1. TRACTOR ROLLOVERS

THE HAZARD

- Tractors have been proven to be the most deadly piece of equipment on Australian farms. Of all tractor deaths, rollovers and backflips are the most common cause. In a study of work-related fatalities in Australia between 1982 and 1984, tractor rollovers and backflips were the largest contributing factor causing 60 fatalities.\(^1\)

- Sideways rollover and backflips account for most of all rollovers. Gravity and Centrifugal Force are the two major forces involved in a sideways rollover. Backflips are produced through Rear Axle Torque and Drawbar Leverage.

- Several concepts need to be understood in order to manage the hazard of tractor rollovers and backflips:

1. **Sideways rollover**

- Sideways rollovers occur most commonly when
  (a) traversing a steep slope or
  (b) cornering too sharply at speed.

- Two concepts which are useful in understanding sideways rollovers are the relationship between the TIPPING AXIS of the tractor and its CENTRE OF GRAVITY together with the amount of CENTRIFUGAL FORCE developed during cornering.

- The Tipping Axis is the line that a tractor will pivot about during tipping if driven over a steep enough slope. This is more easily understood if we look at the crawler tractor. The tipping axis on a crawler tractor is at the outside edge of the track.

The tipping axis of a 2WD and 4WD tractor is more complicated. This is because the front axle is attached to the tractor chassis by a central pivot point. Thus, as the tractor tips, it has two tipping axes. The most important one is in a line from the outside edge of the rear wheel to the central pivoting point of the chassis (Figure 2). This axis line continues to where the axle hits the chassis when the tipping axis moves to the outer edge of the front and rear wheels. When the tractor reaches this second axis, it is usually past the point of no return.

Figure 2: The Tipping Axis of a wheeled tractor
Source: Accident Compensation Corporation of New Zealand, 1988

The Centre of Gravity is the point where all parts of the tractor balance one another. If a tractor could be suspended from the Centre of Gravity it would be perfectly balanced. The position of the Centre of Gravity will change if any implements are added, removed or change position. If a bucket is raised, it will raise the Centre of Gravity and if the bucket is lowered, the Centre of Gravity will also be lowered. Thus, the Centre of Gravity moves toward the weight change (Figure 3).

The Centre of Gravity is normally located in the vicinity of the gearbox in the mid-line of the tractor.

Figure 3: The effect of implement movements on Centre of Gravity
Source: John Deere: 1983
The Centre of Gravity is useful for assessing the stability of a tractor when combined with the tipping axes. If a plumb bob (a weight on the end of a string) is suspended from the Centre of Gravity, it will demonstrate its position in relation to the tipping axes. As the Centre of Gravity is raised, it takes a lesser slope to breach the tipping axes. Once the Centre of Gravity lies outside the tipping axes, a rollover is inevitable (Figure 4).

Figure 4: Representation of a rollover resulting from Centre of Gravity moving outside of the tipping axis.
Source: John Deere. 1983

Centrifugal Force is introduced when a tractor is cornering. This force tends to pivot the tractor on its outside wheels during cornering (Figure 5). This predisposes the tractor to a rollover. An example of Centrifugal Force is the force that pushes you to the outside of the car when going around a corner. The faster you go, the greater the force.

Figure 5: Centrifugal Force tries to pivot the tractor on its outside wheels and tends to cause a rollover.
Source: John Deere. 1983

RELEVANT LEGISLATION AND STANDARDS

- The Occupational Health and Safety Act relevant to each State/Territory and an accompanying Code of Practice or Regulations specifically relating to Plant, Tractors and Passengers.

- AS1636-1996 Parts 1, 2 and 3; ROPS for Tractors, Criteria and Tests. Legislation regarding the ROPS varies from state to state. For instance, in Western Australia, legislation requires all tractors which weigh more than 800 kg and less than 15000 kg to be fitted with a ROPS if sold. Tractors must also have a ROPS when a tractor safety assessment indicates that it is necessary. This amounts to a ROPS being a legal requirement with no exemptions (although fruit growers may use a fold-down ROPS). The requirements for the relevant state or territory should be checked.

- Earth-Moving Machinery-Protective Structures: AS 2294-1990. (Falling-Object Protective Structure or FOPS).

USEFUL REFERENCES


2. AgHealth Fact Sheet: Tractor ROPS. Australian Agricultural Health Unit. Moree

3. Tractor Operation and Maintenance Course. Farmsafe NSW. 1995


5. Video: Crikey, There’s a Tractor on the Farm. Focal Communications. Sydney

The Centrifugal Force varies according to the weight of the tractor, the speed and the turning angle. The force will increase as the angle of turn becomes sharper. Halving the radius of the corner will double the Centrifugal Force. Similarly, doubling the speed from 5 km/h to 10 km/h would increase the Centrifugal Force four times; \(2^2 = 4\). Tripling the speed from 5 km/h to 15 km/h would increase the force 9 times; \(3^2 = 9\).

Centrifugal Force is a factor contributing to tractor upsets on flat ground. It is also important when operating on slopes. When a tractor is turning on slopes its centre of gravity may be approaching its tipping axes, and it may only require a small amount of Centrifugal Force to cause a rollover.

There has often been contention about the correct direction to turn when crossing a hill slope. Remember that when the direction of turning is being discussed with reference to slopes, none of the turns should be sharp. Rather, they should be veering off in an uphill or downhill direction. If the turn is too sharp, there will be large Centrifugal Forces involved.

Some basic rules for safe operation are:

### When working on steep slopes
- Always travel slowly
- If there is not enough room for a gradual turn, use a slow three-point turn.
- Some experienced drivers will actually lightly use the uphill steering brake to slightly point the tractor uphill to increase stability. (Not recommended for inexperienced drivers).

### When working on mild slopes
- If the slope is being traversed at a higher speed, a downhill turn should be made.
- Great care must be taken when doing this and if the tractor becomes unstable the turn should not be completed and you should continue straight down the hill.

### When driving
- Set wheels as wide as possible when traversing slopes.
- Always travel with the Front-End loader as close as possible to the ground as practical.
- Always reverse out of a bog. If this does not work, use another tractor to pull it out.
- The drawbar is the only safe towing point.

The Safe Working Load (SWL) of each tractor should be checked. This is often written somewhere on the tractor and it will be in the Driver’s Manual. However, it is always available from the supplier or manufacturer. Under no circumstances should the Safe Working Load be exceeded.

Correct ballasting of the tractor will assist in maintaining the Centre of Gravity in the safest position and should be checked per Drivers Manual. What is correct for one situation is not necessarily correct for another.

A map of the environmental hazards such as banks, ditches channels etc. needs to be available to every person who operates a tractor on the farm.

Operational

- Always wear your seatbelt when driving a tractor with a ROPS.
- Drive carefully when near ditches or embankments and stay well clear of the edges of trenches or ditches.
- Regular programmed reporting will increase the effectiveness of the radio or mobile phone.
- Frequent short breaks when driving the tractor for long periods of time will help reduce fatigue.

5. Personal Protective Equipment and Clothing

- There is no personal protective equipment specifically recommended to prevent or manage the effects of tractor overturns. However, it is a general recommendation for tractor operation that clothing be of a snug fit, shirts are kept tucked in, buttons done up and sturdy boots are worn. This avoids clothing being caught in levers or moving parts and boots will not slip off foot controls or steps. If working on an uncabinled tractor or if otherwise exposed to the sun, wear sunscreen, a hat and shirt with a collar to reduce the risk of skin cancer.

6. First Aid

- An effective Rescue and First Aid technique can dramatically improve a person’s chance of survival in the event of a tractor rollover or backflip.
- Develop a contingency plan for every recognised crisis situation.
- At least two individuals on each farm should be trained in First Aid.
- First aid kits should be in handy locations on the farm. The size of the kit will vary according to the number of workers on the farm. The legal requirements vary from state to state and should be checked with your local Occupational Health & Safety Authority.
2. Backflips

- The second type of rollover is a backflip. In this scenario, there are two forces in action. These are **REAR-AXLE TORQUE** and **DRAWBAR LEVERAGE**.

- **Rear-axle torque** is the transfer of energy between the engine and rear wheels of a tractor. It occurs when the pinion gear in the Differential meshes with the crown wheel of the axle. Thus, the pinion which is driven by the engine applies a rotational force to the wheels via the crown wheel (Figure 6). This may be described as the rear axle rotating with respect to the chassis.

- **Drawbar leverage** is the transfer of energy between the engine and the drawbar. In this scenario, there are two forces acting in an equal and opposite direction. These are the force of gravity pulling the tractor forward and the force of the drawbar pulling the tractor backward. This may be described as the rear axle rotating with respect to the chassis.

- A backflip can happen in as little as 3/4 of a second. At this speed, there is little chance that the driver will be able to take evasive action (Figure 7). There are many circumstances where the reaction time may be even less than 3/4 of a second. This can occur when the Centre of Gravity is already approaching the rear tipping axis, for example, when the rear wheels of the tractor are stuck in a bog.

- Practices which involve rear axle torque reactive force acting to cause a backflip include:
  1. Driving off in low gear but with high engine speed.
  2. Attempting to drive the tractor forward when the wheels are unable to move forward.
  3. Rapid engagement of the clutch of the tractor.
  4. Rapid acceleration, particularly when driving uphill or pulling a heavy load.

3. Engineering/design options

- A ROPS should be fitted to all tractors. This is not a means of reducing the occurrence of rollovers and backflips. However, it significantly decreases the risk of injury if such an event occurs. The ROPS should be used in conjunction with a seatbelt to keep the driver within the safety zone. Once installed, the ROPS should not be modified in any way.

- The risk of tractor overturn may be reduced by widening the wheel settings of the tractor to the maximum. This increases the stability base of the tractor, thus decreasing the risk of rollover or backflip.

- When working with timber, a Falling-Object Protective Structure which meets AS2294-1990 needs to be fitted to protect the driver from falling objects. This is also important if the tractor is used for moving large hay bales as people have been crushed by round bales rolling backwards down a raised bucket arm. A four post ROPS or cab also protects against falling round hay bales.

- Accessible radios or mobile telephones are a design feature which can reduce the risk by minimising the length of time before any accident victim is found.

4. Safer work practices and procedures

**Pre-operational**

- Improving the work procedures and practice includes providing training for tractor drivers. This may include both instruction using the Driver’s Manual and training provided by recognised training institutions such as TAFE or an Agricultural College. Topics covered should include:
  - Centre of gravity
  - Tractor/load stability
  - Centrifugal force
  - Drawbar leverage and hitching techniques
  - Rear axle torque
  - Safe maintenance and operation
  - “See it, Assess it, Fix it” principle

These topics would be the basis for the following general rules:

- Rules about turning on slopes
- Rules about travel at high speed
- Rules about travel with front-end loaders
- Rules about towing

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**Figure 6: The basic drive mechanism of a tractor**

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TRACTOR ROLLOVERS

Figure 7: The time frame involved with tractor rollovers
Source: John Deere. 1983

- Four wheel drive tractors are less susceptible to backflips as they have more weight over the front axle than a 2WD and the torque is applied to both front and rear axles. However, once the front wheels lift off the ground, there is essentially no difference between the two types of tractor. This also applies to front wheel assist tractors.

- Care must be taken when ascending hills that the correct gear is selected before the commencement of the climb. If the driver has to stop during the climb, it requires only a small amount of rear-axle torque from the jerking of the clutch to cause the tractor to flip due to the other instability factors introduced by the slope.

- If a hill is very steep, the tractor should be reversed up the hill and then when coming down, it should be driven slowly forwards in low gear. Low gear should be selected before you start down the hill. If the tractor is pulling a heavy load uphill, the combination of the slope and drawbar leverage makes it more likely that the tractor will flip. In that case, front-end weights should be added to the tractor and the drawbar set in its longest and lowest position. Rear-wheel weights or tyre-ballast should be added to counter-balance front attachments such as a spray tank or front-end loader.

- **Drawbar Leverage** describes the force which tends to pull the tractor rearwards when it is towing or pulling an object. The magnitude and its effect on tractor stability will vary according to a number of factors including the weight, draft, hitching point used, resistance to movement and angle of pull.

- Tractors are specifically designed to pull objects from the drawbar and this should be strictly adhered to. When an object is being pulled, the pulling force involves both a horizontal and vertical component. This may be equated to an angle of pull. The angle of pull in a downwards direction results in a transfer of weight from the front of the tractor to the rear (Figure 8).

How often and for how long are people exposed to the tractor rollover hazard?

One other factor influences the degree of risk. That is the number of times or length of time that a tractor is used. The more often a tractor is driven, the more likely it is that injury will occur. The longer it is driven, the more chance there is for a tractor rollover to occur.

- As death of the driver and/or passenger is likely if the tractor rolls over or backflips, the level of risk should always be assessed as HIGH and action should be taken immediately.

CONTROL MEASURES

- The following control measures will not be suitable for everybody. They are presented as options which are available to reduce the risk of injury or death while not interfering with farm productivity. In fact, well-designed control measures should increase productivity by decreasing human physical demands and reducing the cost of injury. An option which may seem impractical to one person in their particular situation may well be possible for somebody else in their circumstances. Where an option may not be practical at present, it may become so in the future; for instance, when planning the purchase of new agbikes or tractors.

1. **Elimination of the hazard**

- Elimination of the tractor rollover hazard means the tractor is not used for a particular task. This involves the use of a work procedure for that task which does not require a tractor or elimination of the task itself. For example, a tractor which is difficult to fit with a ROPS may be rendered inoperable for mobile work and used as a stationary power source only. Grazing the grass in a crop or plantation on a very steep slope will eliminate the need for slashing the grass using a tractor.

2. **Substitution for a lesser hazard**

- The substitution control is used, for example, when choosing the appropriate tractor for particular tasks. Instead of using a high clearance 2WD tractor for slashing grass in a steep macadamia plantation, it might be wise to substitute this for a low clearance and low centre of gravity 4WD articulated tractor, or undertake work using eg the ATV.

- When buying a new tractor, it is important both in terms of farm safety and efficient production to choose the best tractor for the intended tasks. Discussion with the tractor dealer will help determine the correct tractor specifications for the most common tasks. Through this careful selection, the right tractor for the task can be substituted as soon as possible.
How common is tractor rollover and how severe is the likely resulting injury?

Although tractors do not roll completely over or backflip very often on Australian farms, the driver and/or passenger is often killed. The likelihood of this occurring is influenced by the following:

**The Roll Over Protective Structure (ROPS)**

- ROPS which comply with the Australian Standard have proven effective in dramatically reducing the fatality rate of tractor drivers in the event of a tractor rollover or backflip.

**Environmental Conditions**

- The environmental conditions have a bearing on the relative risk of rollovers. Situations that present a considerable risk include: steep slopes, wet conditions, high speeds, unfamiliar areas, broken ground and long grass.

- It is possible to roll or flip a tractor over on any terrain carrying out any task. In contrast to popular belief, 90% of tractor accidents occur at speeds less than 8 km/hr. In addition, 60% of all accidents occur on slopes less than 5 degrees. Thus, there is always an element of risk involved with operating a tractor. However, certain environmental conditions pose more of a risk than others. For example, broken ground such as gullies and stumps hidden in long grass represent a significant risk despite the terrain being flat.

- The presence of passengers on a tractor increases the risk of injury or death by exposing a greater number of people to the hazard. Passengers on tractors also increase the risk of death or disability as they are not protected by the ROPS safety zone and are not secured by a seatbelt during a rollover or backflip. Passengers can increase the level of risk of a rollover or backflip by interfering with the operation of the tractor.

- It is a breach of Occupational Health & Safety regulations in many states to carry passengers on a tractor unless a seat of adequate strength is fitted. It must have a backrest as well as handholds and footholds. The seat must lie within the safety zone created by an approved ROPS.

**Driver Training**

- Driver error contributes substantially to tractor rollover. Driver error can be made by inexperienced or experienced tractor drivers. In fact, experienced drivers are often involved in tractor rollovers and backflips. Therefore, drivers should have the training and instruction to complete the task safely. This training and instruction should be included in the identification of the tractor rollover hazard.

__Figure 8: Forces involved in angle of pull__

Source: Accident Compensation Corporation of New Zealand, 1988

- Many backflips are caused by the driver hitching the load too high. Common examples are the top link of the 3-point linkage and the axle housing. The tractor is hitched most safely, when hitched to the drawbar. Care must be taken when pulling loads uphill even when appropriate hitching methods are used. This is because of the close proximity of the Centre of Gravity to the rear tipping axis. Thus, only a small amount of force would be required to cause a backflip.

- If the tractor is not hitched in a safe manner, the angle of pull may not be safely reduced before the tractor overturns. This means that the Centre of Gravity would have moved outside the rear tipping axis.

- The axle load-bearing capacity of a tractor must be taken into account when looking at the factors which can lead to a tractor rollover. The weight of the load carried by the tractor combined with that of the tractor make up the Gross Vehicle Mass.

- Where front-mounted lifting attachments are attached to a tractor, drivers need to be aware of the load-bearing limits on the tractor axle and ensure those limits are not exceeded. If a loader is overloaded, the weight of the Gross Vehicle Mass will be entirely on the front axle and can lead to a backflip. Check the recommended load limits in the Driver’s Manual. If you are still not sure, ask the tractor distributor.

- The recommended limits allow you to maintain control of the equipment. Excessive axle-bearing loads lead to costly repairs, and may cause you to lose control of the tractor. The risk of tractor rollover or backflip is increased by axle failure.

**HAZARD IDENTIFICATION**

- Assessments of tractor safety on the farm should look for all possible causes of tractor rollover and factors which increase the severity of injury from tractor rollover. Consider characteristics of the machine, the environment, the tractor driver and the interaction between them.
When considering the machine, look at:

- The presence of a ROPS (rollover protective structure)

Characteristics of the environment to consider are:

- The slope of the ground where the tractor is used
- The condition of the ground (gullies, hidden stumps and other hazards)
- The presence of wet, slippery ground
- Whether passengers are allowed on the tractor

When considering the tractor driver, look at:

- The training of the driver in safe driving and maintenance of the tractor

Further reading on hazards associated with tractors can be found in:

- Tractor Runovers and Power Take-Offs (Number 2 and Number 3)
- Noise on Farms (Number 4)
- Farm Machinery (Number 5)
- Children on Farms (Number 7)
- Vibration

THE RISK

1. Who is at risk

- All drivers and passengers, including children who are associated with tractors are at risk of being injured or killed in the event of a rollover or backflip.
- As the graph below shows, the older age-groups have the highest death rate for tractor rollover or backflip.

![Age of Death of New South Wales Rollover Victims 1989-1995](image)

Source: New South Wales Workcover Data

Drivers of tractors without a ROPS which complies with the Australian Standard and a seatbelt. Current data shows that there have been no recorded deaths from tractor rollover or backflip in Australia where a ROPS which complies with the Australian Standard and a seatbelt have been used.

- Passengers are more at risk due to the fact that they are often positioned outside the protection zone of the ROPS which is designed for the driver’s safety. Passengers are also placed at higher risk due to the less secure nature of their seating.

- People with sight impairment are at greater risk as they may be either unable or slower to see environmental hazards such as ditches, rocks etc which increase the risk of rollover or backflip.

- Fatigue will increase the risk for drivers of tractors as their reflex times will be slowed and concentration lost. People who are suffering from fatigue have probably spent too long on the tractor, especially at busy times such as harvest or sowing time and will usually be more at risk at night. The increased exposure time to the hazard as well as the slow reaction time and loss of concentration resulting from fatigue places them at higher risk of death or injury from a tractor rollover or backflip.

2. Nature of potential injury/illness

- Injuries associated with tractor rollovers or backflips frequently result in death, where the tractor is not fitted with an approved ROPS and seat belt.

- Death occurs through crushing of the trunk, arm, or leg in a rollover or backflip where there is no ROPS.

- Non-fatal crush injuries may also occur. This may happen if the victim is thrown partially clear of a tractor without a ROPS. Upper or lower limbs may be crushed when tractor with a ROPS rolls over but no seat belt was worn.

- Since many of the tractor accidents occur away from the homestead/shed, there may be a considerable time delay before the victim is found. This worsens the outcome.

3. Degree of risk

When assessing the degree of risk associated with tractor rollover or backflip, consider the following questions:

- How common is tractor rollover or backflip and how severe is the likely resulting injury ?
- How often and for how long are people exposed to the tractor rollover hazard ?
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- Elimination of the tractor rollover hazard means the tractor is not used for a particular task. This involves the use of a work procedure for that task which does not require a tractor or elimination of the task itself. For example, a tractor which is difficult to fit with a ROPS may be rendered inoperable for mobile work and used as a stationary power source only. Grazing the grass in a crop or plantation on a very steep slope will eliminate the need for slashing the grass using a tractor.

2. Substitution for a lesser hazard

- The substitution control is used, for example, when choosing the appropriate tractor for particular tasks. Instead of using a high clearance 2WD tractor for slashing grass in a steep macadamia plantation, it might be wise to substitute this for a low clearance and low centre of gravity 4WD articulated tractor, or undertake work using eg the ATV.

- When buying a new tractor, it is important both in terms of farm safety and efficient production to choose the best tractor for the intended tasks. Discussion with the tractor dealer will help determine the correct tractor specifications for the most common tasks. Through this careful selection, the right tractor for the task can be substituted as soon as possible.
3. Engineering/design options

- A ROPS should be fitted to all tractors. This is not a means of reducing the occurrence of rollovers and backflips. However, it significantly decreases the risk of injury if such an event occurs. The ROPS should be used in conjunction with a seatbelt to keep the driver within the safety zone. Once installed, the ROPS should not be modified in any way.

- The risk of tractor overturn may be reduced by widening the wheel settings of the tractor to the maximum. This increases the stability base of the tractor, thus decreasing the risk of rollover or backflip.

- When working with timber, a Falling-Object Protective Structure which meets AS2294-1990 needs to be fitted to protect the driver from falling objects. This is also important if the tractor is used for moving large hay bales as people have been crushed by round bales rolling backwards down a raised bucket arm. A four post ROPS or cab also protects against falling round hay bales.

- Accessible radios or mobile telephones are a design feature which can reduce the risk by minimising the length of time before any accident victim is found.

4. Safer work practices and procedures

Pre-operational

✓ Improving the work procedures and practice includes providing training for tractor drivers. This may include both instruction using the Driver’s Manual and training provided by recognised training institutions such as TAFE or an Agricultural College. Topics covered should include:

- Centre of gravity
- Tractor/load stability
- Centrifugal force
- Drawbar leverage and hitching techniques
- Rear axle torque
- Safe maintenance and operation
- “See it, Assess it, Fix it” principle

These topics would be the basis for the following general rules:

✓ Rules about turning on slopes
✓ Rules about travel at high speed
✓ Rules about travel with front-end loaders
✓ Rules about towing

2. Backflips

- The second type of rollover is a backflip. In this scenario, there are two forces in action. These are REAR-AXLE TORQUE and DRAWBAR LEVERAGE.

- Rear-axle torque is the transfer of energy between the engine and rear wheels of a tractor. It occurs when the pinion gear in the Differential meshes with the crown wheel of the axle. Thus, the pinion which is driven by the engine applies a rotational force to the wheels via the crown wheel (Figure 6). This may be described as the rear axle rotating with respect to the chassis.

- A backflip can happen in as little as 3/4 of a second. At this speed, there is little chance that the driver will be able to take evasive action (Figure 7). There are many circumstances where the Centre of Gravity is already approaching the rear tipping axis, for example, when the rear wheels of the tractor are stuck in a bog.

- A backflip can happen in as little as 3/4 of a second. At this speed, there is little chance that the driver will be able to take evasive action (Figure 7). There are many circumstances where the reaction time may be even less than 3/4 of a second. This can occur when the Centre of Gravity is already approaching the rear tipping axis, for example, when the rear wheels of the tractor are stuck in a bog.

- Practices which involve rear axle torque reactive force acting to cause a backflip include:
  1. Driving off in low gear but with high engine speed.
  2. Attempting to drive the tractor forward when the wheels are unable to move forward.
  3. Rapid engagement of the clutch of the tractor.
  4. Rapid acceleration, particularly when driving uphill or pulling a heavy load.
● The Centrifugal Force varies according to the weight of the tractor, the speed and the turning angle. The force will increase as the angle of turn becomes sharper. Halving the radius of the corner will double the Centrifugal Force. Similarly, doubling the speed from 5 km/h to 10 km/h would increase the Centrifugal Force four times; \(2^2 = 4\). Tripling the speed from 5 km/h to 15 km/h would increase the force 9 times; \(3^2 = 9\).

● Centrifugal Force is a factor contributing to tractor upsets on flat ground. It is also important when operating on slopes. When a tractor is turning on slopes its centre of gravity may be approaching its tipping axes, and it may only require a small amount of Centrifugal Force to cause a rollover.

● There has often been contention about the correct direction to turn when crossing a hill slope. Remember that when the direction of turning is being discussed with reference to slopes, none of the turns should be sharp. Rather, they should be veering off in an uphill or downhill direction. If the turn is too sharp, there will be large Centrifugal Forces involved.

Some basic rules for safe operation are:

**When working on steep slopes**
- Always travel slowly
- If there is not enough room for a gradual turn, use a slow three-point turn.
- Some experienced drivers will actually lightly use the uphill steering brake to slightly point the tractor uphill to increase stability. (Not recommended for inexperienced drivers).

**When working on mild slopes**
- If the slope is being traversed at a higher speed, a downhill turn should be made.
- Great care must be taken when doing this and if the tractor becomes unstable the turn should not be completed and you should continue straight down the hill.

**When driving**
- Set wheels as wide as possible when traversing slopes.
- Always travel with the Front-End loader as close as possible to the ground as practical.
- Always reverse out of a bog. If this does not work, use another tractor to pull it out.
- The drawbar is the only safe towing point.

- The Safe Working Load (SWL) of each tractor should be checked. This is often written somewhere on the tractor and it will be in the Driver’s Manual. However, it is always available from the supplier or manufacturer. Under no circumstances should the Safe Working Load be exceeded.

- Correct ballasting of the tractor will assist in maintaining the Centre of Gravity in the safest position and should be checked per Drivers Manual. What is correct for one situation is not necessarily correct for another.

- A map of the environmental hazards such as banks, ditches channels etc. needs to be available to every person who operates a tractor on the farm.

**Operational**
- Always wear your seatbelt when driving a tractor with a ROPS.
- Drive carefully when near ditches or embankments and stay well clear of the edges of trenches or ditches.
- Regular programmed reporting will increase the effectiveness of the radio or mobile phone.
- Frequent short breaks when driving the tractor for long periods of time will help reduce fatigue.

**5. Personal Protective Equipment and Clothing**
- There is no personal protective equipment specifically recommended to prevent or manage the effects of tractor overturns. However, it is a general recommendation for tractor operation that clothing be of a snug fit, shirts are kept tucked in, buttons done up and sturdy boots are worn. This avoids clothing being caught in levers or moving parts and boots will not slip off foot controls or steps. If working on an uncabinined tractor or if otherwise exposed to the sun, wear sunscreen, a hat and shirt with a collar to reduce the risk of skin cancer.

**6. First Aid**
- An effective Rescue and First Aid technique can dramatically improve a person’s chance of survival in the event of a tractor rollover or backflip.
- Develop a contingency plan for every recognised crisis situation.
- At least two individuals on each farm should be trained in First Aid.
- First aid kits should be in handy locations on the farm. The size of the kit will vary according to the number of workers on the farm. The legal requirements vary from state to state and should be checked with your local Occupational Health & Safety Authority.
**RELEVANT LEGISLATION AND STANDARDS**

- The Occupational Health and Safety Act relevant to each State/Territory and an accompanying Code of Practice or Regulations specifically relating to Plant, Tractors and Passengers.

- AS1636-1996 Parts 1, 2 and 3; ROPS for Tractors, Criteria and Tests. Legislation regarding the ROPS varies from state to state. For instance, in Western Australia, legislation requires all tractors which weigh more than 800 kg and less than 15000 kg to be fitted with a ROPS if sold. Tractors must also have a ROPS when a tractor safety assessment indicates that it is necessary. This amounts to a ROPS being a legal requirement with no exemptions (although fruit growers may use a fold-down ROPS). The requirements for the relevant state or territory should be checked.

- Earth-Moving Machinery-Protective Structures: AS 2294-1990. (Falling-Object Protective Structure or FOPS).

**USEFUL REFERENCES**


2. AgHealth Fact Sheet: Tractor ROPS. Australian Agricultural Health Unit. Moree

3. Tractor Operation and Maintenance Course. Farmsafe NSW. 1995


5. Video: Crikey, There’s a Tractor on the Farm. Focal Communications. Sydney


- The Centre of Gravity is useful for assessing the stability of a tractor when combined with the tipping axes. If a plumb bob (a weight on the end of a string) is suspended from the Centre of Gravity, it will demonstrate its position in relation to the tipping axes. As the Centre of Gravity is raised, it takes a lesser slope to breach the tipping axes. Once the Centre of Gravity lies outside the tipping axes, a rollover is inevitable (Figure 4).

- Centrifugal Force is introduced when a tractor is cornering. This force tends to pivot the tractor on its outside wheels during cornering (Figure 5). This predisposes the tractor to a rollover. An example of Centrifugal Force is the force that pushes you to the outside of the car when going around a corner. The faster you go, the greater the force.
The tipping axis of a 2WD and 4WD tractor is more complicated. This is because the front axle is attached to the tractor chassis by a central pivot point. Thus, as the tractor tips, it has two tipping axes. The most important one is in a line from the outside edge of the rear wheel to the central pivoting point of the chassis (Figure 2). This axis line continues to where the axle hits the chassis when the tipping axis moves to the outer edge of the front and rear wheels. When the tractor reaches this second axis, it is usually past the point of no return.

Figure 2: The Tipping Axis of a wheeled tractor  
Source: Accident Compensation Corporation of New Zealand, 1988

The Centre of Gravity is the point where all parts of the tractor balance one another. If a tractor could be suspended from the Centre of Gravity it would be perfectly balanced. The position of the Centre of Gravity will change if any implements are added, removed or change position. If a bucket is raised, it will raise the Centre of Gravity and if the bucket is lowered, the Centre of Gravity will also be lowered. Thus, the Centre of Gravity moves toward the weight change (Figure 3).

The Centre of Gravity is normally located in the vicinity of the gearbox in the mid-line of the tractor.

Figure 3: The effect of implement movements on Centre of Gravity  
Source: John Deere: 1983
1. TRACTOR ROLLOVERS

THE HAZARD

- Tractors have been proven to be the most deadly piece of equipment on Australian farms. Of all tractor deaths, rollovers and backflips are the most common cause. In a study of work-related fatalities in Australia between 1982 and 1984, tractor rollovers and backflips were the largest contributing factor causing 60 fatalities.1

- Sideways rollover and backflips account for most of all rollovers. Gravity and Centrifugal Force are the two major forces involved in a sideways rollover. Backflips are produced through Rear Axle Torque and Drawbar Leverage.

- Several concepts need to be understood in order to manage the hazard of tractor rollovers and backflips:

1. Sideways rollover

- Sideways rollovers occur most commonly when (a) traversing a steep slope or (b) cornering too sharply at speed.

- Two concepts which are useful in understanding sideways rollovers are the relationship between the TIPPING AXIS of the tractor and its CENTRE OF GRAVITY together with the amount of CENTRIFUGAL FORCE developed during cornering.

- The Tipping Axis is the line that a tractor will pivot about during tipping if driven over a steep enough slope. This is more easily understood if we look at the crawler tractor. The tipping axis on a crawler tractor is at the outside edge of the track.

Figure 1: The tipping axis of a crawler tractor
Source: Accident Compensation Corporation of New Zealand, 1988