National Safe Tractor and Machinery Operation Program

Tractor Safety

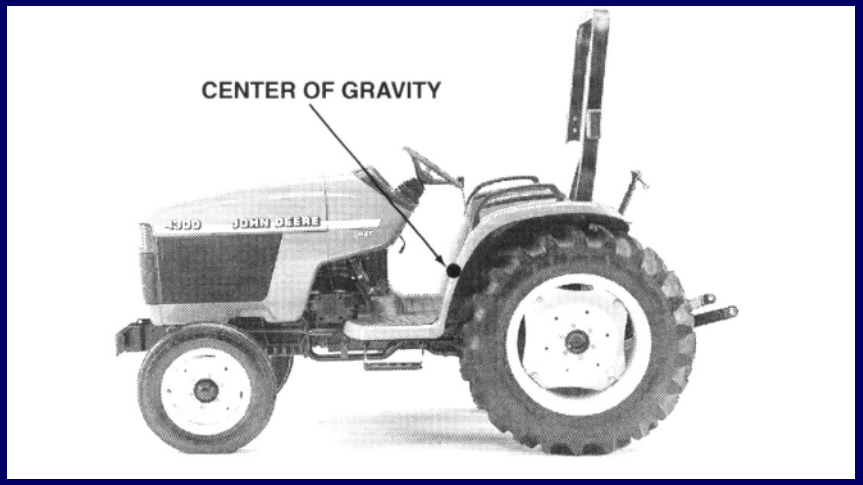
Task Sheets 4.12 – 4.14.1

Tractor Stability

- No other machine is more identified with the hazards of farming as the tractor.
- Nearly 50% of tractor fatalities come from tractor overturns.
- Tractors are used for many different tasks. Because the tractor is a versatile machine, operators sometimes stretch the use of the tractor beyond what the machine can safely do.
- The use of a rollover protective structure (ROPS) and a seat belt can save your life if a tractor overturns while you are driving.

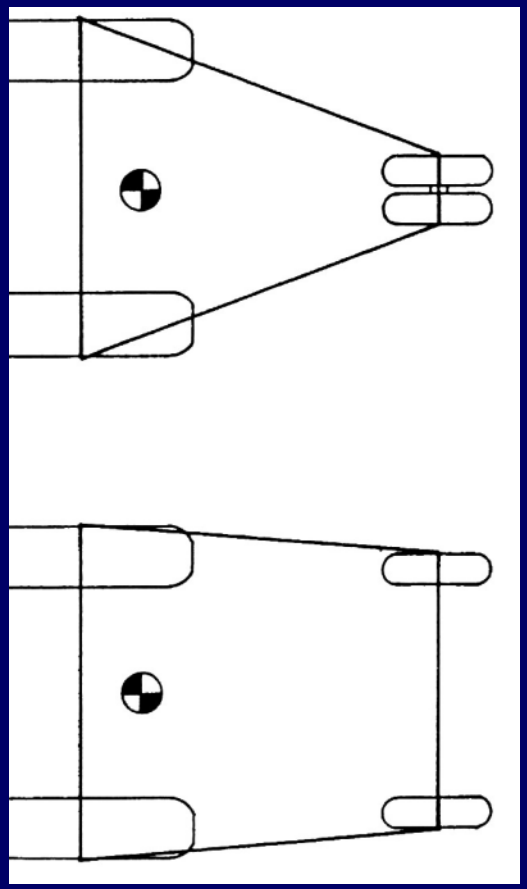
Tractor Stability

- Center of gravity (CG). A center of gravity is the point where all parts of a physical object balance one another.
- On a two-wheel drive tractor, CG is about 10 inches above and 12 inches in front of the rear axle.
- This figure shows the normal position of a tractor's CG.



Tractor Stability

- The CG is inside a tractor's stability baseline.
- Drawing a line to connect all the wheels of the tractor as the wheels set on level ground forms a tractor stability baseline.
- The line connecting the rear tire ground contact points is the rear stability baseline.
- The lines connecting the rear and front tire on the same side are the right and left side stability baselines.



Tractor Stability

There are two very important points to remember about tractor CG and stability baselines:

- The tractor will not overturn if the CG stays inside the stability baseline.
- The CG moves around inside the baseline area as you operate the tractor.
- A wide front-end tractor provides more space for the CG to move around without going outside the stability baseline.

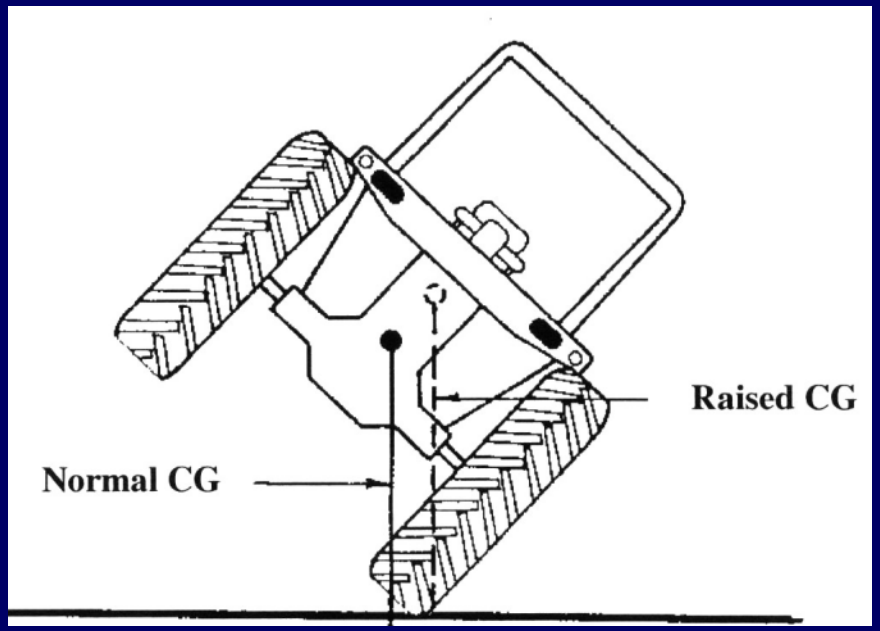
Tractor Stability

There are five main reasons why a tractor's CG moves outside the stability baseline.

- The tractor is operated on a steep slope.
- The tractor's CG is raised higher from its natural location 10 inches above the rear axle.
- The tractor is going too fast for the sharpness of the turn.
- Power is applied to the tractor's rear wheels too quickly.
- The tractor is trying to pull a load that is not hitched to the drawbar.

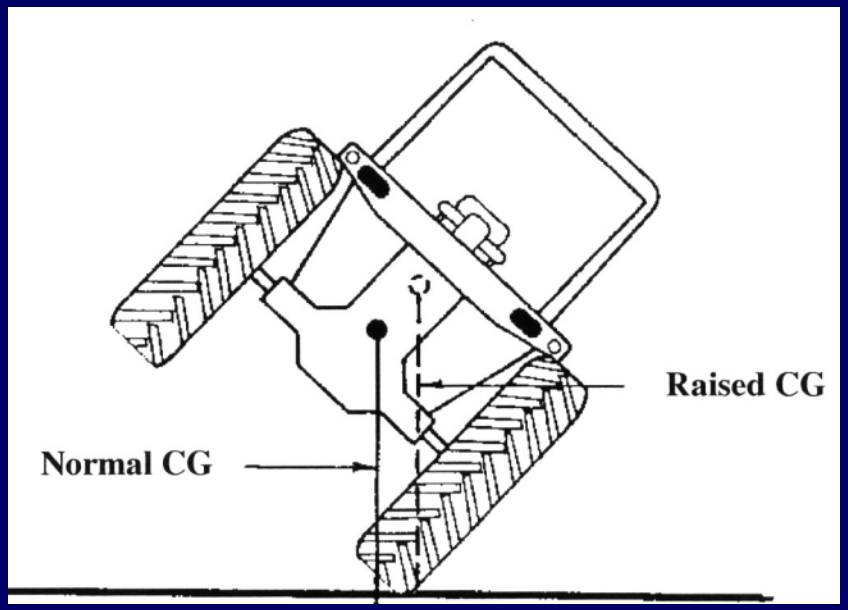
Tractor Stability

- When a tractor is on a slope, the distance between the tractor's CG and stability baseline is reduced.
- On steep slopes, the tractor is already close to an overturn.
- A small bump on the high side, or a groundhog hole on the low side, may be all that is needed for the tractor to overturn.



Tractor Stability

- A front-end loader or other attachment mounted on a tractor can raise the tractor's CG.
- When the bucket is raised high, the balance point for the whole tractor is also raised.
- This figure shows how a raised CG makes it easier for a tractor to turn over sideways



Tractor Stability

- Centrifugal force (CF) is the outward force nature exerts on objects moving in a circular fashion.
- During tractor overturns, CF is that force trying to roll the tractor over whenever the tractor is turning.
- Centrifugal force increases both as the turning angle of the tractor becomes sharper (decreases), and as the speed of the tractor increases during a turn.
- For every degree the tractor is turned tighter, there is an equal amount of increased CF.

Tractor Stability

- The relationship between CF and tractor speed, however, is different.
- Centrifugal force varies in proportion to the square of the tractor's speed.
- For example, doubling tractor speed from 3 mph to 6 mph increases the strength of CF four times (2 x 2 = 4).
- Tripling tractor speed from 3 mph to 9 mph increases CF nine times (3 x 3 = 9).

Tractor Stability

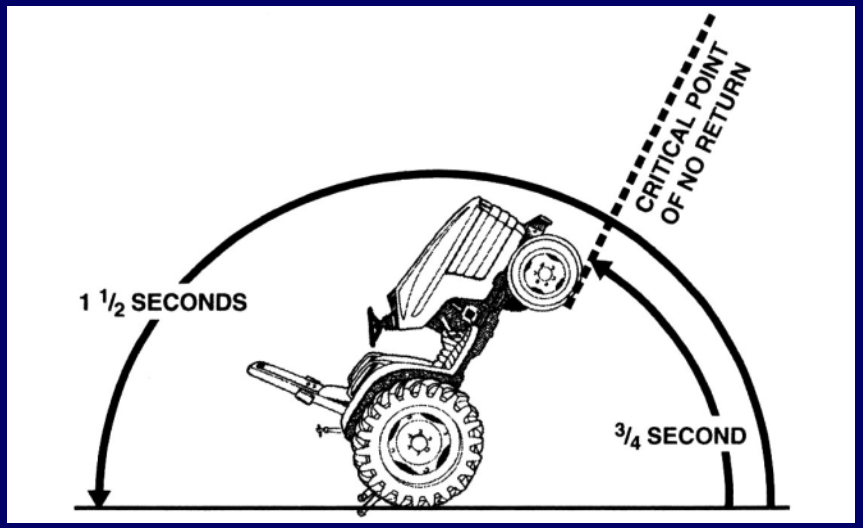
- Centrifugal force is what usually pushes a tractor over when the tractor is driven too fast during a turn or during road travel.
- During road travel, rough roads may result in the tractor's front tires bouncing and landing in a turned position.
- If the tractor starts to veer off the road, over correction of steering can result in side overturns.
- Centrifugal force is often a factor in tractor side overturns.
- When the distance between the tractor's CG and side stability baseline is already reduced from being on a hillside, only a little CF may be needed to push the tractor over.

Tractor Stability

- Engaging the clutch of a tractor results in a twisting force, called torque, on the rear axle.
- Under normal circumstances, the rear axle (and tires) should rotate and the tractor will move ahead.
- If this occurs, the rear axle is said to be rotating about the tractor chassis.
- If the rear axle cannot rotate, then the tractor chassis can rotate about the axle.
- This reverse action results in the front end of the tractor lifting off the ground until the tractor's CG passes the rear stability baseline.
- At this point, the tractor will continue rearward from its own weight until the tractor crashes into the ground or other obstacle.

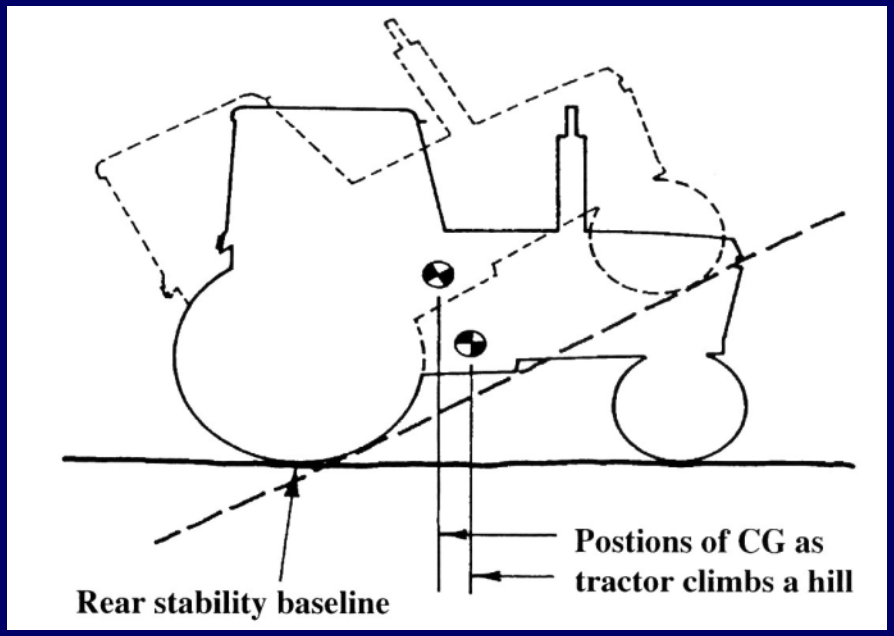
Tractor Stability

- The CG of a tractor is found closer to the rear axle than the front axle.
- A tractor may only have to rear to about 75 degrees from a level surface before its CG passes the rear stability baseline and the tractor continues flipping over.
- This position is commonly called the “point of no return.”
- This point can be reached more quickly than an operator can recognize the problem.



Tractor Stability

- Common examples of this type of tractor overturn are: the rear tires are frozen to the ground; tires stuck in a mud hole; or tires blocked from rotating by the operator.
- Rear overturns can also happen on a slope if an operator applies too much power too quickly to the rear axle.
- When a tractor is pointed up a slope, there is less rise needed to reach the point of no return because the CG has already moved closer to the stability baseline.

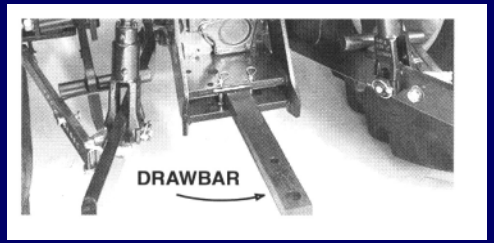


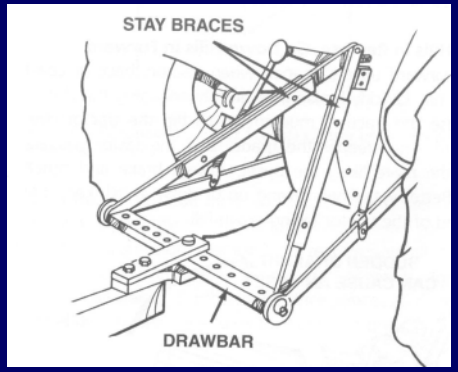
Tractor Stability

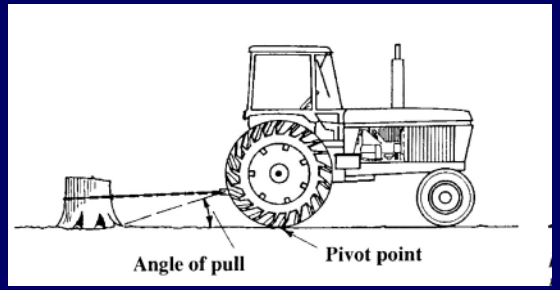
- When a two-wheel drive tractor is pulling a load, the rear tires push against the ground.
- At the same time, the load attached to the tractor is pulling back and down against the forward movement of the tractor.
- The load is described as pulling down because the load is resting on the earth's surface.
- This backward and downward pull results in the rear tires becoming a pivot point, with the load acting as a force trying to tip the tractor rearward.
- An "angle of pull" is created between the ground's surface and the point of attachment on the tractor.

Tractor Stability

- A tractor, including the drawbar, is designed to safely counteract the rearward tipping action of pulled loads.
- When loads are attached to a tractor at any point other than the drawbar, the safety design of the tractor for pulling loads is defeated.
- The heavier the load and the higher the “angle of pull,” the more leverage the load has to tip the tractor rearward.







Tractor Stability

- The rollover protective structure (ROPS) and seat belt, when worn, are the two most important safety devices to protect operators from death during tractor overturns.
  - Remember the ROPS does not prevent tractor overturns, but can prevent the operator from being crushed during an overturn.
  - The operator must stay within the protective frame of the ROPS (Zone of Protection) in order for the ROPS to work as designed.
  - This means the operator must wear the seat belt.
  - Not wearing the seat belt may defeat the primary purpose of the ROPS.

Tractor Stability

- A ROPS often limits the degree of rollover, which may reduce the probability of injury to the operator.
- A ROPS with an enclosed cab further reduces the likelihood of serious injury because the sides and windows of the cab protect the operator.
- This assumes that cab doors and windows are not removed.

Using the Tractor Safely

- Tractors can be operated safely if they are used as designed and operated following recommended practices.
- There are an estimated 300 farm tractor fatalities each year.
  - Teenager killed using tractor to spotlight deer in the woods.
  - Man killed when tractor rolled onto him while dragging logs in the woods.
  - Grandfather killed, but passenger grandson lives when tractor goes over an embankment while going for a fun ride.
  - Tractor overturns while towing stalled pickup full of firewood.
  - Tractor upsets sideways while high lift bucket is in a raised position while traveling across a rough slope.

Using the Tractor Safely

- Tractors serve four purposes:
  - They are a remote power source.
  - They carry/pull machines.
  - They move loads.
  - They transport materials.
- If you are not sure of a specific use for your tractor, consult the Owner's Manual.

Using the Tractor Safely

Figure 4.13.b. Tractors are designed for the operator only. No passengers allowed!

Figure 4.13.c. Tractors provide remote power to machinery. This turning shaft, the PTO, must be guarded to prevent entanglement hazards such as this.

Using the Tractor Safely

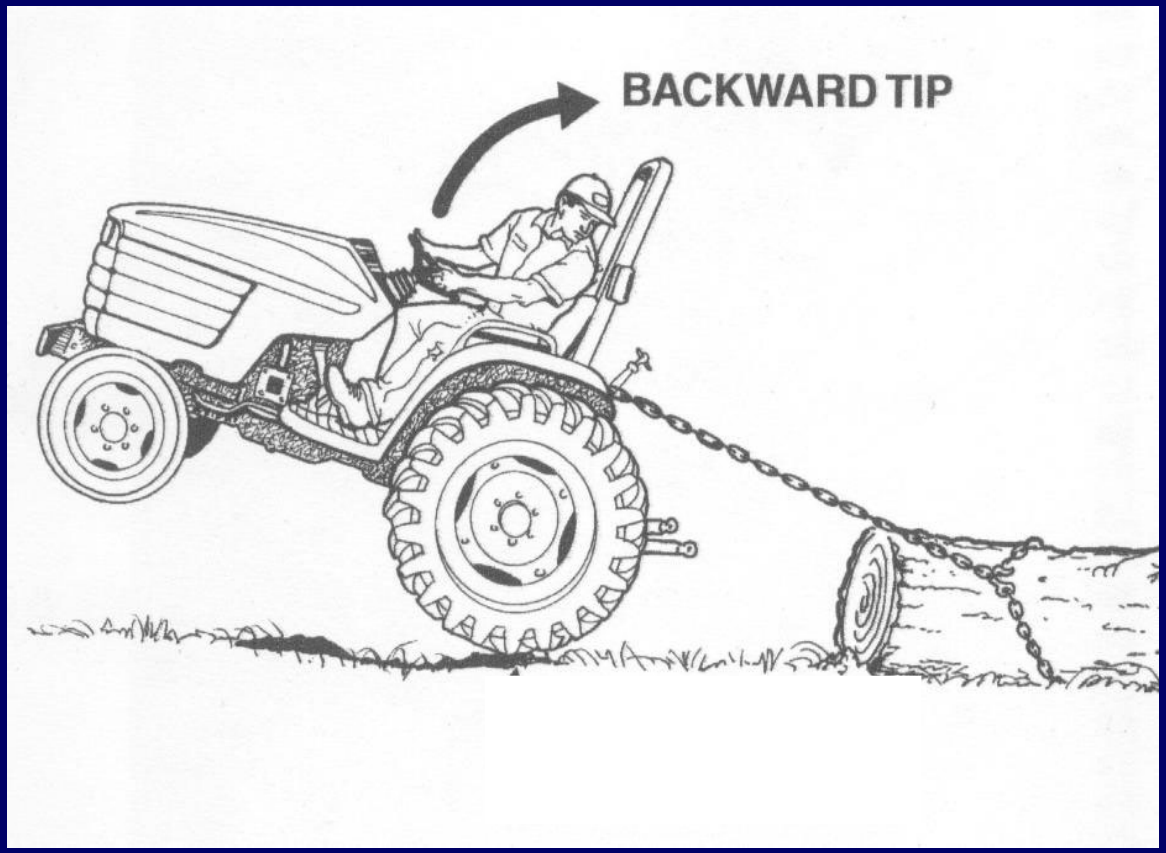


Figure 4.13.d. Hitch loads only to the drawbar. The drawbar has been engineered to pull heavy loads without risking a rear overturn hazard. *Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.*

Using the Tractor Safely

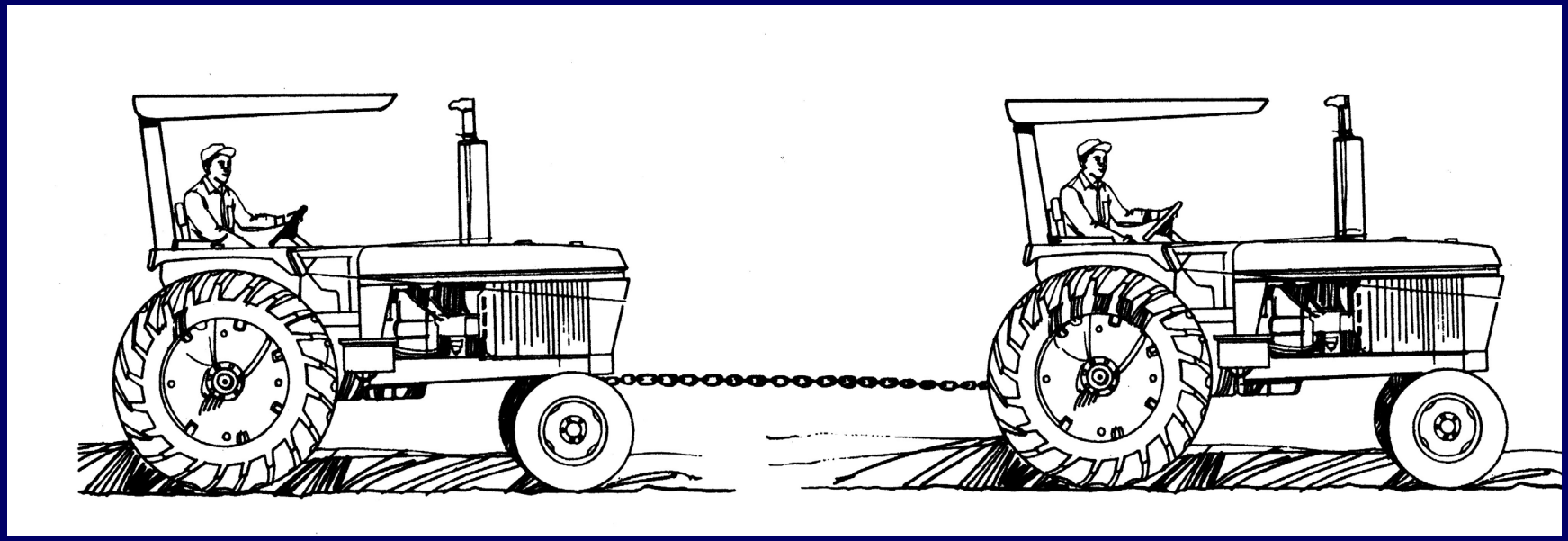


Figure 4.13.e. If you are stuck or need to be towed, you will need help from a second tractor. Use the strongest and best tow strap, cable, or chain that is available. Hitch only to the drawbar. The best advice for a young operator is to get adult help to pull the disabled or stuck tractor. *Farm and Ranch Safety Management, John Deere Publishing, 1994. Illustrations reproduced by permission. All rights reserved.*

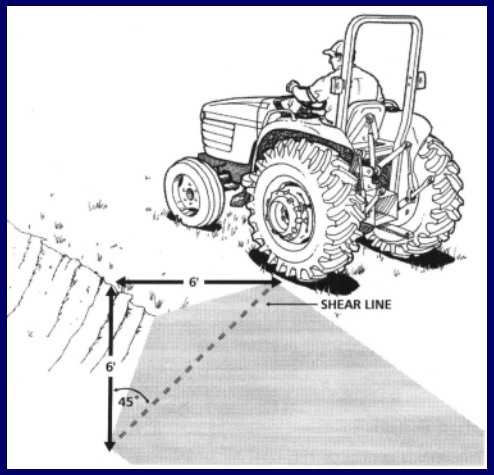


Figure 4.13.f. Avoid ditch embankments. Tractors are heavy and embankments can give way. For example, if the ditch is 6 feet deep, stay back at least 6 feet. *Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.*

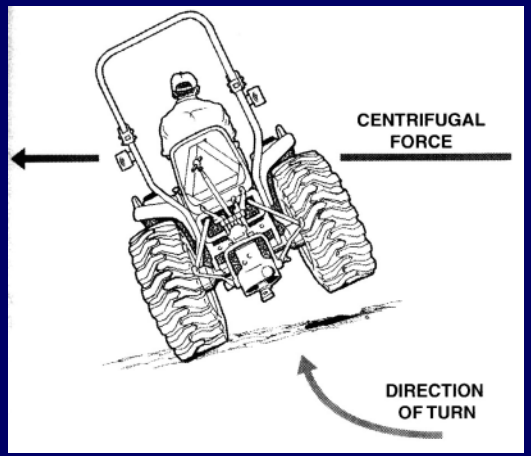


Figure 4.13.g. High speeds while making a turn can cause a sideways overturn. Make sure brakes are locked together. Reduce speed before entering the turn. *Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.*

Figure 4.13.h. Avoid obstacles as you operate the tractor. Some tractor operators will check the field before beginning the operation. Stumps, rocks, animal dens, etc, can upset a tractor.

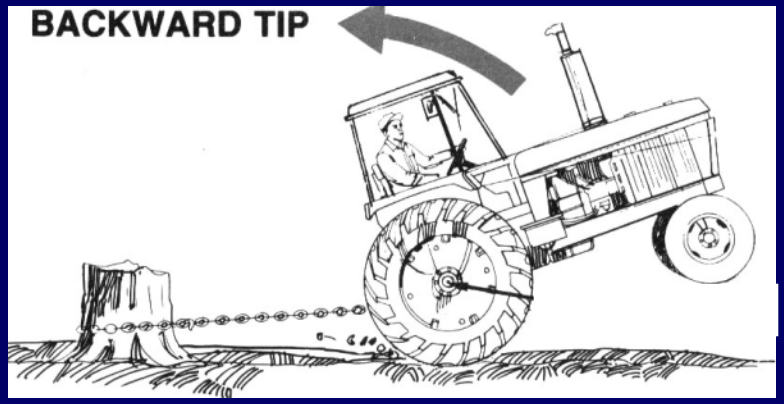


Figure 4.13.i. Tractors are powerful, but each one has a limit to its pulling power. Overloading a tractor could stall the engine, but rearward overturns can occur as well. *Farm and Ranch Safety Management, John Deere Publishing, 1994. Illustrations reproduced by permission. All rights reserved.*

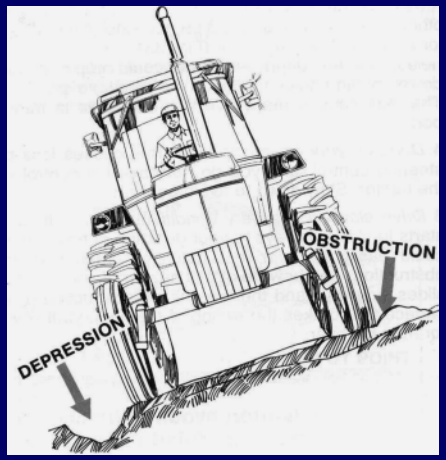


Figure 4.13.j. Field conditions pose special hazards to tractor operation. The operator must know where these obstructions and depressions are located. *Farm and Ranch Safety Management, John Deere Publishing, 1994. Illustrations reproduced by permission. All rights reserved.*

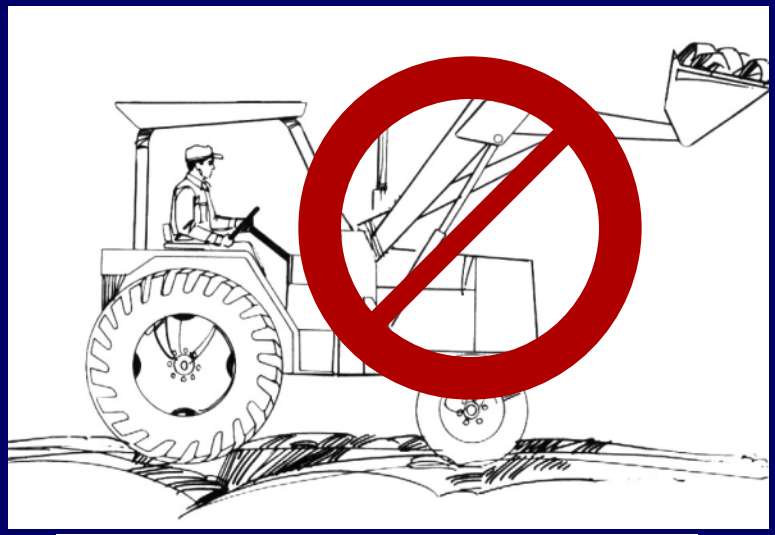


Figure 4.13.k. When operating a high-lift bucket with a load or without a load, keep the bucket as low to the ground as possible while in transport. Sideway overturns are possible if you try to travel with the bucket in the up position. *Farm and Ranch Safety Management, John Deere Publishing, 1994. Illustrations reproduced by permission. All rights reserved.*

Figure 4.13.l. A tractor stuck in mud is immovable without help. Adult supervision is necessary.

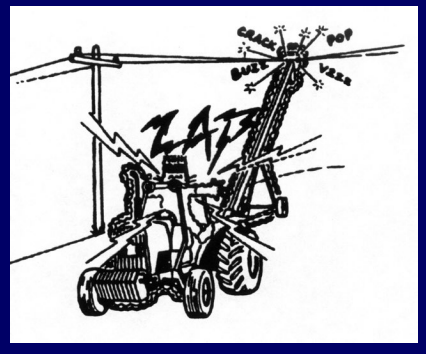


Figure 4.13.m. Avoid overhead power lines while transporting equipment to avoid risk of electrocution.

Operating on Public Roads

- Today's farmers are traveling more miles than ever before on public roads to plant, grow, and harvest crops.
- Slow-moving tractors and implements are no match for the general public's high-speed travels.
- Most crashes between farm equipment and motor vehicles occur during daylight and in good weather.
- You can never let your guard down when traveling on a public road with farm equipment.

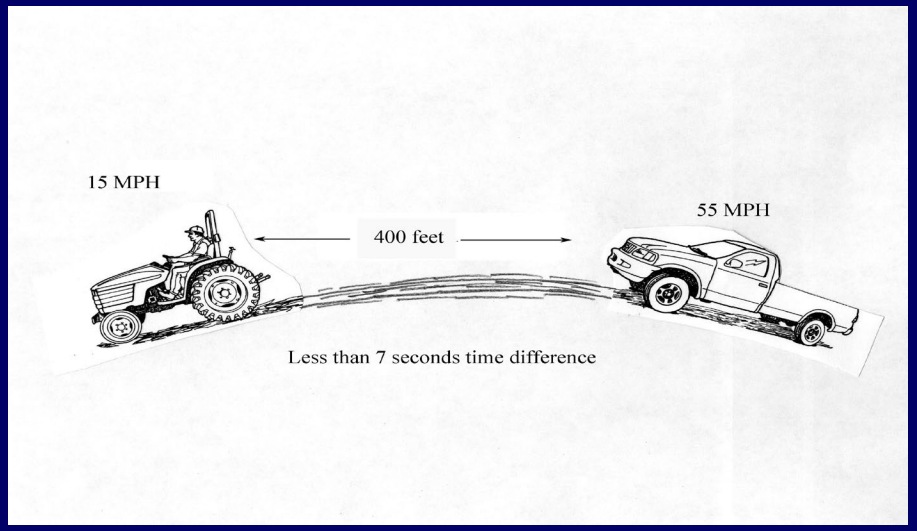


Figure 4.14.a. An automobile traveling 55 mph will cover the 400 ft. distance between the car and tractor in less than 7 seconds. Will that be enough time or space to get slowed or stopped to prevent a rear-end crash?

Operating on Public Roads

- These traffic situations are created by operating tractors on public roadways.
  - Pulling slowly onto roads with long and heavy loads
  - Slow tractor travel speeds
  - Left turns across traffic into narrow field lanes
  - Swinging into the left lane to make a right turn into a field
  - Wide machinery being transported
  - Potential for spilled loads
- All rules of vehicle safety, as well as all rules of courteous driving, must be followed to prevent traffic problems.

Operating on Public Roads

- Each state varies in their highway regulations regarding the ages and places where one may operate a farm tractor.
  - States seldom require a driver's license for a tractor, but many do limit 14 and 15 year-old drivers to crossing over public roadways only or to operating equipment on roads that bisect or adjoin their farm.
- Check with your local state police to learn more about the laws in your area.
- You must also obey all traffic laws and signs as well.

Operating on Public Roads

- American Society of Agricultural Engineers (ASAE) Standards for lighting and marking are summarized in Table 4.14.a.
- Most farm equipment delivered from the factory today will have used these standards.
- Although not included in the ASAE standard, rotary beacons and back-up alarms are optional accessories which may be add-ons depending upon your needs.

Table 4.14.a. Recommendations from ASAE for lighting and marking.

Item	Recommendation
Headlights	Two white lights mounted at the same level
Taillights	Two red lights mounted at the rear
Hazard Flashers	Two or more lamps with amber color to the front and red color to the rear
Turn Indicators	Two amber to the front and two red-colored lights to the rear mounted with flashers
SMV Emblem	One visible at 1000 ft. mounted to the rear and 2-10 ft. above the ground
Reflectors	Two red reflectors (on rear outside corners) and 2 yellow reflectors (on the front outside corners) of the machine
Conspicuity Material	Red retro-reflective and red-orange fluorescent color visible to mark the rear. Yellow retro-reflective material to mark the front.

Operating on Public Roads

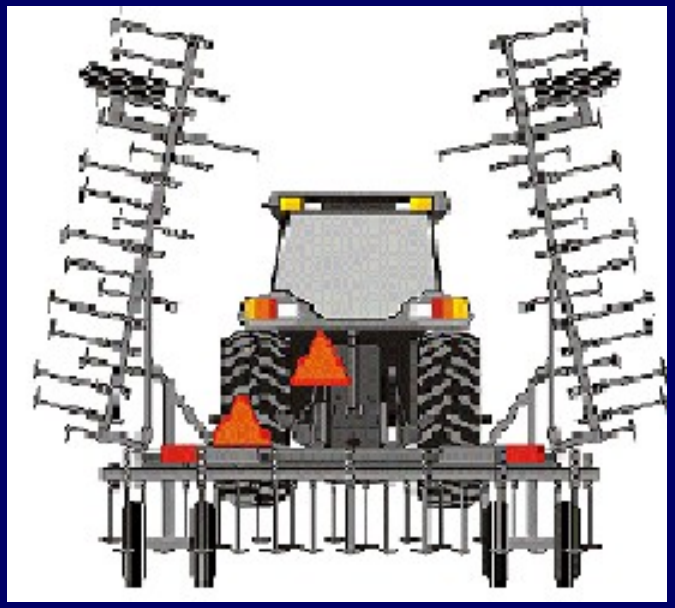


Figure 4.14.b. Lighting and marking standards may or may not be the standards for your state. Check your state laws.

Figure 4.14.c. Be sure that a work light that points to the rear is off during road travel at night. Single white lights may not be recognized as slow-moving or as a tractor light. Also if SMV emblems are worn or obsolete, replace them with newer more reflective SMV emblems.

Operating on Public Roads

Think about the following when traveling on the highway with farm machinery.

- Time of day–Is it possible to avoid the busy times of the day to move equipment? Hauling large loads during early morning or late afternoon while people hurry to and from work creates traffic problems for both of you. Moving loads after nightfall may be better timing, but lighting becomes a necessary consideration.
- Courtesy– Try to be as watchful of others as possible. Let the high-speed traffic go first. Your best manners on the highway will be the first safe practice to follow.

Operating on Public Roads

- Blind spots– Are there locations which pose problems with visibility? Avoid them if possible.
- Shifting loads– If you upset a load of hay, spill a load of manure or a tank of pesticide mixture, or coat the road with mud from the field, you are responsible for getting help for cleanup and alerting traffic to be cautious. If manure or chemical spills endanger waterways, notify your employer who may have reporting requirements with state environmental officials.
- Safe Equipment– Your walk-around inspection should have shown you if you have damaged equipment. Be sure damaged equipment does not create a road hazard. For example, a loose wheel on a hay rake could cause a disaster.

Operating on Public Roads

Figure 4.14.d. Secure hitch pins with locking clips as shown.

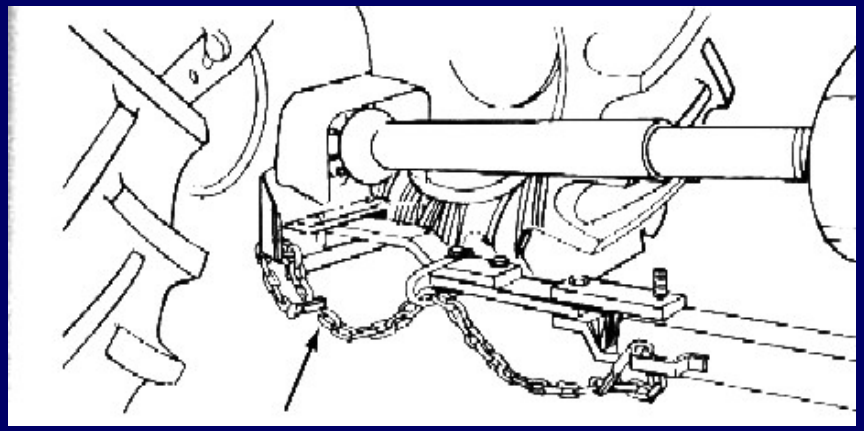


Figure 4.14.e. Use safety chains to insure load hitching safety when possible. Trucks pulling farm loads should have safety chains also. *Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.*

Figure 4.14.f. SMV emblems are required on vehicles designed to travel less than 25 mph while occupying public roadways. SMV emblems should be visible from no less than 1000 feet to the rear of the tractor or towed implement. Therefore, mounting height may vary from 2 to 10 feet above the road surface. Replace faded, damaged SMV emblems.

Operating on Public Roads

Figure 4.14.g. A best practice for transporting wide loads on a public roadway is to use an escort vehicle to assist in alerting other motorists. Be a courteous tractor operator to bring good public relations to the farm community.

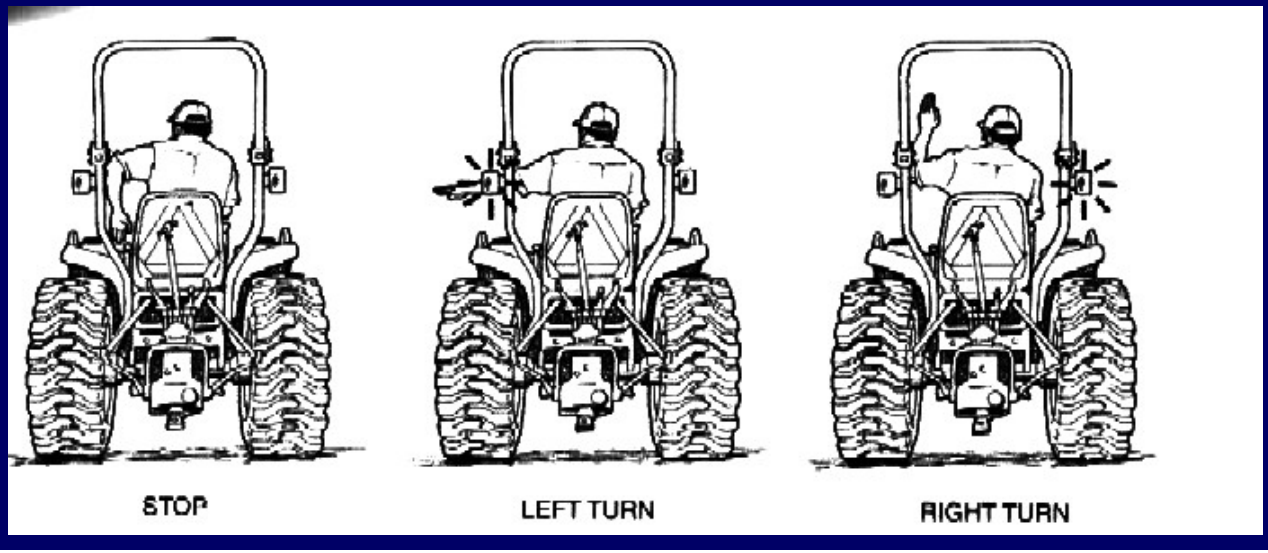


Figure 4.14.h. Use accepted hand signals to inform other drivers of your intentions. *Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.*

Lighting and Marking

- Highway transport of farm equipment at night requires lighting and marking. Older equipment must meet these requirements as well. The requirements are:
  - Slow-moving speed shown by SMV emblem
  - Extremities of width defined by side marker lights or decals
  - Ability to warn of turns by recognizable signals
- If the tractor and equipment or self-propelled equipment does not meet these requirements, the operator increases the risk of injury to him or herself and the public.

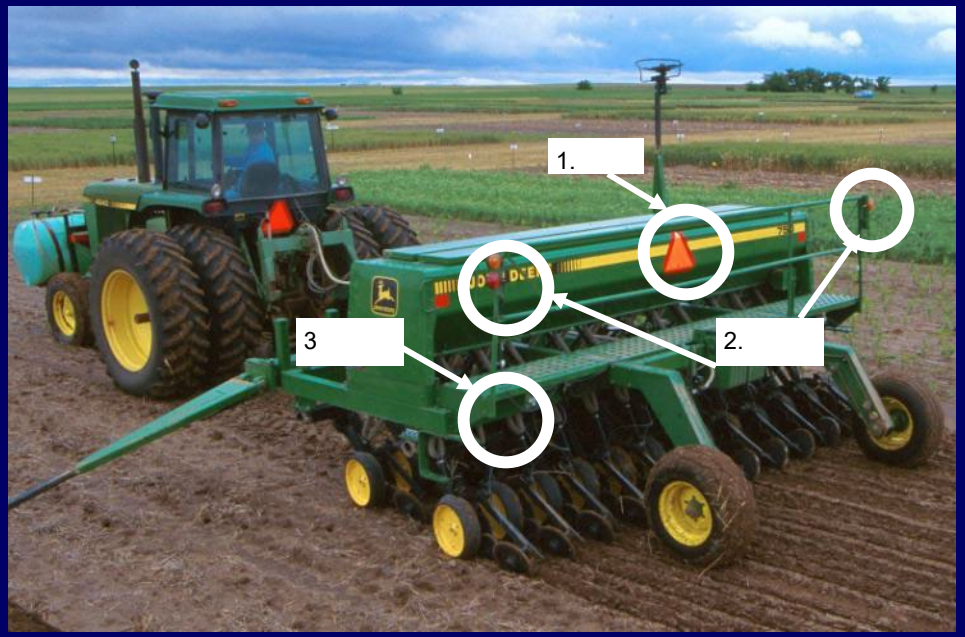


Figure 4.14.1.b. Can you identify the lighting and marking features used on this tractor and grain drill? Number 1 is_____. Number 2 are _____. Number 3 represents_____. Is the equipment safely marked for roadway travel?