Cut back with Naphtha or gasoline	Cut back with kerosene	Cut back with diesel or light lube oil
Cures in hours to days	Cures in days to weeks	Cures in weeks to months
RC–70: Pours like syrup	MC-30: pours like light syrup	SC-70: Pours like syrup
RC-250: Pours like light molasses	MC-70: Pours like syrup	SC-250: Pours like light molasses
RC-800: Pours like molasses	MC-250: Pours like light molasses	SC-800: Pours like molasses
RC-3000: Barely pours	MC-800: Pours like molasses	SC-3000: Barely pours
	MC-3000: Barely pours	

1.1.0 Basic Concepts

The basic idea when building roads, airfields, or parking areas for all-weather use by vehicles is to prepare a suitable foundation, provide necessary drainage, and construct a pavement that has the following characteristics:

- Has sufficient total thickness and internal strength to carry expected traffic loads
- Is capable of preventing both the penetration and accumulation of moisture
- Has a top surface that is smooth and skid resistant
- Is resistant to wear and distortion
- Is resistant to deterioration caused by weather conditions or by deicing chemicals

The foundation carries the traffic loads. Therefore, the structural function of pavement is to support a wheel load (W) on the pavement surface and to transfer and spread that load to the foundation without overloading either the strength of the subgrade or the internal strength of the pavement itself. The W value transmitted to the pavement surface through the tire has an approximately uniform vertical pressure (*Figure 23-2)*. The pavement then spreads the wheel load to the foundation. By proper selection of materials, and with adequate pavement thickness, wear and durability of the paved surface will be increased.

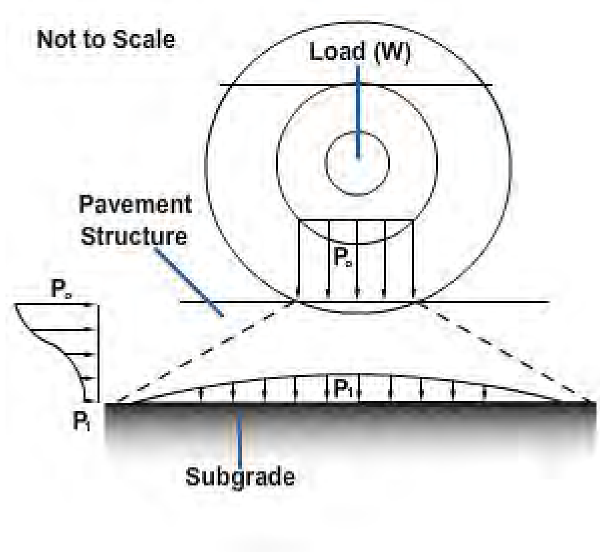


Figure 23-2 – Spread of wheel load through the pavement structure.

Test your Knowledge (Select the Correct Response)

1. What was the primary reason for the rapid growth in the construction of asphalt road surfaces in the late 1800s?

   A. Need for large airport runways
   B. Comparative cheaper cost of asphalt over concrete
   C. Emerging automotive industry
   D. Only available means of hard-surface paving

2. **(True or False)** A pavement is only as good as the material and workmanship that go into it.

   A. True
   B. False

2.0.0 ASPHALT PAVEMENT STRUCTURES

Asphalt pavement is a general term applied to any pavement that has a surface constructed with asphalt (*Figure 23-3*). Normally, it consists of a surface course (layer) of mineral aggregate, coated and cemented with asphalt, and one or more supporting courses, which may be of the following types:

- Asphalt base, consisting of asphalt-aggregate mixtures (macadam)
- Crushed stone (rock), slag, or gravel
- Portland cement concrete
- Old brick or stone block pavements

Asphalt pavement structure consists of all courses above the prepared foundation. The upper or top layer is the asphalt-wearing surface.

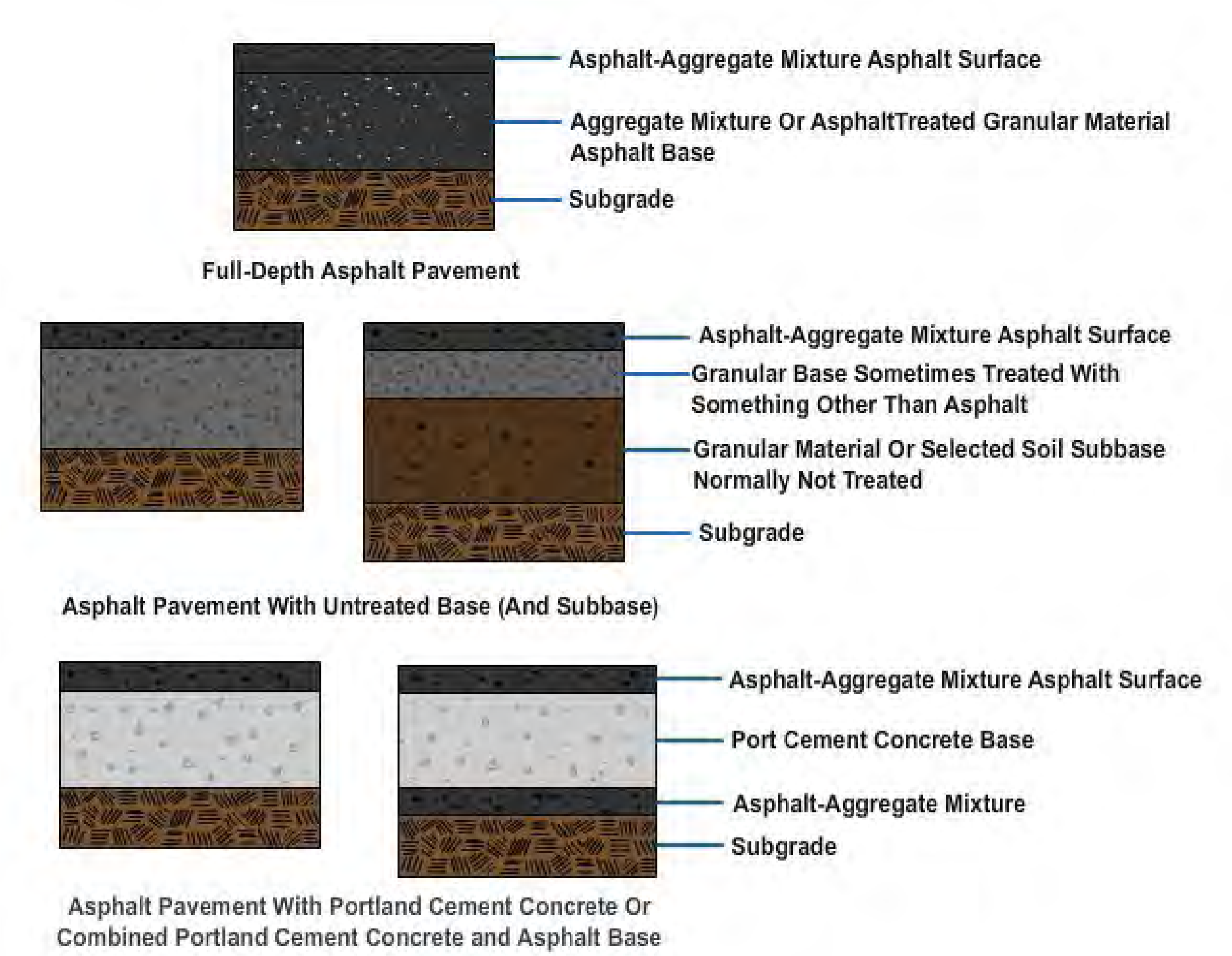


Figure 23-3 – Asphalt pavement cross sections, showing common and typical asphalt pavement structures.

2.1.0 Essential Properties of Asphalt-Wearing Surface

The surface of asphalt pavement exposed to vehicular traffic must be able to resist distortion and provide a smooth riding surface. It must be waterproof and sloped to shed surface water to the roadside and protect the entire asphalt pavement structure and the foundation from the erosive effects of moisture. It must resist wear caused by traffic and still retain necessary anti-skid properties. It must also be bonded to the layer or course beneath it.

2.2.0 Function of Base Course Subgrade

The base course and subgrade are structural elements of the pavement. In conjunction with the overlying asphalt surface, their purpose is to distribute traffic wheel loads over the whole foundation. To perform this function, you build the base course and subgrade with the necessary internal strength properties. In this respect, full depth asphalt pavements have a special advantage over pavements with granular bases. Asphalt pavement layers have both tensile and compressive strength to resist internal stresses. For example, as shown in *Figure 23-4*, wheel load slightly deflects the pavement structure, causing both tensile and compressive stresses within the pavement. Untreated granular bases have no tensile strength; therefore, asphalt bases spread the wheel load over broader areas than untreated granular bases. As a result, an asphalt base requires less total pavement structure thickness.

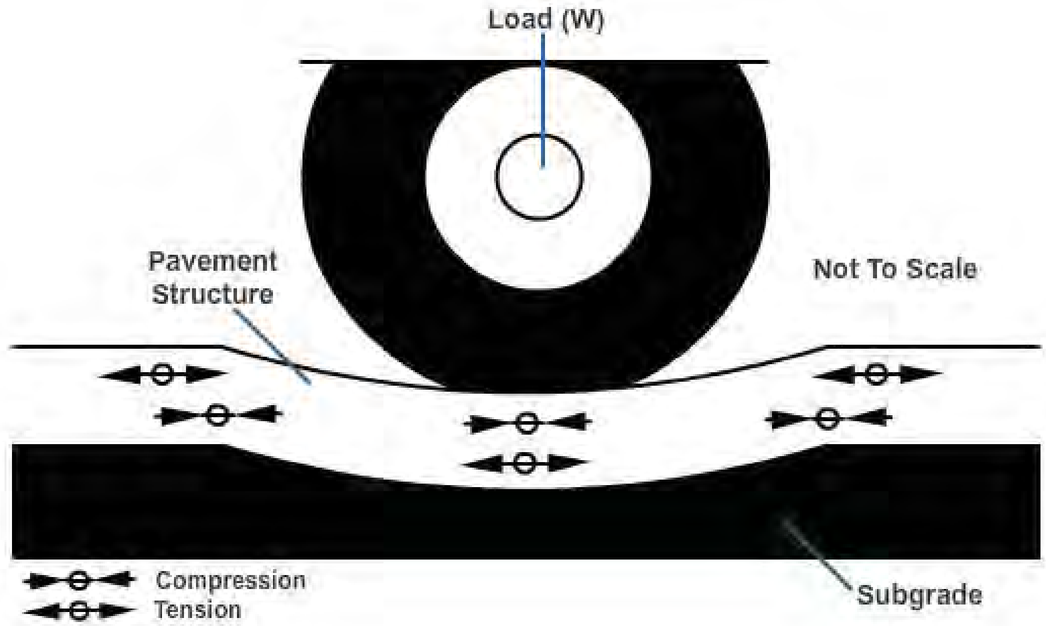


Figure 23-4 – Pavement deflection results in tensile and compressive stresses in pavement structure.

2.3.0 Determining Required Pavement Thickness

A significant advance in highway engineering is the realization and demonstration that structural design of asphalt pavements is similar to the problem of designing any other complex engineering structure. When asphalt pavement was first introduced, determining the proper thickness was a matter of guesswork, rule of thumb, and opinion based on experience. Almost the same situation once prevailed in determining the dimensions of masonry arches and iron and steel structures. However, these early techniques have long since yielded to engineering analysis. Similarly, based on a comprehensive analysis of accumulated data, the structural design of asphalt pavements has now been developed into a reliable engineering procedure.

There is no standard thickness for a pavement. Required total thickness is determined by engineering design procedure. Factors considered in the procedure are as follows:

- Traffic to be served initially and over the design service life of the pavement
- Strength and other pertinent properties of the prepared subgrade
- Strength and other influencing characteristics of the materials available or chosen for the layers (or courses) in the total asphalt pavement structure
- Any special factors peculiar to the road being designed

2.4.0 Stage Construction

Because weight and traffic volume normally increase, pavement originally built thick enough to handle immediate traffic volumes may not be thick enough and strong enough to handle future needs. With asphalt pavement, this problem can be met economically by first building the thickness required and then adding, when needed, layers of asphalt to increase total pavement thickness. This procedure is called stage construction. It avoids excessive investment in the beginning; and when a new layer of asphalt is added, the wearing surface is equal to or better than the original.

2.5.0 Subgrade Evaluation

Several methods for evaluating or estimating the strength and supporting power of a subgrade are in use today, including the following:

- Loading tests in the field on the subgrade itself. For example, the plate-bearing test uses large, circular plates loaded to produce critical amounts of deformation on the subgrade in place.
- Loading tests in a laboratory using representative samples of the sub grade soil. A test commonly used by the Seabees is the California Bearing Ratio (CBR) test, which is sometimes used on the subgrade in place in the field.
- Evaluations based on classification of soil by identifying and testing the constituent particles of the soil.

Two well-known classification systems are the American Association of State Highway and Transportation Officials (AASHTO) Classification System and the Unified Soil Classification System, used by the Department of Defense.

Test your Knowledge (Select the Correct Response)

3. A load-bearing test commonly used by the Seabees is the CBR test. What does CBR represent?

   A. Course Base Repair
   B. California Bearing Ratio
   C. California Base Rate
   D. Cold-Bearing Rate

4. What procedure adds layers of asphalt on top of the original asphalt thickness?

   A. Stage construction
   B. Subgrade evaluation
   C. Asphalt wearing
   D. Sub grading

3.0.0 PREPARING ASPHALT for CONSTRUCTION OPERATIONS

Paving grade asphalt (asphalt cement), which at normal atmospheric temperatures is semisolid and highly viscous, must be made temporarily fluid (liquefied) for handling during construction operations such as pumping through pipes, transporting in tanks, spraying through nozzles, and mixing with aggregate. When pavement construction operations are finished, the asphalt cement solidifies and functions as the cementing (or binding) and waterproofing agent that makes the pavement stable and durable.

Asphalt cement can be made temporarily fluid for construction operations in three ways:

- By heating the asphalt. After construction operations, the hot liquid asphalt cement cools and changes from a fluid to its normal, semisolid condition.
- By dissolving the asphalt in selected petroleum solvents. This process is called cutting back; the diluted asphalt is called cutback asphalt. After construction, the solvent evaporates, leaving the asphalt cement in place.

- By emulsifying the asphalt with an emulsifying agent and water. While asphalt and water ordinarily do not mix, they can be made to mix by churning asphalt in a colloid mill. The resulting product, called emulsified asphalt, is a fluid ready for construction operations. During construction, the water evaporates and the asphalt particles merge into a continuous film that cements the aggregate particles together. When the water evaporates from the asphalt, it is called an emulsion break.

NOTE

The use of cutback asphalt in the United States has declined because of environmental regulations and the petroleum shortage. It is being replaced by emulsified asphalt, which can be used for almost any purpose currently being performed by cutback asphalt.

A hot-mixed or hot-load paving mixture is the best type of pavement; in it, the aggregate and binder are heated to approximately 310°F and laid no colder than 250°F. The exact temperature(s) to use will depend upon the weather and the distance that the material is hauled. Asphalt condition indicators are as follows:

- Overheated asphalt loses some of its binding qualities. Blue smoke rising from the spreader hopper is sometimes an indicator that this condition exists.
- A generally stiff appearance and improper coating of aggregate indicates the mix is too cold.
- Material lying flat in the bed of the truck with a shiny appearance means the mix is too rich in asphalt cement.
- When it is too lean, the mix will look dry and dull.

3.1.0 Prime Coat

Priming consists of the initial treatment on a granular base before surfacing with a bituminous material or pavement. The purpose of a prime coat is to penetrate the base (about 1/4 inch minimum penetration is desired), fill most of the voids, promote adhesion between the base and the bituminous applications placed on top of it, and waterproof the base.

Surfaces must be as clean as possible, and wear and tear conditions exist (dried-out surfaces), consider a light fog spray with water before priming actually begins.

The priming material may be a low-viscosity tar, a low-viscosity asphalt, or a diluted asphalt emulsion. The bituminous materials used for the prime coat should be applied in quantities, known as Rate of Application (ROA), of not less than 0.2 gallon or more than 0.5 gallon per square yard. Normally, the construction project specifications denote the ROA for the prime coat application; however, when the ROA is not included in the project specifications, the Naval Construction Force (NCF) uses an ROA of .3 for planning purposes. When the base absorbs all of the prime material within 1 to 3 hours or when penetration is too shallow, the base is underprimed. Under priming may be corrected by applying a second coating of the prime material.

An overprimed base may fail to cure or set and may contribute to failure of the pavement or bleed up through the asphalt mat. A free film of prime material remaining on the base after a 45-hour curing period indicates that the base is overprimed. Correct this condition by spreading a light, uniform layer of clean, dry sand over the prime coat to absorb the excess material. Application of the sand is usually followed by light rolling and brooming. Correct excess prime held in minor depressions by an application of clean, dry sand. Lightly broom any loose sand from the primed surface before laying the wearing surface.

Adequately cure the primed base before laying the wearing surface. In general, allow a minimum of 48 hours for complete curing. Ordinarily, proper surface condition is indicated by a slight change in the shiny black appearance to a slightly brown color.

When a soil base is to be covered by a bituminous wearing surface, barricade the area to prevent traffic from carrying dust or mud onto the surface both before and after priming. If opening the primed base course to traffic before it has completely cured is necessary, you may use fine sand; when you are ready to place the wearing surface, lightly broom the sand from the primed base course. To estimate the amount of bitumen required for the prime coat, multiply the area to be treated by the ROA.

NOTE

Under certain conditions, the estimate should include sufficient bitumen for an additional width of 1 foot on each side of the surface.

The formula for a prime coat estimate in gallons:

Step 1: *Gallons of Prime Coat Needed* = $\frac{ROA \times L \times W}{9}$

Step 2: Gallons needed for waste = Gallons of prime coat $\times WF$ (.05 or .10)

Step 3: Total gallons required for the project = Gallons of prime coat + waste gallons

Where:

ROA = Rate of application of bitumen in gallons per square yard

L = Length of treated section in feet

W = Width of treated surface in feet

9 = Square feet per yard conversion factor

WF = Waste factor of bitumen = 5% at .05 or 10% at .10. This will depend on the experience of the asphalt distributor truck crew.

Example: The specification and other data for a prime coat application are as follows:

L = 3 miles = 3 x 5280 = 15840 feet

W = 12 feet + 1 foot on each side of the surface course to be constructed on the primed base.

ROA = 0.3 gal/sq yd.

WF = 5% or .05

Calculate the number of gallons of bitumen necessary to spray a tack coat.

Solution:

Step 1: Gallons $= \frac{.3 \times 15840 \times 14}{9} = \frac{66528}{9} = 7392$ gallons

Step 2: Waste = 7392 gallons x WF of .05 = 369.6 gallons

Step 3: Total gallons required for the project = 369.6 + 7392 = 7761.6 gallons.

Always round your answer to the next highest number. In this case, 7761.6 rounds to 7762 gallons.

3.2.0 Tack Coat

A tack coat is an application of asphalt to an existing paved surface to provide bond between the existing surface and the asphalt material to be placed on it. Two essential requirements of a tack coat are as follows:

- It must be thin.
- It must uniformly cover the entire surface to be treated.

A thin tack coat does no harm to the pavement, and it will properly bond the course. Rapid-curing cutbacks, road tar cutbacks, rapid-setting emulsions (may be used in warm weather), and medium-asphalt cements are types of tack coats. Because rapid-curing cutbacks are highly flammable, carefully follow safety precautions. Apply a tack coat only when the surface to be tacked is dry and the atmospheric temperature has not been below 35°F for 12 hours immediately before application.

Before applying the tack coat to a surface that is sufficiently bonded, ensure that all loose material, dirt, clay, or other objectionable materials are removed from the surface to be treated. Use a power broom or blower, supplemented with hand brooms if necessary, to accomplish this operation. Immediately following the preparation of the surface, uniformly apply the bituminous via the bituminous (asphalt) distributor at the spraying temperature specified.

Apply the ROA for a tack coat in quantities not less than 0.05 or more than 0.25 gallon per square yard. The exact quantity varies with the condition of the existing pavement being tack-coated. Normally, the construction project specification denotes the ROA for the tack coat application; however, when the ROA is not included in the project specifications, the NCF uses an ROA of .15 for planning and estimating purposes.

Following the application of bituminous material, allow the surface to dry until it is in a proper condition of tackiness to receive the surface course; otherwise, the volatile substances may act as a lubricant and prevent bonding with the wearing surface. Spread clean, dry sand on all areas that show an excess of bitumen to blot up and cure the excess effectively. After excess bitumen is set, lightly broom any loose sand from the primed surface before laying the wearing surface.

Barricade an existing surface that is to be covered by a bituminous wearing surface to prevent traffic from carrying dust or mud onto the surface, either before or after the tack coat is applied. Should it become necessary for traffic to use the surface, tack coat and pave one lane, and use the other lane as a traffic bypass. Prime and sand the bypass lane before it is opened to traffic and sweep and reprime it after completing the adjacent lane. Doing this preserves the base and acts as a dust palliative (shelter).

The formula for a tack coat estimate in gallons is as follows:

Step 1: Gallons of Tack Coat Needed = $\frac{ROA \times L \times W}{9}$

Step 2: Gallons needed for waste = Gallons of tack coat x WF (.05 or .10)

Step 3: Total gallons required for the project = Gallons of tack coat + waste gallons

Where:

ROA = Rate of application of bitumen in gallons per square yard

L = Length of treated section in feet

W = Width of treated surface in feet

9 = Square feet per yard conversion factor

WF = Waste Factor of bitumen = 5% at .05 or 10% at .10. This will depend on the experience of the asphalt distributor truck crew.

Calculate the number of gallons of bitumen necessary to spray a tack coat.

Solution:

Step 1: Gallons = $\frac{.05 \times 10560 \times 24}{9} = \frac{12672}{9} = 1408$ gallons

Step 2: Waste = 1408 gallons x WF of .05 = 70.4 gallons

Step 3: Total gallons required for the project = 70.4+1408 gallons = 1478.4 gallons.

Always round your answer to the next higher number. In this case, 1478.4 is rounded to 1479 gallons.

Test your Knowledge (Select the Correct Response)

5. Asphalt cement can be made temporarily fluid (liquefied) for construction operation in what three ways?

   A. Emulsifying with water, melting, and crushing
   B. Melting, dissolving, and crushing
   C. Heating, dissolving, and emulsifying
   D. Crushing, heating, and dissolving

6. The aggregate and binder of a hot-mix paving mixture should be heated to what temperature, in degrees Fahrenheit?

   A. 110
   B. 200
   C. 310
   D. 400

4.0.0 TYPES of ASPHALT PAVEMENT CONSTRUCTION

Two major types of asphalt pavement construction are in use today: plant mix construction (so called because the mixture is prepared in a central mixing plant) and mixed-in-place construction (so called because the mixture is prepared in the area to be paved).

4.1.0 Plant-Mix Construction

Asphalt paving mixtures, prepared in an asphalt mixing plant, are known as plant mixes. Plant mix asphalt concrete is considered the highest quality plant mix. It consists of well graded, high-quality aggregate and asphalt cement. The asphalt and aggregate are heated separately from 250°F to 325°F, carefully measured and proportioned, then mixed until the aggregate particles are coated with asphalt. The hot mixture, kept hot during transit, is hauled to the construction site where it is spread on the roadway with an asphalt-paving machine. The smooth layer from the paver is compacted by rollers to proper density before the asphalt cools.

Asphalt concrete is but one of a variety of hot-asphalt plant mixes. Other mixes, such as sand asphalt and coarse-graded mixes are prepared and placed in a similar manner; however, they all contain asphalt cement.

Asphalt mixes containing emulsified or cutback asphalt may also be prepared in asphalt mixing plants. The aggregate may be partially dried and heated or mixed as it is withdrawn from the stockpile. These mixes are usually referred to as cold mixes, even though heated aggregate may have been used in the mixing process.

Both asphalt mixtures, made with emulsified asphalt and some cutback asphalts, can be spread and compacted on the roadway while quite cool. Such mixtures are called cold-laid asphalt plant mixes. They are hauled and placed in normal warm weather temperatures. These mixtures, after being placed on the roadway, are sometimes processed or worked back and forth laterally with a grader before being spread and compacted. This action speeds up setting or curing.

4.1.1 Computing Plant-Mix Materials

Several methods are used to calculate the amount of hot-mix material required for paving projects; however, when the weight of a hot mix per square yard or cubic foot is not known, the NCF uses two equations to compute the number of tons of asphalt required for a project. These equations are as follows:

Equation One:

$$\text{Tons of Asphalt} = \frac{L \times W \times D \times 146}{2{,}000} = \text{Tons x (WF)} =$$

Percent of Tons + Tons = Tons Required

L = Length of project in feet.

W = Width of project in feet.

D = Depth or thickness of compacted mat. You must change inches into feet by dividing the number of inches by 12 (inches in 1 foot). For paver screed height, add 1/8 inch for each inch of the mat to be paved. (Example: For a 2-inch mat, two blocks of wood 2 1/4 inches thick will be required to set under the screed.) The blocks must be thicker than the finished compacted mat to allow for additional compaction by rollers.

146 = This number represents the approximate weight of 1 cubic foot of compacted hot-mix asphalt. This number can vary from 140 to 160 pounds; however, 146 pounds equals the 110 pounds per square yard per 1 inch depth of asphalt used in the second equation for figuring tons require for asphalt.

WF = Waste factor equals 5% or .05, or 10% or .10, depending on the experience of the screed operators and handwork required on the project.

2,000 = 2,000 pounds is equal to one ton; therefore, you must divide the total weight of material by 2,000 to get the tons required.

Equation Two:

$$\text{Tons of asphalt} = \frac{L \times W}{9} = \text{Square Yards x } \frac{110\, poundsper 1'' \; Mat}{2{,}000} =$$

Tons x WF = Percent of Tons + Tons = Tons Required

Where:

L = Length of project.

W = Width of project in feet.

110 = Pounds per square yard of asphalt per 1-inch depth. (Example: A 2-inch mat will equal 220 pounds per square yard.)

9 = To obtain square yards from square feet, divide by 9.

2,000 = 2,000 pounds equal one ton; therefore, you must divide the total weight of material by 2,000 to get the tons required.

WF = Waste factor equals 5% or .05, or 10% or .10, depending on the experience of the screed operators and handwork required on the project.

Example: The specifications for a parking lot paving project are as follows:

L = 90 feet

W = 30 feet

D = 2 inches

WF = .10

To find the amount of asphalt required for this project,

$$\text{Equation One} = \frac{30 feet \times 90 feet \times .167 \times 146}{2{,}000} =$$

$$\frac{65831.4}{2{,}000} = 32.9$$

(32.9 is rounded off to 33)

WF = 33 x .10 = 3.3 Total Tons Required = 3.3 +33 =36.3

(36.3 is rounded off to 37)

$$\text{Equation Two} = \frac{30 feet \times 90 feet}{9} = 300 \text{ Square Yards} =$$

$$\frac{300 SquareYards \times 220}{2{,}000} = 33$$

WF = 33 x .10 = 3.3 Total Tons Required = 33 + 3.3 =36.3

4.1.2 Placing Plant-Mix Materials

The material that arrives at the construction site from the plant must be spread. It must cover the entire width of the road being paved. It is then struck off to the desired shape and thickness and compacted.

Three general methods of spreading and shaping the material are in use today: hand spreading, blade spreading and mechanical spreading. Hand spreading is the oldest method used to spread and shape the mixed material. For this method, dump the mix from the trucks onto dump boards from which the material is shoveled onto the road or runway. After placement, rake it to grade and contour and compact it with a roller.

WARNING

Asphalt and bituminous materials contain coal tars, benzene, and other components which are suspected or known carcinogens. Workers should avoid inhalation of the vapors and prolonged skin contact with these materials. Review the Materials Safety Data Sheet (MSDS) for specific hazards and precautions.

Because of the high cost of labor and the inability to obtain a smooth and even-textured surface, hand spreading is not used to any great extent. It is used primarily to supplement the other spreading methods. For example, hand spreading is used effectively for adjacent curbing and around manholes.

When placing the material by hand, be extremely careful to prevent segregation of the mix. Do NOT throw the material a long distance and do NOT dump it from too great a height. Dump the material in small piles and level it with shovels, rakes, and lutes. Use the shovel to move the excess material, and the lute and rakes to level it. The material should be as level as possible before compacting it.

Blade spreading is done with a grader by a skilled operator. The grader blade can obtain reasonably good surface smoothness. Each successive pass of the grader blade reduces the irregularities in the surface. Often, blade spreading is used in areas too large for hand spreading and inaccessible to mechanical spreading.

Specialized machines have been developed to spread bituminous paving materials. Self-propelled, these machines have a crawler, wheels, or rollers which run on the base course foundation or surface. The mix from the plant is dumped into a hopper on the front of the paver. The paver places the mix evenly on the road itself (*Figure 23-5*)

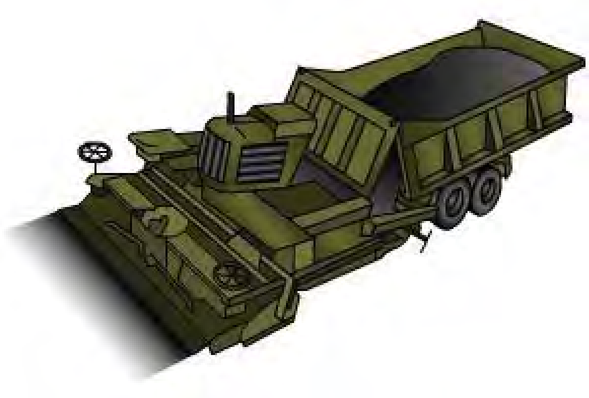


Figure 23-5 — Bituminous paver.

4.1.3 Compacting Plant-Mix Materials

The most important phase of flexible pavement construction is compaction. When the specified density of asphalt pavement mix is not obtained during construction, subsequent traffic will further compact the pavement. This compaction or consolidation occurs principally in the wheel paths and appears as channels in the pavement surface.

Most mixtures compact quite readily when spread and rolled at temperatures that ensure proper asphalt viscosity. Start rolling as soon as possible after the material has been spread by the paver but do it carefully to prevent unduly roughening of the surface.

Mix temperature is a principal factor affecting compaction. Compaction can occur only while the asphalt binder is fluid enough to act as a lubricant. When it cools enough to act as an adhesive, further compaction is extremely difficult to achieve. The best time to roll an asphalt mixture is when its resistance to compaction is the least, while at the same time it is capable of supporting the roller without excessive shoving of the asphalt material. The best rolling temperature is influenced by the interparticle friction of the aggregates, the gradation of the mix, and the viscosity of the asphalt; therefore, it can change if any of these factors change. The critical mix temperature in an asphalt-paving project is the temperature at the time of compaction.

During rolling, keep the roller wheels moist with only enough water to avoid picking up material. Rollers move at a slow but uniform speed with the drive wheels nearest the paver. The speed should not exceed 3 miles per hour (mph) for steel wheeled rollers or 5 mph for pneumatic tired rollers. Maintain the roller in good condition, capable of being reversed without backlash. Do not suddenly change the line of rolling or suddenly reverse the direction of rolling, because these actions will displace the mix. Make any pronounced change in direction on stable material.

When rolling causes material displacement, loosen the affected areas at once with lutes or rakes and restore them to their original grade with loose material before rerolling them. Do not permit heavy equipment, including rollers, to stand on the finished surface before it has thoroughly cooled or set. Roll freshly placed asphalt mix in the following order:

1. Transverse joints
2. Longitudinal joints
3. Breakdown or initial rolling
4. Intermediate or second rolling
5. Finish rolling

4.2.0 Mixed-in-Place Construction

Emulsified asphalt and many cutback asphalts (although the use of cutbacks is declining) are fluid enough to be sprayed onto and mixed into aggregate at moderate to warm weather temperatures. When this is done on the area to be paved, it is called mixed-in-place construction. Although mixed-in-place is the more general term and is applicable whether the construction is on a roadway, parking area, or airfield, the term road mix is often used when construction is on a roadway. Mixed-in-place construction can be used for surface, base, or subgrade courses. As a surface or wearing course, it usually is satisfactory for light and medium traffic, rather than heavy traffic. However, mixed-in-place layers covered by a high-quality asphalt plant-mix surface course make a pavement suitable for heavy traffic service. The advantages of mixed-in-place construction include the following:

1. Utilization of aggregate already on the roadbed or available from nearby sources and usable without extensive processing

2. Elimination of the need for an asphalt mixing plant. Construction can be accomplished with a variety of machinery often more readily available, such as motor graders, rotary mixer with revolving tines, or traveling mixing plants

4.3.0 Road-Mix Pavements

Road-mix pavements consist of mineral aggregate and mineral filler uniformly mixed in place with a bituminous material and compacted on a prepared base course or subgrade. A single layer, about 1 1/2 inches to 3 inches thick, is generally used. This type of pavement is likely to become defective unless it has a sound, well-drained subgrade and is well-mixed, uniformly spread, and properly compacted. Road-mix pavements may be used as a wearing surface on temporary roads and airfields and as a bituminous base or binder course in construction of more permanent types of roads and airfields.

Road mix is an economical method of surfacing small areas when aggregate can be used from the existing base or when satisfactory aggregate is nearby. For road-mix pavements, the grade and type of bituminous material depend upon the aggregate and equipment available as well as weather conditions and time required to complete the project. Good weather is important to the success of a road-mix project. Where possible, schedule road-mixing operations when weather conditions are likely to be hot and dry during, and for some time after, the project.

Recommended types of bituminous materials suitable for road mix are asphalt cutbacks, asphalt emulsions, and road tars. A medium-curing (MC) cutback is generally used in a moderate climate, a rapid-curing (RC) cutback in a cold climate. The viscosity required is determined by the temperature, aggregate gradation, and method of mixing. Use the highest viscosity that will completely and uniformly coat the particles of aggregate. In general, open-graded aggregate requires a high viscosity. A gradation, containing mineral filler, requires a less viscous grade.

Aggregate used in road mix may be scarified from the existing subgrade or hauled in from a nearby source. A wide range of coarse and fine aggregate and mineral filler may be used. The ideal aggregate for road-mix pavement is a well-graded (dense or open) sandy gravel or clean sand. Maximum size of the aggregate, in general, is limited to two thirds of the compacted thickness of the layer. Loose thickness is approximately 1 1/4 times the desired compacted thickness.

"Surface moisture" is defined as the film of water around each particle of stone or sand. The amount present is determined by heating a weighed sample of aggregate at 212°F in an open pan and stirring it with a rod until the surface water disappears (3 to 10 minutes). The difference between the original and final weights is considered to be moisture lost during drying. The loss in weight, expressed as a percent of the final or dry weight, is the moisture content, allowed before the aggregate is mixed with asphalt cutbacks or road tars.

When the aggregate is too wet, it should be worked with mechanical mixers, graders, or improvised plows to allow the excess moisture to evaporate. For cutbacks and tars, the moisture content of coarse-graded aggregate should not exceed 3 percent, and for fine-graded aggregate, 2 percent. For emulsions, moisture content of coarse-graded aggregate should not exceed 5 percent, and of fine-graded aggregate, 3 percent.

The quality of the road-mix pavement depends largely upon the control of the mix. The percentage of bitumen will vary in relation to the absorptive quality of the aggregate, rate of evaporation of the volatile substances, and other factors.

Although an exact formula is difficult to follow, proportioning must be controlled within narrow limits to ensure the stability and life of the mix. With dense-graded aggregates especially, do not use too much bitumen. All particles of the completed mix should be coated and uniform in color. When the mix is too lean, the aggregate in the windrow will stand almost vertically and have a dull look; when the mix is too rich, it will ooze or slip out of shape. When the mix is correctly proportioned, a handful squeezed into a ball will retain its shape when the hand is opened.

Construct road-mix pavements only on a dry base when the weather is not rainy. Atmospheric temperature should be above 50°F. Mixing should take place at the temperature of the aggregate, but not below 50°F or above the recommended temperature of the liquid asphalt being used. The construction procedure depends upon whether the base is a newly constructed base, a scarified existing base, or an existing pavement.

When using a newly constructed base, perform the following procedure:

1. Inspect and condition the base.
2. Prime the base and allow the prime to cure.
3. Haul in and windrow the aggregate at the side of the primed base. (Allow the aggregate to dry, or aerate with a blade when wet.)
4. Spread the aggregate on the cured prime base one-half of the roadbed width.
5. Spray the bitumen on the aggregate in increments of about one third of the total amount required.
6. Mix the bitumen with the aggregate; blade back and forth until a uniform mix is obtained.
7. Repeat as directed in Steps 5 and 6 until thoroughly mixed.
8. Spread the mix to the specified thickness.
9. Compact the surface.
10. Apply a seal coat when necessary.

For a scarified base, the aggregate is scarified when it is not available from other sources. The construction procedures are as follows:

1. Loosen the aggregate from the base.
2. Dry and breakup all lumps of material.
3. Blade into parallel windrows of uniform size at one side or in the center.
4. Sweep the base, when needed.
5. Prime the base and allow time to cure.
6. Continue as directed in Steps 4 through 10 in the above procedure for a newly constructed base.

When an existing pavement is to be used as a base, the construction procedures are as follows:

1. Sweep the base.
2. Apply a tack coat and allow it to cure.
3. Bring in the aggregate and deposit it in windrows at the side of the cured, tacked base.

4. Aerate the aggregate.
5. Spread the aggregate on one half of the tacked base.
6. Spray bitumen on the aggregate in increments of about one third of the total amount required
7. Mix the bitumen with the aggregate by blade.
8. Spread the mix to specified un-compacted thickness.
9. Compact the surface.
10. Apply a seal coat when necessary.

When you are mixing in place (road mix), here are some helpful hints:

1. Do not try to buck nature; stop operations when you are working under adverse weather conditions.
2. Keep the mixture or aggregate in a well-packed windrow for better water shedding and control.
3. Provide drainage cuts through the windrow during heavy rains.
4. When a grader comes to the end of a section with a full blade, lift the blade rapidly to avoid carrying materials into the next section.
5. Cut the distributor spray sharply at sectional joints; carry-over to the next section will cause undesirable fat joints.
6. Plan the work to avoid inconvenience to motorists.
7. Apply the asphalt at the recommended spraying viscosity to ensure uniform application.
8. Using a shoe on the outer end of the grader blade or moldboard helps obtain a good edge during spreading operations.
9. Aggregate in shaded areas usually requires extra aeration.

4.3.1 Road-Mixing Method

Two methods of road mixing are travel plant mixing and blade mixing.

When using a travel plant for mixing, dump, mix, and blade the loose aggregate into uniform windrows, and even it when necessary. The windrow should be sufficient to cover the section of the area to be paved with enough loose material to give the desired compacted depth and width.

As the bucket loader tows the mixer and elevates the aggregate to the mixer hopper, the mixer meters the aggregate, sprays it with the correct amount of bitumen, mixes these two uniformly, and re-deposits the mix into another windrow behind the plant.

Control the rate of travel and the mixing operation so that all particles of the aggregate are coated and the mix is uniform. Accuracy in proportioning the mix is extremely important.

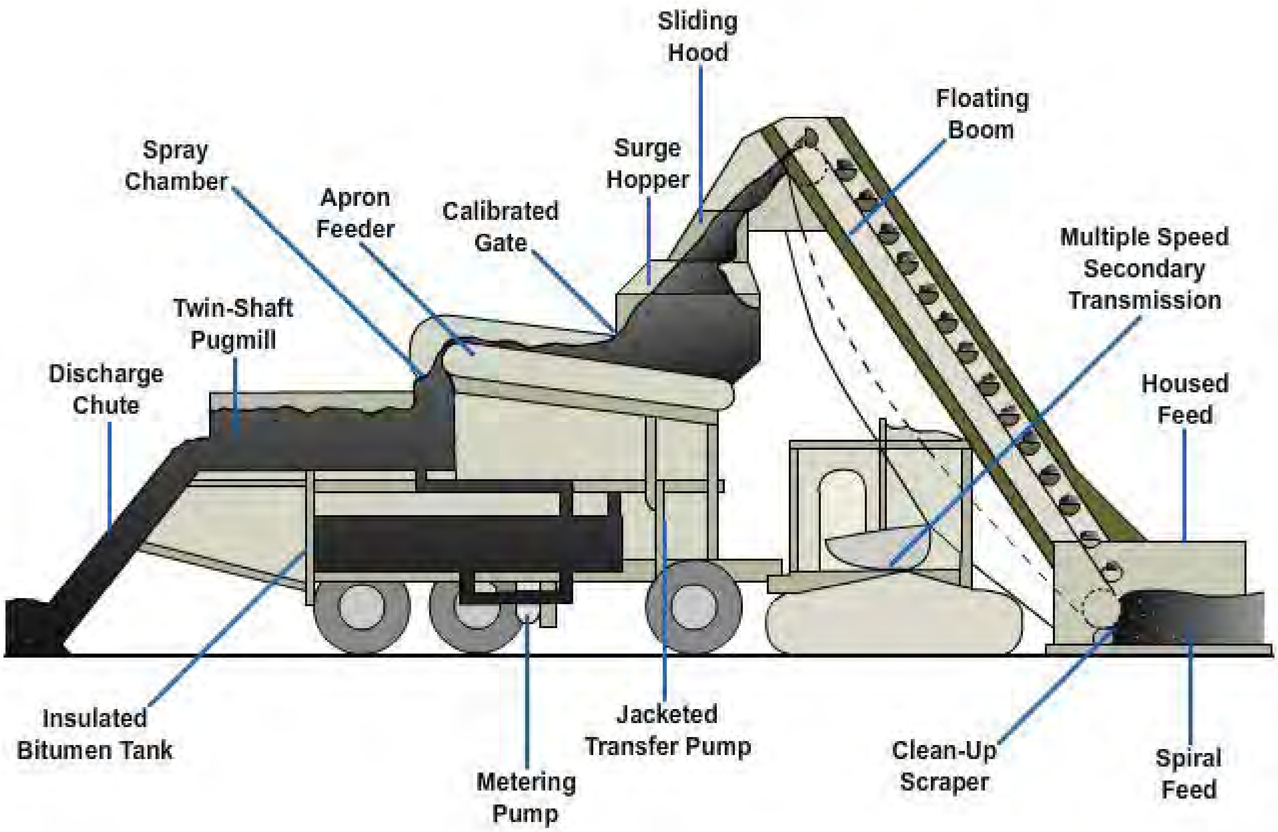


Figure 23-6 – Schematic layout of a travel plant.

The travel plant method (*Figure 23-6*) usually produces a more uniform mix of higher quality than blade mixing. Using heavier types of asphalt cutback and tar in the travel plant method reduces the time required for curing. Use the asphalt finisher concurrently with the travel plant. The hopper of the finisher is kept directly under the travel plant output chute. This arrangement reduces the maximum output of the plant, although it does provide uniform thickness of the mat being laid.

Windrows must contain no more material than the finisher can place. The major advantage of this setup is that in-place aggregate may be used in an intermediate mix and placed with a finisher without the necessity of loading and transporting aggregate. The finisher must be used with the travel plant for construction of some airfields when surface tolerances are critical.

In blade mixing, dry the aggregate and blade it into windrows. Then flatten windrows and apply the bitumen of the specific temperature with a bituminous distributor in three equal applications. Each application is one-third of the amount required.

Immediately following each application of the bituminous material, mix the treated aggregate with spring-tooth or double-disk harrows, graders, rotary tillers, or a combination of this equipment until all the particles of the aggregate are evenly coated. When using a grader, move the windrow from side-to-side by successive cuts with the blade.

Several graders can operate one behind the other to reduce the total time required for complete mixing. In hilly terrain, blading should be from the bottom to the top, as the mix tends to migrate down. After mixing all of the aggregate, blade the mix into a single windrow at or near the center of the road and turn it not less than four complete turns from one side of the road to the other. Correct excess bitumen, deficiency of bitumen, or uneven mix by adding aggregate or bituminous material, followed by remixing. Continue mixing until it is complete and satisfactory; remember, mix will set up if mixed too long.

Suppose that materials, weather conditions, and equipment are well suited to mixed-in-place paving, but the road or airfield must carry traffic during construction. In such cases, mix the aggregate on an out of the way flat surface. Then prime the road or airfield surface, base, or subgrade to be paved or tack-coat it as required to complete construction and to keep portions of the road or airfield open to traffic. As soon as the prime or tack coat cures, pick up the mix, truck it to the jobsite, dump it, and then blade it into windrows for spreading.

Do not spread the bituminous mix when the surface is damp or when the mix itself contains an excess of moisture. Spread the mixed material to the required width in thin, equal layers by a grader or finisher. (When a finisher is used, additional support equipment is required, and the material must be split into two windrows for an 8- to 12-foot-wide pavement.) When spreading the mix from a windrow, take care to prevent cutting into the underlying subgrade or base course. To prevent such cutting, leave a layer of mix, approximately one-half inch thick, at the bottom of the windrow.

Roll the material being spread once and then level it with a grader to remove irregularities. Spread the remaining material and roll it in thin layers until the entire mix is evenly spread to the depth and width specified. During the spreading and compacting, drag or blade the surface, as necessary, to fill any ruts and to remove corrugations, waves, or other irregularities. You may use either pneumatic-tired or steel-wheeled rollers for rolling all surface treatment jobs; however, the pneumatic-tired roller is the preferred type. Refer to *Figure 23-7*.

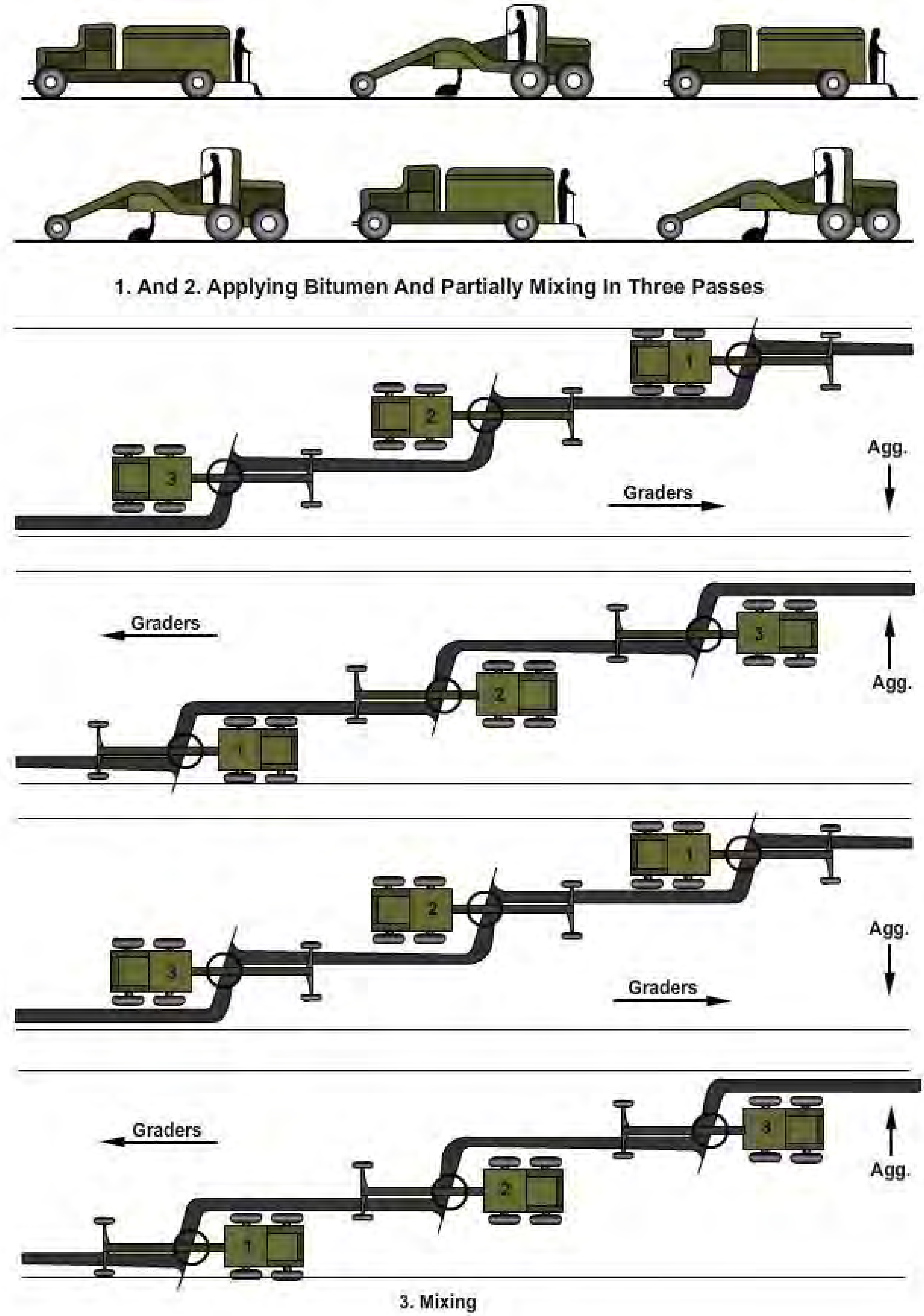


Figure 23-7 – Blade-mix construction.

After all layers have been satisfactorily spread, roll the surface with two-axle tandem rollers. Begin rolling at the outside edge of the surface and proceed to the center, overlapping on successive trips at least one half of the width of the roller wheel. Alternate trips of the roller should be of different lengths. Control the speed of the roller at all times to avoid displacement of the mix. Light blading (or floating) of the surface with the grader during rolling may be required. Continue rolling until you have eliminated all roller marks and obtained maximum density. To prevent adhesion of the mix to the roller, keep the roller wheel moist with water; use only enough water to avoid picking up the material. At places not accessible to the roller, thoroughly compact the mix with hand tampers. When the surface course becomes rough, corrugated, uneven in texture, water soaked, or traffic marked, tear up and rework, relay, or replace unsatisfactory portions. When forms are not used and while the surface is being compacted and finished, trim the outside edges neatly in line.

When the road-mix pavement surface course is constructed from an open-graded aggregate, a surface treatment may be required to waterproof the surface. A surface treatment is unnecessary on a dense-graded, well compacted, road-mix pavement.

When possible, keep traffic off freshly sprayed asphalt or mixed materials. When it is necessary to route traffic over the new work speed must be restricted to 25 mph or less until rolling is completed and the asphalt mixture is firm enough to withstand high-speed traffic.

Test your Knowledge (Select the Correct Response)

7. What is the major difference between plant-mix construction asphalt and mix-in-place construction asphalt?

   A. Plant-mix construction asphalt has a much heavier and stronger type of aggregate than mix-in-place construction asphalt.
   B. Plant-mix construction asphalt requires a different rolling technique.
   C. Plant-mix construction asphalt is prepared in a central mixing plant.
   D. Plant-mix construction asphalt requires a different curing time.

8. When computing plant-mix materials, what pound value represents the approximate weight of one cubic foot of compacted hot-mix asphalt?

   A. 80
   B. 100
   C. 120
   D. 146

5.0.0 DEFECTS in FLEXIBLE PAVEMENT

Defects in flexible pavements can be placed into one of five classes: cracking, distortion, disintegration, slippery surfaces, and surface treatment problems.

5.1.0 Classes of Defects

5.1.1 Cracking

Cracking takes many forms. To make the proper repairs, first you should determine the type of crack and the cause. The most common types of cracks are alligator, edge, edge joint, lane joint, reflection, shrinkage, and slippage.

Alligator cracks are interconnected cracks, forming a series of small blocks resembling an alligator's skin or chicken wire (*Figure 23-8*). In most cases, alligator cracking is caused by excessive movement of the surface over unstable subgrades or base courses. The unstable support is the result of saturated granular bases or subgrade. Normally, the affected area is not large. When it does occur on a large scale, the cracking is most likely due to repeated loads above the designed strength of the pavement.

Edge cracks are longitudinal cracks approximately 1 foot from the edge of the pavement (*Figure 23-9*). Edge cracks can have transverse cracks, branching in towards the shoulder. Normally, edge cracks are caused by a lack of side or shoulder support. They may also be caused by settlement or yielding of the base material underlying the cracked area. This, in turn, may be the result of poor drainage, frost heave, or shrinkage from the drying out of the surrounding earth.

Figure 23-8 – Alligator cracks.

Figure 23-9 – Edge cracks.

Edge joint cracks occur between the pavement and shoulder (*Figure 23-10*). They are caused by alternate wetting and drying beneath the shoulder surface. This can result from poor drainage from a high shoulder, or depressions along the pavement edge. The uneven pavement traps water on top, allowing it to seep into the base. Another cause could be heavy trucks straddling the joint.

Lane joint cracks are longitudinal separations along the seam between two paving lanes (*Figure 23-11*). This type of crack is caused by a weak seam or poor bond between adjoining spreads in the pavement.

Figure 23-10 – Edge joint cracks.

Figure 23-11 – Lane joint cracks.

Reflection cracks occur in asphalt overlays. These cracks reflect the crack pattern in the pavement structure underneath (*Figure 23-12*). They are found in asphalt overlays over Portland concrete and cement-treated bases. Reflection cracks are caused by vertical or horizontal movements in the pavement beneath the overlay, resulting from traffic loads, temperature, and earth movements.

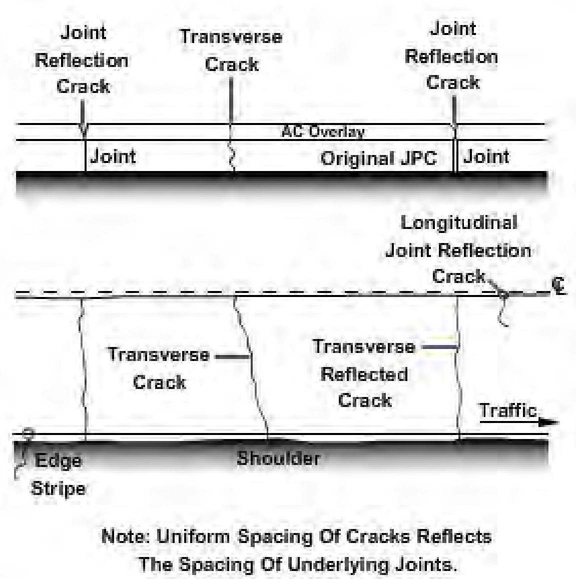


Figure 23-12 – Reflection cracks.

Shrinkage cracks are interconnected cracks, forming a series of large blocks with sharp corners or angles (*Figure 23-13*). Often it is difficult to determine whether shrinkage cracks are caused by volume change in the asphalt mix or in the base or subgrade. Frequently, they are caused by volume change of fine aggregate asphalt mixes that have a high content of high-viscosity asphalt. Lack of traffic hastens shrinkage in these pavements.

Figure 23-13 – Shrinkage cracks.

Slippage cracks are crescent-shaped cracks, resulting from horizontal forces induced by traffic (*Figure 23-14*). They are caused by a lack of bond between the surface layer and the course beneath. The lack of bond may be due to dust, dirt, oil, or the absence of a tack coat.

Figure 23-14 – Slippage cracks.

5.1.2 Distortion

Pavement distortion is any change in a flexible pavement surface. It is the result of a subgrade surface weakness where compaction or movement of the subgrade soil has taken place or where base compaction has occurred. It may or may not be accompanied by cracking, but in either instance, it creates a traffic hazard, permits water to accumulate, and eventually makes matters worse. Distortion takes a number of different forms but is normally classed as channeling, corrugations and shoving, depressions, and upheaval.

Channeling also referred to as “grooving” or “rutting,” is channelized depressions that develop in the wheel tracks of flexible pavements. Channeling may result from consolidation or lateral movement under traffic in one or more of the underlying courses or by displacement in the bituminous surface itself. It may develop under traffic in new flexible pavements that had too little compaction during construction or from plastic movement in a mix that does not have enough stability to support traffic.

Corrugation, or wash boarding, is a form of plastic movement typified by ripples across the flexible pavement surface (*Figure 23-15*). Shoving is the plastic movement of the pavement resulting in localized bulging of the pavement (*Figure 23-16*). Both corrugations and shoving normally occur at points where traffic starts and stops or on hills where vehicles brake on the downgrade.

Figure 23-15 – Corrugations.

Figure 23-16 – Shoving.

Corrugations and shoving usually occur in flexible pavement mixtures that lack stability. This may be the result of too much binder, too much fine aggregate, or round- or smooth-textured coarse aggregate. In the case of emulsified and cutback asphalt mixes, it may be due to a lack of aeration.

Depressions are localized areas of limited size that may or may not be accompanied by cracking. Water collects in depressions that then become not a source of pavement deterioration but a hazard to motorists. Depressions are caused by traffic heavier than that for which the pavement was designed, by poor construction methods, or by consolidation deep within the subgrade.

Upheaval is the localized upward displacement of the pavement due to swelling of the subgrade or some portion of the pavement structure. It is commonly caused by ice expansion in the granular courses beneath the pavement or in the subgrade. Upheaval may also be caused by the swelling effect of moisture on expansive soils.

5.1.3 Disintegration

Disintegration is the breaking up of a pavement into small, loose fragments. This includes the dislodging of aggregate particles. If not stopped in its early stages, disintegration can progress until the pavement requires complete rebuilding. Potholes and raveling are two of the more common types of early stage disintegration.

Potholes are bowl-shaped holes of various sizes in the pavement, resulting from localized disintegration under traffic. They are usually caused by weakness in the pavement, resulting from too little binder, too thin a surface, or poor drainage.

Raveling is the progressive loss of surface material by weathering or traffic abrasion. Usually the fine aggregate wears away first, leaving little pockmarks in the pavement surface. As erosion continues, larger particles eventually break free, and the pavement soon has the rough and jagged appearance typical of surface erosion. Raveling is caused by poor construction methods, inferior aggregates, or poor mix design.

5.1.4 Slippery Surfaces

One of the most common causes of a slippery flexible pavement is a thin film of water over a smooth surface. This can cause vehicles to hydroplane. Other causes of slippery surface in flexible pavements are bleeding and polished aggregates.

Bleeding is the upward movement of bituminous material in a flexible pavement, resulting in the formation of a film of bituminous material on the surface (*Figure 23-17*). The most common cause of bleeding is too much asphalt in one or more of the pavement layers. This is usually the result of a rich plant mix or a prime or tack coat that is too heavy. Bleeding normally occurs in hot weather.

Polished aggregates are those that have been worn smooth under traffic (*Figure 23-18*). Polished aggregates are caused by using the wrong type of aggregate in the pavement mix.

Figure 23-17 – Bleeding asphalt.

Figure 23-18 – Polished aggregate in pavement surface.

5.2.0 Repairing Defective Flexible Pavements

Care and good judgment are necessary in applying suitable methods and in selection of proper materials for maintenance and repairs of bituminous surfaces. Both methods and materials vary considerably with local conditions, but the principles of bituminous work remain the same. The first step in making repairs is to determine the cause of the failure. Repairs must start at the source of the failure.

The first step in removing a defective area is to mark out the area you want to remove. If you are going to use a pavement saw to cut the pavement, make your marks heavy and easy to use. Make the marks with a waterproof material, such as paint or crayon, to prevent it from being washed off by the saw blade.

The shape of the patch is important. If you expect the patch to be strong enough to support traffic, you must make the marked area square or rectangular in shape with two faces at right angles to the flow of traffic. By doing this, you will ensure the patch does not shove or corrugate when traffic flows over the top of it.

After you mark the area you want to remove, you are now ready to make your cuts along the marks. Do this by using a pavement saw to make a fast, neat cut or by using a pneumatic hammer with a 5-inch asphalt cutting bit. The pneumatic hammer will leave the edges of the patch jagged. When making the cut with either tool, make sure the patch has square edges and is rectangular in shape. The cut should also extend at least a foot into the good pavement.

After the outline cuts have been made, break up the defective material with a pneumatic hammer. Break the pavement into pieces that can be removed easily by hand. If the pieces are too large, a front-end loader maybe required to remove them. After the pavement has been broken up, the pieces can then be removed and hauled away (*Figure 23-19*).

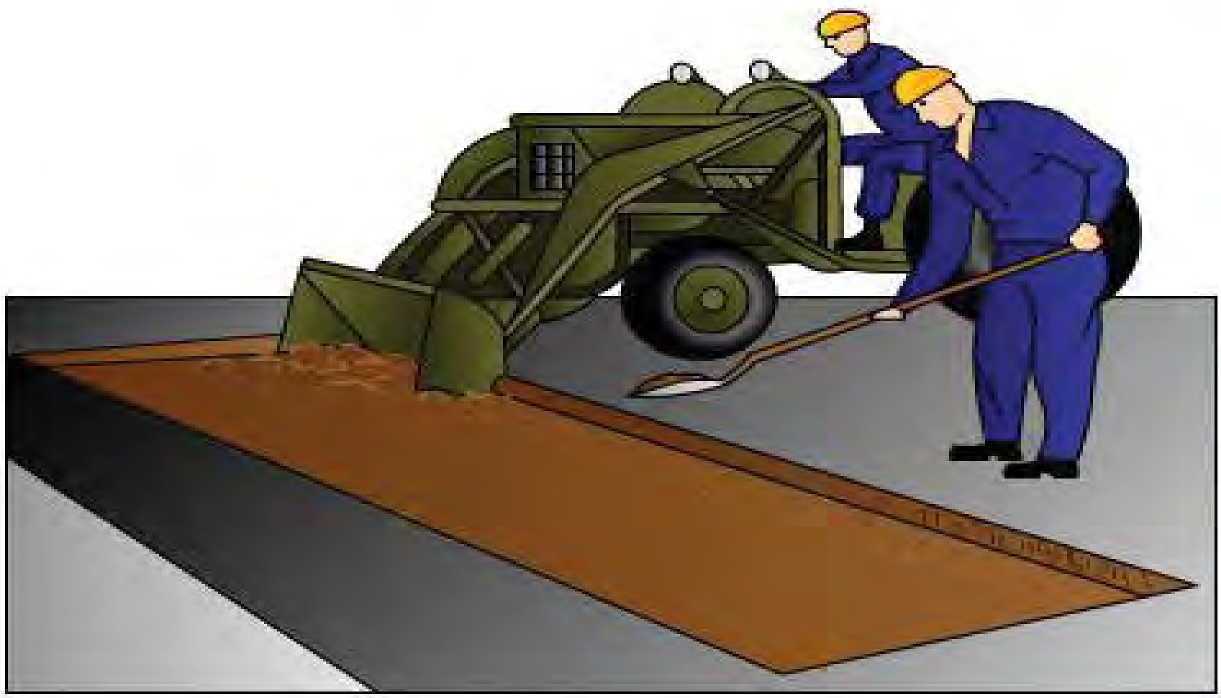


Figure 23-19 – Removing defective flexible pavement.

After removing the pavement, check the condition of the base course material. If the base course is saturated with water, remove this material until you reach firm, dry soil. The sides should be vertical and the bottom as level as possible.

After excavating the hole, clean out all the loose debris with a hand broom. If the hole is wet, allow it to dry. If the hole is deeper than the pavement, fill it with dense-graded aggregate. Fill and compact it in 2-inch lifts up to the lower edge of the pavement. On large patches, compaction can be done with a roller. Small patches must be hand-tamped. On large patches, the edges must be hand-tamped.

NOTE

Specifications may require that a compaction test be performed on the base course before a prime coat application.

After the base course has passed the compaction test, prime the hole with a light application of asphalt, which can either be sprayed or brushed on. The prime material must be thin enough so that it can be applied lightly.

NOTE

An excess of asphalt prime coat will flush into the patch mix and causes bleeding.

The final step in the preparation of the hole is to apply a tack coat to the vertical faces (*Figure 23-20*).

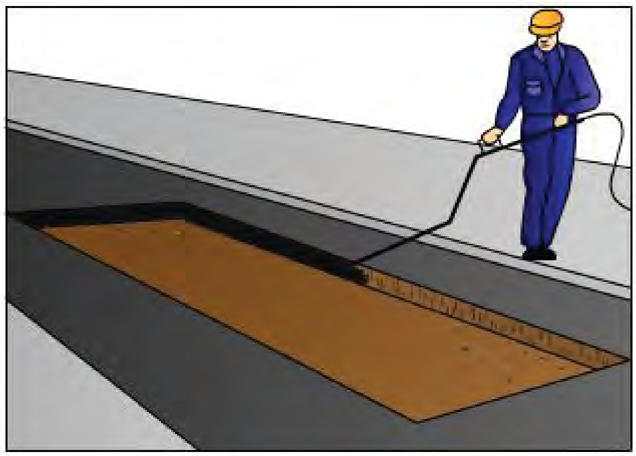


Figure 23-20 – Tack coat application to the vertical faces.

The first step in the replacement of the paving materials is to obtain a sufficient quantity of material to complete the project. Use a hot mix if possible because it is stronger and lasts much longer. To allow for compaction when using a hot mix, overfill the area approximately 40 percent of the pavement thickness. When using a cold mix, spread and roll it in layers with each layer not to exceed 1 1/2 times the maximum aggregate size in the mix. When cold mix is spread, keep the material as level as possible to prevent segregation. Both hot and cold mixes can be spread by grader, paver, or hand, depending on the size of the repair.

Compaction of bituminous materials is done with steel-wheel rollers and pneumatic-tired rollers on larger areas, or with vibrator tampers, vibratory patch rollers, and hand tampers on smaller areas.

Compaction is an important part of the patching operation. Begin the rolling operation on hot mix immediately after placing the material. Roll cold mix after proper aeration of the material. Roll the edges of the patch first. This seals the edges and prevents the material from dishing out and water from infiltrating.

When cold mix is used, the patch may have a porous surface and require waterproofing. Do this by applying a sand seal or by applying a thin layer of Portland cement and tamping it in.

Obtaining a smooth riding surface requires care. Too many patches are built as mounds that result in bumps in the road. Use a straightedge as a guide to finish the patch. The patch should not be lower than the rest of the pavement. Instead, it should be level with or one-eighth inch higher than the surrounding area (*Figure 23-21*).

Figure 23-21 – Steps in patching a pothole.

Test your Knowledge

9. Which of the following types of surface cracks is caused by excessive movement of the surface over unstable subgrades or base courses?

   A. Alligator
   B. Edge
   C. Reflection
   D. Slippage

10. Which of the following types of surface defects is usually the result of a rich plant mix or a prime or tack coat that was placed too heavy?

   A. Polished aggregates
   B. Raveling aggregates
   C. Bleeding aggregates
   D. Rolling aggregates

6.0.0 PURPOSES of SURFACE TREATMENTS

A surface treatment is an application of asphalt materials to any type of road surface with or without a cover of mineral aggregate. This application produces an increase in thickness usually less than one inch. Surface treatments have a variety of uses. They waterproof, provide a non-skid wearing surface, and rejuvenate an old surface.

The simplest types of bituminous surfaces that may be placed over prepared surfaces are called surface treatments. Surface treatments are applications of bituminous material to any type of base or pavement surfaces which, together with an aggregate cover, produce a pavement with a thickness of one inch or less. In some cases, multiple treatments that produce thicker pavements are used.

Surface treatments are applied for one or more of the following purposes:

1. Waterproof the surface

2. Provide a wearing surface
3. Make the surface non-skid
4. Prevent hydroplaning
5. Rejuvenate an old road or runway
6. Make permanent improvements

6.1.0 Types

Surface treatments may be applied to the base course of a new road or to the surface of an old road as a method of repair. Surface treatments are grouped into three categories: sprayed asphalt, sprayed asphalt with cover aggregates, and asphalt-aggregate mixtures. Sprayed asphalt treatments contain no aggregates. They are simply applications of different types of asphaltic materials to a prepared surface. The categories include fog seals, dust-laying, and road oiling. Prime and tack coats are also considered sprayed asphalt treatment.

A fog seal is a light application of diluted slow-setting asphalt emulsion, used to renew old asphalt surfaces and seal small cracks and surface voids. Fog seals are especially useful for pavements carrying a low volume of traffic.

A fog seal may also be used for the following:

1. To seal surface voids in new asphalt plant mixes
2. To prevent dust on sprayed asphalt with cover aggregate surface treatments
3. To increase aggregate retention
4. To provide a uniform dark color

Dilute the asphalt emulsion with an equal amount of water, and spray the diluted material at the ROA of 0.1 to 0.2 gallon per square yard, depending on the texture and dryness of the old pavement. In normal conditions, the separation and evaporation of the water is rapid, permitting traffic within 1 or 2 hours.

Dust-laying consists of spraying an untreated surface with low-viscosity liquid asphalt, such as SC-70, MC-30, MC-70, or a diluted slow-setting asphalt emulsion. The asphalt and dilutant penetrate and coat the fine particles and temporarily relieve the nuisance of dust. Spray the material at a ROA of 0.1 to 0.5 gallon per square yard. When you use emulsion, dilute it with 5 or more parts of water by volume.

Diluted emulsion dust-laying treatments usually require several applications. The dust stirred by traffic between applications eventually conglomerates and no longer rises. This is an effective treatment in a very dusty environment where one application of asphalt is insufficient.

Road oiling differs from dust laying in that it is usually part of a planned buildup of low-cost road surfaces over several years. Each application may be mechanically mixed with the material being treated, or it may be allowed to penetrate. The light oils in the road oil penetrate into the subgrade and tend to repel moisture absorption. The objective in all road oiling work is to form a dustless wearing surface combined with a strong water-repelling subgrade.

Because soils vary widely, procedures for oiling are a matter for local trial and error, rather than scientific analysis. The amount of road oil required in the first year of work will vary from 0.75 to 1.0 gallon per square yard. Apply the first application at the ROA of about one half of the total; make succeeding applications in equal amounts. Place road oiling treatments several weeks apart, depending upon the character of the asphalt soil mat. If some breakup occurs after the first winter, light scarifying and retreatment the second year will produce a thicker and stronger surface.

WARNING

Before planning any road oiling work your supervisor should check with local authorities concerning environmental protection restrictions.

The sprayed asphalt with aggregate cover surface treatments are applications of liquid asphalt followed by an application of aggregate. This can be done in one or more layers of construction. Two types of sprayed asphalt with covered aggregate surface treatments are in use today: single- and multiple-surface treatments.

Single-surface treatments are thin, bituminous-aggregate toppings, applied to existing bases or surfaces, such as concrete or asphalt. Construction involves applying a bituminous prime or tack coat to the base or surface. This coating is followed by an application of bitumen and small-sized aggregate. Single-surface treatments are sometimes called seal coats, because they seal the surface of the road or runway.

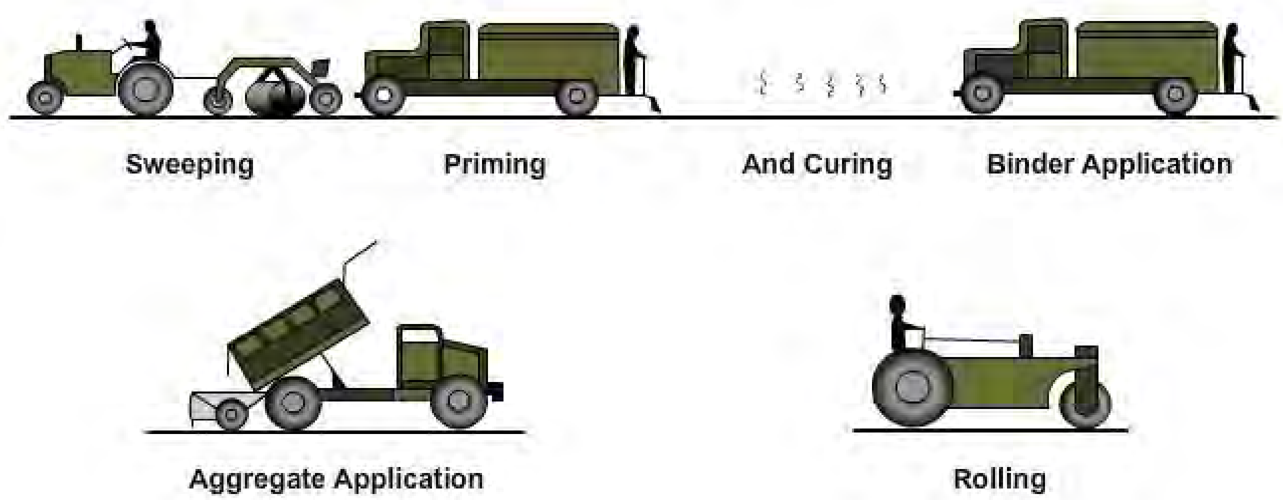


Figure 23-22 – Sequence of operations of the application of a single-service treatment.

Figure 23-22 shows the sequence of operations for the application of a single-surface treatment. The first steps, such as sweeping, priming or tacking, and curing, are the same as those used for applying a prime coat. Apply the binder (bituminous material) over the prime coat with an asphalt distributor. Then spread the aggregate over the binder using aggregate spreaders. Spread the aggregate cover uniformly immediately behind the distributor. As soon as the aggregate is spread, push it into the soft asphalt by rolling it with a pneumatic-tired roller. When you are applying the binder, it should be hot enough to spray properly and cover the surface uniformly. After the binder cools and cures, it should bind the aggregate tightly to prevent dislodgement by traffic. Press individual aggregate stones into the binder but be sure the binder does not cover them. Approximately one half of the individual aggregate stones should be exposed to traffic.

The ROA for the binder material should be between 0.25 and 0.30 gallons of asphalt per square yard. For a single-surface treatment, heat the bitumen and apply it to the surface while hot. The aggregate must be spread and rolled before the bitumen cools.

Under no circumstances permit traffic to travel upon uncovered fresh bitumen. The distributor should NOT apply bitumen until the aggregate is on hand and ready for application. When the distributor moves forward to spray the asphalt, the aggregate spreader should start right behind it. Cover the bitumen within 1 minute if possible; otherwise, the increase in asphalt viscosity may prevent good binding of aggregate.

The size and amount of aggregate used for surface treatments are important. You must use a size that matches the bitumen application rate. For a single-surface treatment, one-half inch to sieve number 4 is needed. The amount of aggregate should be 25-30 pounds per square yard. When aggregate is distributed properly, it requires very little hand work.

At longitudinal joints, the aggregate cover is stopped eight inches from the edge of the bitumen to ensure ample overlap of the bitumen coat. Cover all bare spots by hand spreading, and correct any irregularities of the distribution with hand brooms. Remove excess aggregate in limited areas immediately with square-pointed shovels. Properly setting and operating the aggregate spreader reduces handwork to a minimum.

The aggregate is usually rolled by pneumatic-tired rollers. Steel-wheeled rollers are not recommended by themselves. If you use them, make only one pass (one trip in each direction). Then complete the rolling operation with the pneumatic-tired rolls. Steel-wheeled rollers produce maximum compaction, but use them with care to prevent excessive crushing of the aggregate particles. Also, these rollers will bridge over smaller size particles and small depressions in the surface and will fail to press the aggregate in these places in the asphalt. You can eliminate or minimize faulty rolling by adhering to the following procedures:

1. Roll parallel to the center line of the roadway to reduce the number of times the roller must change direction.
2. Overlap succeeding passes one half of the wheel width of the roller. This action ensures that the aggregate becomes well embedded in the bitumen.
3. Complete rolling before the bitumen hardens. This will ensure that the aggregate becomes well embedded in the bitumen.
4. Make succeeding passes from the low side to the high side of the surface. This operation maintains the surface crown and prevents feathering at the edges.
5. Roll at a slow speed.
6. Wet rollers only enough to prevent bitumen from sticking to the wheels.
7. Be sure the power wheel of the roller passes over the unrolled surface before the steering wheel(s) of the rollers.

After rolling and curing, the surface is ready for traffic. When the surface is used as an airfield, sweep excess aggregate from the surface to avoid damage to aircraft. This practice is also recommended for roads.

A multiple-surface treatment is essentially the same as the single-surface treatment. However, the multiple surface treatments consist of two or more successive layers of binder and aggregate. This type of treatment is done in stages. Each stage is accomplished in the same manner as a single-surface treatment. The only difference is that each additional layer of aggregate should be about one half of the size of the previous layer. This allows the smaller aggregate to interlock with the larger aggregate when rolled.

Test Your Knowledge (Select the Correct Response)

11. Applying a surface treatment results in which of the following improvements?

    A. Waterproofs the surface
    B. Provides a wearing surface
    C. Prevents hydroplaning
    D. All of the above

12. When performing single-surface treatment operations, you should push the aggregate into the bituminous material using what type of roller?

    A. Tower grid
    B. Vibratory steel drum
    C. Pneumatic-tired roller
    D. Vibratory sheepsfoot

7.0.0 PAVING EQUIPMENT

Equipment used in asphalt pavement construction include aggregate spreaders, asphalt distributors and their associated hand sprayers and spray bars, asphalt kettles, asphalt haul trucks, and asphalt pavers.

7.1.0 Self-Propelled Aggregate Spreader

Several types of tailgate spreaders are in use today. The simplest is the vane spreader (*Figure 23-23*). Tailgate spreaders consist of a hopper with a feed roller activated by small wheels driven by contact with the truck wheels. Mechanical spreaders are hoppers on wheels that are hooked onto and propelled by backing aggregate trucks. Hoppers have various widths and capacities. They usually contain augers to distribute the aggregate the full width of the box. They have controls to regulate feed gates, feed roll, augers, and the truck hitch.

Figure 23-23 – Vane spreader.

All tailgate and mechanical spreaders that are pushed by a truck have the disadvantage that the truck must be operated in reverse with consequent loss of steering control and reduction in speed.

A self-propelled spreader (*Figure 23-24*) moves forward and makes a uniform and continuous application of cover aggregate, because it is capable of keeping up with the asphalt distribution. The spreader is self-powered and has a receiving hopper in the rear. Aggregate trucks are hitched to the spreader, dump their loads into the hopper, and are pulled by the spreader. Belt conveyors carry the aggregate to the front of the machine where it is dropped into the spreading hopper. Aggregate flows over a spread roll onto a screen that permits initial placement of larger particles on the asphalt, followed by fine aggregate on top.

Figure 23-24 – Hopper type of tailgate spreader.

Make calibration and adjustments for all types of aggregate according to the manufacturer's instruction and operating manual. Here are some additional checks that ensure good results:

1. A tachometer, used as an aid in maintaining uniform spreader-box speed, is most helpful.
2. Distribution rates are closely controlled by measuring off the length that each truckload of aggregate should cover.
3. Make a quick check on the rate of application of aggregate by laying a 1-square-meter (yard) section of cloth or building paper on the pavement (or by supporting a shallow 1-square-yard box above the asphalt with nails or screws) and by passing over it with the spreader. Then carefully lift the cloth, paper, or box and weigh the aggregate on it. This will give the weight per square yard of aggregate being spread.

7.2.0 Asphalt Distributor

The asphalt distributor (*Figure 23-25*) is a unit consisting of an insulated storage and heating tank, an open flame heating system, an asphalt pump, a low-pressure air blower, and a circulating and spraying system. Power to operate the components is PTO driven.

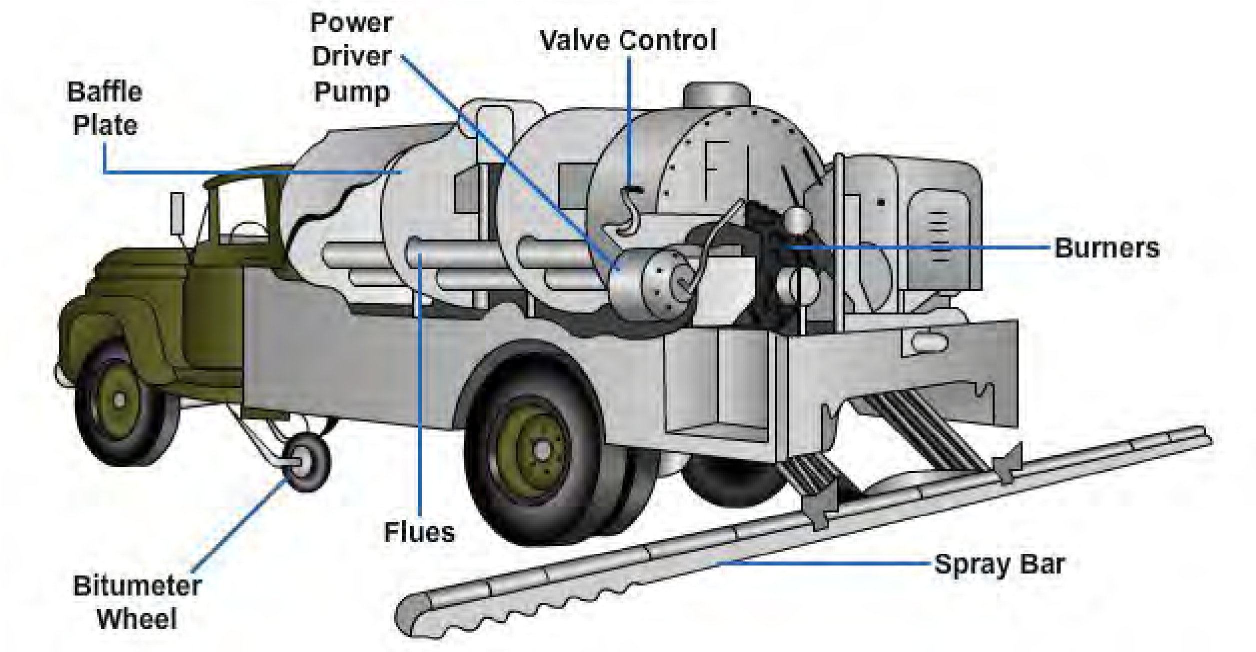


Figure 23-25 – Asphalt distributor.

NOTE

The operation of this truck absolutely requires experienced personnel only. Mishaps, resulting in loss of man-days and equipment, are a direct result of this factor being overlooked.

Within the heating system, the air blower provides low-pressure air to atomize fuel for the burners. The burners heat the tubes, located in the tank. Be sure to maintain asphalt covering over the fire tubes to prevent them from overheating and causing a fire or explosion. Because the distributor is mobile, take care to ensure that heating is performed in a level area that is well ventilated and that the distributor truck is not moving at all. Whenever you are heating cutbacks, the asphalt must be circulating at all times. This is a must to prevent any chance of volatile liquids overheating around the flues, which can be very dangerous.

The spray system consists of necessary piping, a series of hand-operated valves to control the flow of bitumen, and an adjustable length spray bar, capable of providing coverage from 4 to 14 feet wide. The spray bar may be the full-circulating or the non-circulating type, depending on the model of the distributor. The spray bar may be equipped with either 1/8-inch nozzles or 3/8-inch nozzles; the 1/8-inch nozzles are used for most applications. The application rate is controlled by the length of the spray bar, the pump output, and the forward speed of the distributor truck.

For normal use, adjust the spray bar of the distributor so the vertical axes of the nozzles are perpendicular to the roadway. Also, set each nozzle on the spray bar at the same angle. The angle set for each should be between 15 degrees to 30 degrees of the horizontal axis of the spray bar or according to manufacturer's specifications. This action prevents the fan-shaped spray patterns of the nozzles from interfering with each other.

Another adjustment essential for uniform prime or tack coat coverage is the adjustment of the height of the spray bar. The fan-shaped spray patterns from the nozzles overlap to different degrees, depending on the distance between the spray bar and the surface to be covered (*Figure 23-26*). The spray bar should be set high enough, usually 10 to 12 inches above the roadway, for the surface to receive triple coverage. This height varies according to the nozzle spacing of the spray bar. Under heavy wind conditions or depending on the nozzle spacing, it may be necessary to lower the bar farther down so that the surface only receives double coverage.

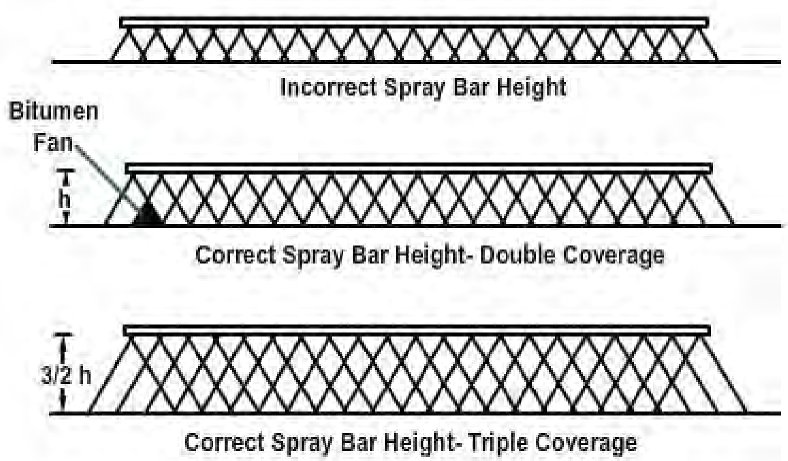


Figure 23-26 – Spray bar height and coverage.

On some distributors, as asphalt is sprayed (and the load lightens), the truck's rear springs rise, raising the distributor and changing the height of the spray bar. Mechanical devices that automatically correct the height of the spray bar as change occurs are usually available.

The uniform application of asphalt prime and tack coat is essential. Do not allow transverse spread to vary more than 15% or the longitudinal spread more than 10%. To ensure the correct application, calibrate the distributor before use. Then check the transverse and longitudinal spread rate variation periodically to determine when the distributor is operating within these limits. A procedure for checking these spread variations in the field has been standardized by ASTM d 2995, published by the American Society for Testing and Materials.

Always use a manhole strainer when filling tanks and distributors unless you are filling them with emulsions. When you do not want material to enter the pump and circulating system, ensure the intake valve lever is in the UP position. When the tank is full of hot bitumen it may start to set up upon entering a cold pump. To keep the bitumen from setting, heat the pump and circulating system before starting to circulate the bitumen. A portable burner is available to use if the pump is cold.

When you are filling lines using a pump, always use a strainer in the filling line except when using emulsions. Be sure that all connections between the distributor and source of supply are tight. Because air leaks reduce vacuum and slow down the heavier bitumens, it may be necessary to preheat the circulating system to ensure that the first material to enter the pump is not to be chilled sufficiently to stop the pump. A portable burner is available for this purpose. An opening in the circulating system housing at the rear, near the bottom of the housing, is provided for the burner.

Normally, 150 gallons per minute (GPM) is the best loading speed. Light materials or heavy materials at spraying temperature may be loaded at faster pump speeds. Check the filling line as well as the pump discharge strainer periodically and clean as needed. When the distributor is to be filled with hot bitumen, proceed cautiously if there is any moisture in the tank or if emulsion was used in the previous load because foaming could occur. A liquid compound, Dow Corning DC-200, can be used to prevent foaming.

When you are heating bitumen in a distributor with low-pressure atomizing burners, using clean, moisture-free fuel is important; therefore, use kerosene, fuel oil, or diesel fuel. **DO NOT USE GASOLINE.** To start the blower, disengage the engine clutch, engage the blower drive clutch, then engage the engine clutch. Air pressure should be sufficient to raise the air relief valve slightly. Excessive engine speed will raise the relief valve too much. The correct air pressure to use is 1 1/2 to 2 psi.

Fuel pressure should not be excessive. High fuel pressure will make the needle valve adjustments more sensitive. The correct fuel pressure is 10 to 20 psi. Pressure is determined by a relief valve located under the fuel tank. An adjusting screw and locknut are inside the dome-shaped cap.

Do not light the burners unless you are sure the flues are covered with six inches of material the full length of the tank. On tanks having high-low flues, it is necessary to cover only the lower flue when using the lower burner. Open the stack cover. To light the burners, turn the air butterfly valves to the START position, light the torch, and hold it under the burner tip. Then turn the valve about one-half turn. The burner should ignite immediately. If it does not, turn off the needle valve and wait until the gas is exhausted from the flues, then try again.

NOTE

The correct amount to turn the needle valve is determined by the fuel pressure. Experience is the only way to determine the correct amount for a particular unit.

At first, the flame will be yellow and smoky. Adjust the fuel valve so that the flame is bright orange with slight color in the exhaust. More adjustment to the fuel will be needed as the flues and tank contents heat up.

WARNING

If the burner goes out, turn off the fuel valve immediately and do NOT attempt to relight until the gas vapors are exhausted from the flues.

For larger flames, increase the air butterfly valve opening and the fuel valve opening in equal increments. Always keep a mix that produces an exhaust that has a slight color. The nozzle of the burner is adjustable for the amount of secondary air desired. Light the burner and turn this nozzle until you secure the type of flame you desire. Further adjustment is not necessary. Do NOT leave the burners unattended. Do NOT heat to a temperature over the maximum spraying temperature recommended by the supplier. To shut off the burners, turn the fuel off before stopping the blower or turning off the air.

Correct spraying cannot be obtained unless the bitumen is heated to the proper spraying temperature. When using 1/8-inch nozzles, set the governor from 120 to 180 GPM for a 12-foot spray bar. In the NCF, a rule of thumb for GPM is 10 gallons per minute for every foot of bar length. Example: 10-foot bar length = 100 GPM. Higher pump speeds cause excessive fogging of the spray. Lower pump speeds cause the bitumen spraying fan to sag with heavy edges. Also, when the fans have heavy edges, the cause could be that the material is too cold or the pump speed is too slow.

At the end of the day, be sure to flush out the pump and circulating system. Performing this easy draining and cleaning operation prevents the pump and circulating system from clogging up because of bitumen setting up and hardening in the system.

Some areas cannot be reached with the spray bar; therefore, it is sometimes necessary to apply asphalt by another means. In such cases, spraying can be done by hand with a spray hose and gun (*Figure 23*-27). This equipment must be operated following the instructions given in the manufacturer's manual.

Figure 23-27 – Hand-spray applications.

WARNING

Application temperatures may, in some cases, be above the flash points of some materials. Always take care to prevent fire or explosion. The maximum temperature (cutback asphalt) shall be below that at which fogging occurs.

7.3.0 Asphalt Haul Truck

Various types of trucks are used to deliver hot mix to the paver. The most common type is the five-ton end-dump truck, but other trucks have been used and can be used to deliver mix.

Trucks must have metal beds, and the beds must be clean, smooth, and free of holes. All trucks must meet minimum safety criteria. Each truck must be clearly numbered for easy identification and must be equipped with a tarpaulin.

Before being loaded, the truck bed must be cleaned of foreign material and hardened asphalt and then lightly coated with a release agent (lubricant) that assists in preventing fresh hot-mix asphalt from sticking to the surfaces of the bed. After the bed is coated, any excess release agent must be drained from the bed.

Before loading, the truck must also be weighed to establish its unloaded weight. This weight is later subtracted from the loaded weight of the truck to determine the weight of the hot mix that the truck is hauling.

The number of trucks required on the project is determined by many factors: the mix production rate at the plant, the length of the haul, the type of traffic encountered, and the expected time needed for unloading.

Each type of truck used for hot-mix delivery must have certain physical features that are required to haul properly and to discharge the mix properly into the paver. Below are listed a few guidelines for the two most common types of trucks.

7.3.1 End-Dump Truck

An end-dump truck must first be inspected to be certain the rear of the bed overhangs the rear wheels enough to discharge mix into the paver hopper. If it does not, add an apron with side plates to increase the overhang and prevent spillage of the mix in front of the paver.

The bed must also be of a size that will fit into the hopper without pressing down on the paver. Inspect the hydraulic system for the truck-bed hoist frequently to guard against hydraulic fluid leakage. Such leakage on the roadway surface will prevent good bonding between the roadway and the new mat. An unstable spot will occur in the pavement if too much hydraulic fluid is absorbed by the mix. For this reason, do not use leaking trucks.

Pull tarpaulins over the mixture during hauling in cool weather or on long hauls to protect the mixture from excessive cooling. A cool mix forms lumps and a crust over its surface. When using a tarpaulin, take care to be sure it is securely fastened to the top of the truck bed so that cold air cannot funnel under it.

During delivery, the driver must direct the truck squarely against the paver and should stop the truck a few inches from the paver before the truck tires make contact with the paver roller bar. Backing the truck against the paver can force the screed back into the mat, leaving a bump in the pavement even after the mat is rolled. The truck bed must be raised slowly. When the mix is dumped too rapidly, segregations occur, because the coarser aggregates will roll down the sides of the load.

7.3.2 Bottom-Dump Truck

Bottom-dump trucks can be used when a grader is spreading the mix or when a pickup device is used to feed the windrow left by the truck into the paver hopper.

Two common methods for unloading bottom-dump trucks are in use. The first involves the use of a spreader box, designed to be operated under the gates of the truck. The amount of material placed in the windrow is governed by the width of the spreader box opening. The disadvantage of this method is that the spreader box can restrict the amount of material to less than the required amount. The second method, which is used more often than the first, is to use chains to control the dump gate opening.

NOTE

Automatic devices are also available for controlling gate openings.

Variations in the size of the windrow deposited by the bottom-dump truck for pickup by the paver, and irregularities in the surface on which the material is to be placed will cause variations in the amount of material fed to the paver hopper. This often causes variations in the finished surface. It is, therefore, essential that the windrow deposited by the truck be as uniform as possible. When the windrow is deficient in size, add material to it to keep the paver from starving. When the windrow contains too much mix, a short gap in depositing with the next truck will compensate for the excess. Also, control the windrow length, particularly in cool weather.

Windrowed material will cool below spreading and compaction temperatures in cool weather, particularly when delay occurs because of paver malfunction. The limit of the windrow should be no more than one truck load ahead of the pickup machine to prevent excessive cooling of the mix in cold weather. When the loader and paver are directly coupled, vibration of the pickup device may be transmitted into the paver, causing ripples and roughness in the mat surface. These vibrations generally result from worn and defective parts or from improper mounting or adjustment.

The purpose of a truck hitch on the front of the paver hopper is to keep the truck dumping hot mix into the hopper in contact with the paver. If, during dumping, the truck and the paver separate and hot mix spills, it must be cleaned up before the paver passes over it.

Two types of truck hitches are in common use. One type uses an extension that reaches under the truck and hooks onto the rear axle of the truck. The other type of hitch has retractable rollers that are attached to the truck push bar and grip the outer side of the rear wheels of the truck. The rollers revolve with the wheels while the truck dumps its load into the hopper.

The pivoted push roller is a device mounted on the front of the paver that adjusts when alignment between the truck and paver is uneven. This device reduces the uneven force exerted on the paver by the misaligned truck, minimizing interference in the steering of both vehicles.

7.4.0 Asphalt Finisher (Paver)

Asphalt pavers consist of two basic sections: the tractor and the screed. The tractor receives the asphalt, delivers the asphalt to the screed, and tows the screed. The screed spreads the asphalt on the surface that is to be paved.

7.4.1 Truck Unit

The tractor (*Figure 23-28*) tows the screed by means of tow arms attached to both sides of the tractor and the screed. The point at which the tow arms connect to the tractor is called the "tow point." Electrically controlled hydraulic cylinders raise and lower the tow point. The position of the tow point affects the screed's angle of attack, which impacts the amount of material passing under the screed.

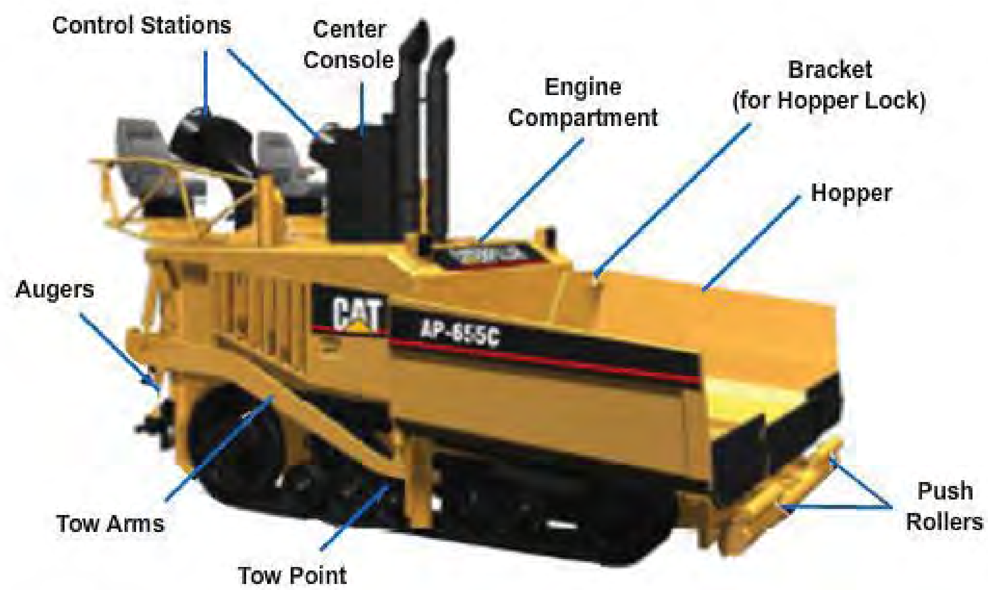


Figure 23-28 – The asphalt paver tractor.

The asphalt is delivered to the hopper at the front of the tractor. The hopper consists of two wings which can be raised and lowered simultaneously. Rubber flashing at the front of the hopper helps to prevent material from spilling out the front of the hopper.

A bracket is welded at the rear top of each hopper wing. A chain can be looped through these brackets when the hopper is closed in order to prevent the hopper wings from opening. Anytime work is to be performed under one of the hopper wings, or whenever the hopper wings are to be stored in the closed position, install a chain.

The front of the tractor is equipped with push rollers. The push rollers contact the rear wheels of a truck, thus allowing the tractor to push a truck during the paving operation. The operator's station is equipped with two operator's seats and control stations, as well as a center console. To provide increased visibility, the seats can be rotated outboard, beyond the side of the tractor. The control stations pivot with the seats. Each operator control station contains a steering wheel and machine controls. The center console is equipped with the Caterpillar Monitoring System panel and machine controls.

The engine compartment is located at the front of the operator's platform. Floor plates in the operator's platform and covers on each side of the machine allow access to the engine and tractor components. Two augers at the rear of the tractor distribute the asphalt to the outside edges of the screed.

The mobile track (*Figure 23-29*) consists of rotating components.

Figure 23-29 – The mobile track.

Each track group includes a two-piece front idler, five rollers which are mounted to bogie assemblies, and a two-piece drive wheel which is mounted to a gear reducer and motor. All of the rotating components have a bonded rubber coating which serves as the wear surface. A hydraulic cylinder and accumulator create friction between the drive wheels and the track, which drives the machine. The track is 406 mm (16 inches) wide with rubber grousers molded into the belt in a chevron pattern. The Mobil-trac system provides excellent flotation and traction.

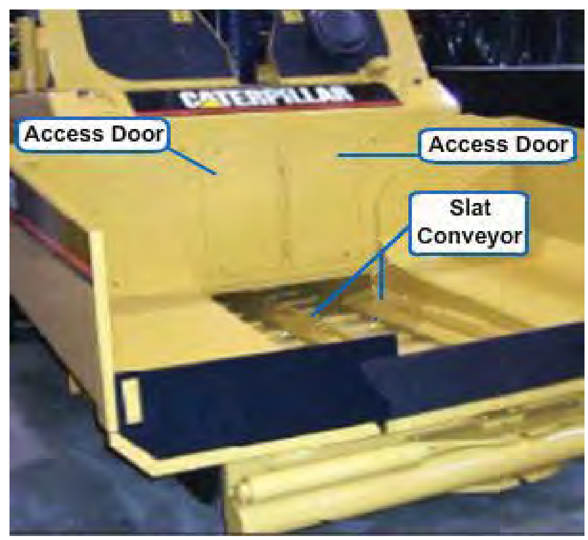


Figure 23-30 – The front of the engine.

Two slat conveyors are located in the floor of the hopper, in the front of the machine. The slat conveyors feed the asphalt through the material delivery tunnel to the augers, which are at the rear of the tractor. Access doors at the back of the hopper provide access to the front of the engine and the hydraulic pumps.

The right door in the hopper (*Figure 23-30*) provides access to the engine ECM, secondary fuel filter, and engine oil S•O•S tap.

The engine ECM controls the engine and transfers information to the machine ECM and Caterpillar Monitoring System through a CAN Bus connection and Cat Data Link lines. Most of the input and output devices for the engine ECM are located on the engine. However, the engine ECM receives input from and generates output signals to some devices which are not part of the engine.

The primary fuel filter, oil filters, and engine coolant S•O•S tap are located on the right side of the engine (*Figure 23-31*). The front door on the right side of the machine provides access to these components.

The base of the primary fuel filter contains the fuel priming pump (not shown). A water separator is installed on the bottom of the filter. Any time a fuel filter is changed or the machine runs out of fuel, the fuel priming pump must be used to remove air from the fuel lines. The inlet line to the filter contains a shutoff valve which can be used during maintenance activities.

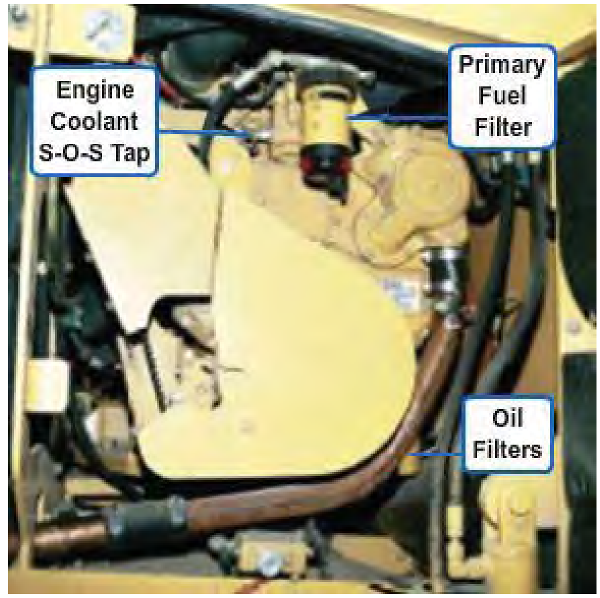


Figure 23-31 – The right side of the engine.

NOTE

Never fill new fuel filters with unfiltered fuel. Doing so can cause damage to the components in the fuel system.

The engine oil dipstick is located at the front of the engine (*Figure 23-32*). When necessary, oil can be added to the crankcase through the engine oil fill port, which is located on the top left side of the engine. The engine oil refill capacity is 12 liters (3.2 U.S. gallons). The cooling package is located behind the engine, on the right side of the machine. The cooling package contains the radiator, air-to-air aftercooler, and hydraulic oil cooler (not shown in the figure).

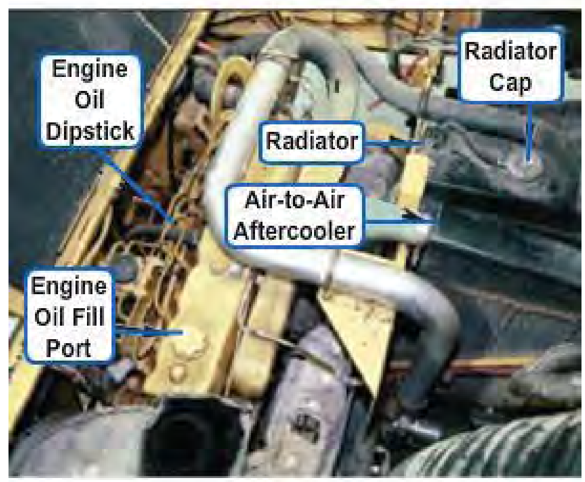


Figure 23-32 – The top of the engine.

The radiator cap must be removed in order to check the coolant level. The refill capacity of the cooling system is 30.3 liters (8.0 U.S. gallons).

WARNING

At operating temperature, the engine coolant is hot and under pressure, and the steam can cause personal injury.

Check the coolant level only after the engine has been stopped and the fill cap is cool enough to touch with a bare hand. Remove the fill cap slowly to relieve pressure. The cooling system conditioner contains alkali. Avoid contact with skin and eyes to prevent personal injury.

The air filter indicator is located on the right side of the air filter housing, on the left side of the engine compartment (*Figure 23-33*). The air filter must be serviced if the yellow piston in the air filter indicator moves into the red zone.

Figure 23-33 – Left side engine compartment and the operator's platform underside.

The hydraulic tank is located under the operator's platform on the left side of the machine (*Figure 23-33*). The left seat must be rotated in order to remove the cover and gain access to the top of the hydraulic tank. Return oil from the auxiliary manifold, screed extension manifold, and return manifold flows into the tank through the return filter. All other sources of return oil are connected directly to the hydraulic tank.

The return filter housing contains a filter indicator and a bypass valve. The filter indicator shows whether the filter is plugged. The filter is plugged if the filter indicator is in the red zone while the engine is running at high idle and the oil is at normal operating temperature. If the pressure differential across the filter is greater than 172 kPa (25 psi), the bypass valve opens, and return oil flows directly into the hydraulic tank.

The pumps of the different hydraulic systems draw oil from the tank through 150μ suction screens which are located inside the tank. The fill port is located to the front of the return filter. The capacity of the hydraulic tank is 151 liters (40 U.S. gallons).

NOTE

The left side of the hydraulic tank is equipped with a sight gauge.

The fuel tank is located under the center floor panel of the operator's platform. The tank contains a lockable cap (arrow) and a fill screen. The capacity of the fuel tank is 378 liters (100 U.S. gallons).

7.4.2 Screed Unit

In operation, the screed is pulled along behind the truck unit. The long screed pull-arms are pivoted, which permits the screed to have a floating action as it travels along the road. As the truck pulls the screed into the mix, the screed seeks the level that

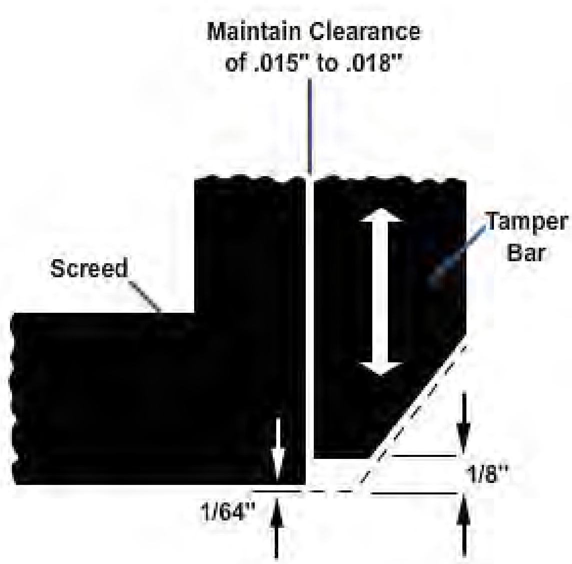


Figure 23-34 – Tamping bar.

allows the path of the screed to be parallel to the direction of pull. At this level, all of the forces acting on the screed are in balance as the paver moves down the road. The screed plate irons the surface of the mixture, leaving the mat thickness at a depth that conforms to job specification. Mat thickness and crown shape are regulated by screed controls. Tamping bars (*Figure 23-34*) or vibratory attachments then compact the mat slightly in preparation for rolling.

Attaining proper mat thickness is a matter of balancing the forces, (*Figure 23-35*) with one another:

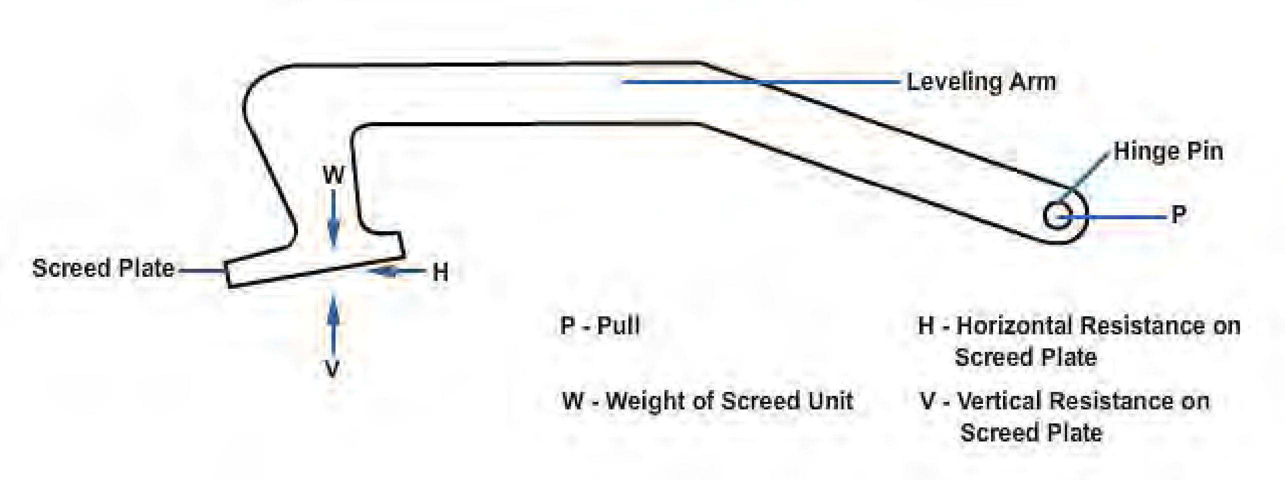


Figure 23-35 - Forces acting on the screed.

- To maintain forward motion of the screed, force P must be greater than force H.
- To increase the thickness of the mat, tilt the screed plate so that more material is crowded under the screed plate. The screed will rise until the finished surface is again in a plane parallel to the direction of pull. Force V will decrease at this point and be balanced by force W.
- To reduce mat thickness, tilt the screed plate so that less material crowds under the screed plate.
- The amount and condition of the material leaving the auger can change the equilibrium of the four forces. Excessive flow of material increases force H. A cold, stiff mix will increase H and to some extent V. An excessively hot, fluid mix decreases H and V. Stopping and starting the paver also cause changes in equilibrium among the forces. The key to controlling the action of the screed is to maintain in a uniform manner those forces acting on the screed.
- The secret of good paver operations is a balance of the forces and uniformity to maintain that balance. When balance and uniformity are attained, the screed path follows the paver in a plane parallel to that of the pivot point. As the paver goes up over an irregularity, the pivot point rises and the screed begins to rise also. However, because the screed reacts to changes in elevation more slowly than the pivot point does, the screed rises very little and thereby maintains the plane of the surface of the mat over the irregularity, and reduces the irregularity's impact. The same is not true of long irregularities (longer than several lengths of the paver). Correct grade line irregularities of this type before placing surface courses with the paver.
- Screeds equipped with tamping bars and vibratory mechanisms are designed to strike off and then compact the mixture slightly as it is placed. The two purposes

for this screed action are that it achieves maximum leveling of the mat surface and ensures that minimum distortion of the mat surface occurs with subsequent rolling.

Tamping bar types of screed compactors compact the mix, strike off the excess thickness, and tuck the material under the screed plate for leveling. The tamper bar has two faces:

- A beveled face on the front that compacts the material, as the screed is pulled forward
- A horizontal face that imparts some compaction, but primarily strikes off excess material, so the screed can ride smoothly over the mat being laid

The adjustment that limits the range of downward travel of the tamping bar is the single most important adjustment affecting the appearance of the finished mat. At the bottom of its stroke, the horizontal face should extend one sixty-fourth of an inch (about the thickness of a fingernail) below the level of the screed plate. When the bar extends down too far, mix builds upon the screed face. This buildup scuffs the surface of the mix being placed and also causes the tamping bar to lift the screed slightly on each downward stroke, and this often causes rippling of the mat surface.

When the horizontal face of the tamping bar is adjusted too high (either by poor adjustment or due to wear of the bottom of the horizontal face), the bar does not strike off excess mix from the mat. Consequently, the screed plate begins to strike off the material, which results in surface pitting of the mix being placed because the leading edge of the screed plate drags the larger aggregates forward. For this reason, always check the tamper bar before operating the paver, and adjust it if necessary. Replace the tamper bar before it approaches knife-edge thinness.

The operation of vibratory screeds is similar to that of tamping screeds, except that the compactive force is generated by electric vibrators, rotating shafts with eccentric weights, or hydraulic motors (*Figure 23-36*). On some pavers, both the frequency (number of vibrations per minute) and the amplitude (range of motion) of the vibrators can be adjusted. In others, the frequency remains constant and only the amplitude can be adjusted.

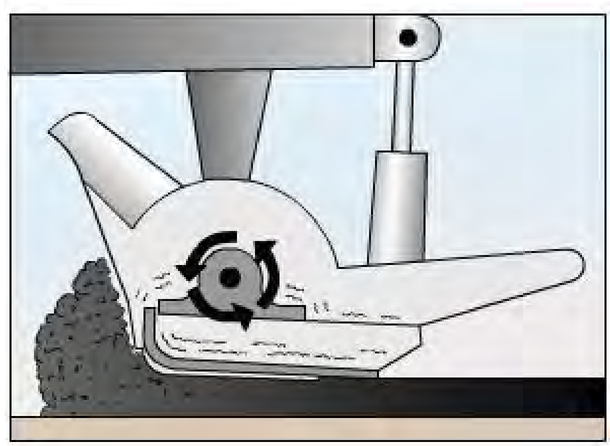


Figure 23-36 – Vibratory type of screed.

Frequency and amplitude must be set according to the type of paver, the thickness of the mat, the speed of the paver, and the characteristics of the mixture being placed. Once set, the frequency and amplitude do not normally need adjustment until the mat thickness or mix characteristics change.

Some vibratory screeds require a pre-strike-off unit. This unit is a rounded moldboard that controls the amount of mix passing under the screed.

In operating the screed, two types of controls are essential:

- Control of the thickness of the mat

- Control of the crown, formed in the mat for proper drainage

Both functions are regulated by controls built into the paver (*Figure 23-37*).

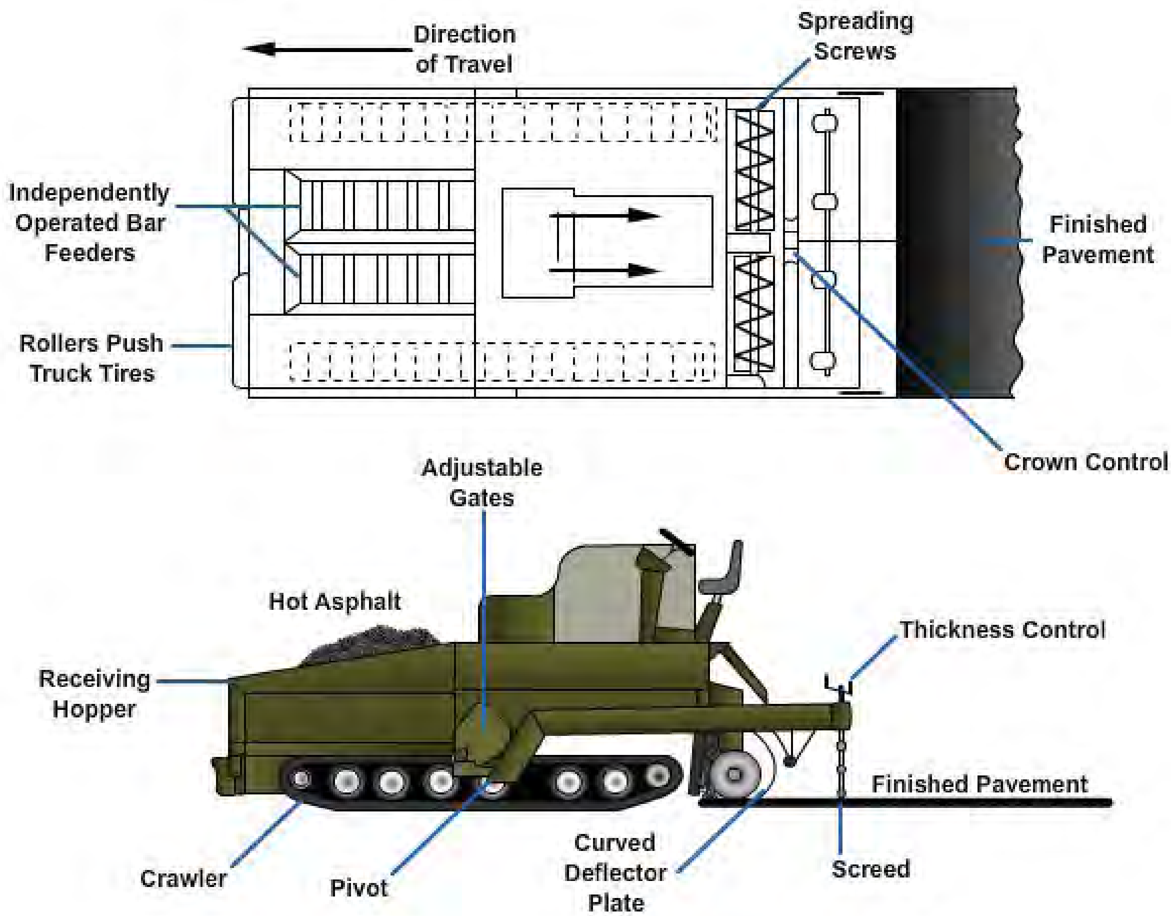


Figure 23-37 – Matt thickness and crown controls.

It is important to understand that when the paver is operating, control adjustments made to the screed take time to go into effect. For example, when a thickness control screw is adjusted to change the thickness of the mat, the paver is likely to move a distance of several feet before the change is completed and the mat is produced in the new thickness. For this reason, it is necessary for a screed operator know the effective delay involved in making adjustments to a particular screed unit and be able to anticipate adjustments accordingly. Furthermore, it is important that after such adjustment of the thickness controls, the paver be allowed to travel far enough for the correction to be completed before another adjustment is made. Excessive adjustment or over-control of the thickness controls is one of the principal contributors to poor pavement smoothness.

The condition of the screed unit is important for placing a high-quality mat. To ensure the screed control linkage is snug, the operator should check the wear points. Also, check the screed plates regularly for signs of wear, such as pitting and warping. Always properly adjust the plates before paving begins.

Both the leading and trailing edges of the screed have a crown adjustment. The leading edge should always have slightly more crown than the trailing edge. This provides a smooth flow of material under the screed. Too much lead crown results in an open texture along the edges of the mat, and too little results in an open texture in the center.

The trailing edge is what actually sets the crown. Crown adjustments may be made independently or simultaneously during the paving operation.

The screed operator must adjust the screed controls as paving progresses. Automatic screed controls are designed to adjust automatically to place a uniform mat of the desired thickness, grade, and shape (*Figure 23-38*).

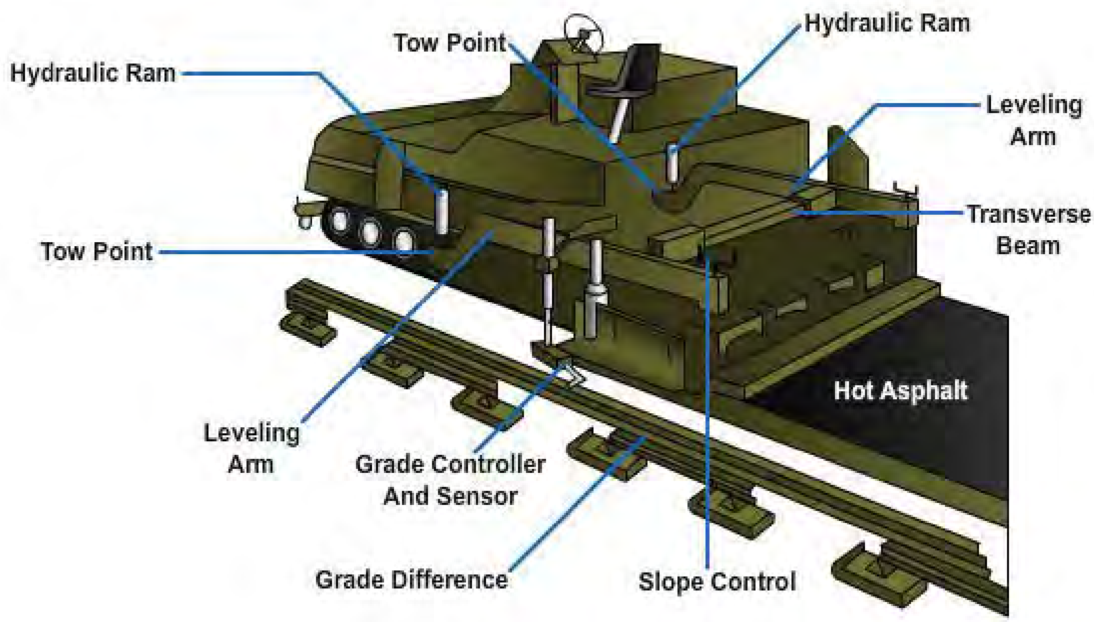


Figure 23-38 – Automatic screed reference system.

Automatic screed controls can be used in several different ways, but all automatic screed control operations require a reference system for the automatic system to follow. This reference system can be the base on which the asphalt hot mix is being placed, the lane next to the material being placed, or a string line.

When a string line is used as a reference, the automatic control will follow the height of the string line exactly, so the mat conforms to it; therefore, placement of the string line (or other reference system) must be precise.

Automatic screed controls can also follow traveling reference systems. A traveling reference system, such as a ski attached to a control arm, notes changes in base contours and adjusts the screed automatically to compensate.

A string line or traveling reference system allows the automatic control to adjust screed height as necessary to maintain proper longitudinal (lengthwise) grade of the pavement.

Automatic screed controls use a system, attached to a beam, running between the two screed pull-arms to maintain proper transverse (widthwise) grade. It works when a pendulum in the slope control housing moves side to side with changes in the transverse grade of the roadway, triggering necessary adjustments in the slope control mechanism.

Automatic control systems have several advantages over manually controlled screed systems. Some of the advantages are as follows:

- Automatic controls compensate for changes in grade and slope more quickly than a screed operator could.

- Automatic controls help disassociate the screed from the erratic vertical movement of the tractor unit.
- Automatic controls adjust the screed tow points to enable the screed to follow a path parallel to the grade and slope of the reference system, which may be different from the path plane of the tractor unit.

The screed is equipped with heaters used to heat the screed plate at the start of each new paving operation. The heaters are not used to heat the mix during the paving operation. If the screed is not initially heated, the mix will tear and the texture will look open and coarse, as it would if the mix were too cold. Do not use the heat from the mix to initially heat the screed. This practice almost always results in a section of unsatisfactory pavement being laid while the screed is being heated.

Three types of commonly used screed accessories are screed extensions, cutoff shoes, and bevel end plates.

Screed extensions (*Figure 23-39*) are attachments that widen the screed, allowing the paver to place a wider-than-normal mat. On some models, screed extensions make it possible to pave widths up to 24 feet in a single pass.

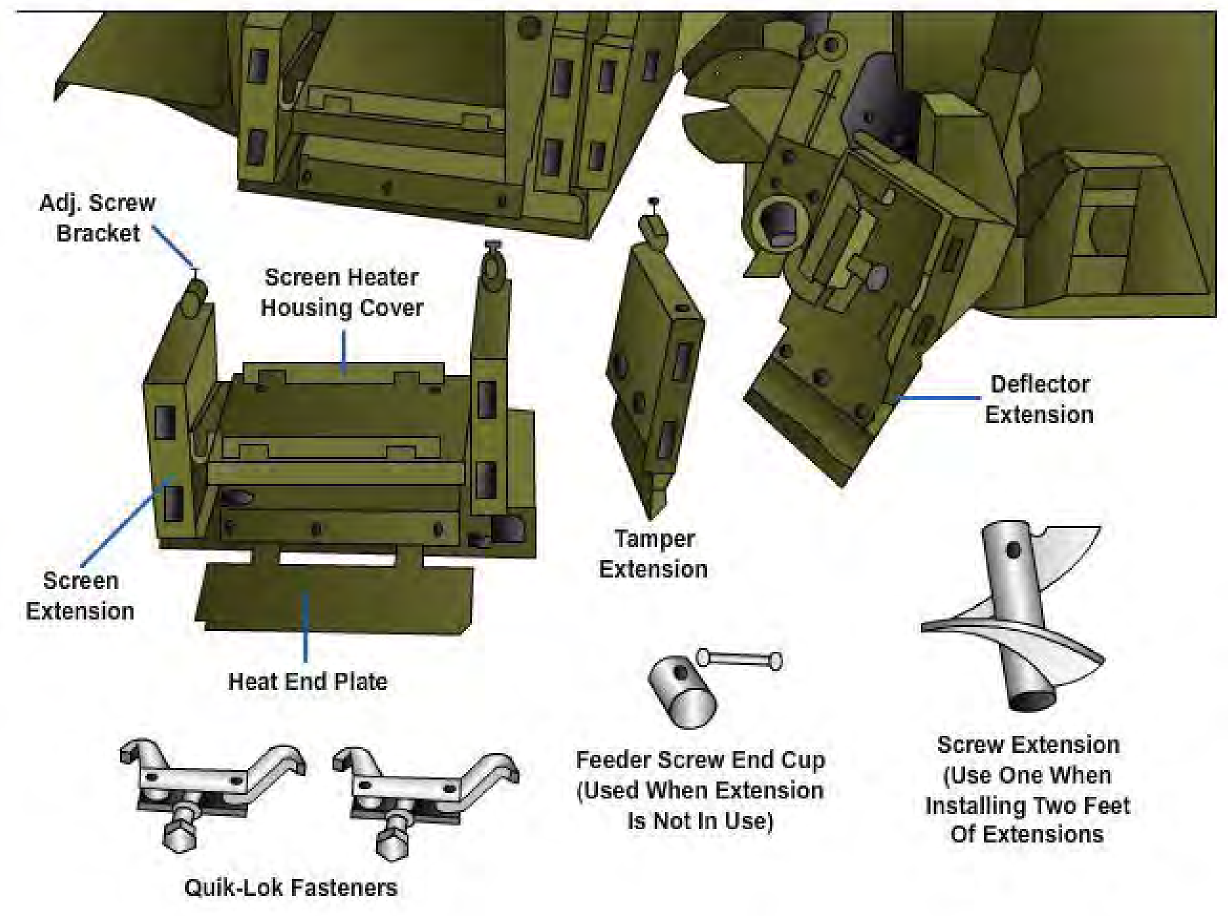


Figure 23-39 – Screed extension accessories.

Cutoff shoes (*Figure 23-40*) have the opposite function of screed extensions. They are metal plates inserted into the screed to reduce the width of the mat being placed.

Bevel end plates are used to bevel the edge of the mat. On some models, the shoes can be set at any one of three positions: vertical, 30 degrees, or 45 degrees.

The equation used to compute the amount of asphalt that can be laid with a paver per hour is as follows:

$$\text{Tons per hour} = \frac{L \times W \times D \times 146}{2{,}000} \times 60$$

Where:

L = Feet per minute. The NCF uses 11 feet per minute for planning purposes.

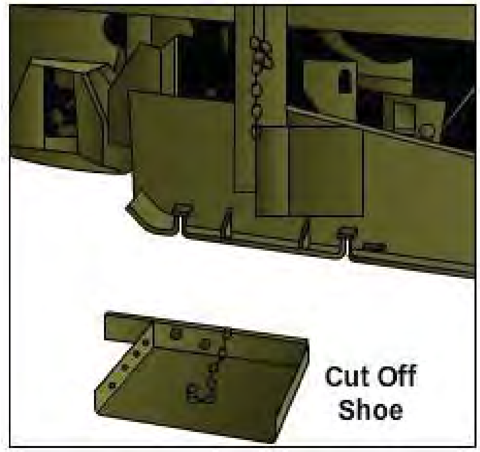
W = Width of the paver screed

D = Depth or thickness of compacted mat

146 = This number represents the approximate weight of one cubic foot of compacted hot-mix asphalt

60 = 60 minutes in one hour

2,000 = There are 2,000 pounds in one ton.



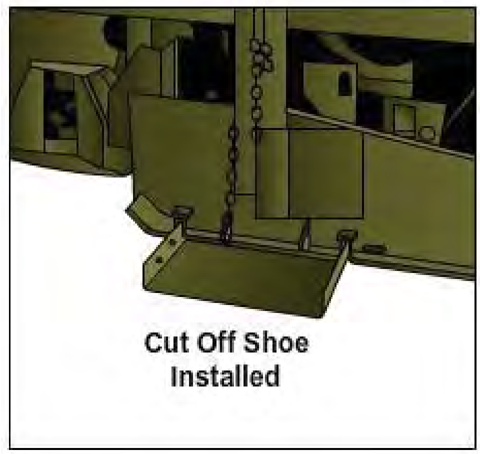


Figure 23-40 – Cutoff shoes.

Example: The required tonnage of hot-mix asphalt for a project is 800 tons. The screed of the paver is set at 10 feet, and the depth of asphalt is 2 inches. Estimate the amount of asphalt that can be laid per hour.

Solution:

$$\frac{11 \times 10 \times .167 \times 146 \times 60}{2{,}000} = \frac{160921.2}{2{,}000} = 80.46 \text{ tons per hour.}$$

By planning and estimating the amount of hot-mix asphalt that can be laid per hour, you are able to tell the asphalt plant exactly how much hot-mix asphalt is required to be delivered per hour or per day.

As an Equipment Operator, it is your responsibility to coordinate the proper operation, care, use, adjusting, cleaning, preservation, and lubrication of paving and support equipment. This includes daily inspections and adjustments required for good operation. Malfunctions in equipment, which go beyond those operating adjustments performed by the EO, should be referred to the field mechanic for corrective action. This does not release you from working with the field mechanic unless you are directed otherwise.

Test your Knowledge (Select the Correct Response)

13. Of the following disadvantages, which is associated with the use of a tailgate spreader?

    A. Truck must be operated in reverse.
    B. Steering control of the truck is reduced.
    C. Operational speed of the truck is reduced.
    D. All of the above

14. **(True or False)** Asphalt heating operations can be performed while the distributor truck is traveling to the jobsite.

    A. True
    B. False

8.0.0 SAFETY

Construction with bituminous materials involves several hazards. One of the most serious dangers is associated with the heating required to convert the solid or semisolid materials to a degree of fluidity which will permit their application or mixing. As a safety measure, make sure fire-extinguishing equipment (foam type) is present at all times.

When readying the distributor and/or asphalt kettle, be sure they are in a level position (before heating) and are located a safe distance from buildings and other flammable materials. Keep covers closed during the heating period to prevent the escape of flammable vapors; avoid exposure to fumes from hot bituminous material--stay on the windward side. Wear gloves and full body clothing to avoid prolonged skin contact or burns from hot bituminous material.

Most flash points are exceeded before the materials reach spraying or working temperature; therefore, exercise additional caution to prevent the exposure of rising fumes to an open flame. A dense yellow cloud or vapor rising from the distributor or kettle is an indication that the material is being overheated to the extent that a small spark is sufficient to ignite the vapors.

Always extinguish burners before spraying bituminous material. When spraying, stand at least 25 feet clear of the spray bar. On a bituminous distributor, spray bars have been known to blow open or rip with sudden pressure of heated materials. Remember that bituminous material must be heated to a high temperature, and any of this material coming in contact with the skin will leave a serious burn.

When handling asphalt that is being processed, you must wear proper protective apparel. Wear loose, heavy clothing that is in good condition. Clothing should be closed at the neck; sleeves should be rolled down over the tops of gloves. You should wear cuffless trousers that extend well down over the top of safety shoes. Wear goggles to prevent eye burns from bubbling or splashing asphalt. In addition, wear a safety hard hat.

Frequently, bituminous operations are planned for roads that must carry traffic while work is in progress. Slow or Caution signs or other warning devices should be conspicuously placed at both 100 yards and 20 yards from each entrance of the project. Flagmen, dressed in safety vests or some other safety attire, should aid in traffic control.

Most airfields must remain operational during bituminous operations. Discuss the construction schedule, equipment routing, and maximum height of equipment with the airfield safety officer. Establish liaison with air traffic control if trucks and other equipment are to cross runways that are in use.

Only qualified and authorized personnel should operate machinery and mechanized equipment. It must not be operated in a manner that will endanger personnel or property. Never exceed the safe operating speeds or loads. Equipment requiring an operator must not be permitted to run unattended. Mounting or dismounting equipment while it is in motion, or riding on equipment by unauthorized personnel, is prohibited. All equipment using fuel must be shut down with the ignition off before and during refueling operations.

When paving equipment is being operated, frequent inspections of running mechanisms and attachments are the operator's responsibility. The operator is also responsible for inspecting such items as the power train, power plant, transmission, tracks, controls, guards, loading or unloading warning devices, and receiving hoppers.

When paving materials are being applied, crew members often become so occupied with their particular job that they are unaware of equipment operating near them. For this reason, at least one crew member should be designated as safety inspector to ensure that reasonable precautions are observed within the assigned working areas. In addition, the safety inspector should periodically hold short (approximately 5 to 15 minutes) safety meetings (called stand-up safety meetings), during which the inspector briefs the crew on the hazards and precautions relating to current work.

All hand tools used for paving purposes must be kept in good repair and used only for the purpose for which they were designed. When you are using hand tools such as rakes, shovels, lutes, and hand tampers on asphalt paving jobs, heat them before use and clean them immediately after use. It is common practice to clean these hand tools by burning off the bitumen collected during paving operations. Crew members should exercise caution and be forewarned that flames are not always visible. One person should stand by with a fire extinguisher capable of controlling a petroleum fire.

In some areas, oiling roads and cleaning asphalt equipment could cause damage to the environment. This is especially important if there are streams or waterways nearby that could be contaminated.

Supervisors and crew members should be advised prior to the start of a job if there are any environmental considerations at the site. Dispose of contaminated rags and waste materials in an environmentally responsible manner. All personnel should be instructed to report immediately all personal injuries and all property damage regardless of how minor. Reports should be prepared according to the instructions set forth in base or command publications.

Test your Knowledge (Select the Correct Response)

15. When spraying, how many feet from the spray bar should you stand?

    A. 15
    B. 25
    C. 30
    D. 50

Summary

In this chapter you were presented with the knowledge critical to perform paving operations efficiently and effectively as well as information relating to the safe and considerate use of paving equipment.

Specifically, the basic concepts and structure of asphalt were covered, as well as how to prepare it and use it successfully with paving equipment. Asphalt pavement construction was reviewed for both plant-mix construction and mixed-in-place construction. Defects in flexible pavement were discussed, as well as options for resolving those defects at minimal cost and investment of time.

Review Questions (Select the Correct Response)

1. In addition to the asphalt content, what other factor determines the principal characteristics of asphalt-paving mixes?

   A. The total weight of both the asphalt content and aggregates
   B. The relative amount of aggregates
   C. The largest size aggregate used
   D. The type of roadbed the asphalt is used on

2. Asphalts are produced from refineries in many types and grades. The one known as asphalt cement is the basic material used in asphalt paving and is produced in which of the following conditions?

   A. Hard
   B. Brittle
   C. Semi-solid
   D. Water thin

3. Blue smoke rising from the spreader hopper is often an indication of which of the following asphalt conditions?

   A. The mix is overheated.
   B. The mix is too cold.
   C. The mix is too rich.
   D. The mix is too lean.

4. What functions does a prime coat of bituminous material serve?

   A. The prime coat penetrates the base course about two inches, fills most voids, and promotes adhesion between the base and previous bituminous applications.
   B. The prime coat penetrates the base course about 1/4 inch, fills most voids, and promotes adhesion between the base and bituminous.
   C. The prime coat waterproofs the wearing surface and controls dust and loose aggregates.
   D. The prime coat increases compaction and binds the aggregates and fines together.

5. A tack coat is an application of asphalt to an existing paved surface that provides a bond between which of the following surfaces?

   A. The subsurface and subgrade surface
   B. The finish surface and the subgrade surface
   C. The existing surface and the asphalt material to be placed on it
   D. The subsurface and the base surface course

6. When you are performing asphalt hand spreading operations, what problem can result if you throw the material a long distance or dump it from too great a height?

   A. The hot-mix will cool too fast.
   B. The hot-mix will splatter all over.
   C. The hot-mix will segregate.
   D. The hot-mix will fail to bind with the mix placed on the ground.

7. What is the most important phase of flexible pavement construction?

   A. Mixing
   B. Transporting
   C. Compacting
   D. Pouring

8. “Surface moisture” is defined as what?

   A. Depth of puddling water
   B. Film of water around each particle of stone or sand
   C. Estimated number of gallons of water a road surface can hold
   D. Amount of moisture that collects on a road surface during early morning hours

9. **(True or False)** The bituminous mix should be spread when the surface is damp or when the mix itself contains an excessive amount of moisture.

   A. True
   B. False

10. Which of the following types of surface cracks is caused by a lack of bond between the surface layer and the course beneath?

   A. Alligator
   B. Edge
   C. Reflection
   D. Slippage

11. What type of surface defect results from either compaction or a movement of the subgrade soil that weakens the subgrade?

   A. Cracking
   B. Distortion
   C. Disintegration
   D. Melting

12. What type of surface defect results from the localized upward displacement of the pavement caused by swelling of the subgrade?

A. Channeling
B. Corrugation
C. Depression
D. Upheaval

13. When performing pavement-cutting operations for patchwork, the cut should extend how many feet into the good pavement?

A. 1
B. 2
C. 3
D. 4

14. When placing a hot mix in a patch, overfill the area by approximately what percentage over the required pavement thickness?

A. 10
B. 20
C. 30
D. 40

15. When performing single-surface treatment operations, ensure aggregates cover the bituminous material within how many minutes after spraying?

A. 1
B. 10
C. 30
D. 60

16. To compute the amount of aggregate required for a single-surface treatment, use what rule of thumb for pounds per square yard?

A. 10 to 15
B. 15 to 25
C. 25 to 30
D. 30 to 35

17. When spraying bitumen with a distributor truck, the application rate is controlled by the length of the spray bar, the pump output, and what other factor?

A. Amount of material carried
B. Existing ground material
C. Forward speed of the distributor truck
D. Amount of turns on the main control valve

18. When operating a distributor truck, the spray bar should be set high enough for the road surface to receive triple coverage. However, under heavy wind conditions or depending on the nozzle spacing, it may be necessary to lower the spray bar more to ensure the surface receives which of the following coverages?

A. Single
B. Double
C. Triple
D. Half

19. When heating bitumen in a distributor truck, you should NOT use which of the following fuels?

A. Kerosene
B. Fuel oil
C. Diesel
D. Gasoline

20. Before the burners are lit on a distributor truck, the flues must be covered by a total of how many inches of material?

A. 3
B. 6
C. 9
D. 12

21. Which of the following factors should be considered when planning the number of trucks required for an asphalt plant?

A. Mix production rate of the plant
B. Length of the haul
C. Type of traffic encountered
D. All of the above

22. When positioning a dump truck to dump a hot-mix asphalt into a paver, ensure the truck is squarely against the paver and the truck tires are in what position in relation to the roller bar on the paver?

A. A few inches away
B. Squarely against the roller
C. At least one foot away
D. Bumped against the roller bar

23. What component of the asphalt paver irons the asphalt mixture surface, leaving the hot mat thickness at a depth that conforms to job specifications?

A. Screed
B. Tamper
C. Conveyor
D. Hopper

24. For paving operations, a paver screed should be heated at what time?

A. During the paving operation
B. Before the paving operation
C. Only sometimes during the paving operations
D. Only when asphalt materials are under the screed

Trade Terms Introduced in this Chapter

Aggregate	Inert mineral matter. Varies in size dependent on the application (heavy traffic, parking lot, etc.).
Asphalt	A dark brown to black cementious material in which the predominating constituents are bitumens that occur in nature or are obtained in petroleum processing. Asphalt is a constituent in varying proportions of most crude petroleum.
Bitumen	A class of black or dark-colored (solid, semisolid, or viscous) cementious substance, natural or manufactured.

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Chapter 24

Miscellaneous Equipment

Topics

To hear audio, click on the box.

Overview

The Naval Construction Force (NCF) uses mixing equipment, drilling equipment, compressed air equipment, and miscellaneous construction and maintenance equipment to support specific construction and maintenance operations.

This chapter covers the basic operating principles of such equipment. As an Equipment Operator (EO), you should become familiar with the operations and capabilities of the equipment and the ways it can be used to serve the purpose for which it was designed.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify types of mixing equipment and their operations.
2. Identify types of drilling equipment and their operations.
3. Identify types of compressed air equipment and their operations.
4. Identify types of miscellaneous construction and maintenance equipment and their operations.

Prerequisites

None

This course map shows all of the chapters in Equipment Operator Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Miscellaneous Equipment	↑	E
Paving Operations and Equipment		Q
Rigging Operations		U
Cranes		I
Rollers		P
Dozers		M
Scrapers		E
Graders		N
Ditchers		T
Excavators		
Backhoe Loaders		O
Front-End Loaders		P
Rough Terrain Forklifts		E
Truck Driving Safety		R
Truck-Tractors and Trailers		A
Tank Trucks		T
Dump Trucks		O
Medium Tactical Vehicle Replacements		R
Earthwork Operations		
Electrical and Hydraulic Systems		B
Chassis Systems		A
Power Train		S
Engine Systems		I
Transportation Operations		C

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 MIXING EQUIPMENT

For operations involving the production and delivery of concrete, the NCF uses equipment such as concrete transmit mixers and mobile concrete mixer plants.

1.1.0 Concrete Transmit Mixer

A concrete transit mix truck, sometimes called a TM, is a traveling concrete mixer (*Figure 24-1*). The truck carries a mixer and a water tank from which the operator can, at the proper time, introduce the required amount of water into the mix. The operator picks up the dry ingredients at the batch plant along with a chit that tells how much water to introduce into the mix. The mixer drum is kept revolving en route and at the jobsite so the dry ingredients do not segregate.

Figure 24-1 – Concrete transmit mixer.

When a TM is used for mixing concrete, 70 to 100 revolutions of the drum at the rate of rotation designated by the manufacturer as mixing speed are usually required to produce the specified uniformity. Do not use more than 100 revolutions at mixing speed. All revolutions after 100 should be at the rate of rotation designated by the manufacturer as agitating speed. Agitating speed is usually about 2 to 6 revolutions per minute, and mixing speed is generally about 6 to 18 revolutions per minute. Mixing for long periods of time at high speeds, about 1 or more hours, can result in concrete strength loss, temperature rise, excessive loss of entrained air, and accelerated slump loss.

Concrete mixed in a transit mixer should be delivered within 1 1/2 hours or before the drum has revolved 300 times after the introduction of water to cement and aggregates or the cement to the aggregates. Always operate mixers and agitators within the limits of the volume and speed of rotation designated by the manufacturer.

1.1.1 Discharge Chutes

The operator must have the proper chutes at the delivery site or on the truck before delivering concrete. Open-trough chutes should be of metal or metal-lined, preferably round-bottomed, and large enough to guard against overflow.

Determine the maximum or minimum slope by the condition of the concrete as discharged from the chute. Quality control personnel on the jobsite provide guidance in this area.

When possible, install a downpipe on the end of the chute to help keep the concrete from segregating when coming off the end of the chute.

1.1.2 Operation

Be sure to read the operator's manual for the type of concrete mixer you are operating. Give special attention to the following:

- Ensure the chain drip oiler is filled and turned on at the beginning of operation.
- Check the oil level in the hydrostatic drive unit at the sight glass.
- Check the water tank and meter valves of the on-board water system for operating condition, clean tank, and clear valves.

1.1.3 Cleaning

Give special care to cleaning the transit mixer. At the beginning of each workday, coat the mixer with form oil to prevent cement and concrete from sticking to the paint or bare metal. After discharging the load of concrete from the mixer, wash off all excess concrete in the mixer drum and blades, the discharge chute opening, and the discharge chute before it has a chance to harden. Spraying 15 to 25 gallons of water into the drum while it is rotating will clean the inside of the drum as well as remove all grout which may have collected in the water nozzle during discharge. A washdown hose is provided on the mixer to clean areas accessible from the outside.

⚠ CAUTION ⚠

Consult your supervisor about any environmental regulations that require collection or diversion of wash water from mixer equipment.

At the plant, flush a minimum of 150 to 250 gallons of water, depending on the size of the mixer, into the drum. With the flushed water in the drum, rotate the drum in the mixing direction for a few minutes, then discharge the flushed water at the maximum drum rpm. Complete the cleaning of the mixer, particularly around the discharge end.

Never pound the bottom of the drum to loosen materials, since doing so may cause dents and bumps in which concrete and cement can stick. During cold weather, always drain the water tank, pump, and lines to prevent possible damage from freezing.

Keep the mixing blades inside the drum clean and free of built-up concrete. If not cleaned properly, the blades in the drum will wear down, and this can result in improper mixing. If this occurs, either change the blades or build them up using hardfacing procedures.

If a loaded transit mixer requires a minor repair, take the TM to the shop for a quick fix. If the downtime is going to be more than an hour, mix in 5 pounds of sugar or concrete retarder to keep the concrete from setting up inside the truck.

NOTE

A small amount of sugar (5 pounds) acts as a retarder; however, a large amount will act as an accelerator.

If a quick fix is not possible, remove the concrete as quickly as possible. Either check for a hydraulic adapter, which can be hooked up to another TM to operate the drum to discharge the concrete, or remove the access hatch from the drum; roll the drum until the access hatch is facing down, and wash out the concrete mix, if possible.

1.1.4 Safety

Like most construction equipment, transit mixers, when not operated safely, can injure or kill personnel and damage property. As a TM operator, keep in mind the following guidelines:

- Transit mixers have a high center of gravity. Their stability is further decreased by the weight of the load. Use extreme caution when traveling over uneven terrain.
- Always use caution and a signalman when backing on a jobsite.
- Remember to secure the discharge chute properly with the chute locked to the right side of the truck for travel.
- Make sure the mixer is stopped before making adjustments.
- Observe environmental regulations concerning disposal of waste and wash water from mixers.
- Avoid prolonged skin contact with concrete or cement.

1.2.0 Mobile Concrete Mixer Plant

The mobile concrete mixer plant, sometimes called a crete mobile, is a combination material transporter and mobile concrete mixing plant. In the NCF, the unit is mounted on a trailer as shown in *Figure 24-2*. It carries unmixed material, such as cement, sand and coarse aggregates, waters, and any chemicals required for the special mix specification to the jobsite.

Figure 24-2 – Mobile concrete mixer plant.

1.2.1 Operation

Figure 24-3 shows the major components of a trailer-mounted crete mobile. Such a crete mobile carries the cement, sand, and coarse aggregates in divided bins mounted on the unit. It carries cement in a separate bin, located across the rear of the unit, and the sand and aggregate on each side of the unit. Water is carried in a single tank, mounted in front of the aggregate bins.

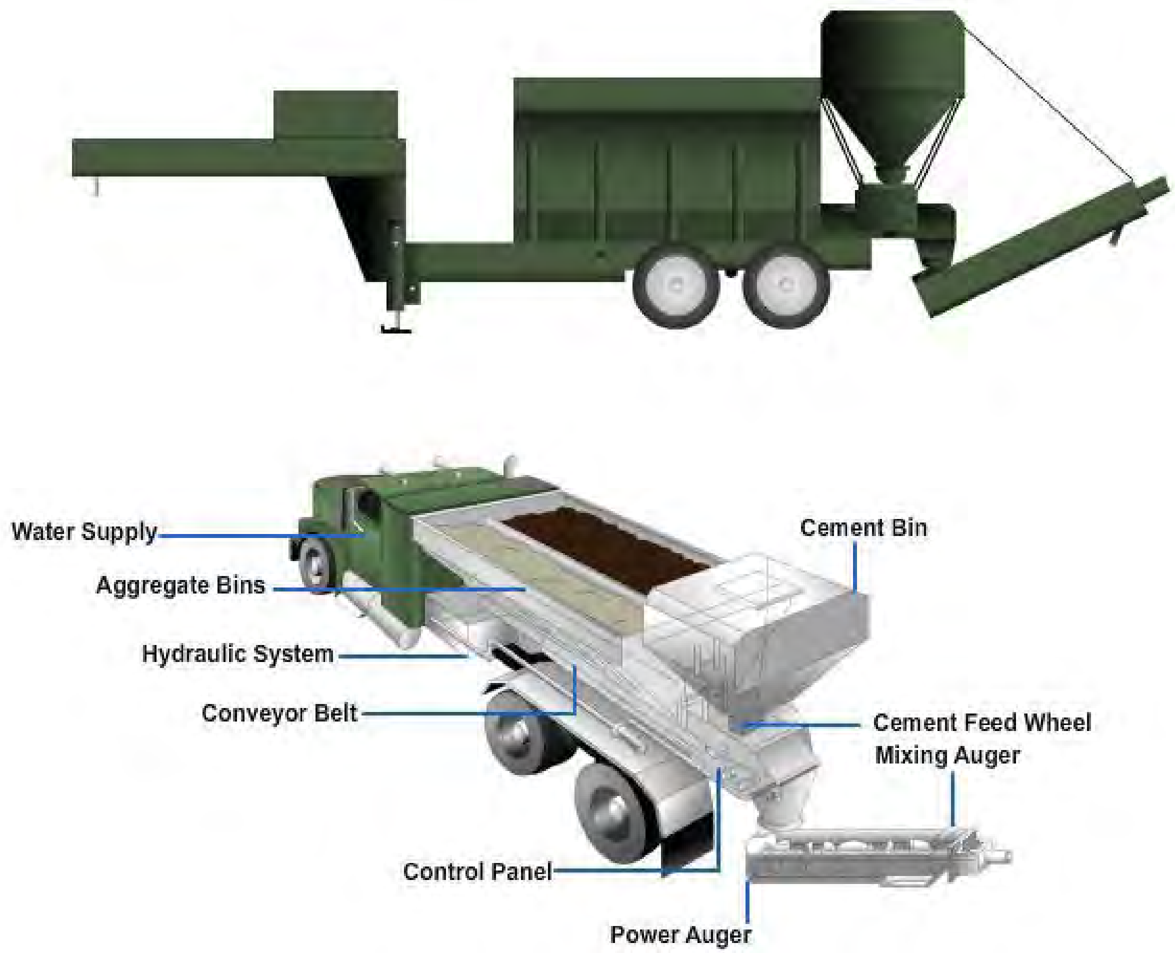

Figure 24-3 – Major components of a mobile concrete mixer plant.

When the operator engages the auger and conveyor controls, located at the rear of the unit, sand and aggregate are prepositioned and placed on a conveyor belt and moved from their respective bins under gates, which are pre-set for the desired mix designed, to the charging end of the unit. The materials pass under the cement bin where the cement feed, consisting of a positive rotary vane-type feed wheel, precisely meters the correct amount of cement onto the sand and aggregate. The conveyor carries the dry materials towards the rear where they drop off the conveyor belt into the continuous mixer. As the dry materials are dropped, water is added and all ingredients are thoroughly mixed by specially designed mixing paddles. Finally, the unit discharges the fresh concrete onto the delivery chute for placement.

Mixing action is a continuous process that can proceed until the aggregate bins are empty. On the other hand, the operator may stop mixing and delivery at any time and then start it again at will. This permits production to be balanced to the demands of the placing and finishing crews and other job requirements.

1.2.2 Cleaning

It is very important to keep the crete mobile clean and free from un-used materials at all times, A few extra minutes each day will ensure the proper operation of the equipment. Rapid auger wear and early bearing failure are directly related to inadequate clean-up.

After each load or delivery, perform the following:

- Clean top of the cement bin (be sure lid is fastened down tightly). If washing, do not wash toward the aggregate bins.
- Brush excess material off the back of the unit.
- Hose down the rear of the machine and the undercarriage of the vehicle.
- If the unit is to be out of service for more than 48 hours, use a scraper and water hose to remove aggregate and cement from the extension area of the conveyor system.
- When there is concrete build-up, it may be necessary to use an air-activated chipping hammer to remove the stubborn build-up. Use acid or other harsh chemicals only as a last resort. And if you use them, take caution to make sure the area is well ventilated and the operator is wearing rubber gloves and protective eye wear.
- If acid is applied, it is important to oil all chains and grease bearings in the area of application. Acid is corrosive and will cause continuing deterioration if not neutralized

Generally, the use of form oil or release agency is not recommended on the main structure. However, properly using it on the auger and turntable assembly greatly reduces clean-up time.

1.2.3 Safety

Operators assigned to the concrete mobile must read and understand the technical manual thoroughly before operating the plant. A few safety precautions when operating the crete mobile areas follow:

- Follow all preventive maintenance procedures.
- Do NOT allow any foreign matter in the cement bin.
- Do NOT allow particles larger than 1 1/2 inches in the aggregate bin.
- Do NOT allow the waterlines and flowmeters to freeze with water in them.
- Do NOT run the water pump dry.
- Do NOT continue to operate the machine if the hydraulic oil temperature exceeds 190°F.
- Wash out the auger within 20 minutes of the last use.
- Never attempt to repair the machine while it is in operation. (Always turn the power source off.)
- Keep your entire body clear from all moving parts.
- Never attempt to walk on top of the aggregate bin to cross from the cement bin to the water tank. (Use the ladder.)
- Never walk or stand under the auger.
- Never climb inside the aggregate bin. (Use a small pole to dislodge any aggregate that has bridged.)
- Never enter the cement bin while it is in operation. (There are moving parts inside the bin.)

Test your Knowledge (Select the Correct Response)

1. On a transit mixer, how many revolutions of the drum at the rate of rotation are usually required to produce a specified uniformity mix of concrete?

   A. 10 to 40
   B. 40 to 70
   C. 70 to 100
   D. 100 to 140

2. The crete mobile carries which of the following ingredients in divided bins mounted on the unit?

   A. Cement
   B. Sand
   C. Coarse aggregates
   D. All of the above

2.0.0 DRILLING EQUIPMENT

For earth drilling operations, the NCF uses equipment such as augers and the crawler-mounted rock drill.

2.1.0 Augers

An auger is rotary drill used for boring holes into the earth for the purpose of creating drainage holes and placing footings. Such a tool can be truck-mounted, as shown in *Figure 24-4*, skid-mounted, or hand-held.

Figure 24-4 – Truck-mounted auger.

Figure 24-5 shows the components of an auger. At the very end of the auger is a bit, also known a boring head, consisting of cutting edges and teeth sometimes referred to as fingers. The bit is the part of the auger that cuts rock or soil by rotary scraping. Most boring heads feature an advance center or pilot cutter that helps keep the drill hole alignment straight and makes the cutting easier for the larger auger head. The auger's helix or screw thread, called flights, carries cuttings away from the surface.

As shown in *Figure 24-6*, augers are available in two configurations: single-flight and continuous-flight.

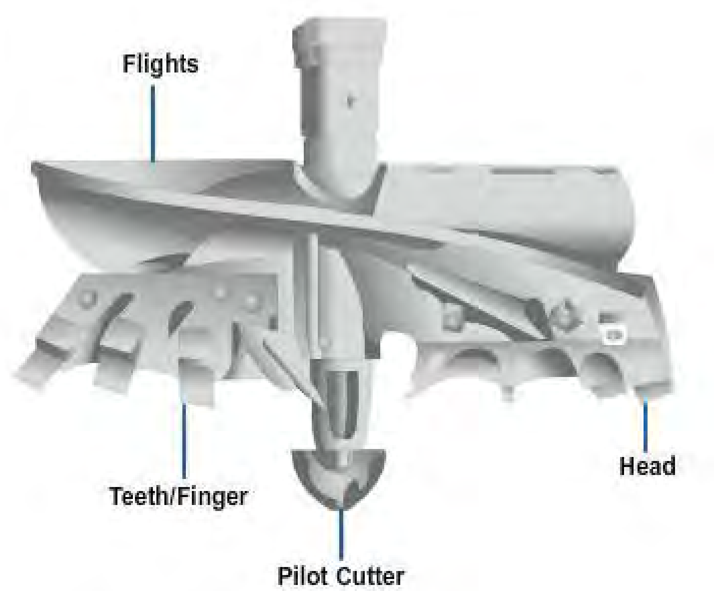

Figure 24-5 – Components of an auger.

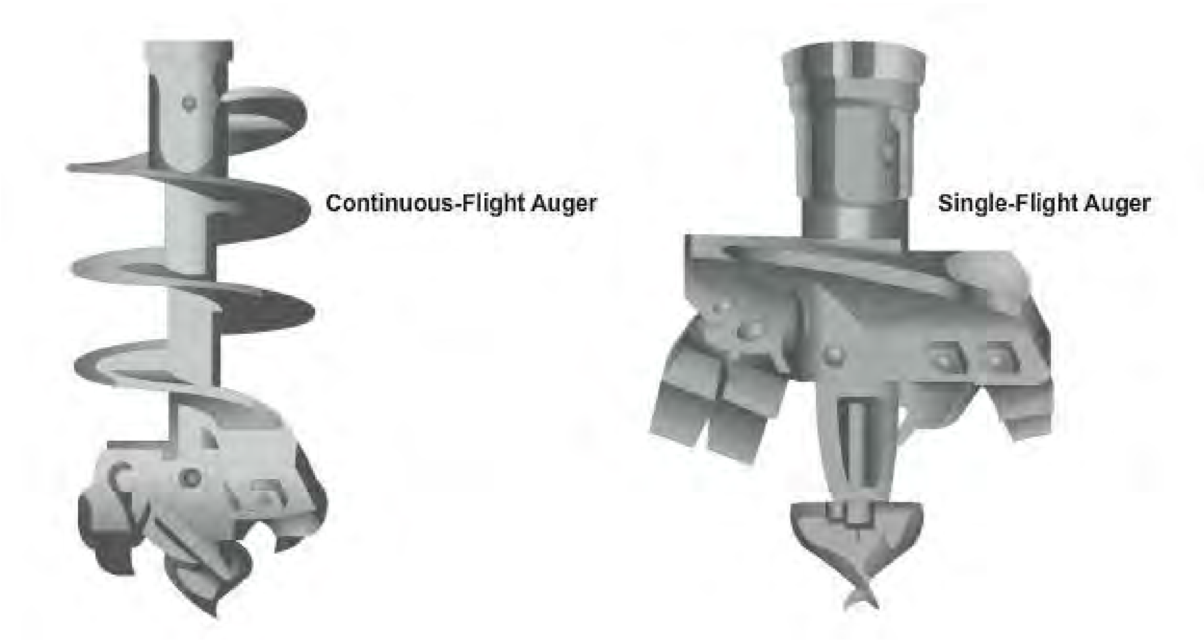

Figure 24-6 – Auger configurations.

The single-flight auger is used to penetrate most types of soil, including those containing large gravel and boulders.

The continuous-flight auger is used to penetrate hard rocks and soil. Because its flight is longer than that of the single-flight auger, operators spend less time raising and lowering the auger to remove soil.

Boring heads are available in various sizes for different job specifications. In addition, they can also be made of different materials to meet varying soil conditions. The head should be slightly larger than the auger flights, so it will not bind or stick in the hole.

The cutting edges and teeth are usually steel-hardened by various means, such as tungsten carbide. Worn or broken teeth may be built up by hard-facing. These teeth are generally detachable or reversible.

2.1.1 Operation

Drilling resistance or control of the rate of feed prevents the auger screw threads from penetrating in proportion to their turning speed. The bit cuts material, the threads grip it, and the screw conveyor action forces it out of the hole.

2.1.2 Safety

A few safety precautions when operating an auger are as follows:

- Obtain a digging permit before drilling or boring.
- Have all underground utilities and obstructions marked and identified.
- When traveling with the auger truck, make sure all attachments are secured properly.
- Always sound the horn and use a backing guide when backing the auger.
- Do NOT travel with an auger bit attached to the drill shank. This practice can result in destruction of the drill shank inner seals.
- Do NOT allow personnel to stand near the auger when boring holes.

- Do NOT allow personnel to stand near the auger when swinging or moving the auger boom.
- Do NOT exceed the capacity of the auger when pulling or setting poles.
- Do NOT try to remove any objects from the auger when the auger is running.
- When boring into material of unknown consistency, run the unit at low speed.
- Always protect personnel from open holes by placing caution tape and covers around and over the holes, and illuminate the area with lighting at night.

2.2.0 Crawler-Mounted Rock Drill

The crawler-mounted rock drill is a self-propelled unit designed primarily to drill vertical and angular blast holes in rock.

2.2.1 Major Components

Figure 24-7 shows the major components on a Terex SD345 Hydra-Trac® crawler-mounted rock drill; however, remember that major components as well as controls on crawler-mounted rock drills vary among the makes and model. You are responsible for reading the operator’s manual for specific information. In addition, you must gain the extensive knowledge and skills required to perform as an effective rock drill operator through either formal training or on-the-job experience.

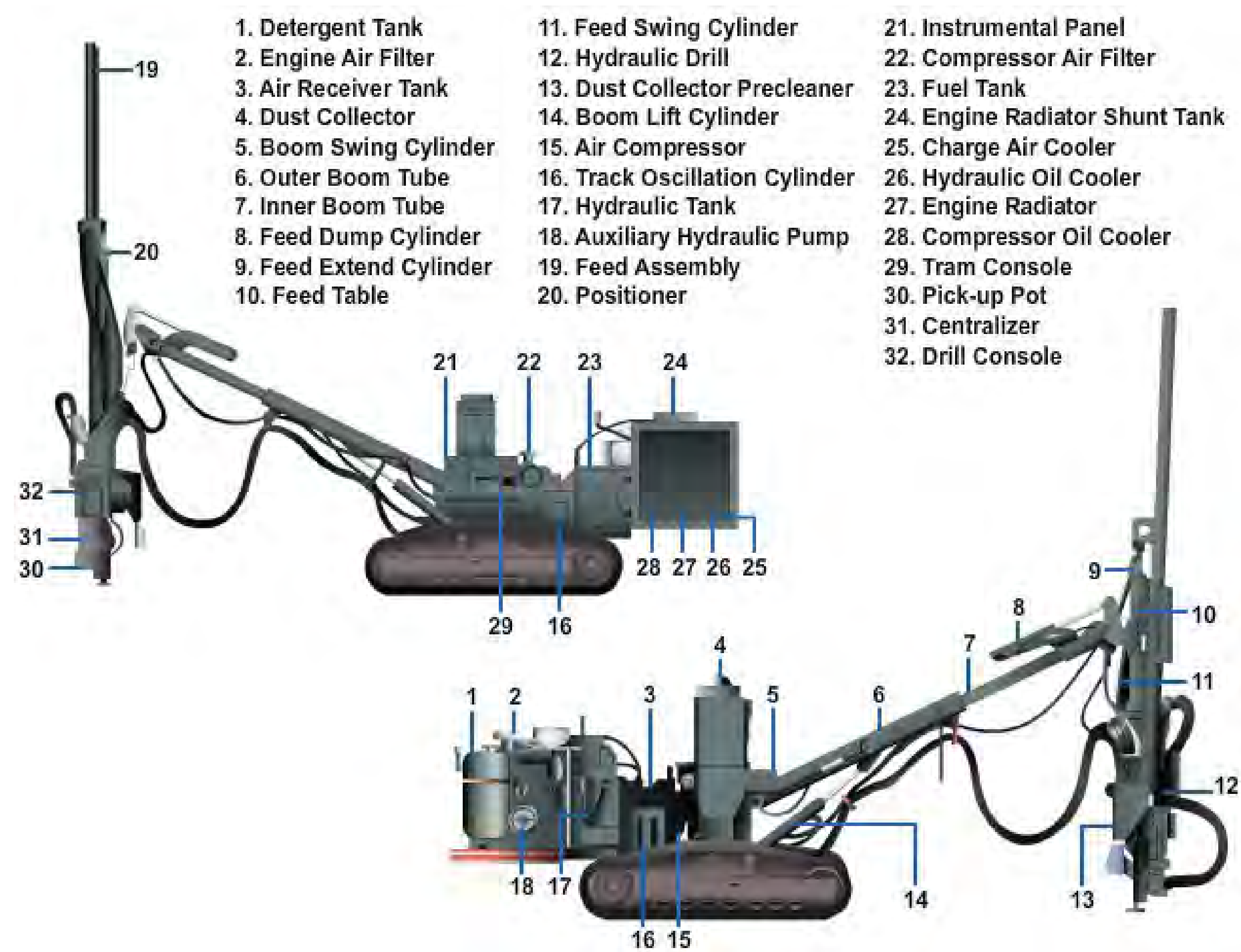

Figure 24-7 – Major components of a crawler-mounted rock drill.

Rock Drill – Sometimes called the hammer or drifter, the rock drill provides the percussive and rotating forces for drilling. The rock drill on the Terex SD345 Hydra-Trac® is capable of drilling holes from 2 ½ feet to 4 feet diameter.

Feed Assembly – The feed assembly is a structure that supports and positions the rock drill. Its assembly consists of the following components: a feed dump cylinder that tilts (dumps) the feed forward and back, a feed extended cylinder that moves the feed up and down, a feed swing cylinder that swings the feed left or right, and a feed table that is attached to a pivoting positioner at the end of the boom by means of a pin and hydraulic cylinder.

Boom Assembly – Commonly called the mast, the boom is a horizontal structure that supports and positions the feed. One end attaches to a pivot at the boom bulkhead at the front of the machine, and the other end attaches to the positioner. Its assembly consists of a boom left cylinder that raises and lowers the boom, a boom swing cylinder that swings the boom left or right, and an inner boom tube that extends and retracts the boom.

Tram Station – The tram station houses the tramming controls used to steer the machine's left and right tracks. In addition, it houses a track oscillation control used to raise and lower the rear of the machine when it operates on grades and over rough terrains. In addition, the tram station houses the positioning controls used to raise, lower, and swing the boom and feed.

Drill Console – The drill console houses the drilling controls such as a drill rotation control used to increase and decrease the speed of the drill and to control its rotating direction. It also houses a drill feed control used to increase and decrease the speed of the feed and to control its direction. On some crawler-mounted rock drills, the drill console also houses the positioning controls for the boom and feed.

Instrument Panel – The instrument panel houses all of the gauges and indicators monitored during drilling operations.

Detergent Tank – Some crawler-mounted rock drills have a detergent system consisting of a tank at the rear of the machine that holds water and detergent solution, which is sometimes, pressurizes and used in conjunction with a pump. While drilling is in process, the detergent system injects water into the hold to suppress dirt. Detergent solution is mixed with water to act as a lubricant for the drill bit.

Dust Collector – Some crawler-mounted rock drills have a dust collector that uses a vacuum for removing dust and cuttings from the hole during drilling operations. The dust collector operates in conjunction with a pickup pot at the end of the feed. Attached to the dust collector by means of a hose, the pickup pot is hydraulically raised or lowered over the hole.

2.2.2 Operation

Rock drilling operations involve collaring, drilling cycle, and encountering obstruction as well as adding and removing drill steel. The following section briefly describes these operations.

Collaring – Usually it is impossible to start drilling a new hole at full rotation and feed pressure. Doing so could cause the drill bit to jump around, enlarging the hole and possibly changing the position of the feed. Collaring allows accurate drilling by eliminating bit jumping. Initial drilling is performed at low rotation and feed pressure until the hole is deep enough so that the bit is guided by the hole.

After the hole is collared, a normal drilling cycle described in the technical manual can begin.

Encountering Obstruction – Some crawler-mounted rock drills have an anti-jam system. Such a system is capable of sensing a change in rotation pressure, such as when the bit breaks into a void or seam in a rock. When this occurs, the system will automatically retract and extend the drill until the bit is clear in the hole, where it will resume to normal drilling.

Adding and Removing Drill Steel – After drilling the first length of steel to depth, add a drill steel by following the instructions outlined in the technical manual. The drill steel is a specially made length of steel with threads on both ends. The threads allow coupling of two pieces of drill steel to both the drill shank and drill bit. Coupling takes place with in the centralizer jaws at the bottom end of the feed. The drill steel transfers energy from the drill to the bit and is also used to convey water for hole cleaning

After reaching the desired depth of the hole, remove the drill steel, following instructions outlined in the technical manual.

2.2.3 Safety

Personnel involved in rock drilling operations must adhere to the safety guidelines outlined in the machine's operator's manual. Additional safety precautions include:

- All personnel involved in rock drilling operations must wear safety equipment such as double-hearing protection, safety goggles, respiratory protection, hard hats, gloves, and safety boots.
- Remember to retract the foot piece of the drill guide from the drilling face before moving the drill rig. Failure to do so can cause extensive damage to the hydraulic components of the drill guide.
- Never use reverse rotation of the drill to break tight or stuck coupling joints.
- Do NOT allow personnel other than the operator to ride on the rock drill.
- Do NOT operate the drill with the coupling resting on the centralizer arms.
- Do NOT move the drifter rotation control lever from forward to reverse without first stopping the drill.
- When securing the drill, position the drill guide in a 90-degree vertical position.
- When the operator is operating the rock drill from the operator's seat, all personnel must stay clear of the drill control console.
- Visitors, unless suited properly with all safety gear, must stay clear of rock drilling operations at a distance of no less than 50 feet.
- Secure all drilling operations during thunderstorm conditions.
- Use gloves when handling drill steel, couplings, and bits. These components get extremely hot when used in rock drilling operations.

Test your Knowledge (Select the Correct Response)

3. In addition to keeping the drill hole alignment straight, the pilot cutter on an auger serves what other function?

   A. Protects the drill head from overheating
   B. Makes cutting easier with larger auger heads
   C. Acts as a safety link between the cutting edge and auger shank
   D. Makes it easier to change drill heads

4. The crawler-mounted rock drill is a self-propelled unit designed primarily to drill which of the following?

   A. Water wells
   B. Auger holes
   C. Vertical holes only
   D. Vertical and angular holes

3.0.0 COMPRESSED AIR EQUIPMENT

The following sections describe compressed air equipment commonly used by the NCF.

3.1.0 Air Compressors

An air compressor, like the one shown in *Figure 24-8*, is a machine that takes in air at atmospheric pressure and delivers it at a higher pressure for the purpose of operating air-powered tools, also known as pneumatic tools.

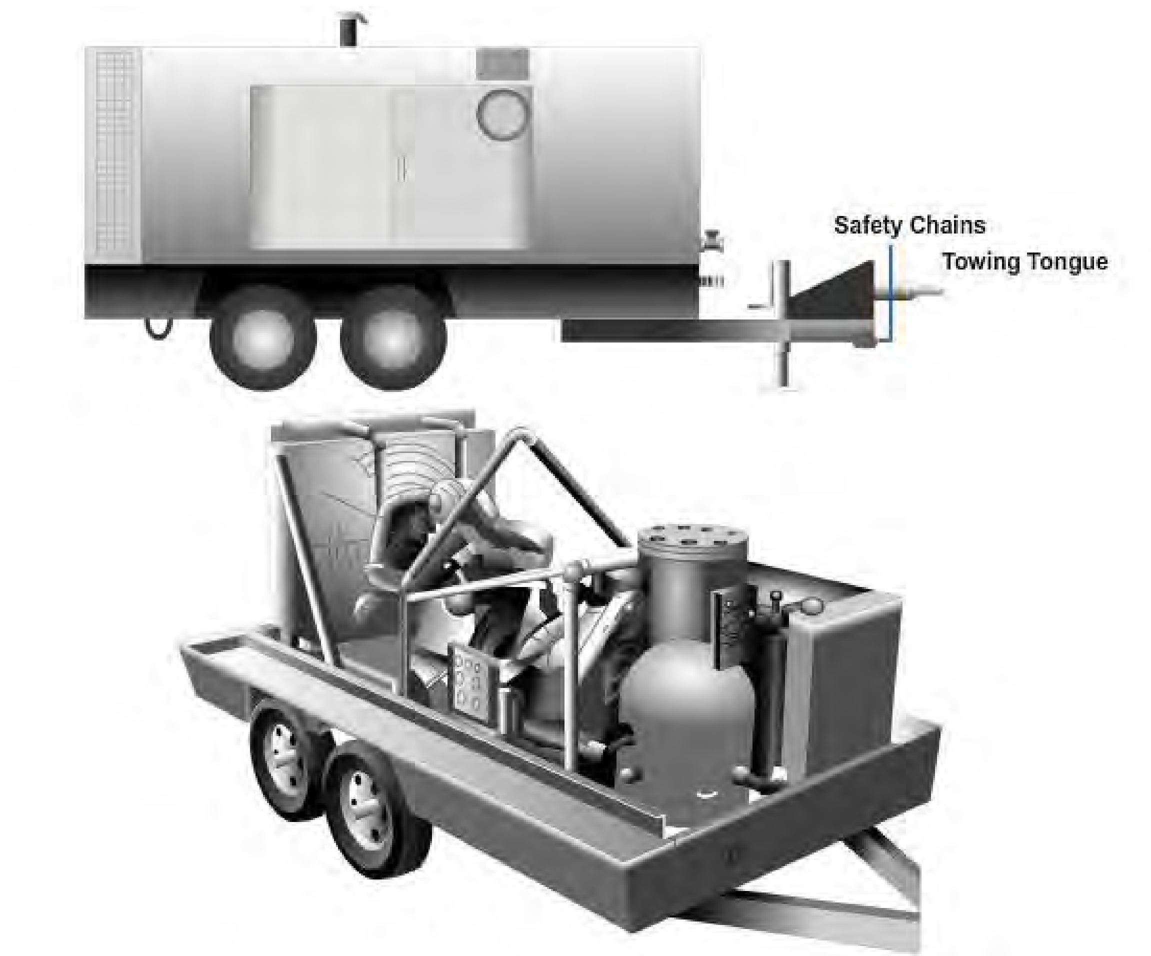

Figure 24-8 – Air compressor.

3.1.1 Components

An air compressor consists of a power source, which may be a diesel or gasoline engine, a pressure control system, a compressor unit, and accessory equipment.

3.1.2 Operation

Based on their construction and operating features, air compressors fall into one of two main classifications: positive displacement type and dynamic type.

- Positive displacement type air compressors mechanically displace a fixed volume of air into a reduced volume. Two examples of positive displacement type air compressors are the reciprocating and the rotary screw.
  - A reciprocating air compressor uses a piston inside a cylinder (compressor chamber) to compress air. Each stock of the piston compresses a fixed quantity of free air at a specific pressure.
  - A rotary screw air compressor uses a male and female screw inside a casing to compress air. Compression take place as these two parts rotate and the space between them is reduced.
- Dynamic type air compressors mechanically impart velocity to the air. This action is produced by impellers rotating at a high speed in enclosed casing. The air is forced into a progressively reduced volume.

- An example of a dynamic type air compressor is a centrifugal air compressor.

Air compressors are further classified as either single-stage or multi-stage.

- A single-stage air compressor has one compressing element that compresses the air from the initial intake pressure to the final discharge pressure in one step.
- A multi-stage air compressor has more than one compressing element. The first stage compresses the air to an intermediate pressure, then through one or more additional stages to final discharge pressure. The multi-stage system is more efficient than the single-stage system because the air cooling that occurs between stages reduces buildup of pressure due to a temperature rise.

3.1.3 Compressor Capacity

The capacity of an air compressor is the amount of free air (at sea level) that it can compress to a specified pressure, usually 100 psi per minute, under the conditions of 68°F and a relative humidity of 38 percent. This capacity is expressed in cubic feet per minute (cfm) and is usually included in the nomenclature of the compressor.

The number of pneumatic tools that can be operated at one time from an air compressor depends on the air requirements of each tool; for example, a 55-pound class rock drill requires 95 cfm of air at 80 psi. A 210-cfm compressor can supply air to operate two of the drills, because their combined requirements are 190 cfm.

However, if a third such drill is added to the compressor, the combined demand is 285 cfm, and this condition overloads the compressor and the tools, and results in serious wear.

NOTE

When the pressure and volume of air to a pneumatic tool drops 10 percent below the designed minimum, the tool efficiency is reduced 41 percent.

3.1.4 Compressor Location

Install the compressor unit so it is as close to level as possible. Compressor design permits a 15-degree lengthwise and a 15-degree sidewise limit on out-of-level operation. The engine, not the compressor, is the limiting factor. When the unit is to be operated out of level, you should be sure to do the following:

- Keep the engine crankcase oil level on the full mark with the unit level.
- Ensure the compressor oil gauge shows full with the unit level.

3.1.5 Safety

General safety precautions for air compressors are as follows:

- Be sure the intake air is cool and free from flammable gases or vapors.
- Do NOT permit flammable materials to touch the air discharge pipe.
- Never operate a compressor that has faulty gauges.
- Never kink a hose to stop the air flow, and keep the hose clamps on tight.
- Before starting an air compressor, check the safety valves, pressure valves, and regulators to see that they are working properly.
- Do NOT leave the compressor after starting it unless you are sure the control, unloading, and governing devices are working properly.

- Do NOT run an air compressor faster than the speed recommended by the manufacturer. Use only the grade and amount of oil recommended by the manufacturer. Use only high flash point oils to lubricate the air cylinders of air compressors.
- Keep compressors, tanks, and accompanying piping clean to guard against oil vapor explosion. Clean intake air filters regularly.
- Use only soapy water or a suitable nontoxic, nonflammable solution for cleaning compressor intake filters, cylinders, or air passages. Never use benzene, kerosene, or other light oils to clean these parts. These oils vaporize easily and form a mixture that is highly explosive under compression.
- Secure the engine before adjusting and repairing an air compressor.
- Before working on or removing any part of a compressor, make certain that the compressor is secured and cannot be started automatically or accidentally and that the air pressure in the compressor is relieved completely. Also, ensure that all valves between the compressor and receivers are closed.
- Be careful with compressed air. At close range, it can put out eyes, burst eardrums, and cause serious skin burns. Always wear impact goggles or safety glasses and dual-hearing protection when using compressed air. Never use compressed air to blow dust off clothing, skin, or hair.
- When transporting an air compressor or any other towed unit, ensure the pulling unit meets specifications. This includes drawbar horsepower and height of towing pintle (not too high or low because it can damage the towing tongue). Ensure all electrical hookups fit and are the right length.
- When parking, be sure to apply the parking brake and chock the wheels.
- Safety chains must be of proper size and length and secured properly.

3.2.0 Pneumatic Tools

Pneumatic tools such as a pavement breaker or hand-held rotary rock drill can be used with any type or size air compressor as long as the psi and cfm requirements for the tool are met. In the NCF, pneumatic tools are normally stored and checked out from the central tool room along with the air supply hose.

When checking out a pneumatic tool, determine if it needs an in-line oiler, which serves as a reservoir when placed in the air line directly in front of the air tool for the purpose of lubricating the tool. As the air passes through the oiler, it picks up the oil, which is carried into the tool. If the tool requires an in-line oiler (*Figure 24-9*), follow the manufacturer's recommendation for the correct lubrication.

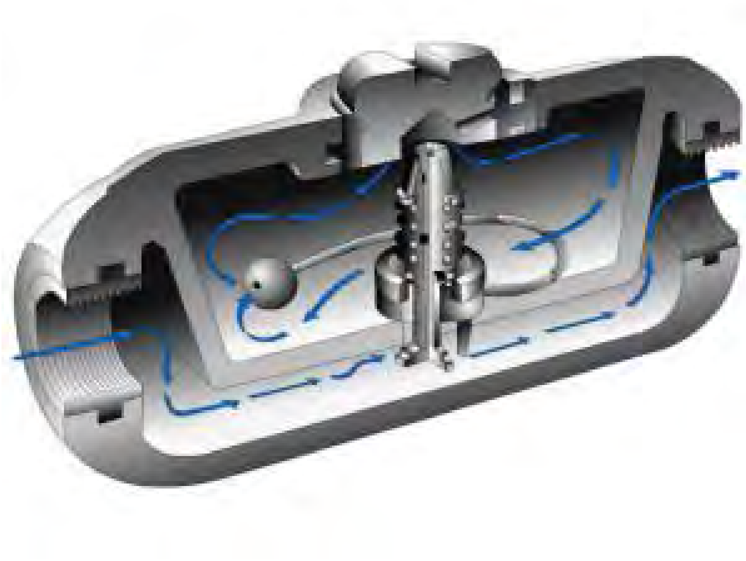

Figure 24-9 – In-line oiler.

3.2 1 Pavement Breaker

One specific type of jackhammer is the pavement breaker, shown in *Figure 24-10*. It is a hand-held percussive drill powered by compressed air. It uses jabbing action to break up concrete, rocks, or other materials.

Components – The pavement breaker has two handles on one end and a chisel-like attachment at the other end that operates in conjunction with a piston within a chamber. As the piston moves under pressure, the attachment rapidly jabs up and down to break up the hard material beneath it.

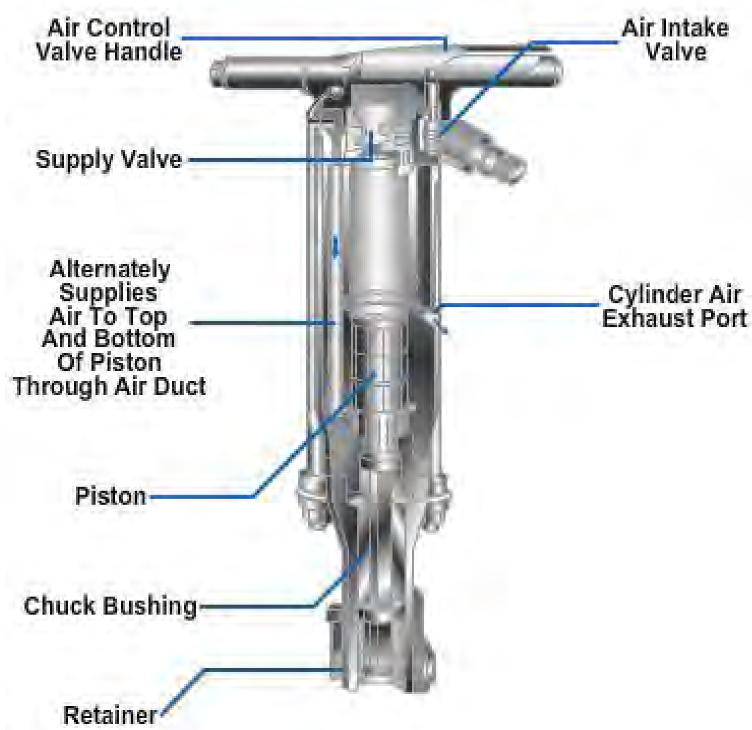

Figure 24-10 - Pavement breaker.

Attachments – Pavement breaker attachments (*Figure 24-11*) include the moil point, the chisel point, the asphalt cutter, and the clay spade.

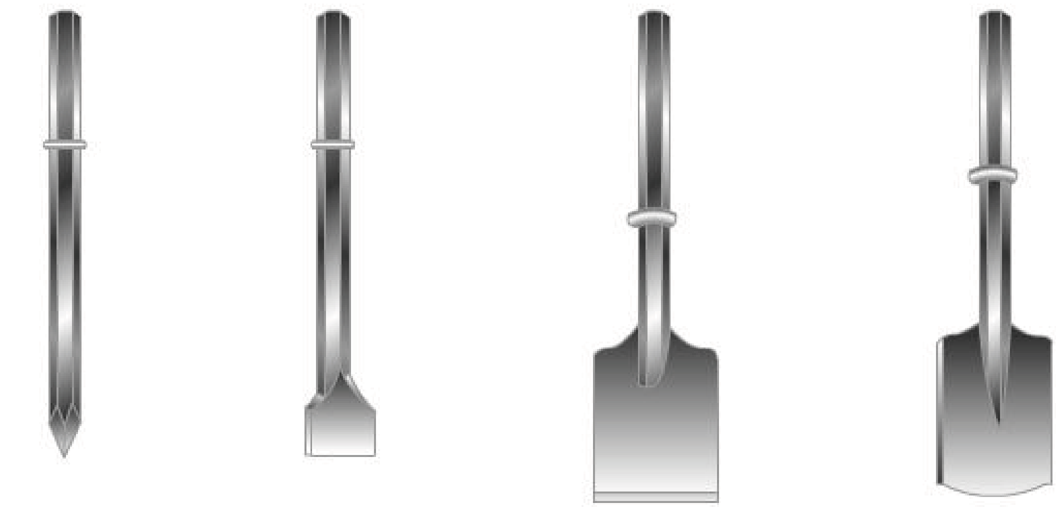

Figure 24-11 – Pavement breaker attachments.

- Moil Point – The moil point is commonly used to break up pavement, rock, asphalt, or concrete. The moil point is a solid bar of case-hardened steel, pointed at one end, with a shank and upset collar at the other. The advantage of the moil point is its sharp point, which allows it to first make a small hole that then slowly deepens and widens until the sides of the point are in full contact with the rock. The effect is like a wedge splitting an object.
- Chisel Point – The chisel point is constructed like the moil point except for its point. This point makes the chisel point the best pavement breaker for trimming corners and splitting seamed rock. Also, when you run into hardpan in trenching or at the bottom of a construction project, you can use the chisel point to slice off rock to reach the desired grade elevation.
- Asphalt Cutter – The primary use of the asphalt cutter is to trim or cut the edges of laid asphalt so major excavation will not harm the existing surface. One good example is asphalt patchwork.
- Clay Spade – The clay spade is used for loosening compacted clay or dressing foundation edges.

Operation – A pavement breaker is used only on horizontal surfaces because it utilizes both its weight and gravity to keep the drill in place and drive the bit into the workface; therefore, it would be impractical to use pavement breaker on walls and steep slopes.

During drilling operations, an operator must firmly hold the pavement breaker and guide it over the material to be broken up. It is not advisable to bear down on the tool. Doing so can cause injury as well as shorten the jabbing action of the tool, resulting in less work output.

Additionally, loud sounds come from both the compressor driving the tool and the bit jabbing into the workface. It is recommended that operators wear hearing protection to prevent hearing loss or damage. Vibration caused by the drill and the tight grip required to control the drill can cause poor circulation in the hands, arms, and wrist. Taking periodic breaks is recommended.

Safety – Safety rules for pneumatic tools are as follows:

- Keep your hands and fingers off the trigger or throttle until you are ready to start the tool.
- Always keep your balance.
- Never get your face close to the tool.
- Wear safety shoes, safety glasses or impact goggles, gloves, hearing protection, and a hard hat.
- Never rest an air tool on your toes.
- Do not allow horseplay.
- Never point an air hose at yourself or others.
- Always keep both hands on the handle of the tool while operating it.
- Always bleed the airline before removing it from the tool.

3.2.2 Hand-Held Rotary Rock Drill

Another type of jackhammer is the hand-held pneumatic rock drill. It uses rotating action similar to that of an auger to drill hard rock; however, it is equally efficient in soft and medium formations.

Components – The components of the hand-held rotary rock drill are shown in *Figure 24-12.* The drill consists of a back head group, cylinder unit, and front head group. The back head group consists of the four-position throttle, handle, and live air inlet. The cylinder unit consists of a cylinder with a reciprocating piston. The front head group consists of the chuck, retainer latch, and anvil. The drill design directs air through the drill, down the drill steel, and into the bottom of the hole to blow out rock cuttings.

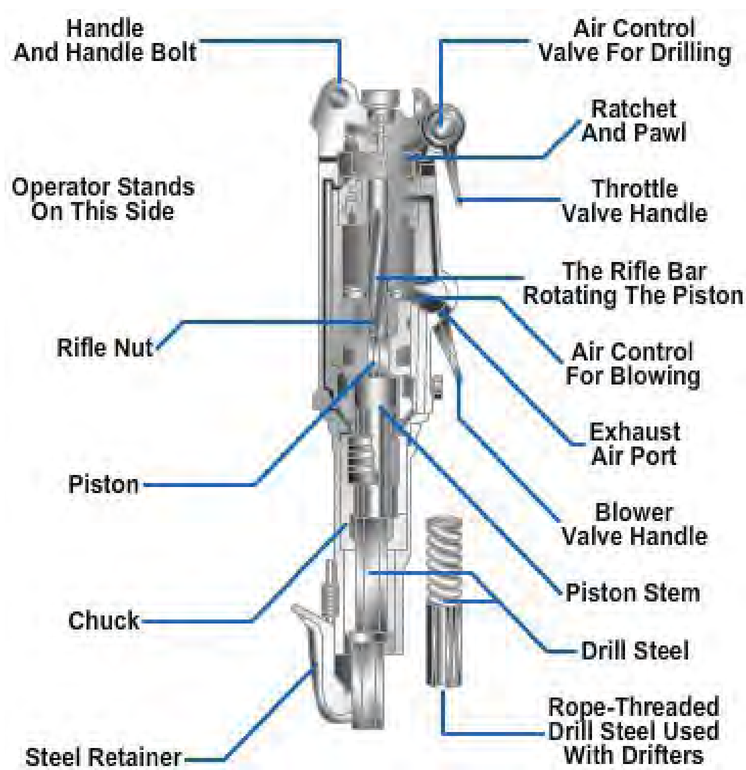

Figure 24-12 – Components of a hand-held rotary rock drill.

Four classes of rotary rock drills are as follows:

- The first class is a light drill weighing about 15 pounds. This class is used for drilling shallow holes in quarry operations.
- The second class is a light drill weighing 25 to 40 pounds. This class is used for light work, such as potholing and drilling concrete.
- The third class weighs from 40 to 50 pounds. This class is used for drilling in limestone and other soft rock.
- The fourth class is a hand-held drill weighing from 50 to 65 pounds. This class is used for drilling holes up to 6 feet during quarry operations.

NOTE

All of these drills use hollow drill steel and are built with automatic rotation.

Hand-held rotary rock drills used in quarry operations may be the dry drill, the blower drill, or the wet drill.

Dry Drill – The dry drill allows very little air to pass through the drill steel while drilling; therefore, drill 30 seconds and blow 60 seconds. When the hammer is not running, the dry drill allows enough air to pass through for cuttings to be blown out of the hole. Drill steels for this drill come in lengths of 2, 4, and 6 feet with tips made of carbon inserts, diamond, or star.

Blower Drill – The blower drill allows a steady supply of air to pass through the drill steel to help remove cuttings from the hole while the hammer is running. This type also permits air to pass through the drill steel when the hammer is not running.

Wet Drill – The wet drill provides a constant supply of water through the drill steel while the hammer is running.

Lubrication – Most rock drill failures and complaints result from bad lubrication. Correct lubrication of rock drills depends on the following:

- Selection of the proper lubricant
- Application of enough lubricant for all working parts

The lubricant must have the correct viscosity for a uniform rate of feed under many temperatures. Besides being just viscous (thick) enough, a good rock drill oil must have the following:

- Possess high-film strength and the ability to withstand shock loads
- Not “blow” readily, or interfere with valve action
- Not fog, or exhaust toxic gases
- Not corrode under any operating condition
- Lubricate perfectly at maximum drill speed, at both high and low temperatures
- Not form gummy leftovers in either hot or cold air

Use an in-line oiler with each drill. Drill manufacturers recommend installing the in-line oiler within 10 to 12 feet from the drill. If the oiler is too far from the drill, oil droplets tend to gather on the inside of the hose. This condition results in sporadic delivery of oil to the drill and can result in serious damage to the drill.

Safety – Before operating the drill, ensure the drill steel and bits are in good condition. Drill steel center holes should be clear and the shanks should be flat and square, not chipped or rounded off. Rock bits should be sharp. Dull rock bits are hard on the drill and the operator. To avoid injury to yourself and fellow workers, operate the drill as follows:

- Never pound on stuck steel. Nothing is achieved, and you may damage the drill and bit.
- Never retract the steel at full throttle. This may damage the front head parts.
- Never strike the drill with teds. This may dent the cylinder or cause other damage.
- Never drag a drill along the ground, because the exhaust ports and other openings may scoop up dirt that will cause trouble and possible failure.
- Blow out the air supply hose and flush out the water hose before connecting it to the drill to rid the line of dirt.
- Ensure the drill is well lubricated. Adjust the in-line oiler so the steel shank always shows a film of oil.
- Keep the drill aligned with the drill steel and hole.
- Hold the drill firmly and apply even pressure with both hands.
- Keep all hands off the trigger or throttle until ready to start drilling operations.
- When drilling, keep your balance and never get your face close to the drill.
- Wear safety shoes, safety glasses or impact goggles, gloves, hearing protection, and a hard hat.
- Never rest an air tool on the toes of your boots.
- Never point a drill at another person or start an air drill while it is lying on the ground.
- Do NOT use your body to control an active drill and never point an air hose at yourself or others.
- Always bleed the airline before removing it from the drill.

Test your Knowledge (Select the Correct Response)

5. **(True or False)** Dynamic air compressors mechanically displace a fixed volume of air into a reduced volume.

    A. True
    B. False

6. What serves as a reservoir when placed in the air line directly in front of a pneumatic tool for the purpose of lubricating the tool?

    A. Air-line oiler
    B. In-line oiler
    C. Lubricant line
    D. Reservoir line

4.0.0 Miscellaneous Construction and Maintenance Equipment

Floodlights, generators, lubricators, pumps, and sweepers are categorized as miscellaneous construction and maintenance equipment. Such equipment is listed under the registration series USN 50-00000.

4.1.0 Floodlight Unit

The floodlight unit (*Figure 24-13*), commonly known as a light plant, is intended for field use in all climates. Being self-contained, it is especially suited for use in remote locations as an emergency floodlight source.

Figure 24-13 – Floodlight unit.

4.1.1 Components

The light plant unit consists of an engine generator set, extension cords, a floodlight mounted on a tower, and a grounding rod. The floodlights, extension cords, floodlight mounts, and the grounding rod are all accountable collateral gear assigned to each unit; therefore, it is important to return these components and store them in their assigned light plant. All of the components are mounted on a two-wheel trailer, covered by weatherproof sheet metal housing. By using a winch, the light tower can be raised to distribute light over a large area. It can also be extended to a desired angle. Extension cords are supplied so that the floodlights can be used away from the unit. These extension cords have special plugs for use only with the floodlight.

⚠ CAUTION ⚠

Do not run power tools from a light plant. The power surge and power draw from these tools can overload the exciter and result in damage to the generator.

4.1.2 Operation

Before placing the light plant in operation, be sure to ground the unit using the grounding rod and grounding cable. Additionally, position the light plant suitably for adequate operating room and ventilation for dissipation of engine heat and exhaust. Remove the number of floodlights and cables required and place them in the desired locations. Plug the cables into the output receptacles.

CAUTION

Do not idle the engine with the generator excited. If the engine is idled with the generator excited, excessive field current may burn out the generator field winding.

4.1.3 Safety

Safety is a vital part of floodlight operation. Many floodlight safety practices are simple and obvious. Major safety precautions applicable to floodlight operation and care are as follows:

- Always pipe exhaust fumes outside when operating a floodlight unit in an enclosed area.
- Always ground the unit before it is placed into operation.
- Always stop the unit before servicing with fuel or lubricants.

CAUTION

Do NOT shut the engine down when the generator is under load. If you are not qualified to secure the generator, find someone who is.

- Do NOT allow extension cords to contact sharp objects, oil or grease, hot surfaces, or chemicals.
- Extension cords should not be allowed to kink or be left where they might be run over.
- Replace damaged cords. Do not patch them with tape.
- Store cords in their proper place, coiled loosely.
- Wear hearing protection when in the vicinity of a running generator.
- Do not attempt to install, hook up, or place any electrical apparatus when your hands are wet or when you are wearing wet clothing or shoes.
- Whenever it becomes necessary to check a circuit, have a Construction Electrician (CE) do this with appropriate testing equipment.

4.2.0 Generators

The generator is a combination of an engine and an electric generator that converts mechanical energy into electrical energy. Generators are commonly used on jobsites. They come in a variety of different sizes and configurations including portable, tow-behind, and skid-mounted, equipped with lifting and tie-down.

Figure 24-14 shows a tactical Quiet Generator – Bravo (TQG-B), commonly used by the NCF. It has an output of 30,000 kilowatts (kW).

Figure 24-14 – Tactical quiet generator – bravo (TQG-B).

4.2.2 Operation

The CEs normally make the selection of a generator based on the electrical demands, the voltage phase, and the frequency requirements. When selecting a site to set up a generator, keep in mind that the noise level of the generator may present a problem in low-noise level or quiet areas. For example, the operating 100-kW generator presents a noise hazard that exceeds the allowable limits for unprotected personnel in the immediate area; therefore, all personnel in the immediate area must wear single- or double-hearing protection.

Other factors to consider when selecting a site to set up a generator are as follows:

- Placing a generator near points of large demand reduces the size of the wire required, holds the line loss (voltage) to a minimum, and provides adequate voltage control at the remote ends of the line.
- Place the generator on a stable, preferably level, foundation. Do not operate it on an incline of more than 15 degrees from level.
- In an area where the ground is soft, stabilize the foundation with wood planking, sand bags, or other materials to provide a firm foundation for the generator. Although generators are designed to be operated outdoors, prolonged exposure to wind, rain, and other adverse conditions will shorten their lives. When generators are to remain on site for an extended period of time, mount them on solid-concrete foundations and install them under some type of shelter.

Grounding – Connect the generator set to a suitable ground before operation.

WARNING

Electrical faults in the generator set, load lines, or load equipment can cause injury or electrocution from contact with an ungrounded generator.

Various types of grounding systems are used, such as an underground metallic water piping system (*Figure 24-15, View A*), a driven-metal rod (*Figure 24-15, View B*), or a buried metal plate (*Figure 24-15, View C*). A ground rod must have a minimum diameter of 5/8 inch if solid and 3/4 inch if pipe. The ground rod must be driven to a minimum depth of 8 feet. A ground plate must have a minimum area of 2 square feet and, where practical, be embedded below the permanent moisture level.

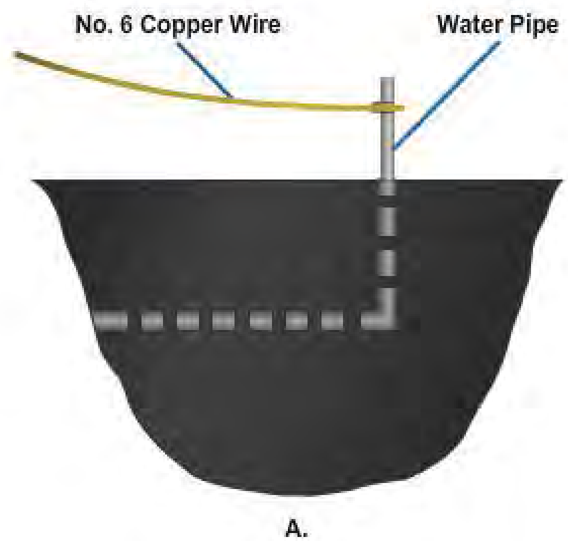

Figure 24-15 – Methods of grounding generators.

NOTE

The ground rod is accountable collateral gear for a generator.

The ground lead must be at least No. 6 AWG copper wire. Be sure to bolt or clamp the lead to the rod, plate, or piping system. Connect the other end of the ground lead to the generator set ground terminal stud (*Figure 24-16*).

Use the following procedure to install ground rods:

- Install the ground cable into the slot in the ground stud and tighten the nut against the cable.
- Connect a ground rod coupling to the rod and install the driving stud in the coupling (*Figure 24-16*). Make sure that the driving stud is bottomed on the ground rod.
- Drive the ground rod into the ground until the coupling is just above the ground surface.
- Connect additional rod sections, as required, by removing the driving stud from the coupling. Make sure the new ground rod section is bottomed on the ground rod section previously installed. Connect another coupling on the new section and again install the driving stud.
- After the rod(s) have been driven into the ground, remove the driving stud and the top coupling.

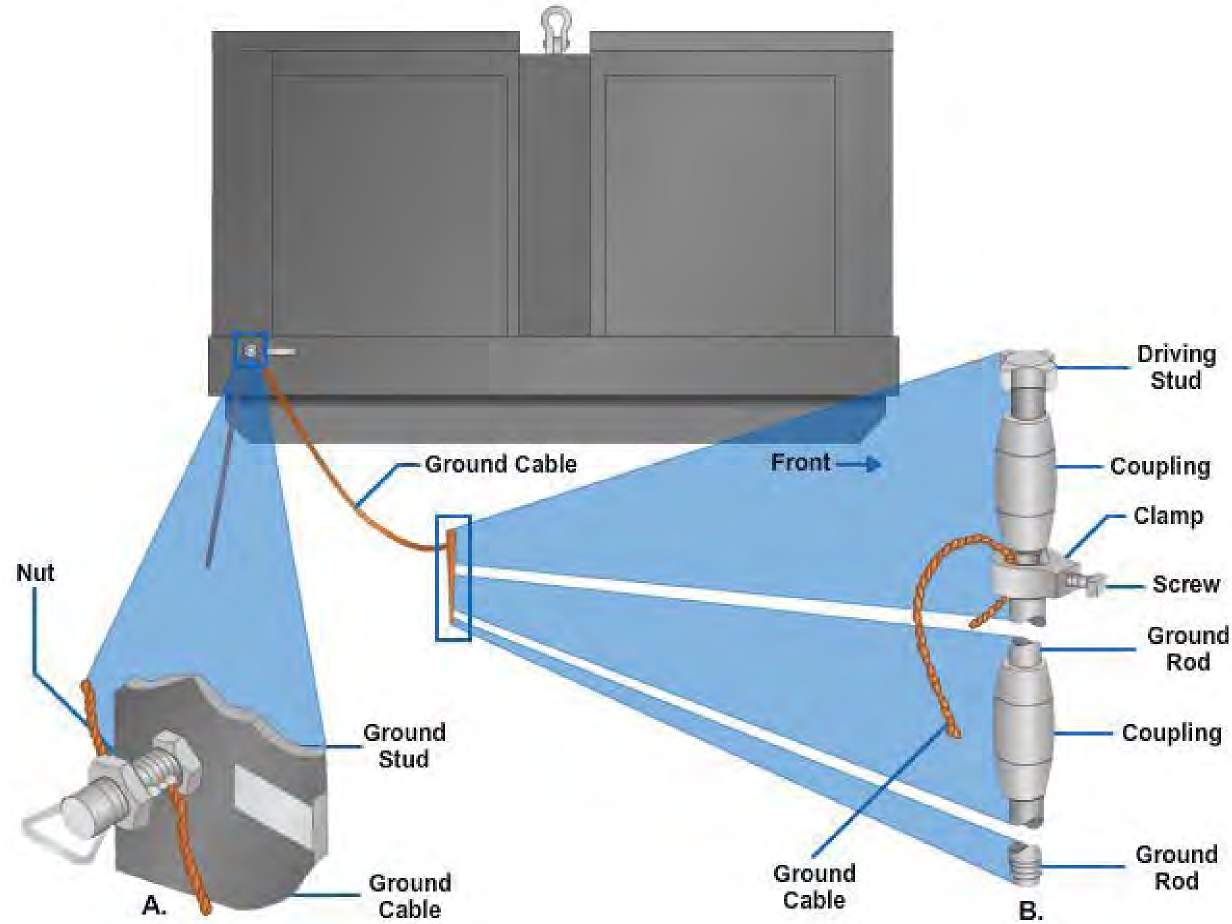

Figure 25-16 – Grounding procedures.

4.2.3 Cleaning

Cleaning the generator requires only cleaning of dirt, grime, and grease off the protective covering, the engine department, the batteries, and the skid base.

4.2.4 Safety

Any time a generator is placed into operation, a generator watch should be established. The primary purpose of the generator watch is to produce power in a safe, responsible manner, notice any maintenance or repair problems of the generator that require immediate attention, and ensure the generator does not run out of fuel.

4.3.0 Lubricators

The most common lubricators used in the NCF are truck-mounted, as shown in *Figure 24-17*.

When using automotive and construction equipment on a project site some distance from the maintenance shop, use the portable self-contained lubricator to save the time and expense involved in moving the equipment long distances for lubrication and service.

Figure 24-17 – Truck-mounted lubricator.

4.3.1 Uses

To grease fittings, pull out the length of hose you need, wipe the fitting clean, and push the coupler of the control valve onto the fitting. Squeeze the valve lever. When grease is forced out, release the lever and twist the coupler to one side to remove it. Do not try to pull it straight off. After servicing is complete, wipe the control valve coupler clean, rewind the hose, and put the control valve into its holder.

NOTE

When greasing, follow the manufacturer's lubrication chart to ensure all grease fittings are greased at the proper intervals.

NOTE

Be careful not to overgrease, as overgreasing can cause damage to seals and packings.

NOTE

Wipe up any excessive grease that can fall onto the deck of the equipment or onto components that do not require greasing.

In dispensing motor or gear oil, pull out the necessary length of hose, clean all dirt off the fill hole plug and surrounding area, and then remove the plug. Check to see that the meter is on zero, insert the control valve nozzle into the fill hole, and squeeze the valve lever. After the required quantity of motor or gear oil has been dispensed, release the lever. Reinstall the plug you removed earlier. Clean the control valve nozzle, reset the meter to zero, turn counterclockwise, and store the hose and valve.

For gauging and inflating tires, an air gauge with two sizes of air chucks is in the storage cabinet. The gauge has a pin fitting that snaps into the air hose coupler. When inflating tires, release the gauge lever to check the pressure of the tire; depress to inflate the tire.

4.3.2 Safety

- Always have a firm metal-to-metal contact when filling the fuel tank.
- Never stand directly in front of a tire when it is being inflated. Stand to one side.
- Always pipe the exhaust fumes to the outside when operating the lubricator in an enclosed area.
- Never fill the fuel tank while the engine is running. Never direct a jet of compressed air at yourself or anyone else.
- Always stop all operations of a unit before servicing it.
- Always use Navy-approved solvents for cleaning.
- Always relieve all pressures before servicing any component of the lubricator.
- Always check the engine and the compressor crankcase oil level at the start of each workday.
- Always review the Material Safety Data Sheet (MSDS) for every hazardous material, fuel, lubricant, and solvent before use for precautions and hazards.
- Always dispose of greases, oils, and contaminated materials in an environmentally responsible manner.

4.4.0 Pumps

A pump uses the mechanical energy produced by its prime mover to move liquid from one point to another. The pump moves the liquid by pushing, pulling, or throwing. Pumps are often named or classified by the section that causes fluid movement, either diaphragm or centrifugal.

Regardless of its design or classification, each pump has a power end and a liquid end. The power end is some form of prime mover, such as an electric motor, internal combustion engine, or steam turbine. In steam-driven pumps, the power end is often referred to as the steam end. The basic purpose of the power end is to develop the mechanical motion or force required by the liquid end.

In the liquid end, mechanical motion, developed by the prime mover, is exerted over the liquid. This part of the pump must allow for suction and discharge. The liquid end is often referred to as the pump end, the water end, or the oil end to show the nature of the substance pumped.

4.4.1 Diaphragm Pump

The diaphragm pump shown in *Figure 24-18* uses a flexible diaphragm to move liquid. The prime mover is usually a small gasoline engine with an eccentric connecting rod arrangement that converts rotary motion to reciprocating motion. On the suction stroke, the diaphragm is drawn upward into a concave configuration. This movement of the diaphragm results in a partial vacuum that causes the suction ball valve to unseat and to admit liquid to the pump cylinder. On the discharge stroke, the diaphragm is pushed downward forcing the trapped liquid out through the discharge valve. Thus the liquid is made to move by the reciprocating motion of a flexible diaphragm.

Figure 24-18 – Diaphragm pump.

Since the diaphragm forms a tight seal in the pump cylinder between the liquid being pumped and the rest of the pump and driving mechanisms, there is little danger of liquid abrasion or corrosion of moving parts behind the diaphragm.

NOTE

Diaphragm pumps are especially well suited for pumping mud, slime, silt, and other wastes or heavy liquids containing debris such as sticks, stones, or rags.

Liquid strainers are fitted at the suction inlet to prevent large objects from fouling the suction and discharge valves or possibly damaging the diaphragm.

You may have to use the diaphragm pump for such duties as dewatering trenches where sewer lines or waterlines are to be laid, dewatering cofferdams or cave-ins, or repairing breaks in water or sewage lines.

Two of the most popular types of diaphragm pumps are the mud hog (closed discharge) and the water hog (open discharge).

- The mud hog is for jobs that require pumping heavy and thick liquids that must be discharged at a distance away from the pump. The pump is fitted with discharge hose connections, and the ball valves and chambers are designed to prevent fouling by sticks, stones, or rags.
- The water hog is used for pumping thinner or less viscous liquids. It can handle liquids containing sand, gravel, or mud. The discharge outlet from the water hog is open to permit free flow and to increase discharge capacity. The liquid is discharged directly at the pump. A discharge hose, however, can be fitted to the pump if desired, but the hose connection can reduce the efficiency of the pump.

You must know the operation of the diaphragm pump. Since nearly every job presents a different problem, you may have to vary the operating procedure to fit the individual job. Before starting the pump, place the suction line and screen in the liquid to be removed by the pump. Construct a trough to drain the pump discharge away from the pump.

Operation – Start the engine first. If the pump does not pick up the liquid in a minute or two, check the suction line for leaks. You can do this by pouring water over the hose connections. In the event there is a leak, air bubbles will appear. Should the connections be tight and no leaks appear, check the diaphragm for cracks or punctures. If the diaphragm is damaged, replace it. A mechanic inspector must make any further inspections.

Inspection – Because of the nature of the liquids handled by diaphragm pumps, inspection during pump operation is particularly important. Inspect the suction inlet strainer often to avoid accumulations of debris that reduce suction efficiency. Most diaphragm pump installations also permit easy access to the suction and discharge ball check valves. These valve mechanisms should also be inspected frequently to detect scoring, fouling, and improper valve seating.

NOTE

Sand, gravel, and other material can corrode the diaphragm and ball check valves; expect these parts to require the most frequent operator inspections.

4.4.2 Centrifugal Pump

The basic centrifugal pump, shown in *Figure 24-19* has only one moving part: a wheel or impeller that is connected to the drive shaft of a prime mover and that rotates within the pump casing. The impeller is designed to impart a whirling or revolving motion to the liquid in the pump. When the impeller rotates at relatively high speeds, it develops sufficient centrifugal force to throw the liquid outward and away from the center of rotation. Thus the liquid is sucked in at the center, or eye, or the impeller and discharged at the outer rim of the impeller.

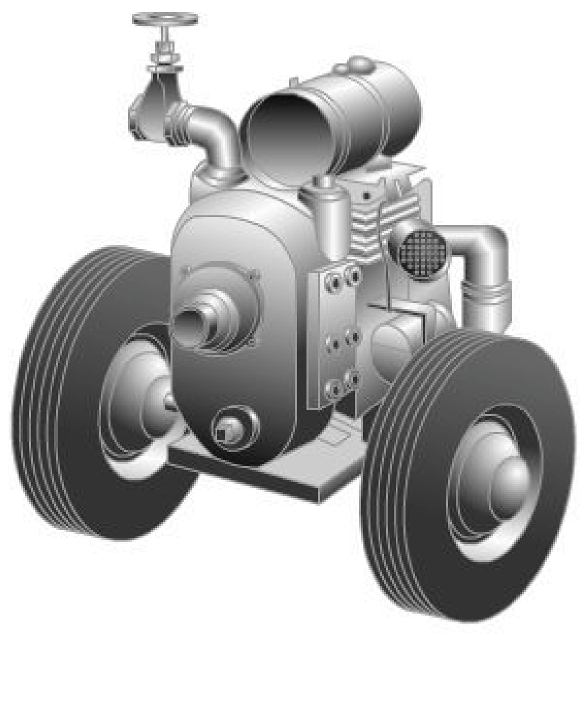

Figure 24-19 – Centrifugal pump.

The centrifugal pump, like the diaphragm pump, is driven by a single-cylinder, four-cycle, air-cooled gasoline engine. To operate the engine properly, you should be familiar with its controls.

NOTE

Refer to the operator’s manual for specific instructions for the type of pump you are operating.

Operation – The operation of centrifugal pumps is generally similar to the operation of diaphragm pumps. Centrifugal pumps are also fitted with stuffing boxes and various types of bearings that require periodic operator's maintenance and inspection.

NOTE

Unlike positive displacement pumps, the discharge stop valve on centrifugal pumps must be closed before starting the pump.

The reason for closing the stop valve is to allow the pump to work against the sealed discharge and build up an effective pressure head before attempting to move and distribute the liquid downstream. After the pump is up to speed and the discharge valve is opened, it will continue to maintain that pressure head unless the operating conditions change.

There is no danger of building excessive pressure while the pump is running with the discharge closed. If the centrifugal pump were permitted to continue operation with the discharge sealed, it would simply build up toward its maximum discharge pressure and then begin to churn the liquid, that is, the discharge pressure would overcome the suction pressure and the liquid would continually slip back to the suction side of the pump. Nothing more would happen, except that the pump would build up heat since the liquid would not be able to carry away heat generated by the moving parts.

Inspection – There is little for you to inspect other than routine operator's maintenance. If you follow all of the operator's manual instruction and the pump does not function properly, call for a field mechanic or turn it in to the dispatcher with a hard card for repair.

4.5.0 Sweepers

Many different types of sweepers are used in the Navy. Some of the most common are the towed sweeper, the street sweeper, and the magnetic sweeper.

4.5.1 Towed Sweeper

The NCF primarily uses the towed sweeper, like the one shown in *Figure 24-20*. Its size and easy maintenance give it an advantage over the street sweeper. Its disadvantage is that it requires a prime mover, and windrows the debris to one side or the other only and does not pick it up.

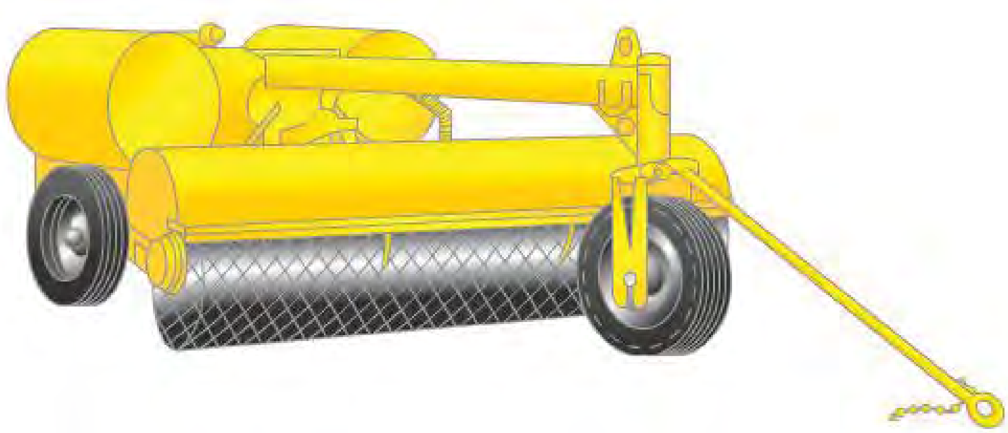

Figure 24-20 – Towed sweeper.

4.5.2 Street Sweeper

The NCF also uses different types and makes of street sweepers, the most common being the self-propelled type. The self-propelled street sweeper, like the one shown in *Figure 24-21*, is used mainly to remove loose debris from the surface of streets, roads, parking areas, taxiways, and airport runways.

Figure 24-21 – Street sweeper.

Operation – Procedures to adhere to when operating a street sweeper are as follows:

- During sweeper operations, you should plan ahead and select routes where water is available to refill the water tank of the sweeper. This effort saves time and the expense of having to travel long distances to refill.
- The sweeper is equipped with a prime mover, controls, and a basic machine for steering, sweeping, and water spraying, as well as for picking up, containing, and disposing of debris.
- When refueling a street sweeper, make sure the engine is turned off and see that metal-to-metal contact is maintained with the fuel tank and fuel nozzle.
- Keep personnel away from the brushes and scrubbers of the sweeper during operation.
- Always stop operations when adjusting, cleaning, and lubricating the equipment.
- Keep hands clear of drive chains.
- Park the sweeper on level ground with the hand brake applied.

- Except in emergencies, do not turn the steering wheel sharply when the machine is in motion. The sweeper is highly responsive to small movements of the steering wheel.

4.5.3 Magnetic Sweeper

The magnetic sweeper, like the one shown in *Figure 24-22*, picks up miscellaneous small steel items from runways, roads, maintenance, and recreation areas. The sweeper functions by picking up the small steel items as it is being towed around an area at a slow rate. The items are attracted to magnets mounted on the sweeper. Retainer pans are provided to collect the metal debris the sweeper picks up.

Figure 24-22 – Magnetic sweeper.

The A & A Magnetics sweeper is one of many different makes and models of magnetic sweepers used by the Seabees. It is capable of picking up 99% of 30 pounds of small steel items when traveling 5 mph or less with the sweeping clearance 3 inches from the ground. The magnetic sweeper is capable of travel and use in rough areas that contain rocks, pot holes, dust, and other obstructions. The sweeper will operate efficiently in temperatures between -25°F and 125°F.

Operation – Under normal conditions, using the magnetic sweeper around work areas one or two times a week will keep areas free of metal debris. If construction or demolition is in progress, the magnetic sweeper should be used as often as needed to keep areas free of metal debris. Using the magnetic sweeper helps prevent flat tires on wheeled equipment.

After sweeping an area, be sure to take the magnetic sweeper to an assigned trash area, dump the debris collected by shutting off the magnetic circuit breaker, and place the debris in the container provided.

When refueling a magnetic sweeper, make sure the engine is shut off, and see that the fuel tank and fuel nozzle maintain metal-to-metal contact.

Safety – Perform the following when operating the magnetic sweeper:

- Allow no riders.
- Stop operations when adjusting, cleaning, and lubricating the unit.
- Do NOT drop material from the magnet and then run the sweeper over the material. Pick up the material and dispose of it before securing the sweeper.

Test your Knowledge (Select the Correct Response)

7. Which of the following is NOT categorized as miscellaneous construction and maintenance equipment?

   A. Floodlights
   B. Generators
   C. Lubricators
   D. Augers

Summary

This chapter introduced you to the basic operations of mixing equipment such as the concrete transmit mixer and mobile concrete mixer plant, two units that transport and mix concrete. You were also introduced to drilling equipment such as single- and continuous-flight augers and the crawler-mounted rock drill. Additionally, you were introduced to the construction and operating features of air compressors used to power pneumatic tools such as the hand-held rotary rock drill and pavement breaker. Lastly, you were introduced to miscellaneous construction and maintenance equipment, which included floodlights, generators, truck-mounted lubricators, and various types of sweepers.

Review Questions (Select the Correct Response)

1. Concrete mixed in a transit mixer should be delivered within 1 1/2 hours or before the drum has revolved a maximum of how many times after the introduction of water?

   A. 100
   B. 200
   C. 300
   D. 400

2. To keep the concrete from setting up inside the truck, you should add a total of how many pounds of sugar to the concrete?

   A. 2
   B. 5
   C. 10
   D. 15

3. **(True or False)** The mixing action of a crete mobile is a continuous process that can proceed until the aggregate bins are empty.

   A. True
   B. False

4. What component of an auger carries cuttings away from the surface?

   A. Flights
   B. Pilot cutting
   C. Cutting edges
   D. Teeth

5. **(True or False)** An auger's boring head should be slightly smaller than the auger flights so it will not bind or stick in the hole.

   A. True
   B. False

6. **(True or False)** Before performing any drilling or boring operations, you must have a digging permit and have all underground utilities and obstructions clearly marked and identified.

   A. True
   B. False

7. **(True or False)** Traveling with an auger bit attached to the drill shank can result in destruction of the drill shank inner seals.

   A. True
   B. False

8. On a crawler-mounted rock drill, what component supports and positions the rock drill?

   A. Feed
   B. Boom
   C. Drifter
   D. Tram station

9. **(True or False)** On a crawler-mounted rock drill, the drill console houses the tramming controls for steering the machine.

   A. True
   B. False

10. **(True or False)** The purpose of the detergent system on a crawler-mounted rock drill is to suppress dirt and lubricate the drill bit.

    A. True
    B. False

11. When drilling with a rock drill, what is the purpose of collaring?

    A. Elimination of drilling obstruction
    B. Elimination of bit jumping
    C. Faster drilling
    D. Deeper drilling

12. Visitors to rock drill operations, unless suited properly with all required safety gear, must stay at least how many feet away?

    A. 25
    B. 50
    C. 75
    D. 100

13. What type of air compressor uses a male and female screw inside a casing to compress air?

    A. Reciprocating
    B. Rotary screw
    C. Centrifugal
    D. Dynamic

14. What type of air compressor mechanically imparts velocity to the air?

    A. Reciprocating
    B. Rotary screw
    C. Centrifugal
    D. Dynamic

15. A multi-stage air compressor system is more efficient than a single-stage system because the air cooled between stages in the multi-stage system provides what advantage?

A. Increases the temperature of the compressed air
B. Reduces buildup of pressure due to temperature rise
C. Has the capacity to hold more air at a higher pressure
D. Compresses the air to one thousandth of its original size

16. **(True or False)** Cfm stands for cubic-meter feet per minute.

A. True
B. False

17. Pneumatic tools can be used with any type or size of compressor as long as what two requirements of the tool are met?

A. Psi and lubrication
B. Cfm and lubrication
C. Air regulation and lubrication
D. Psi and cfm

18. **(True or False)** The pavement breaker uses rotating action to break up rock.

A. True
B. False

19. Which of the following pavement breaker attachments is best suited for trimming corners and splitting seamed rock?

A. Moil point
B. Chisel point
C. Asphalt cutter
D. Clay spade

20. The rotary rock drill is used for what type of rock drilling?

A. Hard rock
B. Shallow depth rock
C. Medium depth rock
D. Deep boring rock

21. The fourth class rotary rock drill weighs from 50 to 65 pounds and is used for drill holes up to a maximum of how many feet?

A. 18
B. 12
C. 10
D. 6

22. On the blower type of drill, cuttings are removed in what manner?

    A. By blowing water from the bottom of the hole
    B. By passing a steady supply of air through the drill steel
    C. By stopping the drill and blowing the cuttings out through the drill steel
    D. By stopping the drill and blowing the hole for 30 seconds after every 2 feet or 1 minute of drilling operations

23. Floodlights used by the NCF are designed to operate in which of the following climatic conditions?

    A. Dry
    B. Wet
    C. Cold
    D. All of the above

24. **(True or False)** You should NOT use a light plant as a power source for power tools because the power surge and power draw from the tools can overload the exciter and result in damage to the generator.

    A. True
    B. False

25. What is one of the first requirements you must ensure is met before placing a light unit in operation?

    A. Adequate ventilation is available.
    B. The unit is at a 30–degree incline.
    C. The unit is jacked up off the ground and level.
    D. All circuits are closed.

26. If a light plant engine idles down while the generator is excited, what damage is likely to occur to the light plant generator?

    A. Main fuse will blow.
    B. Clutch will overheat.
    C. Circuits will melt.
    D. Field winding will burn.

27. Placing a generator near points of large demand provides which of the following advantages?

    A. Reduces the size of wire required
    B. Holds line loss (voltage) to a minimum
    C. Provides adequate voltage control at the remote ends of the line
    D. All of the above

28. A generator should NOT be operated on an incline that exceeds what maximum degrees from level?

A. 10
B. 15
C. 20
D. 25

29. A solid ground rod must have a minimum diameter of how many inches?

A. 1/4
B. 1/2
C. 5/8
D. 3/4

30. **(True or False)** The ground rod is accountable collateral gear for a generator.

A. True
B. False

31. A pump uses what type(s) of force to move liquid from one point to another?

A. Pushing only
B. Pulling and pushing only
C. Throwing and pulling only
D. Pushing, pulling, and throwing

32. What term is used to describe the part of a pump where mechanical motion is applied to the liquid being pumped?

A. Liquid end
B. Rotating end
C. Power end
D. Prime mover end

33. In a diaphragm pump, what force moves the liquid from intake to discharge?

A. Centrifugal motion
B. Rotary motion
C. Reciprocating motion of a flexible diaphragm
D. Rocking motion of an impeller

34. The mud hog and water hog are what type of pumps?

A. Centrifugal
B. Diaphragm
C. Rotary
D. Gear

35. Fluid entering the centrifugal pump is first directed to what location?

A. Diaphragm
B. Blades of the rotor
C. Center of the impeller
D. Splines of the fan clutch

36. When you are starting a centrifugal pump, the discharge valve should be in what position?

A. Open
B. Run
C. Stop
D. Closed

37. A pull type of sweeper removes debris from a sweep area in which of the following ways?

A. By windrowing debris to the side
B. By vacuuming up debris
C. By washing the debris
D. By pushing the debris straight ahead of the sweeper

38. You are planning to use a rotary street sweeper to sweep streets. You should check the availability of what sweeping requirement along the route?

A. Fuel
B. Place to dispose of debris
C. Water
D. Air

39. Debris collected by a magnetic sweeper is dumped in which of the following ways?

A. By shutting down the engine
B. By releasing the collector hopper dump lever
C. By idling down the engine throttle
D. By shutting off the magnetic circuit breaker

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Construction Electrician 3, NAVEDTRA 12523, Naval Education and Training Program Management Support Activity, Pensacola, FL, 1993.

Earthmoving Operations, FM 5-434, Headquarters Department of the Army, Washington, DC, 2000.

Operating, Maintenance, and Overhaul Manual: Magnetic Sweeper Model MRS 96, A and A Magnetic Inc., IL, Issued 3, 1994.

Operating, Maintenance, Parts Manual: Light Tower Models L6/L8, Ingersoll-Rand, 2001.

Operation, Maintenance, Parts, and Service Manual: Mobile Concrete Mixer, Model MT/9T, Mobile Technologies Inc., OK.

Operator and Maintenance Manual: Part No. 419396, 2nd ed., SD345 Hydra-Trac®, Hydraulic Track Drill, Terex Reedrill, TX.

Operator's Manual and Parts List: Portable Air Compressor, H750CFM/300 PSI, Sullair Corporation, IN, 1993.

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