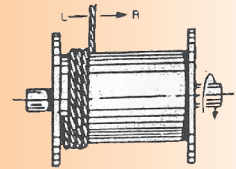
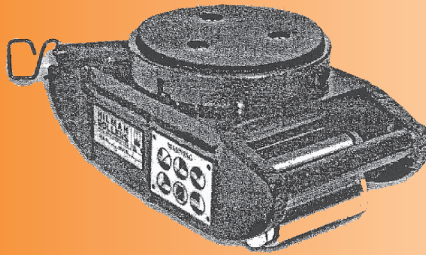
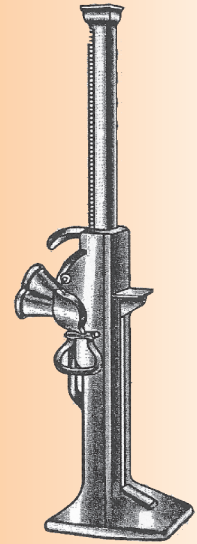
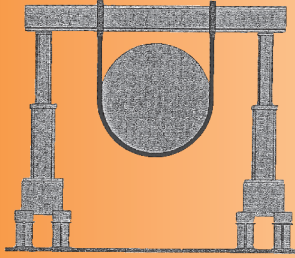




**CONSTRUCTION  
SAFETY**



## **Specialized Rigging**

**Safety Guidelines for Construction**

**Hydraulic Gantry Systems  
Overhead Cranes  
Jacks and Rollers  
Tuggers**

# Acknowledgement

The Specialized Rigging Subcommittee of the Provincial Labour-Management Health and Safety Committee identified the need for this data sheet and worked closely with CSAO during its production.

Representatives of various trade labour-management committees came together in the subcommittee to undertake this work: Boilermakers, Ironworkers, Millwrights, Operating Engineers (Hoisting Operations), Pipe Trades, Refrigeration and Air Conditioning, and Sprinkler and Fire Protection Trades.

CSAO would like to acknowledge the efforts of all the members of the Specialized Rigging Subcommittee in producing this data sheet.

In the past, members of the public have used printed information that was outdated by subsequent improvements in knowledge and technology. We therefore make the following statement for their protection in the future.

The information presented here is, to the best of our knowledge, current at time of printing and is intended for general application. This publication is not a definitive guide to government regulations or to practices and procedures wholly applicable under every circumstance. The appropriate regulations and statutes should be consulted. Although the Construction Safety Association of Ontario cannot guarantee the accuracy of, nor assume liability for, the information presented here, we are pleased to answer individual requests for counselling and advice.

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# **SPECIALIZED RIGGING**

## **Safety Guidelines for Construction**

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# Rigging with Hydraulic Gantry Systems

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## 1. INTRODUCTION AND OBJECTIVES

Hydraulic gantries are a useful type of heavy equipment for lifting and manoeuvring heavy loads. Gantry systems range from those using small, five-ton capacity jacks up to systems capable of lifting 1,000 tons. The fully extended height of some systems can reach 40 feet.

Proprietary systems may also be engineered and built by contractors capable in specialized lifting and moving.

In virtually all heavy lifting applications with this equipment, you will need knowledgeable engineering, planning, and coordination. Professional engineering assistance should be considered a necessity for some aspects of this type of work.

Tradespersons, supervision, and management can all benefit from having more information on the subject of gantry lifting. This chapter is intended to provide useful information on a number of related topics, including

- description of a basic hydraulic gantry system
- hazards
- responsibilities of workplace parties
- lift types
- planning, coordination, and preparation
- personnel training and safety
- information to be expected on the equipment, and questions to ask.

This chapter is intended to provide construction *tradespersons, supervision, and management* with an awareness of hydraulic gantry lifting. It focuses particularly on hazards, as well as on good procedures and practices to follow when using this equipment. It is intended to be a useful planning, preparation, and training tool.

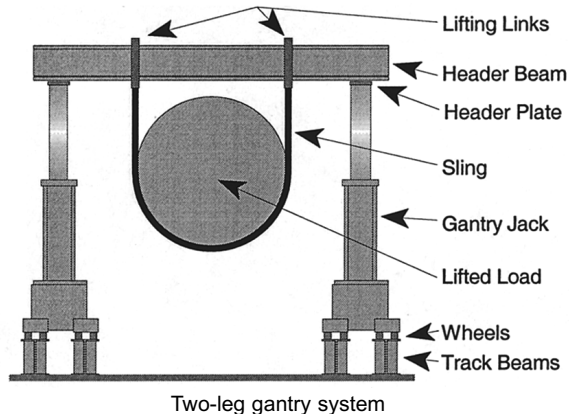
## 2. BASIC SYSTEM TYPES AND COMPONENTS

### TYPES

A **basic two-leg gantry system** consists of a number of parts as illustrated.

At the heart of the system are the gantry jacking units which support a header beam. If wheel-mounted, the jacking units can run on track beams.

The lifted load is usually picked up using a sling arrangement which is attached to the header beam by means of lifting links on the beam. In more elaborate systems, using more sophisticated lifting links, the load can be shifted laterally along the header beam.



### Four-leg gantries

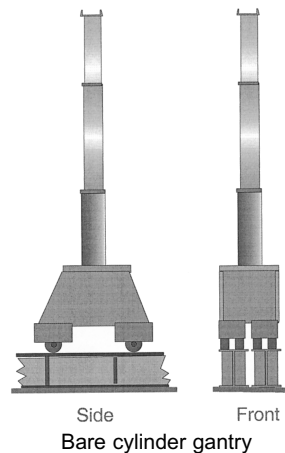
- Capacity is from about 20 tons. Large system capacity is from 200 to 1,000 tons.
- Typical height capabilities are from 20 to 30 feet.
- The height capability of some is up to about 40 feet.

## COMPONENTS

**GANTRY JACKING UNITS** can be divided into two types:

### 1. Vertical lift cylinder

Bare cylinder machines usually consist of a fabricated steel structural base, which is

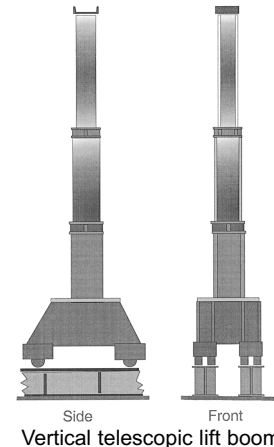


wheel-mounted, and have one to four vertically mounted hydraulic cylinders on top. They can be either single-stage or multiple-stage. The cylinders can be either one-way (pressure extend, gravity retract) or double-acting (pressure extend and retract). The units are generally less complex and lighter than telescopic boom units.

## 2. Vertical telescopic lift boom

Telescopic boom machines have a similar, but usually larger and often wheel-mounted, structural base. The base carries square or rectangular multiple-section steel boxes or booms, similar to a hydraulic crane boom, which can resist horizontal forces during lifts. The telescoping of the boom is driven by one or more internal or external hydraulic cylinders.

This type of gantry system usually allows the sections to be locked together to support the load structurally, rather than hydraulically, if the load has to be held elevated for any length of time. A desirable safety feature is the system's ability to lock the leg mechanically as it extends or retracts to prevent unbalanced loading and collapse, in the event of hydraulic failure.



## CONTROL/POWER UNIT

This is a remote control station that provides power to actuate the cylinders in the jacking units.

On all-hydraulic machines, this unit contains a motor and hydraulic pump that pressurizes the system. It also has control valves which the operator uses to control oil flow through hoses to the lift cylinders.

In some machines, the controls at the station used to actuate the operation of the jacking legs are electric. In these systems there are only electrical connections to the jacking units, which have a self-contained hydraulic system composed of the oil reservoir, motor, and hydraulic pump.

## Hydraulic Gantries

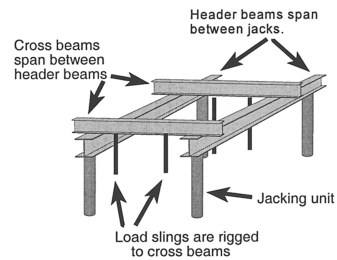
### HEADER PLATE

The header plate is an adapter plate with a swivel fitting, located at the top of the lift cylinder or boom. It is used to attach the header beam to the jacking unit.

### HEADER BEAMS

Header beams are structural sections—usually rolled wide flange shapes or fabricated box sections. They are supported on the header plates.

Different header beam arrangements are used with four-leg gantry systems. A four-beam header arrangement allows more flexibility in positioning lifting links to match the pickup points on the load, or in putting slings on the load. Typically the lower two beams span the jack legs while the upper header beams span the lower beams.



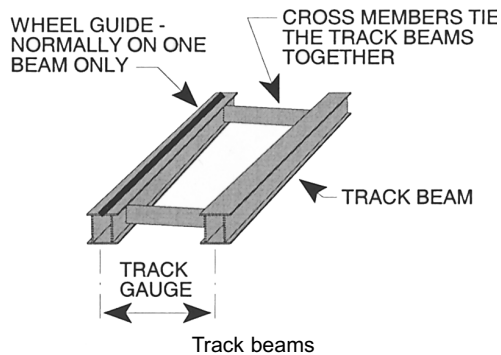
Header and cross beams

### CROSS BEAMS

Cross beams are typically used to make up a four-beam header arrangement and are a second set of header beams (or one beam), to which the load is attached, placed across the first set.

### TRACK SYSTEMS

Track systems consist of two parallel beams, usually wide flange shapes or fabricated box sections, that are fitted with a wheel guide to direct the jacking unit's wheels. The function is to provide a smooth and guided surface for the wheels.



The track beams are normally tied together at regular intervals. The spacing matches the transverse wheel spacing of the jacking unit. The track units are usually fabricated in sections short enough to be shipped easily and then bolted together end to end.

Track units can be designed to carry the jacking unit wheel loads over clear spans, such as pits or weak floor sections, or they can be designed for full support from an underlying surface.

Hydraulic gantry systems must be solidly supported. If wheeled, they must run on strong, solidly supported track systems with minimal deflection to keep them both stable and upright.

## PROPULSION DEVICES

The jacking system must be propelled along the track or floor. There are three basic concepts for the propulsion devices:

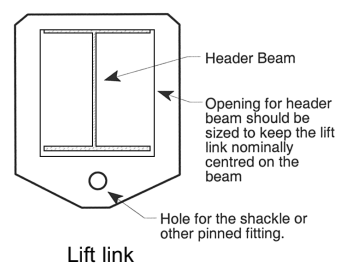
- 1) *Built-in*: The jacking unit has a motor that drives some or all of its wheels using chain or gears.
- 2) *External cylinder(s)*: For use on free-wheeling units, a cylinder is pinned close to the bottom of the jacking unit's base at one end, and to the track at the other. The cylinder is extended and retracted repeatedly to move the jacking system along the track.
- 3) *External drive wheels*: One or more drive wheels are mounted to the base of the jacking unit. In order to develop enough friction and tractive force to drive the jacking unit, the wheels must be loaded somehow.

## LOAD SENSORS/GAUGES

These are devices used to measure the weight being carried by each jacking unit. They can be installed on the control panel or on each jacking unit. It is better to install them on each cylinder directly—not on the hydraulic pressure line—so that they provide more accurate and individual readings.

## LIFTING LINKS

Lifting links are a means of attachment between the header beams and the load rigging. They are often made from a piece of flat plate cut to fit around the header beam with a hole at the bottom for attaching rigging hardware such as a shackle. Simple static-plate



## Hydraulic Gantries

style lifting links are adequate for simple lift-and-lower or lift-and-roll jobs. More complex lifting link configurations are needed for side-shifting or rotating a load using swivels.

### RIGGING

A variety of hardware is used to attach the lifted load to the lifting links. Typical rigging items include shackles, wire rope slings, synthetic slings, chains, or slings made from wire rope and clips.

### LONGITUDINAL DIRECTION

This is the horizontal direction parallel to the axis of the jacking system track.

### LATERAL DIRECTION

This is the horizontal direction perpendicular to the axis of the jacking system track.

### SIDE-SHIFTING

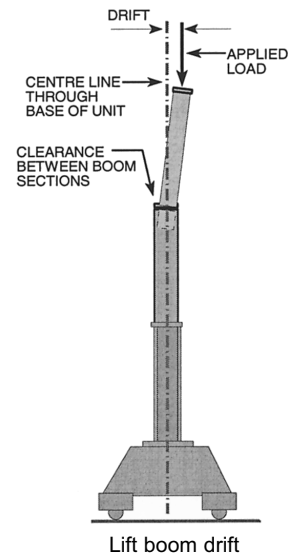
This is the lateral movement of a suspended load, usually using wheel-mounted or sliding lifting links with a means of lateral propulsion.

### DRIFT

This is the horizontal movement of the top of a telescopic lifting boom due to clearance between the boom sections.

### PUNCHING

This is the failure of a structural support, such as a concrete floor, due to excessive shear stress from a heavy locally concentrated load.



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## 3. HAZARDS

Headings suggest the area of deficiency.

### PLANNING

- Inadequate knowledge or training
- Loading that exceeds floor load capacity or causes unexpected deflection
- Poor load distribution for weak or irregular structural support conditions
- Poor sub-grade conditions.

### PREPARATION

- Excess track deflections
- Track beam deflection causing “uphill” or “downhill” condition, or differential movement of track sections at connections
- Unequal track deflection from side to side, e.g., due to pits, obstacles
- Lack of system manual or load chart information
- Unanticipated loads: rigging misaligned due to clearance problems.

### SETUP

- Track misalignment
- Damage to high-pressure hydraulics and hoses
- Unbalanced or non-centred loads
- Unequal load distribution between legs, e.g., corner loading on 4-leg bridles, etc.
- Water such as ground water or leaks.

### OPERATIONAL

- A gantry or an individual leg going out of plumb
- Jack misalignment, “racking” during load travel along the track beams
- Debris or obstacles on the track or path of travel
- Rigging not vertical, causing horizontal forces on the header beams
- Horizontal forces: transferred through the rigging during up-ending or standing up a load, or from pendulum action of the load
- Lateral forces
- Excess lift boom drift
- Chock stops/locks not deployed
- Electrical contacts (powerlines or power rails)
- Vibrations (operating plant or moving equipment)
- Environmental (wind forces, etc.)

**PERSONNEL**

- Fall hazards while rigging
- Fall hazards while preparing mating surfaces
- Fall hazards during assembly and breakdown
- Overexertion injuries during setup and dismantling operations
- Pinch points and crush injuries.

**4. GENERAL PRACTICES**

This type of equipment was originally developed for lifting and moving heavy machinery components inside buildings where clearances were small and where conventional cranes were not practical. It remains an effective and economical alternative to cranes for lifting heavy loads.

The majority of gantry lifts are of the basic rig-lift-and-roll type or straight-up-and-down type for transloading from one carrier to another. Types of lifts will be discussed in more detail later in this chapter.

The basic procedures for using hydraulic gantry systems for lifting are not unlike those for using conventional cranes.

- The supplier provides a set of manufacturer's operating instructions and a load chart or charts with the equipment.
- The user is responsible for the selection of rigging, the preparation of the base on which the equipment will be set up, and the safe operation of the equipment.
- As a general rule it is advisable to use rigging which has excess capacity—some suppliers recommend rigging that will support twice the anticipated load. This recommendation should definitely be followed if there is any chance of "cross-cornering"—i.e., when two slings can end up carrying all the load of a four-point lift (or any multi-point lift). As in all lifting activities, be sure to include the weight of the rigging in the calculations.
- A competent operator is required, one who is familiar with the gantry system being used. Sometimes the supplier will provide a skilled operator.



- Prevent unauthorized personnel from entering the working area by using warning signs and by cordoning off the area with barrier tape.
- Before starting operations, make sure that the plant supervision is informed.
- Check that no other operations are going on in the work area and/or are locked out, such as overhead cranes or heavy equipment.
- Check the area for hazards such as electrical contact (powerlines), vibration (operating equipment), water (ground water, leaks, etc.), or environmental hazards (wind forces, etc.).

## **5. RESPONSIBILITIES OF WORKPLACE PARTIES**

### **OWNER/CONSTRUCTOR**

- clearly define the required tasks and schedule
- provide necessary drawings and information about the plant or facility
- cooperate in planning and emphasize that safety must be a priority in all operations
- cooperate with other requirements such as limiting access of non-essential personnel during moves.

### **CONTRACTOR**

- plan and organize all activities
- work with the supplier and owner/constructor to plan and schedule the moves
- make sure that accurate load information has been provided and approved, including load weights, sizes, shapes, and rigging plans
- perform detailed “risk assessment” activities before the moves
- have competent supervision on the job
- ensure there is a trained competent operator—checked out or provided by the supplier
- ensure there are trained competent operators for other equipment (e.g., forklifts)
- designate crew members for all tasks
- make sure that your crew is trained on the equipment and given job-

## Hydraulic Gantries

- specific training
- provide necessary personal protective equipment (PPE) and equipment for the crew.

### MANUFACTURER/SUPPLIER

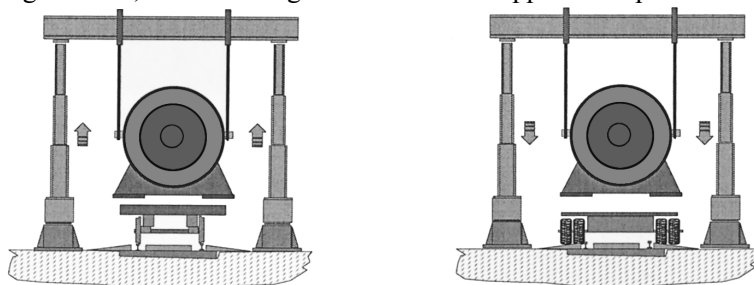
- provide the lifting equipment in proper working condition
- provide all necessary documentation such as manuals and load charts for the equipment
- ensure that the equipment has enough capacity for the job
- provide a competent, experienced operator if required
- ensure that adequate training is provided on the use of the equipment.

### CONTRACTOR/TRADESPERSONS

- understand fully the use and operation of the lifting equipment
- be sure there is job-specific training
- know and follow the load-handling procedures
- make sure you are informed about emergency preparedness and procedures
- work in a safe manner.

## 6. LIFT TYPES

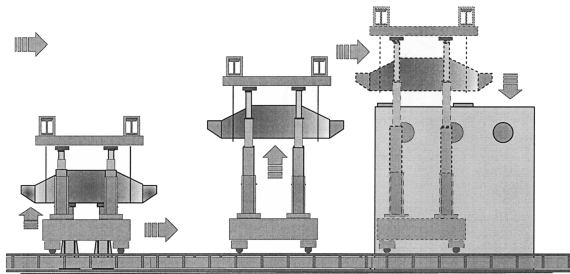
**Straight up and down.** This type of lift consists of rigging, lifting, and holding the load, then lowering it when its new support is in place.



A common use is for transferring a heavy piece of equipment from one vehicle to another—for instance, from a railcar to a trailer. In this case the gantry might be set up over the rails while the loaded rail car is driven between the gantry tracks. The load is then rigged to the header beams and the gantry extended to lift the load clear of the car. The railcar can be moved out and the trailer moved in under the load. The load can then be lowered to the trailer bed for transport.

## Straight up and down with travel.

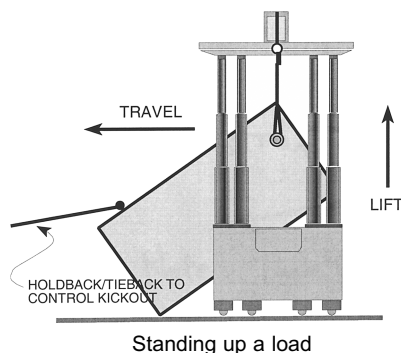
This type of lift consists of rigging the load, lifting it with the gantry, driving the loaded gantry along a track system, raising and lowering the load as required, and then finally lowering it to its final location.



An example of this kind of lift is placing a large component—such as the crown—on top of a mill or press inside a plant. Some form of motive power is required to move and control the longitudinal travel of the loaded gantry along the tracks.

**Stand up/lay over.** In this lift, the longitudinal axis is rotated to stand up a tall component which has been shipped horizontally, or to lay one over.

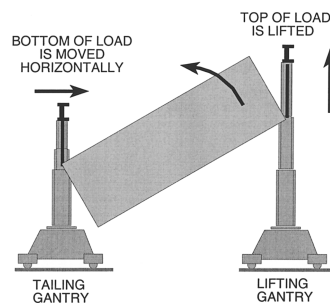
This type of lift can be used to place tall vessels or large castings. More complex than straight lifting, it requires the coordination of simultaneous horizontal and vertical movement of at least one pair of gantry legs.



Standing up a load

In operations with a four-legged system, the gantries supporting the upper end are typically stationary and lift only. The gantries controlling the lower end are rolled along the tracks to bring the bottom end under the top of the load, similar to the use of a tailing crane.

Advance planning is very important, along with careful coordination during the lift, in order to minimize horizontal forces being generated by out-of-plumb rigging during such lifts.



Standing up a load

## Hydraulic Gantries

**Lifts on top of header beams.** In this lift, the load is carried on the header beam system rather than being suspended below.

This technique allows the load to be elevated when the placement location has insufficient headroom for the headers and rigging to place the load in its final position.

In order to do this the gantry must be able to pass under the load either by positioning the load in an elevated pickup location or by using a pit arrangement which permits the gantry to pass under the load for pickup.

The bearing points or surfaces on which the load is supported prior to pickup must leave clear access for the pickup locations on the header beams when the gantry moves under the supported load. Similarly, at the placement location, there must be no interference as the load is moved and placed on its final bearing surfaces.

**Combination lifts with a crane, forklift, etc.** This type of lift is similar in some ways to a tilt-up or lay-down situation with two gantries. In this case, one of the gantries has been replaced by a crane, forklift, or other equipment. Such lifts are both complex and potentially hazardous. They require specialized knowledge and careful planning, as in any type of tandem lift.

Care must be taken to keep the rigging vertical in order to avoid horizontal loading which can quickly make the whole system unstable, resulting in rapid tipover. Cranes and forklifts are not designed to take on and resist horizontal loads or components of loads. **Tiebacks or holdbacks tied to the structure** or other stable anchor points may be required to stabilize the load to prevent kickout or swing as the load balance shifts during movement.

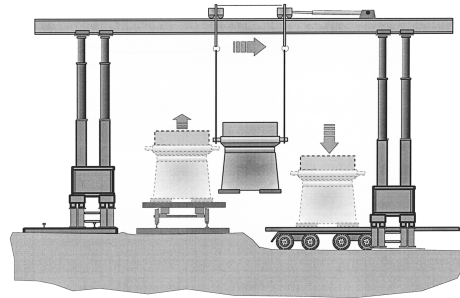
**Take care that tiebacks don't introduce unbalanced tipping forces.**

Ideally, the support structures or vehicles (gantry, crane, or forklift) should be tied together to minimize the opportunities for horizontal components of load and tipping—if only due to the simple rigidity of the load. The motive power for travel can come from one of the pieces of equipment, such as a forklift.

**Straight up and down with side-shift.** The load is lifted, moved laterally along header beams, then lowered. A more complex lifting link is needed to enable lateral travel along the header beams as well as a means of

powering the travel. Even more complex lifting links are necessary for other movements such as rotating the load. As the load moves within the gantry framework, the load on each leg changes as does the potential deflection of track beams, which can cause the legs to lean and drift.

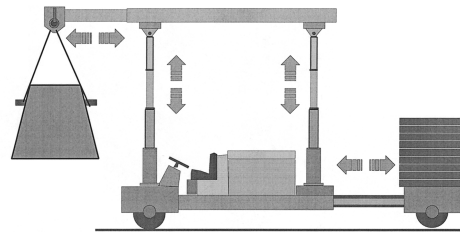
### Other configurations: Boom lifters



Side shifting a load from rail to road transport

Equipment such as “boom lifters” can offer more flexibility for somewhat lighter loads.

The safety standard to which these units are made is ASME Standard B 56.7 for Industrial Mobile Cranes.



Boom lifter

These units operate on a counterbalance principle. They can have adjustable extendable booms and extendable counterweighting systems which can be adjusted depending on the counterbalance moment required.

Several types and capacities of unit are available. Lifting features or options may allow the unit to

- pick and carry suspended loads, as shown above, for tilt-up or other work in tight areas
- be equipped with a fork-type attachment and perform as a high-capacity forklift
- operate as a gantry, lifting on top of the boom, for tasks such as installing or removing overhead crane bridges
- travel with a suspended load, carefully secured or tied back to control load swing. Follow the manufacturer's directions.

## **7. SYSTEM SUPPORT AND LOAD DISTRIBUTION**

Qualified professionals should carry out an engineering assessment and detailed calculation of these factors in advance. It's valuable, however, for all personnel involved in the lifting process to understand factors that must be considered.

**Uniformity of settlement or deflection of the track is critical to keep the entire gantry system stable.**

Any vertical movement under the load must be kept uniform to prevent one side or corner of the gantry system settling more than others, and to prevent the system from leaning and becoming unstable. The whole system must be kept essentially plumb throughout the move in order to avoid the risk of total collapse.

## **SUPPORT COMPONENTS AND METHODS**

### **TRACK SYSTEM**

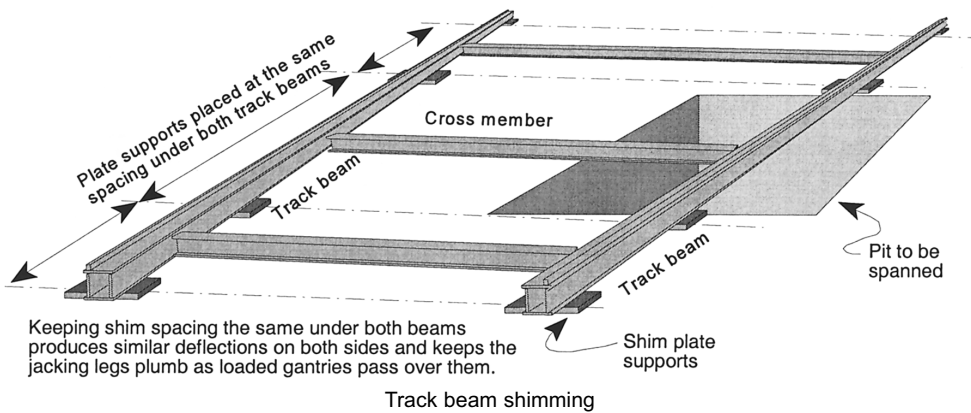
The ideal support for the track would allow no deflection and therefore no tilt or drift. If such conditions can be achieved, then levelling the track at the beginning is adequate. In reality there will always be some deflection. It's important to remember that **track deflection must be predicted and controlled to cause little or no tilt of the gantry—especially sideways.**

Any deflection of the track beams on both sides must be kept within tight limits. The deflection must also be essentially equal for both tracks to prevent tilting of the gantry structure. A number of things can be done to help make this happen, including:

- allowing little or no track deflection by laying track on a solid, strong base
- using very stiff track beams to keep deflections to a minimum

- if a track beam on one side must span a pit or obstacle, shimming the track beam on the other side at locations matching the span supports
- shimming the track beams to provide firm supports at matching positions on both sides so that expected deflections will be the same on both sides (but still within acceptable limits)
- matching the height of adjacent sections of track beam, and adequately bracing and supporting them, to prevent height differences when the loaded gantry travels across the joint.

The sketch below illustrates some steps to take to help ensure that track beam deflection is constant on both sides.



## PLATES

Steel plates can provide a hard surface for the jacking units to bear on and thus distribute loads over a large enough area to prevent punching through a slab on grade or a floor slab. Plates can sometimes reduce the bearing pressure on a weak subgrade to an acceptable level. Plates are also used as shims to support the track beams at predetermined locations.

## STANDS

Structural frames can be made to support a jacking unit or a track system and distribute the loads.

## MATS/TIMBER

Crane mats, built-up cribbing, or other timbers can be used to support jacking system legs or track beams in order to provide a system of load distribution—spreading the load over a wider area.

## **DEALING WITH SITE CONDITIONS**

### **SOIL/STONE/ASPHALT**

Poor or weak subgrade conditions might exist at the site. Compaction may be needed and/or the placement of timbers, mats, or cribbing to spread the load over a large area.

Whatever method of support or load distribution is selected, the deflection must be predictable to prevent differential settlement of the track beams when loaded. Inconsistencies in the subsoil or underground construction, such as buried pipelines or other services, may require bridging over to provide consistent support.

### **SLAB ON GRADE**

Slabs on grade need to be checked for strength. The load must be sufficiently distributed to prevent punching through the slab or overloading any section. One solution may be to use steel plates.

If heavy loading is applied well away from the centre of a slab—or especially near the edge—there can be a greater chance of the slab cracking, deflecting, or tipping.

### **FLOOR OR DECK SYSTEMS**

The capacity of existing floor systems must be checked. Floors must be checked for both local and general weakness and inspected for deterioration. If loading exceeds floor capacity, reinforcing or shoring the floor may be required to strengthen it. Steel plates are one means to distribute the load enough to prevent failure.

### **PITS OR BULKHEADS**

A typical two-leg gantry has one leg on each of two track beams. Track beams can be designed or selected to be strong enough to span, with limited deflection, support points over pits or obstructions.

Deflection of track beams must be limited. When it does occur, deflection of both beams must be more or less equal to prevent the gantry from going out of plumb. Both track beams can be designed to have equivalent



stiffness and deflection to keep the gantry level from side to side. To ensure equal deflection of both track beams they can be shimmed at matching support points on both sides—even if only one side has to span a pit.

## **OFFSHORE/WATER SUPPORTED**

If the use of floating platform or barge-mounted gantry systems is being considered, other factors must be taken into account. The transfer of a load onto or off a floating platform will cause the platform to lower in the water as it receives the weight and to rise in the water as the weight is off-loaded. The floating platform will be raised or lowered relative to any adjacent dock or structure.

Load transfers on water require careful assessment because of many factors, including the following:

- risk of off-centre loads tilting a floating platform and causing tipping forces on the gantry
- grounding or partial grounding of the barge when loaded
- tidal and weather conditions
- need to anchor or tie the floating platform to prevent movement.

## **OTHER CONDITIONS OR VARIATIONS**

All support conditions must be considered and planned for in order to provide a stable and solid foundation and prevent any chance of instability during the lift.

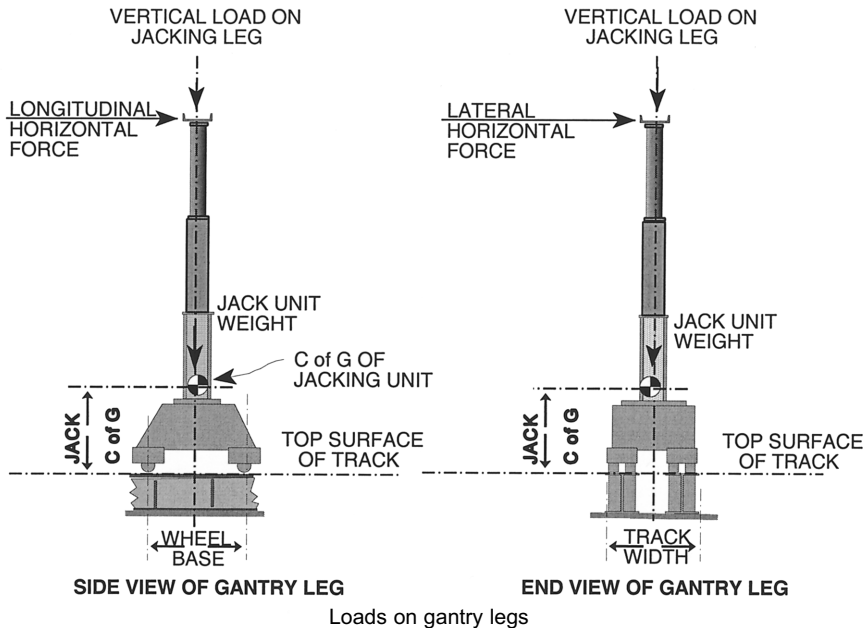
# **8. GANTRY COLLAPSE VS STAYING PLUMB**

Lifting using hydraulic gantries can be done safely. It is important, however, to understand that gantries can quickly become unstable and topple. Gantry legs have limited safety factors against tipping because their bases are small compared to their height.

Engineering checks must be done before any lifts are made in the field. Personnel familiar with this type of work must do the design, planning, and coordination.

## Hydraulic Gantries

Workers must appreciate the critical importance of the legs staying vertical or plumb as well as the need to eliminate any horizontal forces. A sure sign that some horizontal forces are beginning to be applied to the top of the jacking leg, at the header plate level, is that the rigging is not vertical, but is out-of-plumb. If not corrected, these forces can lead to overturning or collapse.



**Overturning in the direction of the tracks**, due to longitudinal forces, is avoided by keeping the line of the vertical loads within the wheel spread, or wheel base, and far enough inside the tipping axis to more than balance any overturning forces.

Causes of longitudinal horizontal forces, in the direction of the tracks, include

- off-level setup of track beams causing an uphill/downhill track configuration
- sway of suspended load due to overcoming inertia or a change in travel speed along the track
- forces from out-of-plumb rigging during standing up or laying down of a load
- adjacent sections of track beam that are out of level.

Another cause is that during standing up or laying down of a load using dual two-leg gantries, opposing horizontal forces can be imposed on each due to tension in out-of-plumb rigging.

**Side-to-side (lateral) overturning** comes from sideways forces and is avoided by keeping the line of vertical loads within the wheel span at the top surface of the track and by the vertical forces staying within the track width at ground level.

Possible causes of sideways (lateral) horizontal loads include

- hangup of a suspended load during side-shift along the header beams
- uneven deflection of the track beams on each side due to different size beams or different support conditions
- rotation of single track rails because they are off-level or poorly supported
- twin track rails on each side which are not at the same level or poorly supported.

**Other possible sources of horizontal forces include**

- the jacking legs operating at different rates during the jacking (raising or lowering) of a load (Install a tape measure on each leg to allow for frequent checking.)
- wind on large loads being rigged outdoors
- equipment vibration or earthquake forces.

**Centre loads on the header plate**

Vertical loads should be applied at the centre of each jacking leg on the header plate. If the jacking leg is plumb, then the vertical force will pass through the vertical axis to the ground or supporting structure. Loads applied off-centre will make the system less stable. Vertical loads applied to an already out-of-plumb jacking leg will force it more out-of-plumb.

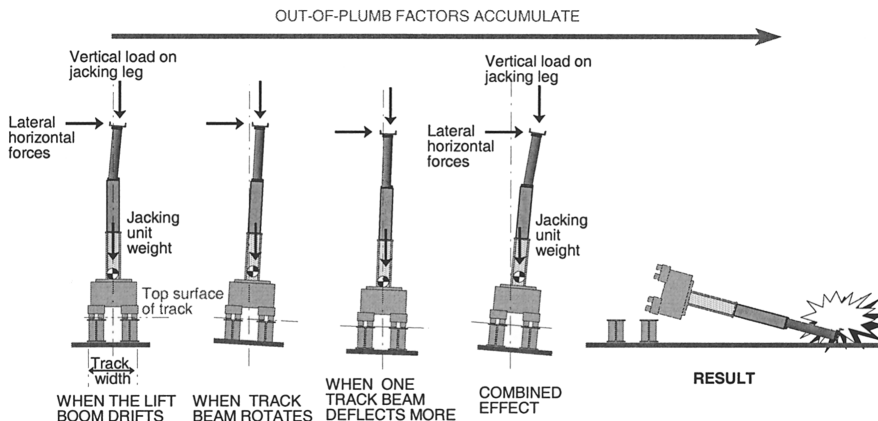
A number of conditions can contribute to a jacking leg being non-vertical, including the following:

- There can be lateral drift of the jacking leg in telescopic boom gantries. Clearances between boom sections can allow the top of the jack to drift off-centre. Even when on a level track the top can lean one way or another due to these clearances.
- Off-level track beam or beams, or rotation of a track beam, will cause a tilting of the entire jacking leg, reducing the line of action of vertical

## Hydraulic Gantries

- loads which keep the leg upright.
- The track beam or beams can deflect unequally.

If several conditions are present, then the effect will be cumulative. The figure below illustrates these effects and their possible combined result. If the jacking leg is not plumb, any vertical load that is applied will reduce its resistance to overturning and could lead to a collapse of the entire gantry system.



Each factor or a combination can lead to collapse

## 9. PLANNING THE MOVE

Planning is the key step in this kind of work, as in most complex rigging. Always keep some basic considerations in mind.

**Know the scope:** Have a clear definition of what must be done.

**Preliminary layout:** Prepare or use a preliminary equipment layout to define the lift parameters, including the clearances and any potential obstacles.

**Preliminary equipment:** Assess lift type and make preliminary selection of lifting equipment as well as alternative methods of lifting.

**Accurate loads:** Knowing the load weight and size is critical.

**Load shape and orientation:** The load's shape, weight distribution (location of centre of gravity), and pickup points must be accurately determined in order to select or design header beams, rigging, etc. Calculations must be completed and must be made available.

**Site Assessment:** Do a detailed assessment of the site for track support, obstacles, and inconsistencies that need to be considered. Do subgrade and/or floor assessments. Determine whether cribbing or other support is needed.

**Lifting equipment:** Select gantry system, size, and capabilities as well as all the components of the system. Lay out the system to minimize side-loading. Confirm that the gantries can lift the load high enough for clearances. Also confirm the clearances above the header beams at the roof, etc.

**Shifting loads:** If the lift includes such moves as standing up, laying over, or side-shifting a load, be sure that in the capacity checks of the equipment you account for the changing distribution of the load among the jacking units.

**Rigging plans:** Have rigging devices and assemblies designed and approved for each load and type. Have calculations done and available. Confirm that the load can be raised high enough to clear any obstacles and that the load or rigging clears the roof or other overhead obstacles. This is similar to preventing two-blocking in crane operations.

Select the pickup location carefully to ensure that the load aligns accurately when reaching its placement location. Locate any supports or stands accordingly. In a pick-and-travel lift, such as placing a crown on a press, attempting to pull over an elevated but misaligned crown is dangerous and could cause gantry collapse. If the rigging is pulled out-of-plumb, the lateral horizontal loads introduced at the header beams can quickly tip over the entire system.

When up-ending a load, check that there is clearance between the load and gantries in all positions and confirm that the rigging can be kept plumb during the operation.

When planning a four-point lift, consider the possible effects of “cross-cornering”—when two slings and lift points might be carrying all or most of the load.

**Assignments:** Provide and communicate clear assignments to personnel for each task.

**Training:** Ensure that personnel are properly trained for their assignments.

## Hydraulic Gantries

**Site safety:** Ensure fall prevention and fall protection. Protect pits and access openings. Do a complete site cleanup. Remove any loose objects. Identify barrier locations to cordon off the area.

**System and rigging inspection:** Ensure that there are certificates of test for rigging devices and assemblies and that there has been adequate inspection of rigging components. Ensure compliance with rigging plans, the manual, and the load charts for the gantry system.

## 10. SAFE OPERATING PRACTICES

When using a hydraulic gantry system, good operating practices include the following.

- Follow the manufacturer's directions and load charts. Is there a load-equalizing feature in the system?
- Confirm that the load, in its pickup location, is oriented to be properly aligned for final accurate placement at its destination.
- Mount a tape measure on each jacking leg to monitor the rate of extension or contraction of each leg while raising or lowering the load in order to ensure that the system stays level.
- Keep unnecessary personnel out of the work area. Cordon off the area.
- Conduct a site hazard assessment before any gantry move to make sure that the track is clear of debris or objects and that the travel path is obstacle free. When several lifts are made using the same track setup, make sure the track has not shifted or suffered damage before each move.
- As in all other heavy rigging, ***move slowly***. This helps prevent unsafe movements such as side-loading, pendulum action, jerking, or sudden stops. Operating slowly provides more time to notice potential problems and take corrective action.

- **Keep the load as low as possible**—just high enough to clear obstacles, especially while moving it along the track or moving it laterally.
- Constantly monitor the pressures in the hydraulic system and in each jacking leg if they have independent hydraulic systems. Increasing pressures or a variation in pressure between the jacking legs can indicate problems such as corner-loading with two of four legs carrying most of the load instead of it being shared equally.
- Make sure the track beams along the line of travel are kept clear of objects, debris, or dirt that can obstruct travel.
- During longitudinal movement of gantries (moving a load along the track beams) make sure that the two legs of each gantry move in unison so that one side does not lag behind.
- When using two two-legged gantries, the leading and trailing gantries must move in unison.
- Monitor the rigging to make sure it stays plumb. **An out-of-plumb condition indicates the presence of horizontal forces on the system.**
- **At any sign of a problem, STOP and find out what's wrong.**
- Periodically—and whenever changing any condition or direction of lift or travel—stop and check the following items:
  - ☐ Are the jacking units plumb and level at their base?
  - ☐ Are jacking unit supports, stands, or track rails still level? Have they settled under the load?
  - ☐ Are there signs of horizontal drift of any jacking leg?
  - ☐ Is there excessive header beam deflection, especially if side-shifting a load?
  - ☐ Is the header beam staying level and not rotating?
  - ☐ Is the loading on each jacking leg equal or as predicted?
  - ☐ Are the jacking units travelling uniformly and in-sync (side-to-side, no racking, etc.)?
  - ☐ Is there still adequate clearance past obstructions, including those overhead?
  - ☐ Is the rigging staying plumb? Out-of-plumb rigging indicates dangerous horizontal loads being applied at the top of the jacking legs.

## Hydraulic Gantries

- Has the travel path been inspected for debris, obstructions, and signs of track shifting?

## 11. POST-LIFT CONSIDERATIONS

Dismantling and removing the equipment must be planned and carried out in a safe way.

Heavy lifts using hydraulic gantries are usually a central focus of construction activities during their set-up and while they are under way. When the lifts are complete, the pressure is off and participants naturally relax after a job well done. It's easy for a less-than-cautious, complacent attitude to develop.

Safe practices can slip when your attention begins to focus on the next job. Disassembly and removal of the gantries can be seen as a routine job. At times such as this, it is easy for accidents and injuries to occur. Safety and safe practices must remain in the forefront at all times. The gantries themselves are large and heavy pieces of equipment. Their breakdown and removal must be planned and carried out carefully, as in any other rigging job.

## 12. TRAINING GUIDELINES

Identify the training requirements for both tradespersons and supervisors.

- 1) Manufacturers must make training available in the operation and servicing of every piece of equipment they sell. They must also provide the necessary documentation, including manuals and load charts, with each piece of equipment.
- 2) The division of responsibility between the supplier/manufacturer and contractor(s) must be clearly defined to permit clear accountability for adequate training before the job proceeds.
- 3) The contractor providing the lifting services using hydraulic gantries must ensure that, at all times, only operators trained and competent in the operation of the specific equipment are used on the site.



- 4) Job-specific training must be provided to all personnel on the tasks which they are assigned. Adequate engineering and planning must be performed far enough in advance to allow for enough training to accomplish all designated tasks safely.

## **13. SAFETY OF PERSONNEL**

### **GENERAL**

- Everybody on the site must comply with the legislated, site, and contractor requirements for personal protective equipment (PPE) including footwear, hard hats, eye protection, and hearing protection where required.
- Keeping a clean, well-ordered work site is a constant requirement for gantry operations since once the move starts, worker attention should not be diverted from lift responsibilities.
- Use a safety person with a warning air horn who is familiar with the lift operation to look out for any potential hazards and to make sure that no unwanted personnel or traffic enters the work area.

### **FALL HAZARDS**

- Working at heights is a frequent requirement in this kind of work, especially during the preparation and cleaning of mating surfaces and during the engagement and disengagement of rigging. Fall protection systems must be provided and installed for any workers exposed to fall hazards during these tasks. The systems should only be installed in locations where they won't interfere with any of the load-handling and rigging activities or subject a worker to injury in the event of a fall.
- Individual vertical lifelines or retractable block lifelines can be provided in appropriate locations.
- In some situations horizontal lifelines for multiple attachment can be installed. Their design and installation must be performed or at least reviewed by a professional engineer. Suitable anchor locations must be identified and used. They must be strong enough to support any potential fall-arrest forces.

## **EQUIPMENT HAZARDS**

- Hoses and electrical cables must be protected from damage, especially when a gantry is moving a load along the track. Hoses and electrical cables are also a constant tripping hazard.
- High-pressure hydraulic systems are the core of gantry lifting systems. There are ongoing hazards of injury from hydraulic leaks due to their high pressures.

# **14. PRE-LIFT CHECKLIST**

## **1. Secure area**

- ☐ Close off the work area with caution tape and other visible warning signs or barriers necessary to prevent unauthorized entry.
- ☐ Check for overhead crane operations.
- ☐ Notify area foremen of impending operations.
- ☐ Have non-essential personnel cleared from the area.
- ☐ Check for hazards: electrical, wind, vibrations, water, etc.
- ☐ Move other heavy equipment clear of lift area.

## **2. NOTIFY OWNER**

- ☐ Notify plant security of impending lift.
- ☐ Notify plant engineer of impending lift and invite to pre-lift safety meeting.

## **3. PRE-LIFT SAFETY MEETING**

- ☐ Check area for debris.
- ☐ Assign personnel to specific lift tasks.
- ☐ Explain in detail how lift will be safely accomplished.
- ☐ Verify that personnel understand tasks.
- ☐ Identify escape routes and other emergency procedures.
- ☐ Confirm alignment of pickup and placement locations to avoid adjustments after the load is elevated.
- ☐ Perform a dry run.

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## 4. JACKING SYSTEM CHECK

- ☐ Fuel supply
- ☐ Fluid levels
- ☐ Loose couplings
- ☐ Rigging
- ☐ Jack alignment.

# 15. REVIEW EXERCISES

This chapter can be used as a supplement to support your safety training for rigging with hydraulic gantry lifts. A useful awareness exercise is to brainstorm the hazards to avoid when using gantries and list the hazards on flipcharts. This can be an introductory exercise before handing out the data sheet or after the session as a review exercise. Refer to Section 3 (Hazards) to confirm and supplement the hazard lists developed during the exercise.

## QUESTIONS (BY SECTION)

### *Section 4—General Practices*

1. What two documents need to be supplied and used with a hydraulic gantry system in order to operate it safely?
2. Some suppliers recommend that rigging should have double the calculated capacity requirement. The rigging must have at least this “double” capacity if there is any chance of “cross-cornering” during four-point or multi-point lifting.
  - a) In cross-cornering, how many lines must be able to carry the entire load?
  - b) In addition to the weight of the object being rigged, what must be included in the load weight?
3. Before starting operations, list at least four activities which must be carried out.

## Hydraulic Gantries

### *Section 8—Gantry Collapse vs Staying Plumb*

4. List at least two things which prevent gantry collapse during lifting operations.
5. List at least four conditions that can reduce the stability of a gantry during a move.

### *Section 10—Safe Operating Practices*

6. Fill in the missing words in these incomplete statements:
  - a) A useful means of monitoring the rate of extension or contraction of each leg is to mount a \_\_\_\_\_ on each.
  - b) When moving a load with a gantry system, as with all heavy rigging, always \_\_\_\_\_.
  - c) Always keep the load as \_\_\_\_\_ as possible.
  - d) Constantly monitor the \_\_\_\_\_ in the \_\_\_\_\_ system and in each jacking leg if they have independent hydraulic systems.
  - e) If there is any sign of a problem during a heavy equipment move with a gantry system, you should \_\_\_\_\_.

---

## ANSWER SHEET

1. — Manufacturer's operating instructions  
— Load chart(s)
2. a) Two of the lines must be able to carry the entire load.  
b) The rigging.
3. — Inform plant/owner management before work commences.  
— Check site area for hazards such as electrical contact (powerlines), vibrating equipment, and water leaks.  
— Inspect the site for unexpected changes which might have taken place and for environmental effects (such as wind forces).  
— Review with the crew the procedure and responsibilities.  
— Check that no other operations are going on near the work area that can interfere. Examples include overhead cranes and mobile equipment.  
— Make sure steps are in place to prevent unauthorized personnel from entering the work area—such as using warning signs and cordoning off the work area with barrier tape.
4. — gantry legs must stay vertical or plumb  
— no horizontal force on gantry  
— make sure rigging remains vertical
5. — off-level track beams  
— misaligned track beams  
— horizontal forces on header plate during stand-up or lay-over of load  
— unequal deflection of track beams  
— uneven raising or lowering of jacking legs  
— external forces such as wind or heavy equipment vibration  
— load swing while moving  
— off-centre load bearing on header plate
6. Fill in the missing word or words in the following incomplete statements.
  - a) A useful means of monitoring the rate of extension or contraction of each leg is to mount a **tape measure** on each.
  - b) When moving a load with a gantry system, as with all heavy rigging, always **move slowly**.
  - c) Always keep the load as **low** as possible.
  - d) Constantly monitor the **pressures** in the **hydraulic** system and in each jacking leg if they have independent hydraulic systems.
  - e) If there is any sign of a problem during a heavy equipment move with a gantry system, you should **stop**.

# Overhead Cranes

Overhead cranes are generally used for indoor hoisting activities. They are often installed for specific repetitive tasks. The capacity of these cranes is wide-ranging. Contractors may use them for specialized hoisting operations such as removing or installing major plant equipment.

Safe operation of overhead cranes requires operators to have the knowledge and competence to employ safe rigging practices. The rigger must rig the load to ensure its stability when lifted.

The following points highlight safety tips for overhead crane operation.

- Before use, ensure the crane is suitable for the planned hoisting tasks. Confirm it has appropriate travel, lift, and capacity.
- Visually and physically inspect the crane before use. Check for damage, wear, and proper operation of all functions.
- Confirm the load weight. Check the capacity of all equipment including the hardware, rope, and slings. *Do not exceed these capacities.*
- Select the right sling for each lift. Inspect slings and other rigging hardware before use for wear, stretch, or other damage. Do not use damaged or defective slings. Use softeners around sharp corners. Do not splice broken slings.
- When communicating with a crane operator, use clear, agreed-upon signals. Except for the stop signal, the crane operator should follow instructions from only one person – a designated signaller. Where a wired or remote controller is used, the operator should become familiar with all of its functions before lifting the load.



- Warn all people in the load lift area before starting the lift. Ensure that the path of the load is clear of persons and obstructions. Do not lift loads over anyone.
- Centre the crane hoist over the load before hoisting to prevent swinging of the load.
- Slide the sling fully onto the hoisting hook and ensure the safety catch is closed. Do not load the hook tip or hammer a sling into place.
- Secure unused sling legs. Do not drag slings or leave loose materials on a load being hoisted.
- Keep hands and fingers from being trapped when slack is taken out of a sling. Step away before the lift is made.

## Caution

Ensure that the load is free to move. If a load is stuck and the crane begins or continues to lift, it may reach its full capacity quickly. There may be little or no warning of this condition and rigging components may fail.

- Move the load and controls smoothly. Minimize load swing.
- Walk ahead of the load during travel and warn people to keep clear. Use a tag line to prevent rotation or other uncontrolled motion. Raise the load only as high as necessary to clear objects. Do not ride on hook or load.
- Set loads down on blocking, never directly on a sling. Do not pull or push loads out from under the hoist.
- Do not leave the load (or the crane) unattended while the load is suspended.
- Where crane operation by other personnel must be restricted, employ lockout and tagging procedures.
- Store slings off the floor in a clean, dry location on hooks or racks. Do not leave slings, accessories, or blocking lying on the floor.

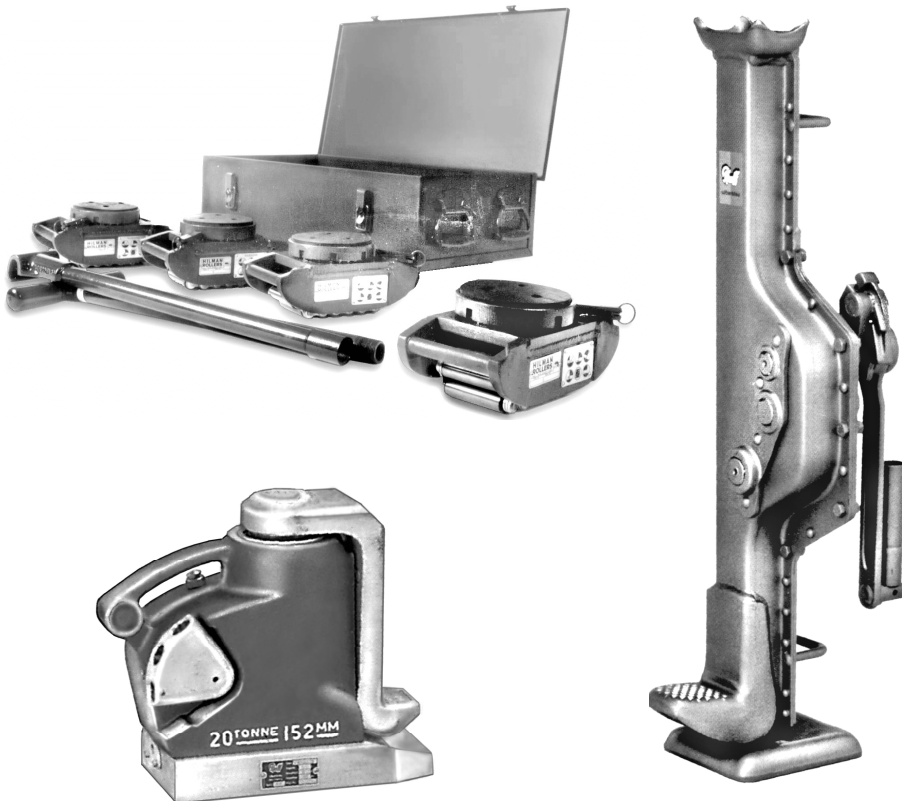


# Jacks and Rollers

## 1. INTRODUCTION

Sometimes large and heavy loads must be moved and placed with pinpoint accuracy. Cranes may not have the capacity or be available to reach the point of location. Jacks and rollers are two types of moving systems commonly used in such circumstances.

Safety has to be first and foremost in planning work involving large or heavy loads. A mishap can result in catastrophic failure of the whole rigging system and possibly the injury or death of workers. Use and maintain all equipment in accordance with manufacturers' recommendations.





## 2. JACKS

While there are a great many types of jacks, the mechanical jack and heavy-duty hydraulic jack are two types commonly used in construction.

### MECHANICAL JACKS

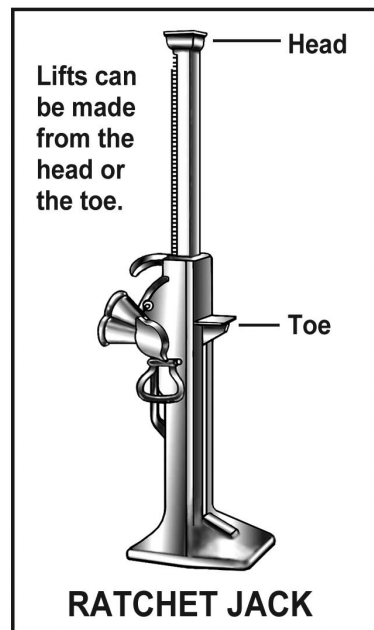
Mechanical jacks work on the same principle as jacks found in some automobiles. Mechanical jacks are usually limited to capacities under 20 tons because of the physical effort required to raise such a load. They do, however, have a much longer travel than hydraulic jacks and can therefore lift loads higher without having to re-block. Most mechanical jacks have a foot lift or “toe” near the base for lifting loads that are close to the ground. Lifts can be made from either the “head” or the “toe” of the jack.

Two types of mechanical jacks are prevalent in construction, the *rack and pinion* type and the *ratchet* type. These jacks are sometimes called toe jacks or track jacks.

*Ratchet jacks* require a removable handle.

Avoid leaning over the handle. A sudden release of the load, or release of the hand force on the bar could result in a sudden violent upward movement or release of the bar. Stand to one side. Do not release the speed trip lever when under load. The speed trip lever is to be used only for dropping the rack bar under no load.

Ensure the mechanisms are free of grit and rust. Lubricate only those parts recommended for lubrication with a manufacturer-approved lubricant. Do not lubricate the tooth side of the rack bar.

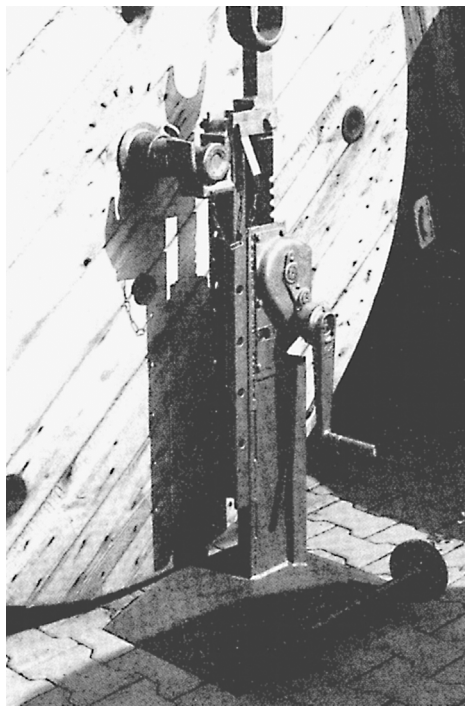


The rack bar should always be greased, except on the toothed side

## Jacks and Rollers

*Rack and pinion mechanical jacks* incorporate a crank operated, gear lift design. Lifting and lowering is performed by turning a safety crank which operates the spur gears, raising or lowering the toothed rack depending on the direction you turn the crank. Reduction gears are always engaged, allowing for smaller lift increments than is typical of ratchet-type jacks.

Ensure that the gearboxes on your jacks are lubricated periodically in accordance with the operating instructions. Do not lubricate the brake.



**Rack and Pinion Jack**

**Before placing any jack under load, become familiar with its operation by reading the manufacturer's instructions.**

Operate the jack without a load to ensure that all mechanisms work properly. Inspect jacks before use for signs of damage. Check the jack before use for

- wear
- improper engagement of pawl and rack
- excessive lubricant
- cracked or broken rack teeth
- damage to housing
- bent frame.

Lifting jacks must be equipped with a positive stop to prevent over-travel or, if a positive stop is not present, an over-travel indicator. A lifting jack must have its rated capacity legibly cast or stamped on it in a place where it can be readily seen. Confirm the load to be raised is within the capacity stamped on the jack and the lift distance is within the jack's stated travel range.

When you're ready to lift, ensure that the jack is firmly supported on a flat stable surface, that the jack is secure, and that it's located directly under the load. Do not use extensions or "cheaters" on the handles supplied with jacks. If you need cheaters, the jack is overloaded. Verify that there is enough room for the lever bar to travel through its operating range.

During lifting, follow the load with cribbing or blocking whenever possible. Lift vertically, keeping the centre of gravity from shifting. When you're using multiple jacks, ensure that all the operators understand the procedures and signals to use. Ensure that the load is distributed evenly by working the jacks in unison with slow, coordinated strokes.

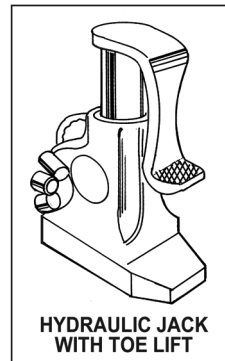
When not raising or lowering the load, remove jack handles (if applicable) and secure the load with cribbing or blocking.

**Uneven load distribution can result in**

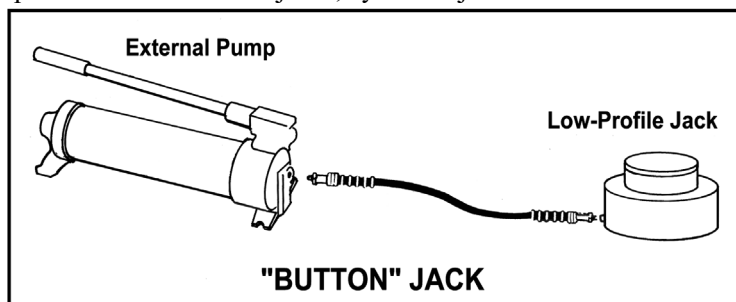
- a sudden shift of the load's centre of gravity
- overloading the jack
- the inability to hold or control the load or lever bar

## HYDRAULIC JACKS

Hydraulic jacks are very popular in construction because they are quite compact and can lift very heavy loads. They are readily available in capacities ranging from a few tons to 100 tons. Some specialty units have capacities up to 1,000 tons. Lift heights are usually limited to approximately 8 inches or less but some can go as high as 36 inches.



Hydraulic jacks are also available in low-profile models that can be positioned under a load that is close to the ground. Also known as "button jacks," these are useful for lifting a load high enough to get a regular jack in place. Like mechanical jacks, hydraulic jacks are available with toe lifts.



## Jacks and Rollers

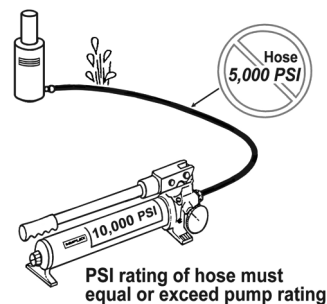
Selecting a jack is the first step for any lift. **Choose a jack that is rated for a capacity of at least 10% more than the load weight.** Where multiple jacks are used, each jack may not share the load equally due to the configuration of the load, or fluctuating jack heights may shift the load's centre of gravity as the load is raised.

Inspect the system before using it. Familiarize yourself with the operation of the equipment. Run each jack through a lift-and-release cycle prior to loading, and inspect each jack for

- cracked or broken cylinders
- hydraulic fluid leaks
- scored or damaged plungers
- damaged or improperly assembled accessories
- damaged threads or leaking fittings
- reservoir oil level
- frayed or damaged electric cords (on electric pumps)
- dirt or foreign matter in ports
- hose damage such as punctures, nicks, cracks, and kinks.

Pay careful attention to the hoses connecting pumps to jacks. Check the couplings, especially at the crimp. This area is prone to cracking and is often the weak link in the hose assembly. Check hoses for cracks, kinks, or other damage. Threads should also be checked for damage, wear, cross threading, and tightness. Some hoses have to withstand pressures up to 10,000 PSI. Do not use damaged or worn components. Do not use hydraulic jacks that are leaking oil. Turn them in for repair or replacement. Use only approved fluids in hydraulic jacks—never use water in a hydraulic jack as a temporary measure.

Don't use hoses that are unnecessarily long. Shorter hoses will leave the area less congested and reduce the chance of accidental damage. When making connections with quick disconnect couplings, ensure the couplings are fully engaged. Tighten threaded connections to prevent leaks without using excessive force that may distort the fittings.



Check for the capacity rating on the jack, and verify that the load will not exceed it. All components in the system should be rated for a pressure equal to or greater than the pressures generated by the pump.

The pump powering a hydraulic jack may be contained within the jack itself, or as a separate external power unit that can be operated at a safe distance from the load. Separate units may be hand-operated or electrically powered. Most external power units are equipped with pressure relief valves. One valve is typically factory-set at the absolute maximum pressure, while another will be adjustable to lower settings by the user. Make sure you are familiar with the operation of this safety feature. Use caution around pressure relief valves. The valve can discharge oil with considerable force—you can be seriously injured.

Most hydraulic jacks can be fitted with a gauge on the housing or at the pump to monitor hydraulic pressure. The gauges can be calibrated to measure the approximate load on the unit.

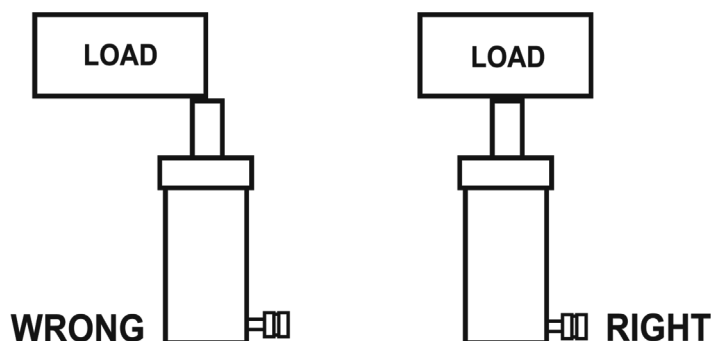
Wear personal protective equipment. At a minimum, wear safety glasses, a hardhat, a long sleeve shirt, and long pants. Failure of any component under pressure can send metal fragments and oil through the air. Avoid contact with a hydraulic leak—escaping oil can penetrate the skin and cause serious injury.

Support each ram in the jacking system on a solid, firm, non-sliding foundation that supports the full base of the jack. Because jack bases are relatively small, ensure that the floor or ground can withstand the high pressures often associated with jacking operations. Blocking or matting under the jacks will distribute the load over a greater area and reduce the bearing pressure. Centre the load on the lifting point. Ensure that the point on the load which contacts the ram can withstand the pressures it will take. Jacks should only be used in a true vertical position for lifting. Otherwise, side-loading can cause the piston to rub against the housing. If this happens, the piston will be scored and allow fluid to leak at the seal which may cause the jack to slip.

Where multiple jacks are used, space the jacks to distribute the load evenly between them as much as possible. Check valves should be incorporated into each branch to protect against pressure loss, and more importantly to prevent interflow between jacks.

Hydraulic jacks are generally not equipped with check valves. But it's good practice to install check valves in the hoses of an external pump. Alternatively, some hydraulic jacks have retaining nuts that can be screwed against the housing to hold the load for a short time.

## **CENTRE THE LOAD ON THE LIFTING POINT**



The handles on jacks or hand-operated pump units are designed so that you can get to the rated capacity and pressure with little physical effort. Do not use extensions or “cheaters” on the handles. If the load cannot be raised with the handle supplied, the jack is probably overloaded.

With all types of hydraulic jacks it is critical that no further force be applied after the ram has run its full travel. The resultant high pressure in the hydraulic fluid can damage the seals and, in the case of external power units, burst the hoses.

Place blocking or cribbing under the load as it's being raised. When placing blocking under the load, position your body to keep clear of the load and keep hands from getting between the load and the blocking. Do not rely on a jack as a permanent support—blocking or cribbing should be used whenever you need to hold the load for a length of time.

Never disconnect hydraulic hoses while the jack is under load. Release the pressure with the appropriate valves. Depressurized hoses will become less stiff and more flexible. If your pump has gauges, check them for the amount of pressure.

Be extremely careful when using hydraulic jacks around welding or corrosive chemicals. Sparks or acids can pit the ram or damage the hoses.

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## GENERAL

Both types of jacks are marked with load capacities on their nameplates and should not be loaded beyond these.

Lift loads a little at a time on one end only and follow closely with blocking. The load should be progressively blocked as jacking proceeds. Always jack loads at the **end** (as opposed to jacking the **side**)—this will make the lift more stable. The farther apart you place the jacks, the more stable your load.

Using blocks between the jack and the load can avoid damage to the surface. However, ensure the blocking is clean, dry, and will not slip. Ensure the floor or ground under the jack can withstand the high pressures created at the base of the jack. Blocking or matting under the jack can be used to distribute the load over a greater area. The base should be fully supported by a solid, firm foundation that will not slide.

Jacks should never be used at an angle.

Don't use jacks for long-term support—blocking and cribbing are much more stable. If you need to work under a load, or even reach under it while it is on the jacks, place safety blocking under the load as a precaution.

All jacks should be thoroughly inspected periodically, depending on how they are used. They should be inspected more frequently if the lifts approach capacity. Jacks sent out for special jobs should be inspected when received on site and when returned to the shop. Jacks subjected to high loads or shock should be inspected immediately.

Further information on jacking systems is contained in the chapter on *Rigging with Hydraulic Gantry Systems*.

### 3. BLOCKING

Blocking timbers are used to support heavy loads or as a foundation for jacks. They may be used individually or in tiers to form cribbing. Timbers should be large enough for the load and be a suitable type of wood. Often used are Douglas fir and white oak, and in some cases an exotic African hardwood (called “Ipe”) because of its durability and compactness.



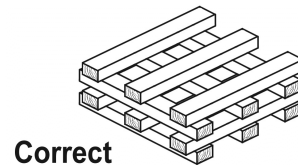
**Avoid pinch-points while blocking**

### 4. CRIBBING

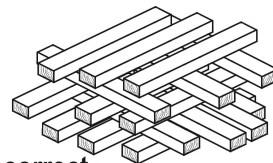
Cribbing gives you height and stability and reduces bearing pressure by distributing the load over a greater area.

The two main considerations in blocking operations are stability and bearing pressure. Make sure the timbers used for blocking or cribbing are long enough to distribute the load over a large enough area to provide sufficient stability. The height of the cribbing should not exceed the length of the timbers used. For example, cribs built with 4-foot timbers should be no more than 4 feet high. Cribbing and blocking must be

- sufficient to support the load
- set on firm, level ground or floor
- close together
- dry and free of grease or oil
- distributed over a large enough area to provide stability.



**Correct**



**Incorrect**

Blocking and cribbing should have enough area in contact with the ground or floor so that you don't exceed the bearing capacity and there is no chance of settlement. Rugged steel or hardwood mats can be used between the cribbing and the ground surface to distribute the load and reduce the bearing pressure. For extremely heavy loads, use solid layers of timbers for the cribbing. This will distribute the load over more timbers and prevent damage by crushing.



Centre loads on blocking and cribbing to ensure that the load is transmitted evenly to the ground.

Cribbing is frequently used with jacks for lifting loads in stages. Cribbing is built up so the jacks contact the pick up points in their lowered position. One end is then jacked just enough (2 inches for example) to allow a small piece of blocking to be inserted between the load and cribbing. The process is repeated at the other end. The jacks at the first end are then lowered and another piece of 2-inch blocking is placed under the jack.



After jacking the load another 2 inches, the 2-inch blocking can be replaced with a 4-inch timber, which forms part of the cribbing. This process is repeated until you reach the desired height.

Always jack the load one end at a time and follow closely with blocking. Never jack a load one side at a time, since this will be far less stable than jacking the ends.

If you need to work under a load, or even reach under it while it is on the jacks, place safety blocking under the load as a precaution.

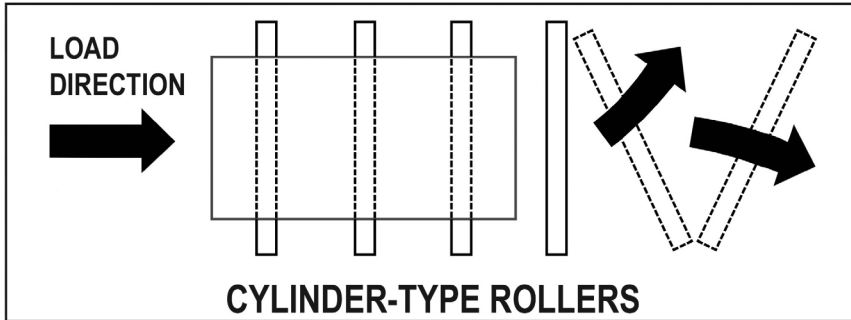
## 5. ROLLERS

Rollers can be used for moving loads horizontally or on slight inclines, provided the surface is firm and even. Rollers may be aluminum or steel round stock, heavy steel pipe, or a manufactured caster unit.

## Jacks and Rollers

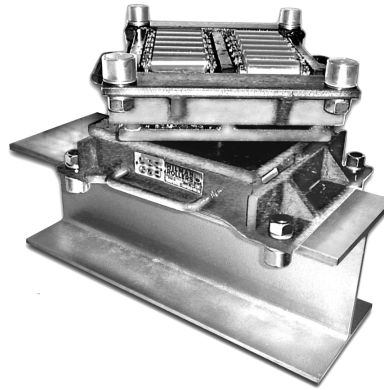
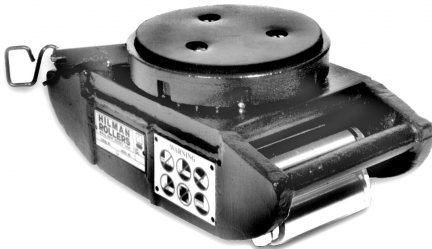
### CYLINDER ROLLERS

Cylinder rollers are useful for short distances or where the load will have to negotiate corners. Cylinder-type rollers are generally 2 to 3 inches in diameter. Cylinder rollers should be round, true, and smooth to minimize the force required to move the load. The rollers can be placed on angles to swing the ends of the load, allowing turns in tight areas.



### CASTER ROLLERS

Caster rollers are available in a number of configurations for flat surfaces, tracks, I-beams or channels. They create minimal friction and allow heavy loads to be moved with relatively little force.



Caster-type rollers have the advantage of not having to be continually repositioned in front of a load. They operate with caterpillar-like action and roll freely under load. These rollers are available with capacities ranging from 1 to 500 tons and can be equipped with swivel tops for turning and positioning loads.

Whatever type is used, each roller must be inspected before use. Check the following:

- Inspect for cracks and/or corrosion.
- Check for pin wear on ends.
- Check chain linkage for excess freedom of movement.
- Ensure chain and chain rolls are moving freely and all other parts are functional.

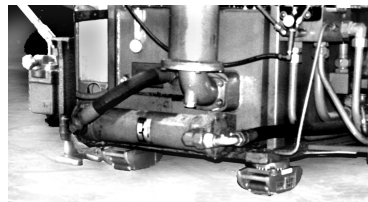
In addition, check the roller housing for cracks, corrosion, excessive wear, and tightness of bolts. You can apply a light oil or grease to keep the parts moving freely. Clean off excessive grease and dirt prior to use.



Before installing rollers, ensure that you won't exceed the load rating. Read and follow the manufacturer's operating instructions. The rolling or floor surface should be free of all debris and protrusions.

Although rollers have a low profile, use caution when raising loads. Top-heavy loads may tip when you're installing the rollers and during travel. Rollers should be aligned to reduce surface friction. Severe misalignment may cause the load to shift.

The load should rest upon the roller's entire load plate. The roller should be fixed to the load if there is a chance for contact to be broken or for the load to shift, and also if you'll be moving the load on inclined or uneven surfaces. As well, manufacturers offer various kinds of roller surfaces in order to accommodate varying load surfaces. For uneven load surfaces, you can use compression padding to maintain contact between the load and the roller. When elevations differ under the load, you can use wood spacers to fill the gap.



## Jacks and Rollers

High pressures can damage floors—don't fail to consider and anticipate these pressures. The bearing capacity of a floor is a function of its intended use, its size, and its general condition, among other factors. Confirm its capacity with the building owner or general contractor. Confirm that recently poured floors have had time to cure. The area should be carefully inspected at the planning stage of the move. Using more rollers and large steel or aluminum mats to distribute the stress can reduce bearing pressure on the surface. Make sure the joints in the mats or skids are staggered. You often need to assess the structure that supports the floors. You may need temporary shoring.

When deciding on roller capacity, remember that uneven surfaces can lead to uneven loading. Loads could be balanced on three or possibly two points.

**Always calculate at least 25% extra capacity when sizing rollers.**

Use the steering handles provided with caster rollers for steering only—they should not be used for towing.

### Moving on inclined planes demands extra caution

When there is not enough headroom for a crane, and winches and tackle systems are insufficient to lift a load vertically, you may need to erect an inclined plane to roll or skid the load up.

When moving loads on an incline, the most important aspect in rolling is controlling the load. Make sure that all equipment including slings and hardware is sufficient to handle the loads that will occur at each stage of the operation. Always attach a second means of restraint to the load—such as a tior or winch—to allow for the unexpected. Consider the possibility of shock loads when sizing winches or tiorors.

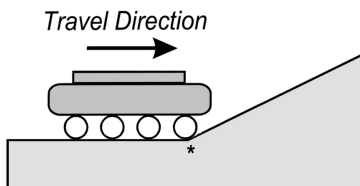
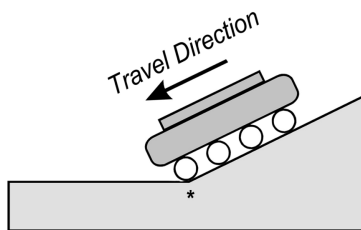
Generally, caster rollers are designed for flat surfaces, not for moving loads on an incline. While on an incline, the loading characteristics change. Horizontal forces can cause the load to shift on the caster much more easily. Floor surface changes are a particular concern. Point loading can occur where the caster is in contact with two different surface planes. For clarity, the explanations of point loading below will use the term “caster” to mean the whole body of the device, and “roller” to mean a single wheel upon which the device rolls.

## POINT LOADING

There are additional concerns you need to address if you're moving down or up an incline. Point loading occurs when all or part of the load is on one or more rollers (that is, when the load is on anything less than all the rollers). Point loading of the caster can happen where an incline meets a horizontal surface. Depending on circumstances, it is possible for only one roller to bear the total forces on that caster. To reduce stress on individual rollers, slow the movement of the load at the intersection of the two surfaces. A near stop of the load will permit a slow controlled transfer of the load forces to the different inclined surfaces and rollers.

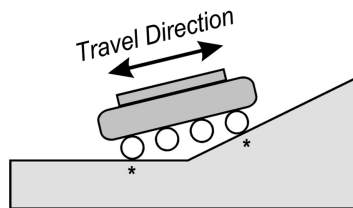
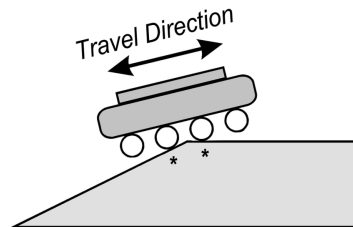
In addition to point loading the rollers, the load may lose contact with the caster. As the caster tries to follow the plane of the floor surface, it may fall away from or pivot on the load surface. You may need to attach the caster to the load to ensure that it maintains contact with the load. Or, the caster may be designed to pivot over the floor surface so that it maintains full contact with both the load and the floor surface.

### Impact on One Roller



**\* IMPACT ON LEAD ROLLER**

### Two-Roller Contact



**\* LOAD ON TWO ROLLERS**

Poor planning around point loading of casters may result in caster failure or damage. The caster can slip under or away from the load. Many scenarios could play out. Be cautious, plan for point loading, and go slow.

Another potential hazard occurs at the point where the caster travels from the upper elevation (such as a concrete floor edge or raised slab surface) to the built incline surface. At this point, the load will be at the very edge of the

## Jacks and Rollers

concrete and the weight of the load could cause the corner to break away. Also, the leading roller of the caster may fall into any gap between the incline surface and the concrete slab, or the incline may be pushed away from the slab by the force of the roller, creating a gap the roller could fall into. Examine the slab and incline, and take preventive measures to ensure a smooth transfer from slab to incline. Ensure that the supporting surfaces are capable of supporting the load and that any added support (such as steel plating) is in place.

It is also dangerous when the load's centre of gravity shifts. When the load has one end on the incline and one on the horizontal surface, the load's centre of gravity will typically shift toward the lower rollers. Top-heavy loads may tip over.

### **CALCULATING PULL REQUIRED**

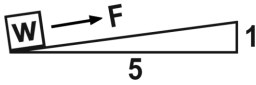
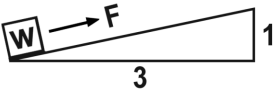
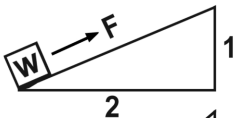
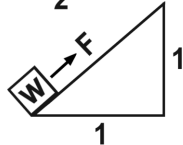
Horizontal moves require relatively little force to move. Generally, the force to move the load on a smooth, clean and flat surface, using rollers in excellent condition will be about 5% of the load weight. This is roughly the force required to overcome friction and start the load moving.

To calculate the amount of pull you need to move up an incline, use the following method.

**Caution:**

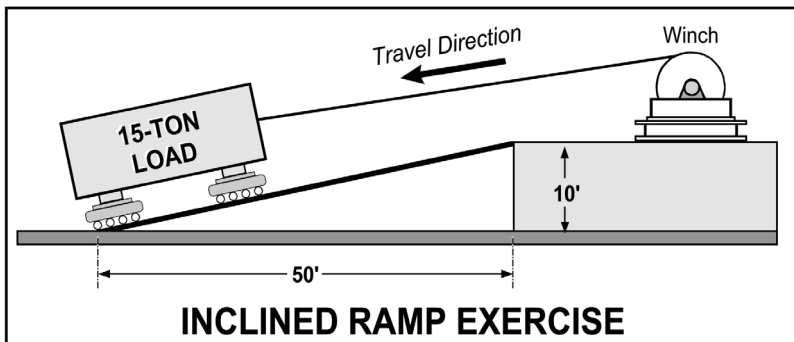
Though widely used because of its simplicity, this method provides an approximate value that is higher than the actual force required. The formula is more accurate for slight inclines (1:5) than steep inclines (1:1). Table 1 shows the difference between the actual pull required and the pull calculated. This simplified method is adequate for most applications. You may need more accurate calculations for large loads.

Table 1

Force Calculated by Simplified Method vs. Actual Force	
	Simplified Method $F = .250 W$ Actual Force $F = .245 W$ Error 2%
	Simplified Method $F = .383 W$ Actual Force $F = .364 W$ Error 5%
	Simplified Method $F = .550 W$ Actual Force $F = .492 W$ Error 12%
	Simplified Method $F = 1.05 W$ Actual Force $F = .742 W$ Error 42%

## EXERCISE

Calculate the force of the load in the following situation. A 15-ton compressor is to be lowered 10 feet. A ramp has been built with a horizontal run of 50 feet.



*Note: For illustration purposes, a second means of restraint has been omitted.*

### Formula

$F$  (total force) =  $W \times H \div L$  (lift force) +  $.05W$  (horizontal force or resistance)

$F$  = Force that the winch must overcome,  $H$  = Height,  $L$  = Length,  
 $W$  = Weight of Load

## Jacks and Rollers

The slope of the ramp is 10 divided by 50 or 1/5th; so the force required is then 15 tons times 1/5th, plus 5% of 15 tons to allow for friction.

This is equal to 3 tons plus .75 tons. Therefore the required pull is 3.75 tons.

With a winch, use its rated capacity for vertical lifting rather than its horizontal capacity so that you maintain an adequate margin of safety.

Table 2 lists some examples of coefficients of friction. Note that some of the combinations of materials have a considerable range of values.

Table 2

Examples of Friction Coefficients	
Steel on Steel	40 – 60%
Leather on Metal	60%
Wood on Stone	40%
Iron on Stone	30 – 70%
Grease Plates	15%
Load on Wheels or Rollers	2 – 5%

## 6. SAFETY ZONES

You must establish safety zones before jacks or rollers are put into operation. Here are two types of safety zones:

**Interior zone** – This includes areas where immediate hazards exist, such as underneath a raised load or downhill on a slope where the load is being raised or lowered. No one should enter this zone.

**Exterior zone** – This includes the area where workers involved in moving the load are working. Personnel not directly involved in moving the load should be restricted from this zone.

To keep *personnel not directly involved* in the work from entering the work area (exterior zone), the area immediately around the moving operation must be cordoned off. There must be signage with wording such as “Danger – Authorized Personnel Only.” The barricade (rope, fence, etc.) must be placed at a distance far enough from any hazard to eliminate the potential for injury to personnel outside the barricaded area. There must be enough signs on the



barricade so that at least one sign is visible from any point of the barricade. The other zone (interior zone) exists to keep **all** personnel out, and will ideally have similar signage with words such as “Danger – No Entry.” The requirement for signs is stated in the Construction Regulation (Ontario Regulation 213/91).

In addition, it is good practice to post information at the site describing the nature of the hazard. The information should also include the name of a person to contact for more information about the hazard and the procedures for entry, particularly if workers will be away from the site for some period of time.

The risk of injury is greatest during the moving operation. No one should be in an area where failure of a component would create a danger. For example, if a load is being raised up an incline, no one should be working or walking downhill from the load (in the path of a potential runaway load), or uphill alongside the rigging attached to the load (a snapped cable could whip back towards its anchorage). Workers involved in the operation should be positioned to minimize exposure to danger while handling the load.

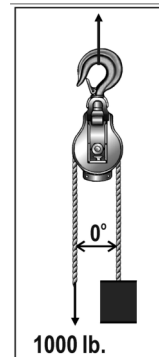
When a load is being raised up an incline with a tugger, there is “potential” energy stored in the tugger and rigging components. A failure could result in a violent and quick energy release, causing a sudden whipping of the line, or movement of other components or the load. Every person involved must be made aware of such hazards, and workers must avoid these areas when the tugger is operating. Prevent access to these areas when practical.

## 7. REVIEW EXERCISES

1. Which is the number-one issue in planning an operation involving moving large and/or heavy loads?
  - a) Load calculations
  - b) Route planning
  - c) Speed
  - d) Safety
2. List four things to look for when you’re inspecting a *mechanical jack* before use.

## Jacks and Rollers

3. List five things to look for when you're inspecting a *hydraulic jack* before use.
4. What should all jacks be clearly marked with?
5. Stability and floor bearing pressure are two major considerations in blocking operations. Specify four additional requirements applicable to cribbing.
6. Each caster must be inspected before use. List three things to check for.
7. How many means of attachment should be used on a load being raised up an incline?
  - a) One
  - b) Two
  - c) Three
8. The capacity of the floor or slab should be confirmed with the building owner or general contractor in the planning stage of a tugger operation.
  - a) True
  - b) False
9. What is the force exerted on the hook in the diagram?
  - a) 2000 lb.
  - b) 1500 lb.
  - c) 1000 lb.
  - d) 500 lb.
10. You must establish safety zones before jacks or rollers are put into operation. What are two types of safety zones?



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## ANSWER SHEET

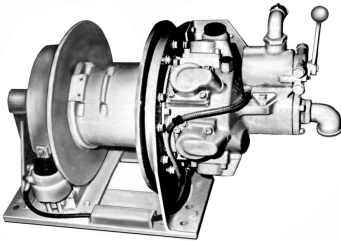
1. d) Safety
2.
  - 1) Wear
  - 2) Improper engagement of pawl and rack
  - 3) Excessive lubricant
  - 4) Cracked or broken rack teeth
  - 5) Damage to housing
  - 6) Bent frame
3.
  - 1) Cracked or broken cylinder
  - 2) Hydraulic fluid leaks
  - 3) Scored or damaged plungers
  - 4) Damaged or improperly assembled accessories
  - 5) Damaged threads or leaking fittings
  - 6) Reservoir oil level
  - 7) Frayed or damaged electric cords (on electric pumps)
  - 8) Dirt or foreign matter in ports
  - 9) Hose damage such as punctures, nicks, cracks, and kinks
4. Load capacity
5.
  - 1) Sufficient to support the load
  - 2) Set on firm, level ground or floor
  - 3) Close together
  - 4) Dry and free of grease or oil
  - 5) Distributed over a large enough area to provide stability
6.
  - 1) Inspect rolls for cracks and/or corrosion.
  - 2) Check for pin wear on ends.
  - 3) Check chain linkage for excess freedom of movement.
  - 4) Ensure chain and chain rolls are moving freely and all other parts are functional.
7. b) Two
8. a) True
9. a) 2000 lb.
10.
  - 1) Interior
  - 2) Exterior

# Tuggers

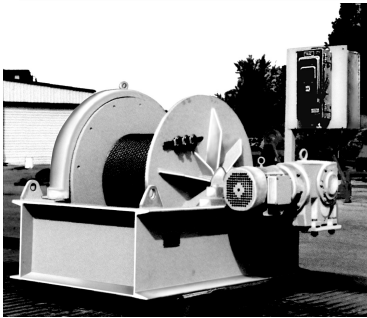
## 1. INTRODUCTION

Many trades in construction use tuggers (or powered winches). These are basically rope-pulling machines, often described as boomless cranes. The rope may be fibre or wire, depending on application. Compared to cranes, tuggers

- have lower operating costs
- weigh less and are more portable
- are smaller and better suited to tight spots – ideal for use inside buildings.



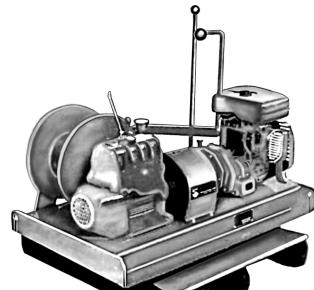
Tuggers can be used for hoisting (vertical lift) and hauling (horizontal or incline pulls). They may be powered hydraulically, electrically, by compressed air, or by internal combustion engine. The most common tuggers in construction are electric tuggers for light lifting and pulling and air-powered tuggers for heavier loads. Heavy applications use wire rope while lighter ones use fibre rope.



Tuggers are used in construction to

- pull electrical cables
- move heavy machinery
- lift vessels
- install structural steel.

Tuggers are often used with other rigging attachments. The most common attachments include snatch blocks, sheaves, and rollers. Snatch blocks and sheaves are used to change the direction of pull while rollers are used to support the load. Because tugger operations involve rigging, users must beware of rigging hazards.



This chapter is intended to foster **hazard awareness** and provide a general understanding of **safe tugger operation**. Personnel should know rigging and have completed training in rigging safety. Further job-specific planning and equipment training are required.

The Ontario Construction Regulation (O. Reg. 213/91) does not specifically address tugger operation. However, as a minimum, tugger operation should comply with the sections under “General Equipment” (sections 93-116). These sections deal with maintenance, inspection, worker competence, and overhead lifting. Training, capacity, and records are covered under sections 150-156. The rigging aspect of tugger operation must comply with sections 168-179. Please refer to the Construction Regulation for details.

## 2. HAZARDS

Hazards in tugging operations are similar to those in rigging operations:

- Poor communication
- Lack of training
- Overloading
- Failure of assembly
- Failure to incorporate a fall protection system
- Failure of anchorage points
- Undesired movement under load
- Brake failure under load
- Worker or equipment struck or crushed while handling the load
- Hand pinched or crushed at drum or sheaves
- Loose clothing or jewellery caught in drum or sheaves
- Electrocutation (with electrically powered tuggers)
- Carbon monoxide poisoning from combustion by-products
- Fire or explosion during operation in a combustible area or atmosphere
- Rope jumping off the drum
- Operational area not isolated from other workers or public during hoisting or hauling.

When a tugger is under load, it will have stored energy. In most cases, this stored energy is more than enough to move the load. For example, a tugger with a 5-ton pull capacity can create as much as 15 tons of energy in the system (larger loads develop larger energy forces). A failure anywhere in the rigging system can result in a violent whipping action of the line.

## Tuggers

In addition, the hazards of tugger operation are not confined to the tugger. It is absolutely essential to ensure that all rigging and all anchorage points can bear not only the load but any potential load they may be subjected to.

**All rigging components and anchorage points can be subjected to forces greater than the force being generated by the tugger itself.**

### 3. TUGGER SELECTION

#### LOAD CALCULATION

To plan a rigging application, all load information must be known. This involves calculating the total load. Total load determines the selection of the tugger, associated rigging accessories, and restrictions in travel route. When tugger selection is limited, total load is also used to determine the type of reeving needed on the line. Total load calculation must determine the maximum load the tugger will be subjected to and includes the following:

- friction—ground surface (horizontal pulls) and sheave
- weight of all rigging attachments (mainly on vertical lifts)
- load weight
- additional dynamic forces such as shock, wind, and snow or ice loads (in some cases, static loads may need to be estimated to free stuck equipment).

Calculation of load weight and potential dynamic forces involves adding up each factor and arriving at a total. Once the total load is calculated, the anchorage method for the tugger and the capacity of associated rigging can be determined. The direction in which the load will be moved (pulling or hoisting) must also be determined.

**Remember—the strength of your rigging assembly is only as strong as its weakest link.**

#### HORIZONTAL PULL VERSUS VERTICAL LIFT

Some manufacturers distinguish between hauling (horizontal pull) and hoisting (vertical lift) tuggers. This is because the factor of safety is different for each. Hauling capacity is based on a factor of safety of 3:1 while hoisting capacity is based on a factor of safety of 5:1. When ordering a tugger, tell the supplier whether or not the operation involves hoisting.



## HOISTING WITH CAPSTANS

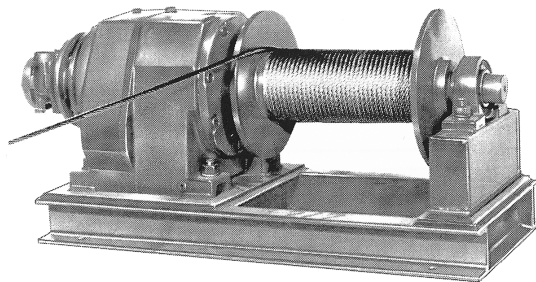
Due to pull of the load, capstans generally do not reverse. However, that does not prevent the load from reversing direction. The load is only held in place by the force applied to the fall line and the binding friction around the drum. Should the operator fail to maintain a pulling force on the fall line for any reason (such as a fall, distraction, heart attack, etc.) the rope can slip around the drum permitting the load to fall. For this reason, using a capstan for hoisting requires extreme caution.

## DIAMETER AND LENGTH OF ROPE

The total load weight calculation determines the minimum rope diameter required. The distance between the tugger and the load determines the length of rope required; however, if the lift involves blocks and multiple reeving, additional rope will be needed. These requirements must be compared with the tugger manufacturer's recommendations for rope size and rope construction for the particular tugger being considered. When determining the length of rope, take into account that there should be a minimum of three full wraps of rope on the drum at all times—i.e., the rope encircles the drum three times.

## DRUM SIZE

Once the length of rope is determined, the drum diameter and overall size can be specified. Ideally, there would only be one *layer* of rope on the drum. As the number of layers increases, there is a greater chance of crushing the bottom layer and pinching the ends. Ensure smooth, uniform wrapping to reduce this effect. The drum design and the type of rope influence



## Tuggers

the maximum number of layers you should put on the drum. Check the manufacturer's recommendations regarding the maximum number of layers. Try not to exceed three layers. Some rope types, because of their construction, are very susceptible to crushing. ASME Standard B30.7 requires a minimum of 2 inches between the top wrap and the edge of the flange to prevent the rope from winding off the drum. It is recommended to have at least 2 times the rope diameter or 2 inches (whichever is greater) for grooved drums, and 2 times the rope diameter or 2 1/2 inches (whichever is greater) for smooth drums.

### ROPE TYPE

Tuggers can be designed for either fibre rope or wire rope. The rope must be compatible with the drum in load capacity, size, and groove diameter. Tuggers equipped with wire rope hardware should not be used with fibre rope and vice-versa.

### DRUM SPEED

As the load increases, the hauling or hoisting speed tends to decrease. If the hauling or hoisting speed is too slow, it may be necessary to select a tugger with greater capacity.

Some manufacturers feature variable speed winches. This feature not only changes the line speed, but can also change the capacity of the tugger.

Where drum speed may be too fast, adding lines in the reeving of the rigging system will reduce travel speed of the load.

### BRAKING DEVICE

Brakes should be self-setting and capable of supporting all rated loads. The tugger should have sufficient braking power, complete with adjustments to compensate for wear and to maintain adequate force in springs where used. For hoisting, tuggers should always be equipped with a brake (usually electro-magnetic) that will activate automatically in the event of a power failure. A clutch or power-engaging device should facilitate immediate starting and stopping motions.

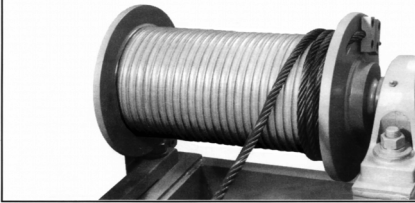


Gear reducers used to change drum speed can perform like a secondary braking system, though the reducer will not hold the load at a stop.

Lowering a load should not be done using only the braking system. Tuggers are typically designed to allow the load to be “powered down.” When “powered down,” the load is lowered under the power and control of the tugger in the same way it is hoisted. This feature eliminates the potential for the load to free-fall and is essential in hoisting operations.

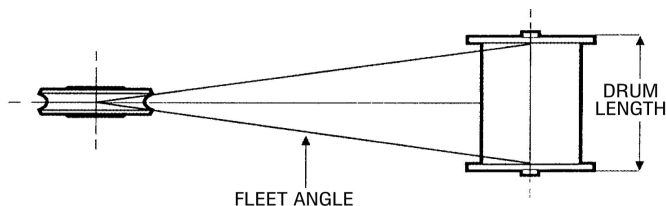
#### Grooved Drums

In installations where space is restricted, grooved drums are necessary to correct the fleet angle and ensure level winding. For critical push-pull type applications, grooved drums ensure that equal diameters are maintained during winding and unwinding operations. Grooved drums also eliminate excessive rope friction.



## GROOVED OR SMOOTH DRUMS

A grooved drum reduces rope friction. A more practical benefit of using a grooved drum is the ability to reduce the minimum distance to the first sheave and the ability to correct the fleet angle – a valuable asset in tight spaces. But this advantage only applies when the first layer of the rope is exposed.



## TUGGER SAFETY FEATURES

Some manufacturers provide tuggers with safety features such as

- anti-reversing mechanism
- guards on drive system
- guarded on and off switch
- guard on rope drum
- drive chain limiting internal force
- rope overlap prevention system
- tapered drum for capstan rope tension release
- pressure regulator
- emergency stop button.

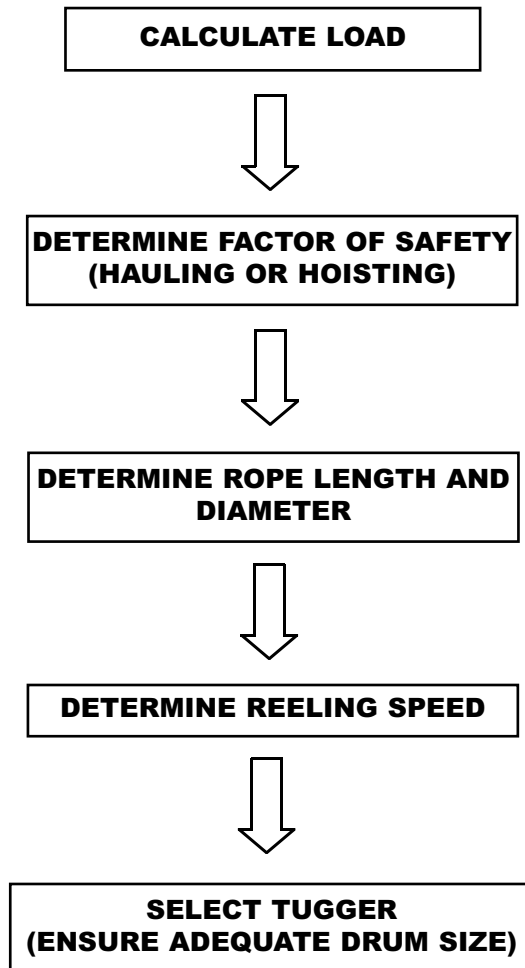
## Tuggers

Other safety features that can be installed include

- slack rope detector
- limit switches, such as a rotary limit switch on the drum that regulates the number of turns of the drum
- drum rotating indicator that provides a method of sensing the rotation of the drum when the operator cannot see drum or rope.

The chart below summarizes the main steps in selecting the right tugger for the job.

### TUGGER SELECTION PROCESS



## 4. RIGGING ATTACHMENTS

### LOAD REQUIREMENTS

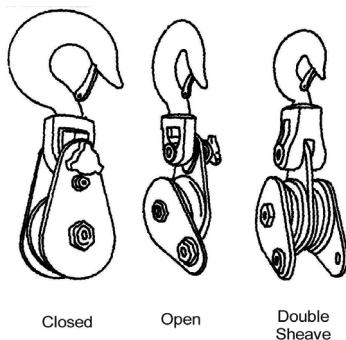
All rigging attachments must be able to hold the load they are subjected to. A safety factor of 5 to 1 should be used for all hardware in construction applications.

### WIRE AND FIBRE ROPE

Match the block and tackle with the type of rope used. Block and tackle designed for fibre rope has wider grooves than that designed for wire rope. In addition, blocks designed for fibre rope employ softer sheave material and, if used with wire rope, the sheave will deteriorate prematurely. When fibre rope is used with blocks designed for wire rope, the rope will fatigue quicker.

Two types of wire rope construction are widely used in rigging. For diameters less than 3/8 inches, galvanized aircraft cable is used (typically 7x19 construction). For heavier applications, a rope (such as 6x37 construction) with independent wire (or fibre) rope core (IWRC) is often used. A swivel connection to this type of rope is not recommended.

### SNATCH BLOCKS AND SHEAVES



Typical Snatch Blocks

The most common rigging accessories used with tuggers are snatch blocks and sheaves. Snatch blocks and sheaves typically come with a hook, swivel shackle, or eye. Some snatch blocks are designed for multiple reeving.



Plain Yoke

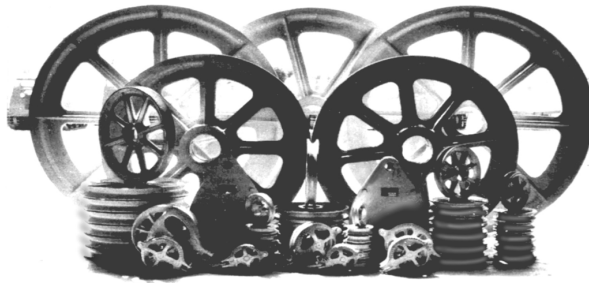
Snatch blocks and sheaves are used to change the direction of pull. When selecting blocks or sheaves, consider the type of rope used, the speed of the line, and the *D/d ratio*.

## Tuggers

### D/d RATIO

Other than changing direction of pull, the function of a sheave is to support the shape of the rope. The bending action of a wire rope as it runs through a sheave reduces the rope's strength. This reduction in capacity is proportional to the ratio of the diameter of the sheave (D) to the diameter of the rope (d)—the D/d ratio. As the sheave diameter is reduced, so too is the capacity of the rope. The sheave diameter must be compatible with the rope diameter. The minimum ratio of sheave diameter to rope diameter (D/d) is 15. In most cases, the groove size of a sheave is directly proportional to the diameter of the sheave. Wider (or larger) grooves are found on larger diameter sheaves.

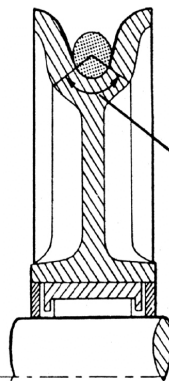
### SHEAVES



The use of sheaves changes the rope's capacity and the total friction force. The number of sheaves used is directly proportional to the decrease in rope capacity and increase in friction force. This is true whether the rigging arrangement uses a multi-part-line configuration or uses several sheaves throughout its layout.

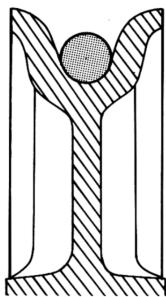
When the groove of a sheave is too large for the diameter of the rope, the sheave groove will not fully support the rope under load. As a result, the rope will tend to flatten. Continual flattening of the rope will eventually lead to premature failure.

When the groove of the sheave is too small, the rope becomes pinched between the sheave flanges, causing the rope to rub and wear the flange prematurely.

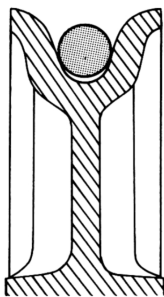


In properly matched ropes and sheaves the rope should be supported by the sheave over an arc of 120-150°

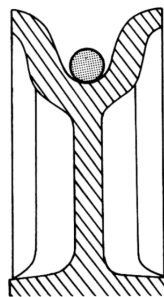
Check for proper sizing of the rope when selecting blocks and sheaves. The following diagrams illustrate the relationship between sheave and rope diameter.



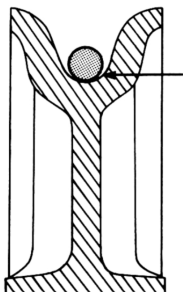
Properly matched  
Rope and Sheave



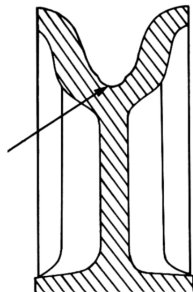
Rope is too large  
-- will pinch



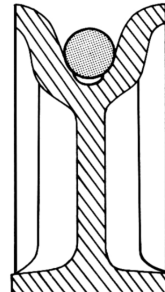
Rope is too small  
-- will flatten



If rope is too  
small for sheave,

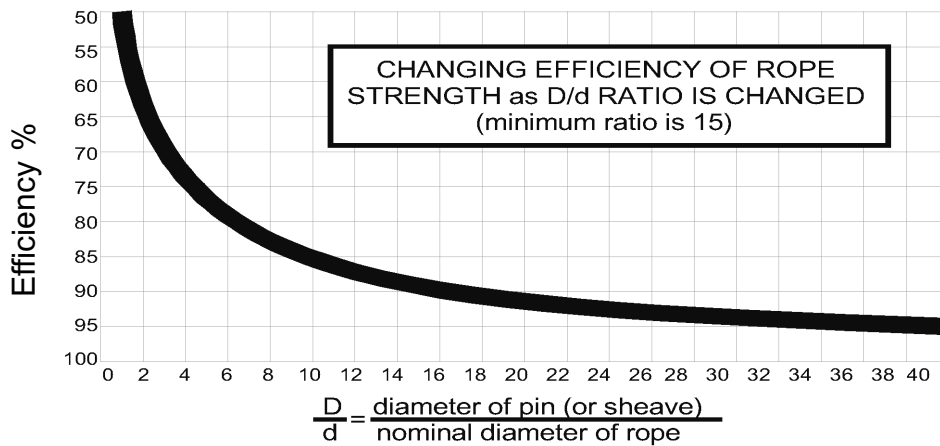


An undersized  
groove will be cut.



If another correctly sized  
rope is installed, it will be  
severely damaged by an  
undersized groove.

## Tuggers

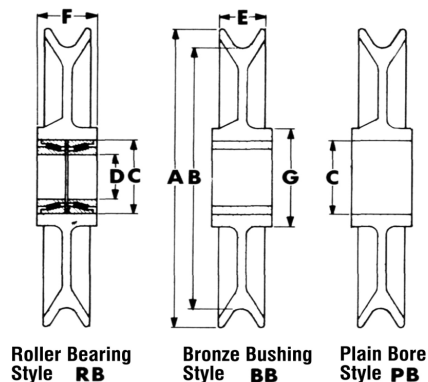


### SHEAVE BEARINGS

The speed of the line determines the type of sheave bearing suitable for the application:

- **plain or common bore bearings**—designed for very low line speeds and very infrequent use
- **self-lubricating bronze bushings**—used for slow line speeds with infrequent use
- **bronze bushings with pressure lubrication**—used for slow line speed and more frequent use at greater loads
- **anti-friction bearings**—used for faster speed and more frequent use at greater loads.

Some sheave manufacturers provide options for bearing selection with certain models.



## 5. SAFETY CONSIDERATIONS

### PLANNING

Safe completion of hoisting and rigging operations using tuggers requires careful hazard assessment. Before a tugger operation begins, all potential hazards must be identified. The operation must be planned and reviewed to ensure that tasks can be completed safely and potential hazards controlled.

### LOAD SHAPE, ORIENTATION, AND ROUTE OF TRAVEL

Load shape and orientation can affect handling of the load. If the load must be turned or rotated at any point during travel the following questions should be answered:

- Does the rigging set-up permit turning and rotating?
- Do other factors prevent turning or rotating the load (for example, vessels with fluid or gas inside)?
- Is there enough room to manoeuvre the load?

Once the load shape and orientation are determined, a travel path can be mapped out. Route of travel must be checked to ensure that it can accommodate the size and orientation of the load and will permit the load to be rotated or turned if needed. Before committing to any route, however, the **structural strength of the building** must be verified.

### STRUCTURAL STRENGTH OF BUILDING

The building must be able to carry all loads and all forces generated by the tugger operation. In most cases, this involves checking structural strength of floors, beams, trusses, and columns.

### FLOOR OR SLAB

Floors are supported directly by the ground or by columns and beams. In both cases, the floor must have enough compressive and bending strength to carry the load.

**When the tugger operation requires working on recently poured concrete floors, care must be taken to ensure that the concrete slab has had time to cure and reach full strength.**

The floor surface must be protected from damage by rollers or movement of the tugger. In some cases, it may be necessary to cover the floor with steel

## Tuggers

sheets. In such instances, the weight of the steel sheets must also be taken into account as part of the load on the floor slab.

### COLUMNS, TRUSSES, AND BEAMS

Columns, trusses, and beams are often used as points of anchorage. Their structural integrity and capacity must be verified before designating them as anchorage points. If there is doubt about the ability of the structure to take expected additional forces, get a written opinion from a structural engineer.

### SURROUNDING CONSTRUCTION ACTIVITY

When combined with tugger operations, other construction activity above or below the work area may create excessive loads on the building structure. Consult with the client, general contractor, and other subcontractors before starting a tugger operation. This will help to ensure that loads on the building structure are within safe parameters.

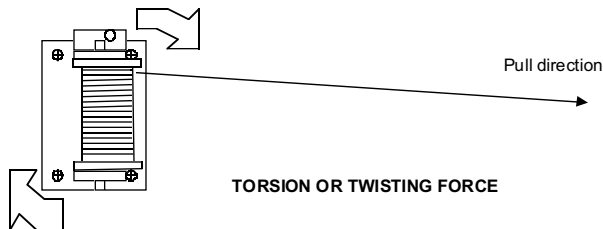
## 6. ANCHORING

Aside from knowing load weight and tugger capacity, method of anchorage is probably the most critical aspect of safe tugger operation. Always confirm the structural integrity of any anchor point before relying on it. When in doubt, get a written opinion from a structural engineer. Safety concerns over anchorage apply equally to the tugger and to rigging accessories such as sheaves and blocks.

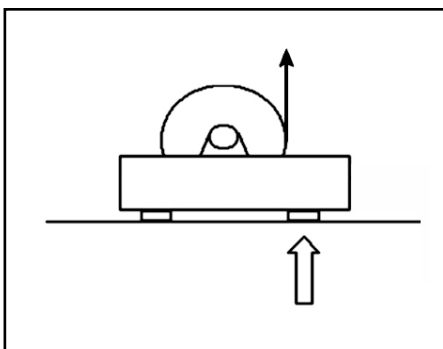
### FLOORS

Tuggers are often anchored to the floor when the location of the first sheave (relative to the tugger) does not vary much during the tugging operation. Most tugger manufacturers supply a template for anchor layout. The manufacturer will also specify the size and grade of anchor bolts to use.

The anchorage must be able to withstand the direct pull and torsion (twisting) forces when the tugger is under load. Similarly the bolts must be strong enough to prevent them from shearing off under load.



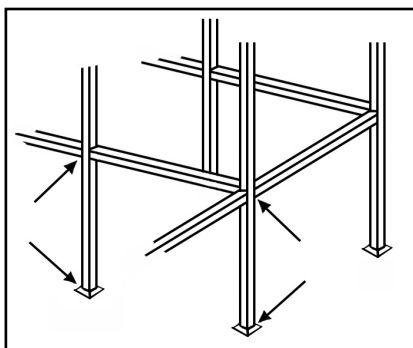




When securing to floors, it is important to verify the integrity of the floor to prevent the anchor from pulling out.

If job conditions necessitate reeving the tucker with a straight upward pull, the tucker needs to be secured to the floor carefully. To ensure hold, use only fasteners with a known pullout value of sufficient strength.

Although all anchors resist some force, the anchors on the pull side will bear most and should be selected accordingly. Blocks and sheaves are sometimes anchored to the floor, but more practical anchoring methods are usually available nearby.



ANCHOR POINTS ON  
COLUMNS AND BEAMS

## COLUMNS

Columns are generally not designed to withstand lateral forces.

Anchorage points should be placed as close to the base as possible, near a connection to a beam or other lateral support. Since columns are already under load, additional forces on the column could overload it, causing it to buckle.

The common way of anchoring to a column includes using

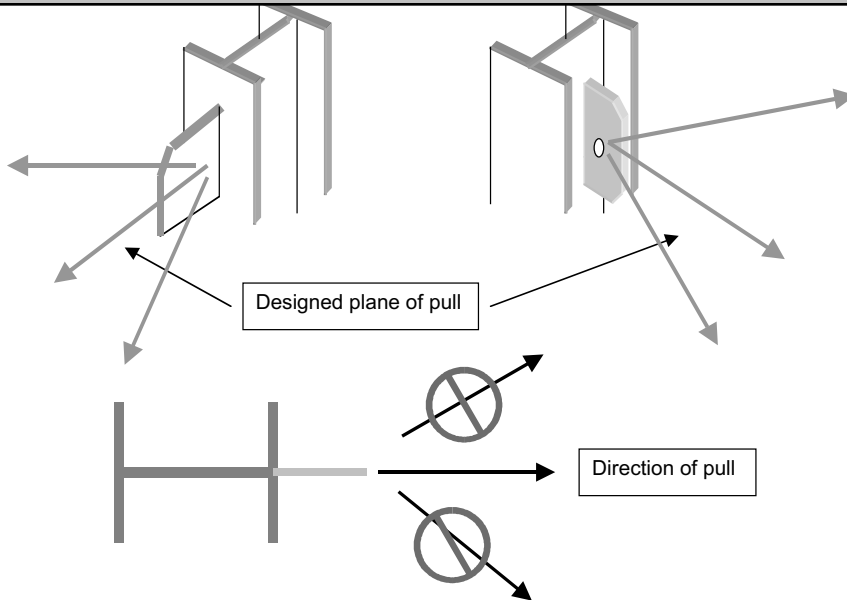
- 1) welded lugs or plate
- 2) choking a sling
- 3) framing.

### 1) WELDED LUGS (PLATE)

Welded lugs can be installed either on the web or on the flange of the column. Lugs welded on the web and in line with the flange are preferable since the column is designed to take forces in this direction. Welding the lug on the flange is less preferable because it will not withstand the same pulling force.

## Tuggers

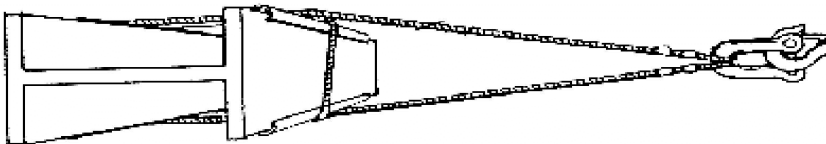
**Welding to structural steel requires a welding procedure and approval by a structural engineer.**



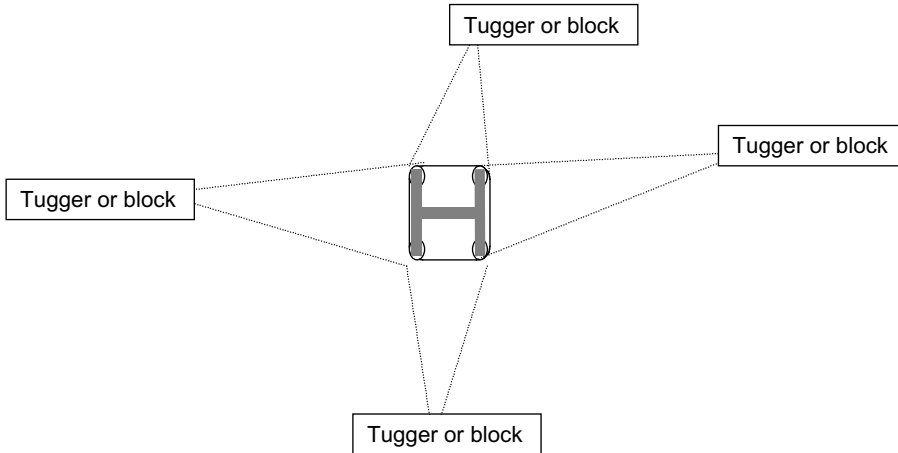
Welded lugs are designed to take a force in line with the same plane as the welded plate. Loading from any other direction should be avoided.

## 2) CHOKING

Choking a sling to a column is one of the simplest, quickest, and most common methods of anchoring. Most blocks are anchored this way for relatively light applications. Anchoring to columns permits easy movement of the block (or tugger) when there is a need to change the direction of pull.

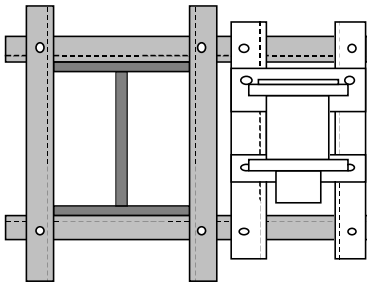


Where the first sheave from the tugger changes location, the line should be pulled slowly to allow the tugger to re-align itself to the new direction of pull. The choke on the column may need to be loosened to facilitate equal tension on both sides of the sling legs.



The integrity of the column to withstand forces from varying directions must be verified before the operation. Softeners must be used around the column to protect the choker. The floor must be relatively smooth to allow the tugger to slide to varying orientations.

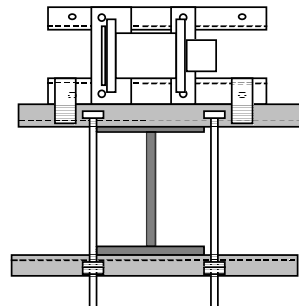
### 3) FRAMING AROUND COLUMNS



Framing steel members around a column is another method of securing tuggers.

Channel iron is the preferred choice (rather than angle iron or beams) since the shape provides a good combination of rigidity and lightness.

The illustration above shows a typical framing method, using four channels to box the column. The tugger is bolted to the “legs” of the frame. Another method uses two channels, framed tightly against the column by anchor bolts. The tugger is secured to the channel by means of two plates.



## Tuggers

### BEAMS

As with columns, anchorage points to beams should be installed closest to a connecting column or other vertical support to increase support strength and prevent bending of the beam. To withstand the additional forces, beams may need to be stiffened by welding a plate to the web.

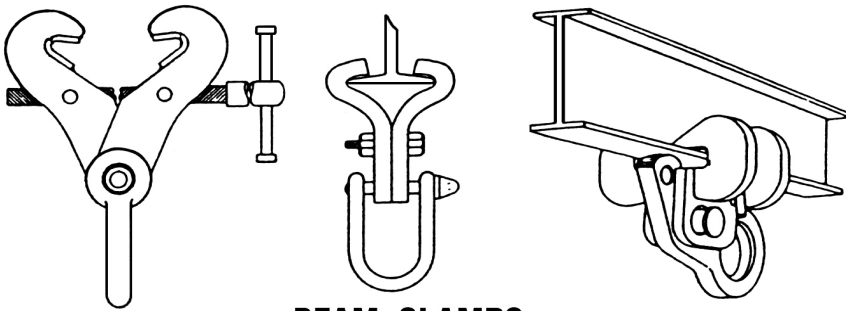
Securing methods for anchoring to beams commonly include 1) beam clamps, 2) beam trolleys, and 3) choking a sling.

#### 1) BEAM CLAMPS

The most common hardware for anchoring to a beam is a beam clamp.

**When using beam clamps, ensure that the pulling forces do not deform the beam or the clamp.**

Special care must be taken when clamping to beams with wide and thin flanges. These types of beams are not designed to take this kind of loading and will tend to deform. Using an undersized clamp can cause clamp deformation.



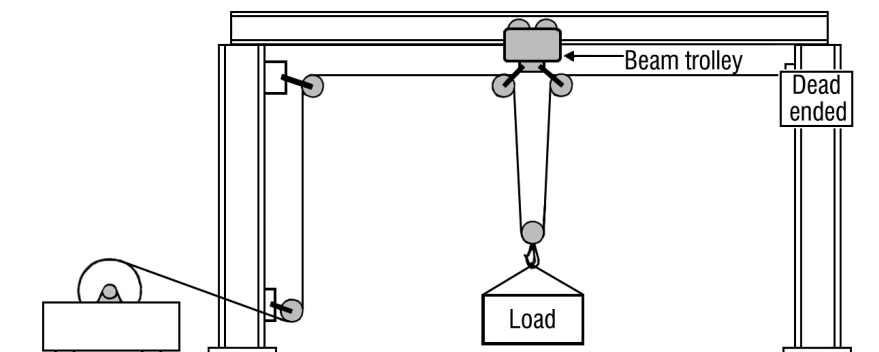
**BEAM CLAMPS**

The angle of pull at the clamp should be kept as small as possible to prevent the web from deforming and the clamp from slipping.

**Drifting a load is not advisable when beam clamps are used.**

Beam clamps should be centred on the flange and properly seated. Remember—the load rating on the beam clamp applies only to the clamp, not to the beam. The capacity of the beam must be determined separately.

## 2) BEAM TROLLEYS



Beam trolleys are beam attachments that can move horizontally along the beam's length. The arrangement above works similar to a gantry crane. It permits up-and-down as well as horizontal movement. In addition, the system uses, at minimum, a two-part-line system that slows the hoisting speed (compared to drum reeling speed) for safe application. An electric hoist could be attached to the beam trolley for similar results.

This arrangement can exert loading forces anywhere along the length of the beam. Ensure that load calculations are verified before using such a system.

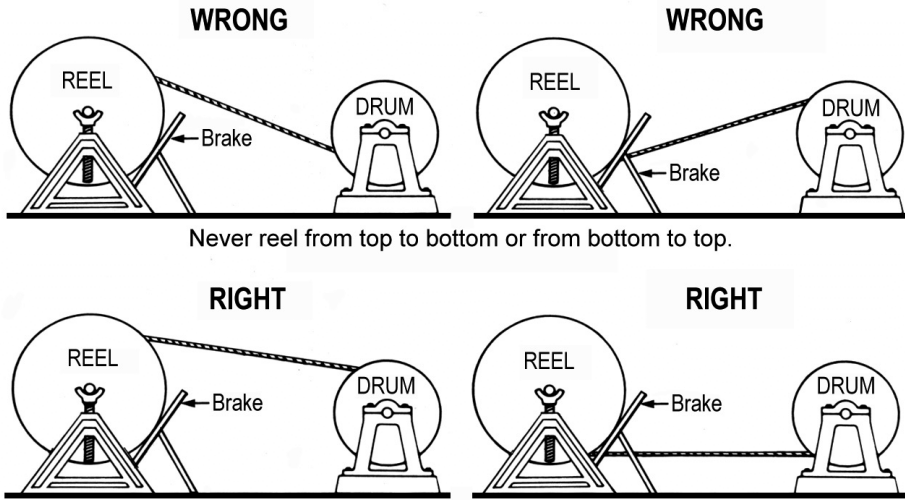
## 3) CHOKING

Choking around beams requires the same safety principles as choking around columns. The sling used for choking must be protected from sharp edges by softeners and should be choked (or otherwise secured) to prevent it from sliding along the beam because of horizontal pull from the load line.

# 7. WIRE ROPE HANDLING

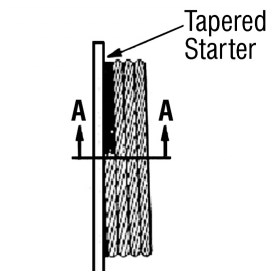
Handling any kind of rope can be hazardous. Handling wire rope presents particular hazards. Personnel should wear appropriate personal protective equipment such as gloves and use caution to keep clothing or gloves from getting caught in sheaves or drums during tugger operation.

## Tuggers

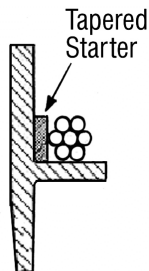


### WINDING ONTO DRUM OR REEL

When winding wire rope onto a drum or reel, make sure that its bending direction is maintained on the new reel (see diagrams above). When transferring rope from drum to drum, feed it from the top of one reel to the top of the other, or from the bottom of one reel to the bottom of the other. Applying tension to the rope is also necessary to achieve good spooling. A simple brake such as a plank, rigged to bear against the reel flanges, can provide ample rope tension for winding.

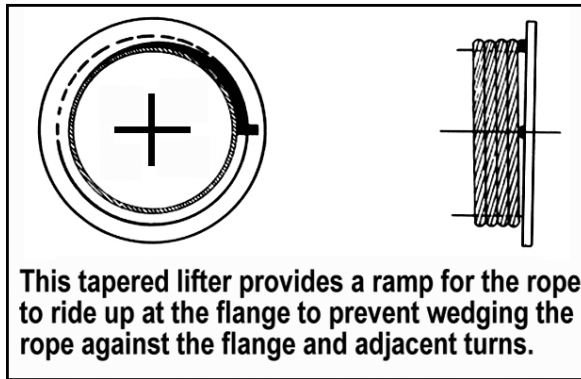


**VIEW of PART OF DRUM  
SHOWING STARTING PIECE  
TO ASSIST EVEN WINDING**

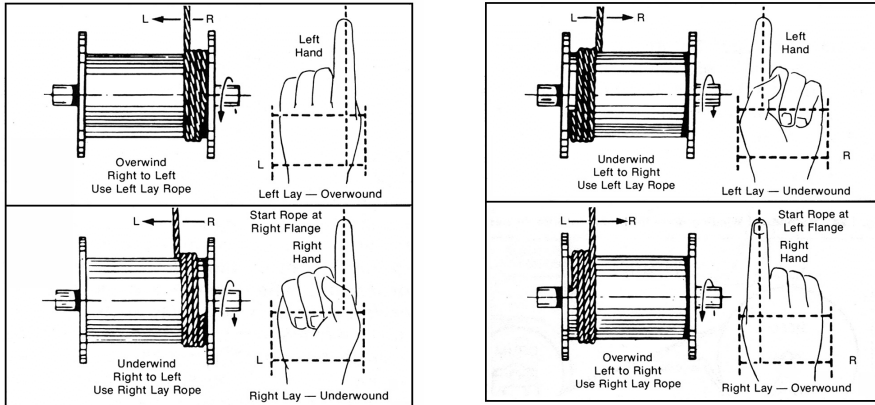


**SECTION A-A**

On flat-faced drums (as opposed to groove-faced drums), it is important that the rope winds in a straight helix at its proper angle. This can be accomplished by installing a taper to fill the space between the first turn and the flange (see diagram at left). It is important that the first layer on the drum be tight and true. Open or wavy winding will result in serious damage under multiple windings due to abrasion and wedging action between layers.

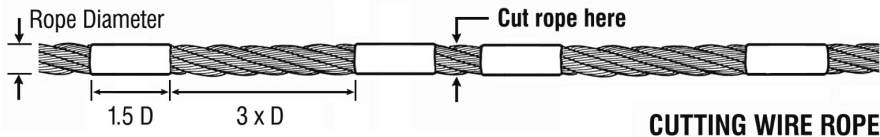


## LOCATING DRUM ANCHORAGE POINT



Most tuggers have an overwound configuration on the drum. The anchorage point on the drum depends on the lay of the rope. Check the diagram above for proper anchorage point for right and left lay rope.

## CUTTING WIRE ROPE



Each side of the rope should be properly seized before cutting (see above). Seizing is ideally done using soft iron wire.

## Tuggers

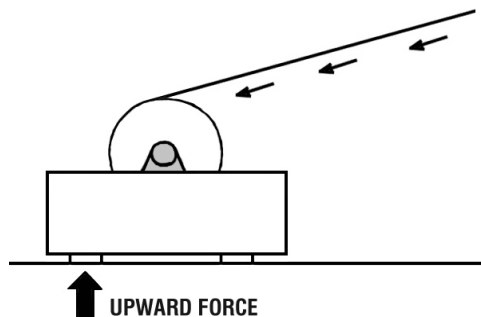
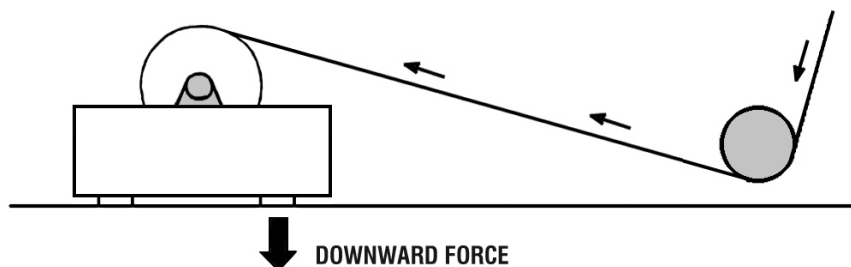
### DEAD-ENDING

Always use forged or stainless steel clips made for hoisting and rigging applications. Do not use soft malleable clips. Follow manufacturer's instructions for the correct number of clips, spacing between clips, and torquing requirements. Please note that wire rope clips need to be re-torqued after loading, especially when using new rope. Check tightness of wire rope clips after each shift.

Although most tugger operations use wire rope clips for dead-end termination, other methods such as wedge sockets can be used. When using wedge socket connections, ensure that the live end of the wire rope is left unclipped.

## 8. OPERATIONAL SET-UP

### DIRECTION OF PULL



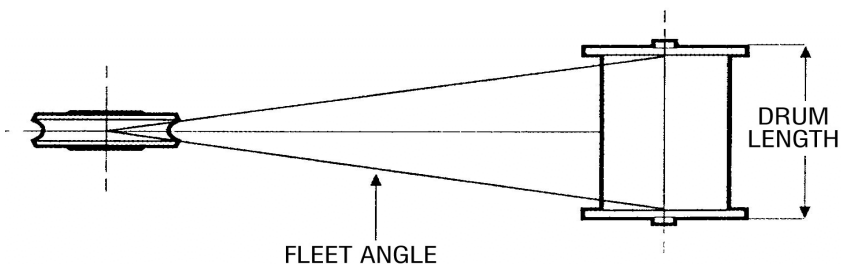
Whenever possible, direction of pull coming to the tugger should either be parallel to the ground or slope downwards. When the pull is upwards, the force will have a tendency to lift the tugger up, possibly dislodging it from its anchorage. Regardless of the direction of pull, the anchors located on the side opposite to the direction of pull may bear most of the pull-out force. The

tugger will want to pivot on the leading anchors (those closest to the first pulley). Anchors must therefore be sized to account for this potential effect.



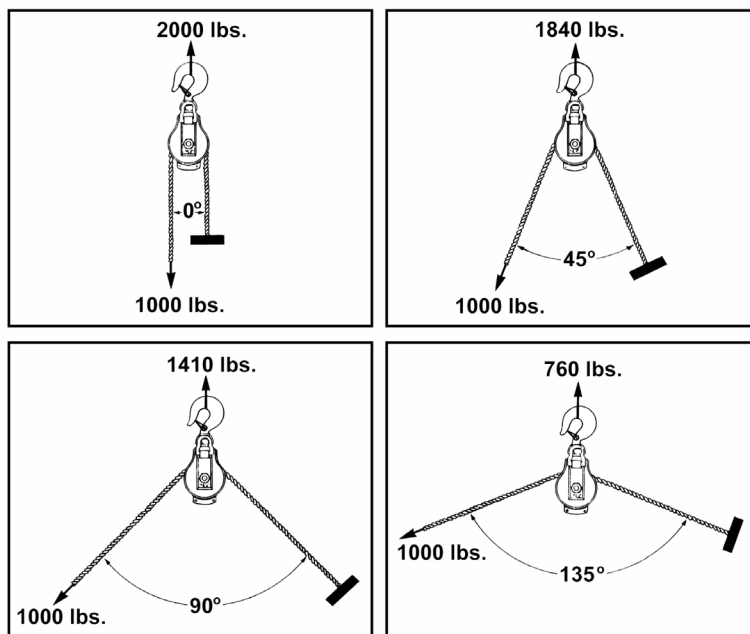
## DISTANCE TO THE FIRST SHEAVE

Generally, the minimum distance to the first sheave is 15 times the drum width. Other factors may permit some variation. For example, grooved drums can reduce the minimum distance to the first sheave, and correct the fleet angle. See page 60, "Grooved or smooth drums." Check with the tugger manufacturer for the actual minimum distance. The first sheave should be located in line and square with the centreline of the winch.



## PULLING ANGLE

Changing the angles of a pull can dramatically change the force exerted on the anchor point. As the following figures illustrate, reducing the angle between the load line and the pull line increases the load on the anchor. A  $0^\circ$  pulling angle doubles the load force on the anchor.

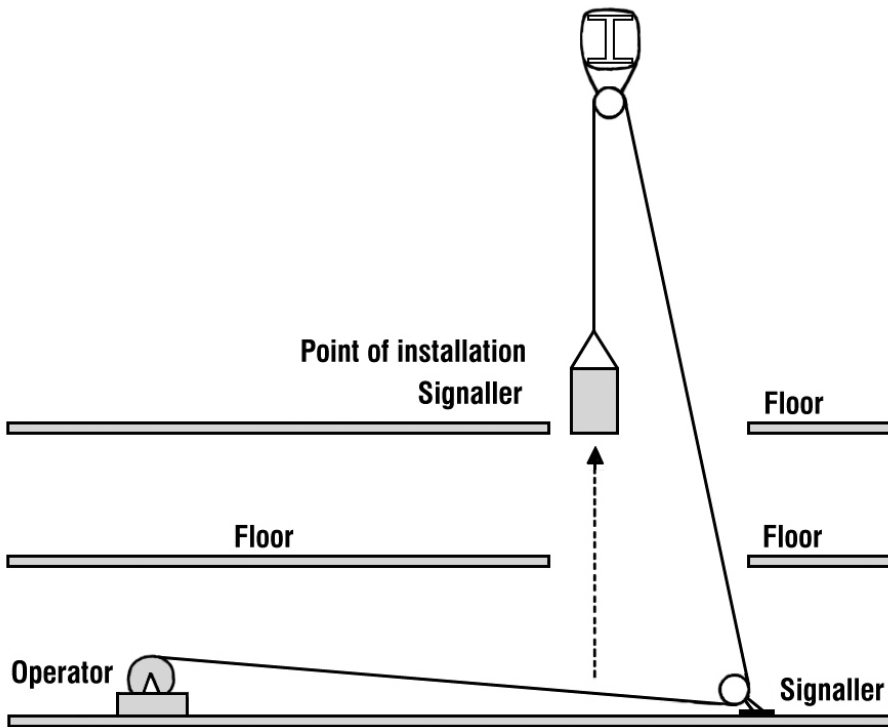


## Tuggers

When the operation involves load drifting, choose a higher point to attach a block or sheave. Higher pick points reduce the lateral forces needed to drift a load, therefore increasing control, travel distance, and ease in drifting loads.

## 9. COMMUNICATION

An appropriate method of communication must be pre-arranged between all personnel involved in the tugging operation. When the material being pulled or hoisted cannot be seen by the tugger operator, a radio or other continuous and reliable form of communication must be provided.



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## 10. SAFETY ZONES

Safety zones must be established before the tugger is put into operation. The following are two examples of safety zones:

*Interior zone*—This would include areas such as where the load is being landed. No personnel should enter this zone.

*Exterior zone*—This would include the area where workers involved in the tugging operation are working. Personnel not directly involved in the tugging operation should be restricted from entering this zone.

To keep *personnel not directly involved* in the work from entering the work area (exterior zone), the area immediately around the tugger operation must be cordoned off and must be signed with wording such as “Danger – Authorized Personnel Only.” The barricade (rope, fence, etc.) must be placed at a distance far enough from any hazard to eliminate the risk of injury to personnel outside the barricaded area. Signs must also be placed on this barricade in sufficient number so that at least one sign is visible from any point of the barricade. The other zone (interior zone) is in place to keep **all** personnel out, and should have similar signage with words such as “Danger—No Entry.” Signs are required under section 44 of the Construction Regulation.

Additionally, it is good practice to post information at the site describing the nature of the hazard and the name of a person to contact for more information about the hazard and for entry, particularly if workers will be away from the site for any period of time.

The risk of injury is greatest during the tugger operation. No one should be in an area where failure of a component involved in the operation would create a danger. For example, if a beam is used as a point of anchorage, no one should be working or walking under the beam or the rigging attached to it. Workers involved in the tugger operation should be positioned to minimize their exposure to danger while handling the load.

When a tugger is under load, “potential” energy is stored in the tugger and the rigging. Failure of any component can result in a quick, violent release of energy causing a sudden whipping of the line, movement of other components, or movement of the load. Therefore every person involved must

## Tuggers

be made aware of such hazards and warned to avoid areas where the tugger is operating. Access to such areas should be prevented wherever practical.

# 11. INSPECTION

Inspect the tugger and rigging before use. Ensure the integrity of all components before the operation gets under way.

## TUGGER POWER SOURCE

- Electrically powered units—check the power cord.
- Gas-powered units—check the gas tank for fuel and for leaks; make sure ventilation will be adequate to remove products of combustion and vapours from the fuel tank.
- Air-powered units—check hoses and fittings; make sure connections are secure and cannot work loose. Ensure hoses are out of the way of traffic and protected from damage. Ensure there is an uninterrupted air supply at a pressure high enough to power the tugger.

## TUGGER BRAKES

Brakes should be checked on the first lift:

- Lift the load slightly off the ground and apply the brakes for a few minutes.
- The load should remain in position.
- Any load movement may signal that the brakes are failing or that the tugger is too small for the load.

## ROPE

- *Wire rope* must be checked for wear and defects. Look for kinks, birdcaging, knots, and broken wires in strands.
- *Fibre rope* must be inspected for tear in the weave and any other signs of damage or degeneration. With fibre rope, it is recommended that a new rope be used at the start of a new project.

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## **ANCHORAGE**

All anchorage points must be inspected before use. During use they must be inspected for signs of deformation or movement. If such signs are detected, the tugging operation must cease immediately. The anchorage point should not be reused until it has been re-evaluated and shown to be safe.

Inspect anchor bolts and nuts for signs of loosening or shearing. Check for signs of loose concrete around the anchorage.

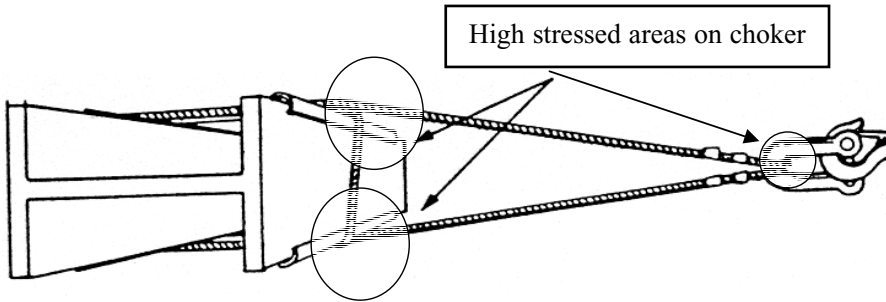
When anchorage involves a plate welded to a column, check for cracking around the weld and signs of the plate bending. Make sure the column has not moved or deformed. Check the hole in the lug for signs of fatigue.

When beam clamps are used, inspect clamps and beam for deformation. Check that the clamp has not moved from its original position.

When using a choker on a beam

- check for horizontal movement
- make sure that softeners around the column remain in place
- make sure that the sling is in good condition
- check for kinks
- look for broken wires in strands
- pay particular attention to areas that have been subjected to sharp bends (these areas are under the greatest stress).

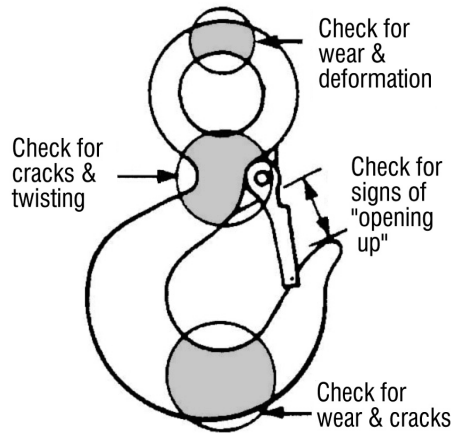
## Tuggers



### SHACKLES AND BLOCKS

Blocks must be inspected for sheave wear and seized bearings. Before using blocks that can be opened, ensure that the pins are in place. Blocks equipped with a hook and/or shackles must be inspected for hook and shackle wear and deformation.

Hooks must have a working safety latch with positive lock. Shackle bolts or pins must also be inspected for tightness.



### WORK AREA

Before and during the tugger operation, safety zones must be respected. Ensure that barricades and warning signs are in place and that signallers are in position.

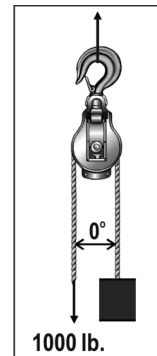
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## 12. REVIEW EXERCISES

1. What forces could be exerted on rigging components where a 5-ton pull capacity tugger is being used?
  - a) 2.5 tons
  - b) 5 tons
  - c) 10 tons
  - d) 15 tons
2. When hoisting with capstan winches, what is required?
  - a) Wire rope
  - b) Gas power
  - c) Extreme caution
  - d) Cannot be used
3. In construction applications, all rigging attachments require a factor of safety of:
  - a) 2 to 1
  - b) 3 to 1
  - c) 5 to 1
  - d) 10 to 1
4. The D/d ratio describes:
  - a) The diameter of the rope to the diameter of the sheave
  - b) The diameter of the sheave to the diameter of the rope
5. The minimum D/d ratio is:
  - a) 5
  - b) 10
  - c) 15
6. Complete the following sentence.  
Rope diameter should be:
  - a) Just larger than the groove in the sheave
  - b) Equal to the groove in the sheave
  - c) Just smaller than the groove in the sheave

## Tuggers

7. Aside from the rigging hardware and the tugger, name at least two other things that may be subject to stress or weight from the tugger operation.
8. When using beam clamps, drifting a load is not advisable.
  - a) True
  - b) False
9. Ideally, the direction of pull off the tugger should be:
  - a) Slightly upward from the tugger
  - b) Parallel to the tugger
  - c) Slightly down from the tugger
10. Generally, the distance to the first sheave from the tugger should be no less than:
  - a) 10 times the drum width
  - b) 10 feet
  - c) 15 times the drum width
  - d) 15 feet
11. What is the force exerted on the hook in the diagram?
  - a) 2000 lb.
  - b) 1500 lb.
  - c) 1000 lb.
  - d) 500 lb.
12. List five things that must be inspected prior to beginning a tugger operation.





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## ANSWER SHEET

1. Any of a), b), c), or d).
2. c) Extreme caution
3. c) 5 to 1
4. b) The diameter of the sheave to the diameter of the rope.
5. c) 15
6. b) Equal to the groove in the sheave.
7.
  - 1) Floor or slab
  - 2) Columns
  - 3) Trusses
  - 4) Beams
8. a) True
9. c) Slightly down from the tugger.
10. c) 15 times the drum width.
11. a) 2000 lb.
12.
  - 1) Tugger
  - 2) Shackles
  - 3) Blocks
  - 4) Rope
  - 5) Work area

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## Notes

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## Notes

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## Notes

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## Notes

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ISBN 0-919465-78-1

DS035