

Forklift Stability and Other Technical Safety Issues

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Forklift stability and other technical safety issues

The stability of forklifts has impacts on safety in respect of:

1. The likelihood of forward tipover – that is, the forklift tilting forward;
2. The likelihood of side tipover – that is, the forklift tilting to either side; and
3. The maximum levels of braking that can be applied for any loading situation, and hence the stopping distance – too high a level of braking will initiate forward tipover; and
4. The maximum levels of rearward acceleration - too high a level will also initiate forward tipover.

1. Counterbalance forklifts

This report and the associated Monash University Accident Research Centre produced guidebook (*A Guidebook of Industrial Traffic Management & Forklift Safety*) focus on counterbalance forklifts of the style shown below, as they are the most common style used in Victoria



These forklifts generally have:

- The body with its counterbalance and cage rigidly attached to the front or drive axle;
- The mast pivoted at or near the front axle;
- The steer axle pivoted about its centre so that the steer tyres remain in contact with the ground where there are small variations in the level of the operating surface; and
- Brakes fitted to the front drive axle only.

For the one body, forklifts can be fitted with:

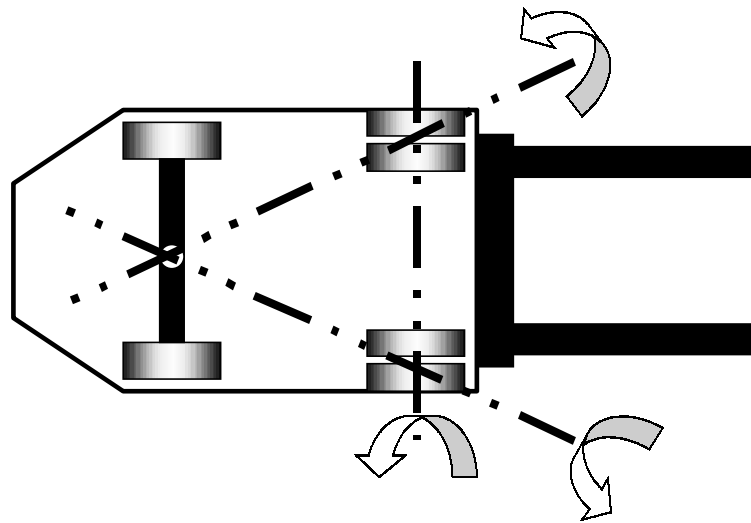
- Different masts to suit various lift heights. These range from 1500 to 7500 mm. The number of mast stages can vary depending on available headroom.
- Different wheels and tyres – solid, pneumatic shaped cushion or pneumatic tyres;
- A range of fork tynes suited to the forklift operation, with or without side shift; and
- Other specialist attachments.

2. “Stability triangle”

There are three ways a counterbalance forklift can tipover forwards or sideways:

1. It can tip forward with the contact points of the drive axle tyres and the ground acting as the pivot;
2. It can tip sideways to the left with tipover initially pivoting along a line through the left hand front tyre contact point and the pivot point of the rear steer axle; or
3. It can tip sideways to the right with tipover initially pivoting along a line through the right hand front tyre contact point and the pivot point of the rear steer axle.

These three lines combined define the stability triangle as shown in the diagram.



Note that the rear steer axle has a limit to its travel around its pivot point, so that at some point side tipover changes to pivot about the two left hand or two right hand tyres. At this stage the forklift sometimes stops tipping over and falls back on its wheels. Mostly however tipover continues.

3. Centre of mass

Any physical object has a point located in three dimensions where it acts as though all its mass is located. This is known as its centre of mass.

It is a point about which the forklift would balance if placed on top of a pointed support.

When the forklift is stationary, the only force acting on this point is the force of gravity vertically down. For a stationary forklift, provided this centre of mass is within the stability triangle, the forklift will neither tip forwards or sideways.

When we place an increasing load on the fork tynes, the centre of mass of the forklift and load combined moves forward towards the front axle

If sufficient load is added the forklift will reach a point where it tips forward. This generally occurs if an operator tries to lift a load that is much too heavy for the forklift, and the steer axle lifts off the ground.

4. Dynamic forces, centre of mass and stability

When a forklift travels on a slope, or when a forklift is travelling around a corner at some speed, or when a forklift brakes or accelerates, forces are developed that act on the forklift sideways or to the front or rear.

If the sum of all the forces acting on the centre of mass act such that they pass outside the stability triangle, then the forklift either tips forwards or sideways.

5. Tipover sideways versus tipover forwards

As noted above, adding load to the tynes makes the centre of mass of the forklift and tynes combined move forward closer to the forward tipover axis of the stability triangle. The forklift becomes progressively less stable in respect of forward tip over.

However the centre of mass at the same time is moving away from the two other tipping axis. So the Forklift becomes more stable in respect of tipping sideways.

Hence forklifts are much more likely to tip sideways when empty – 75% of these incidents occur when the forklift is empty.

And they are more likely to tip forward when loaded.

6. Stability and raised loads

Raising the load reduces stability in all tip over directions as the size of side, front or rear forces required to cause forward or side or tipover are reduced.

7. Australian and international standards for forklift stability or safety

A list of these standards is shown below. Note that in addition Japan, a major supplier of forklifts, has its own standards.

And there are other standards that also impact on forklift safety including standards for pallets and containers.

STANDARD	COMMENT
AS/NZS 1425:1999 LP Gas fuel systems for vehicle engines	For LPG powered forklifts
AS/NZS 1596:2002 The storage and handling of LP Gas	For LPG powered forklifts
AS 2402-1994 Traction batteries - Lead-acid	For battery powered forklifts
AS 2548.1-1998 Battery chargers for lead-acid traction batteries - Battery chargers for vented cells	For battery powered forklifts
AS 1763-1985 Industrial trucks - Glossary of terms	
AS 2359 -1995 Powered industrial trucks – Part 1: General Requirements. Part 2: Operation. Part 3: Counterbalanced forklift trucks - Stability tests. Part 4: Reach and straddle forklift trucks - Stability tests. Part 5: Control symbols. Part 6: Safety Code. Part 7: Terminology. Part 8: Pallet stackers and high-lift platform trucks – Stability tests. Part 9: High-lift rider trucks – Overhead guards. Part 10: Forklift trucks – Hook on type fork arms - Vocabulary. Part 11: Forklift trucks – Hook on type fork arms – Dimensions. Part 12: Hazardous areas	Principal Australian standard for forklifts. Being progressively changed by the adoption of equivalent ISO standards
AS 3713-1989 Acoustics - Industrial trucks - Noise measurement	

AS 4972(Int)-2001 Counterbalanced trucks handling freight containers for 6 m (20 ft) length and above - Additional stability tests	Australian version of ISO 10525 – additional notes on risks added
AS 4973-2001 Industrial trucks - Inspection and repair of fork arms in service on fork-lift trucks	Based on ISO 5057:1993
ISO 1074:1991 Counterbalanced fork-lift trucks; stability tests	Equivalent to AS 2359 Pt 3: 1995
ISO 2328:1993 Fork-lift trucks; hook-on type fork arms and fork arm carriages; mounting dimensions	Equivalent to AS 2359 Pt 11: 1995
ISO 2330:2002 Fork-lift trucks - Fork arms - Technical characteristics and testing	
ISO 2331:1974 Fork-lift trucks – Hook on type fork arms - Vocabulary	Equivalent to AS 2359 Pt 10: 1995
ISO 3184:1998 Reach and straddle fork-lift trucks - Stability tests	Equivalent to AS 2359 Pt 4: 1995
ISO 5057:1993 Industrial trucks; inspection and repair of fork arms in service on fork-lift trucks	Equivalent to AS 4973: 2001
ISO 5766:1990 Pallet stackers and high lift platform trucks. Stability tests	Equivalent to AS 2359 Pt 8: 1995
ISO 5767:1992 Industrial trucks operating in special condition of stacking with mast tilted forward; additional stability test	
ISO 6292:1996 Powered industrial trucks and tractors - Brake performance and component strength	To be an Australian Standard - additional notes relating to risk
ISO 10525:1997 Counterbalanced trucks handling freight containers of 6 m (20 ft) length and above - Additional stability tests	Equivalent to AS 4972 (Int) 2001 less Appendix ZZ
ISO 10658:1996 Industrial trucks operating in special conditions of stacking with load laterally displaced by powered devices - Additional stability test	
ISO 13284:2003 Fork-lift trucks - Fork-arm extensions and telescopic fork arms - Technical characteristics and strength requirements	
ISO 13562: 2000 Industrial variable-reach trucks - Part 1: Stability tests. Part 2: Additional stability tests for trucks handling freight containers of 6 m length and above.	
ISO 13563-1:2001 Single side loading fork-lift trucks - Part 1: Stability tests. Part 2: Additional stability tests for trucks handling freight containers of 6 m length and above	Covered in AS 2359 Pt 1: 1985: Appendix A5
ISO 15794:2001 Bi-directional and multi-directional fork-lift trucks - Stability tests	
ISO 15870:2000 Powered industrial trucks - Safety signs and hazard pictorials - General principles	
ISO 15871:2000 Industrial trucks - Specifications for indicator lights for container handling and grapple arm operations	

8. Australian and international standards - forklift stability tests

The required tests to determine the maximum rated capacity of forklifts are included in AS 2359 and its parts, and in AS 4972(Int). For other styles of forklift trucks ISO 13563 or ISO 15794 may apply

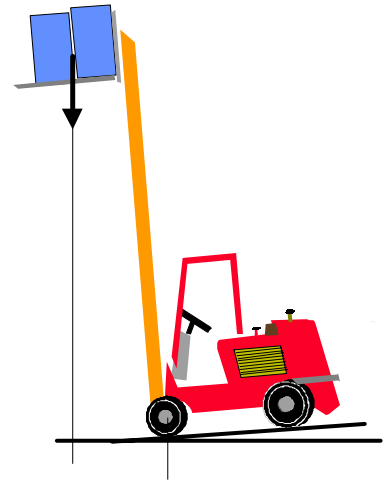
In general, for every forklift style, there are four stability tests, plus others as appropriate for the style of forklift.

Australian and international standards - counterbalance forklift stability tests

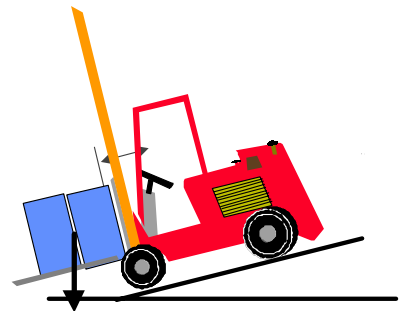
For counterbalance forklifts there are four tests:

1. Stacking – with the mast vertical and forks at maximum height, the maximum load is determined when the forklift is tilted forward on a platform to:

- A slope of 4% for forklifts of rated capacity up to 4999 kg; and
- A slope of 3.5% for forklifts with capacities of 5000 kg to 50000 kg



2. Travelling – with the mast at full rearward tilt and forks lowered, the maximum load is determined when the forklift is tilted forward on a platform to a slope of 18%



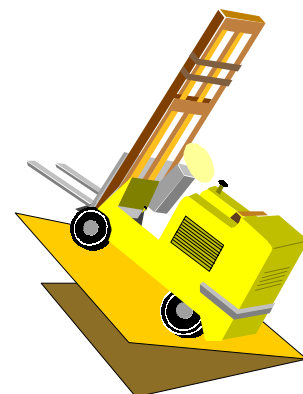
3. Stacking – with the mast at full rearward tilt and forks at maximum height, the maximum load is determined when the forklift is tilted sideways on a platform to a slope of 6%



4. Travelling – with the mast at full rearward tilt and forks lowered, the forklift is tilted sideways on a platform to

- a slope of up to 40% for forklifts of rated capacity up to 4999 kg; and
- A slope of 50% for forklifts with capacities of 5000 kg to 50000 kg

depending on the forklift capacity and maximum speed



Tests 1 and 2 primarily determine forward tipover stability, test 3 determines side tipover stability when loaded, and test 4 determines side tipover stability when empty.

AS and ISO standards - counterbalance forklift stability tests - limitations

All the above tests are undertaken under a quasi-static situation. Hence dynamic effects such as tyre bounce and energy due to the build up in motion that may make the forklift more likely to tipover are not included.

Further *“it is permissible in lateral tests for one of the load wheels to lose contact with the test platform and it is acceptable for parts of the structure or other designed features to make contact with the test platform.”* In practice this situation is likely to cause the forklift to become unstable if it were travelling.

And for stability tests, the forks and side shift are centred (provided the side shift has a lateral displacement that does not exceed 100 mm for forklifts with capacities to 6300 kg and 150 mm for larger forklifts). A sideshift of 100 mm would increase the sideways displacement of the rated load by around 1/3rd at a 4300 mm lift height, or 25% at a 6000 mm lift height. This potentially would reduce side stability significantly.

Rated capacity may be determined by one or more of the three tests. Hence it is possible that safety margins in excess of the Standards exist in respect to the other factors. It is therefore possible that having the sideshift fully to the right or the left may not result in a lower rated capacity.

However as manufacturers do not provide information as to which test was the limiting one in respect of rated capacity no assessment can be made of the impact of sideshift movement on safety margins.

It is recommended that manufacturers provide customers with information as to the stability test that determined a forklift’s capacity. And it is further recommended that stability tests be undertaken for the worst case scenario – that is for instance with the side shift in its worst position

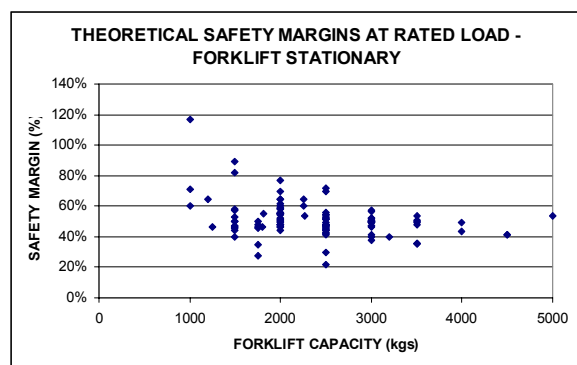
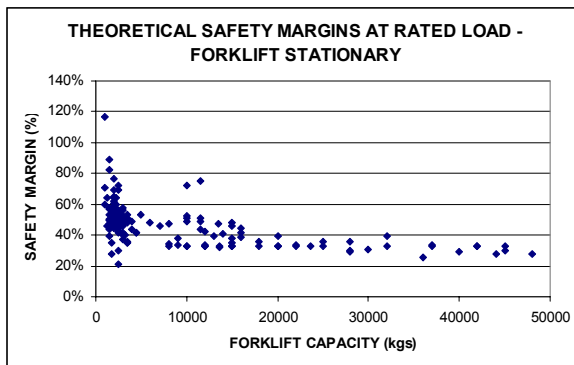
AS and ISO standards - counterbalance forklift stability tests – tipover when stationary

Data has been collected on 178 forklifts with capacities from 1 – 48 tonnes. This data has been analysed in respect of tipover and other safety issues.

The result of stability tests one and two are that with the forklift stationary on a level surface, and the forks down:

- On average the rated load could be increased by 37% without tipover;
- At a minimum it could be increased by 21% without tipover; and
- 80% of forklifts could have increases ranging from 33% to 60% without tipover.

These data are shown in the graphs below.



AS and ISO standards - counterbalance forklift stability tests – tipover when braking

When in use, and the forklift is travelling forward and then the brakes are applied, the safety factor above is reduced because the braking force acts through the centres of mass of the forklift and the load to tend to cause the forklift to tipover forwards.

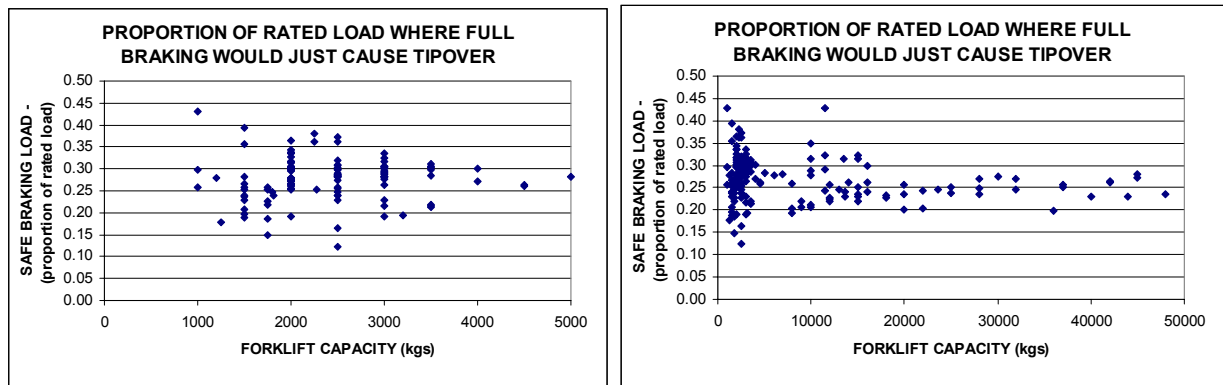
Tests undertaken at Monash University show that empty forklifts can achieve decelerations of around 0.6 g on concrete with a rough surface. They do not tipover forward.

However as load is placed on the forks, the counterbalance safety margin is reduced, and the overturning moment from the combined forklift and its load increases. At some point under full braking and increasing load the forklift will be at the point of forward tipover.

Analysis showed that with the top of the forks 200 mm above the ground:

- On average at 0.27 times the rated load full braking would cause forward tipover; and
- At best, 0.43 times the rated load at full braking would cause forward tipover.

These data are shown in the graphs below.

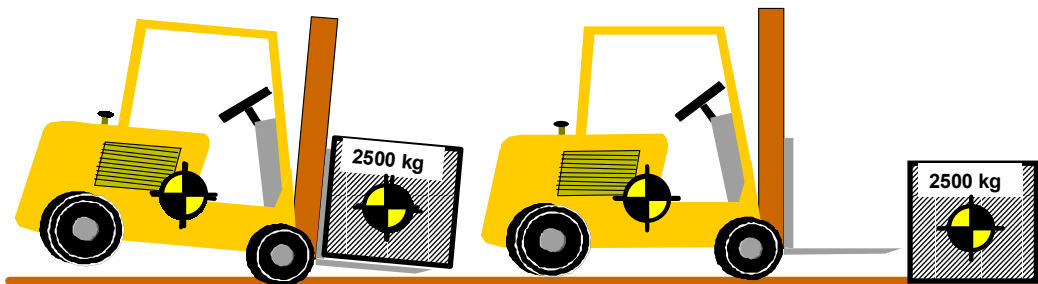


Note that rapid acceleration backwards from a stationary position can have the same effect as braking.

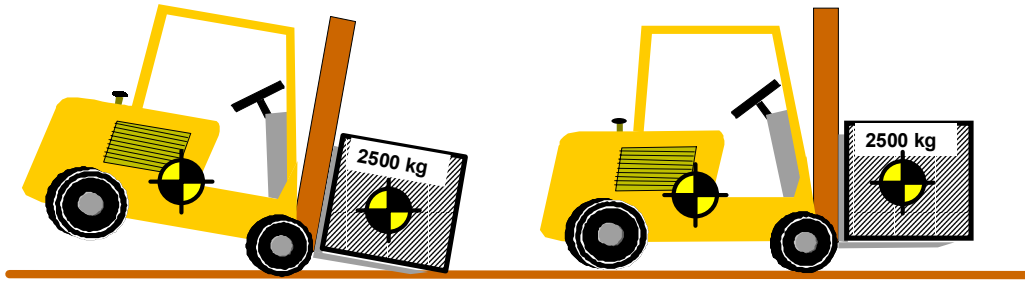
Outcomes from forward tipover when braking

The outcomes of initiating forward tipover by braking or accelerating backwards depend on the type of forklift attachment, and the type of load.

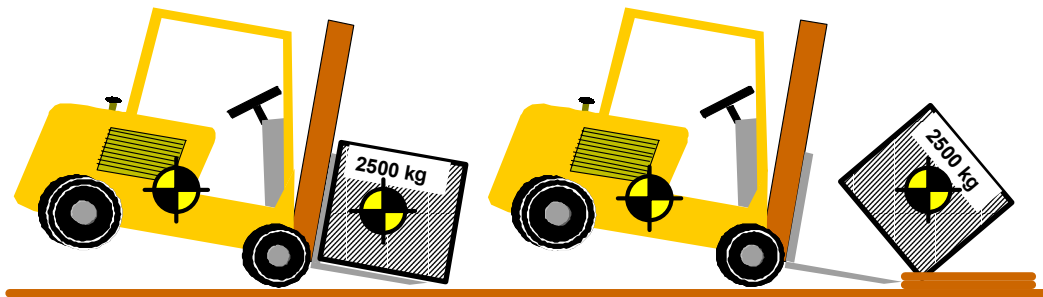
- The forklift may tilt and the load slide off so the forklift drops back down on its wheels



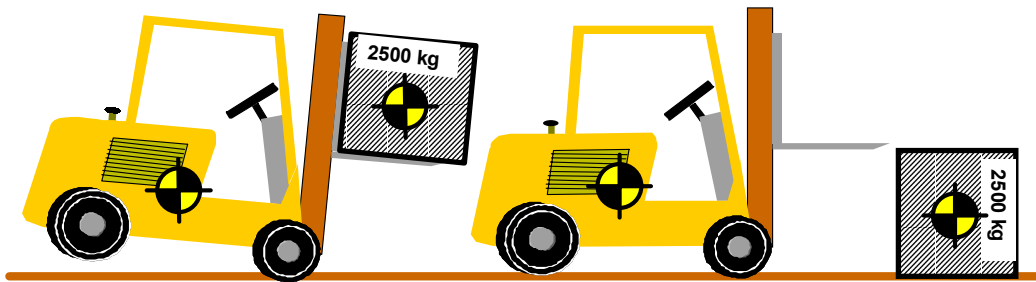
- The forklift may tilt and the load stays on the forks that slide along the floor. When the forklift stops it falls back down on its wheels.



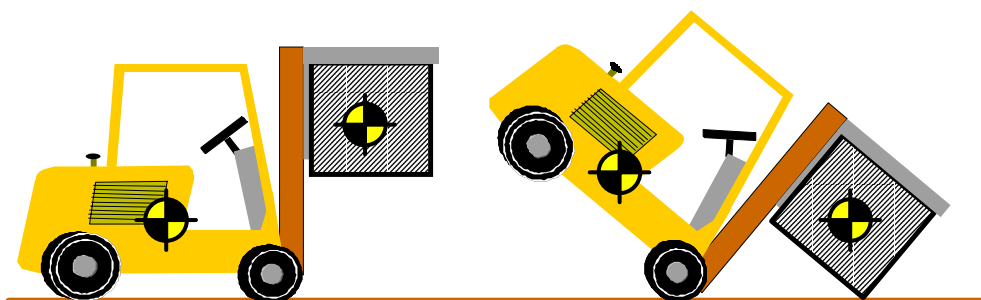
- The forklift may tilt and the forks hit an obstruction. The load will then come off and the operator will be thrown against the mast if not wearing a seat belt.



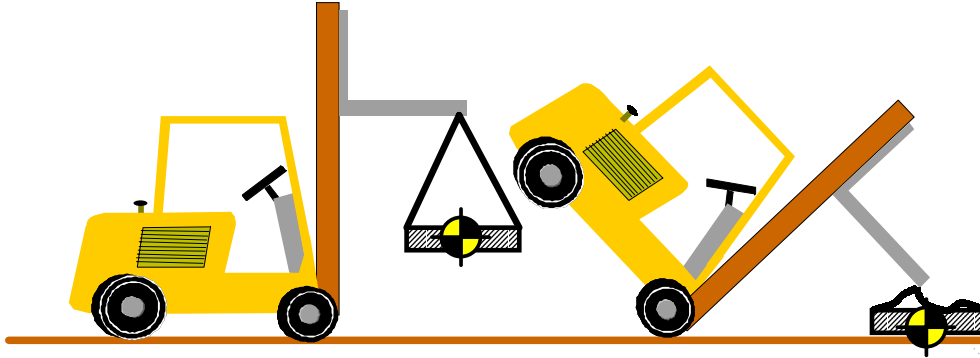
- The load is being carried at height - forklift may tilt and the load fall off so the forklift drops back down on its wheels



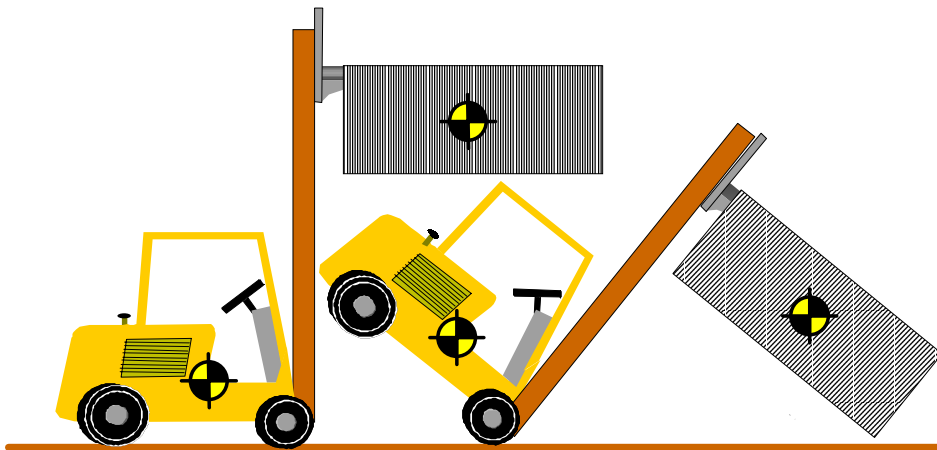
- The load is attached and being carried at height – for example a forklift handling a container. The forklift tips over forwards.



- The load is slung from the forks and being carried at height – The forklift tips over forward.



- The load is on a long prong and being carried at height – The forklift tips over forward because the load does not have time to slide off the forks before the forklift is beyond the point of recovery.

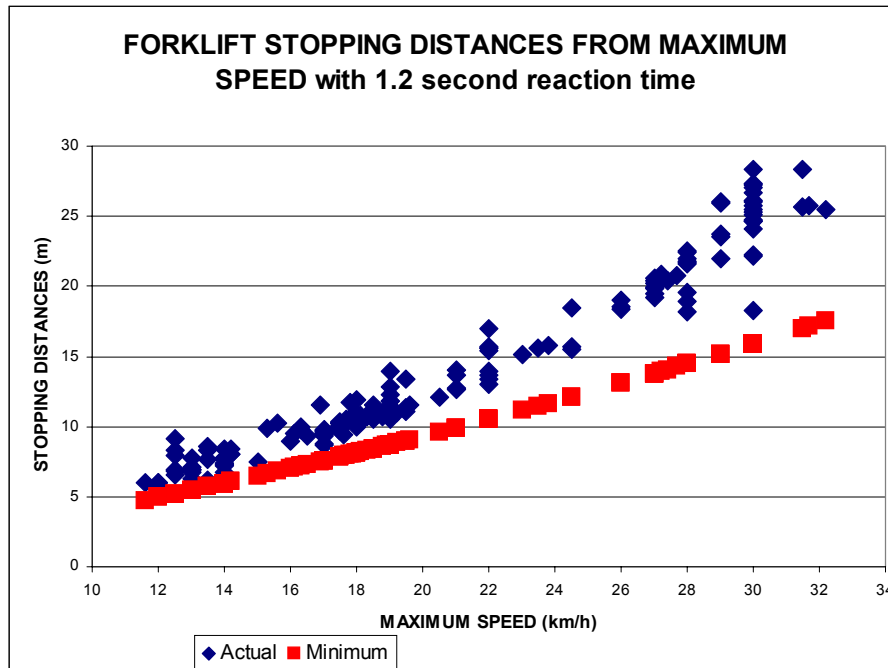


In summary, in the majority of cases where the forklift is loaded and heavy braking is attempted the forklift does not tip forwards. Most often the load slips or falls off the tynes.

However there are higher risks when the load is attached, or effectively attached to the forklift. In these cases forward tipover will more often occur.

Much more commonly the forklift driver does not brake heavily, but regulates brake pedal pressure to prevent tipover starting. This however has the disadvantage of increasing stopping distances.

The graph below shows achievable stopping distances versus maximum speed versus the stopping distance that could be achieved if full braking was possible.



Typically the increase in stopping distance is around 40% with a range of 10%-80%.

In situations where collisions with pedestrians are possible, the extra stopping distance may constitute an unacceptable risk. In those cases speed limiting is a strategy to bring stopping distances down to acceptable lengths.

To ensure stopping distances are not degraded, it is recommended that manufacturers or others further develop intelligent speed limiters that reduce forklift speed as the load being carried increases.

AS and ISO standards - counterbalance forklift stability tests – side tipover when empty

In 75% of cases of side tipover the forklift is empty. As noted above this is because adding load increases stability in respect of side tipover.

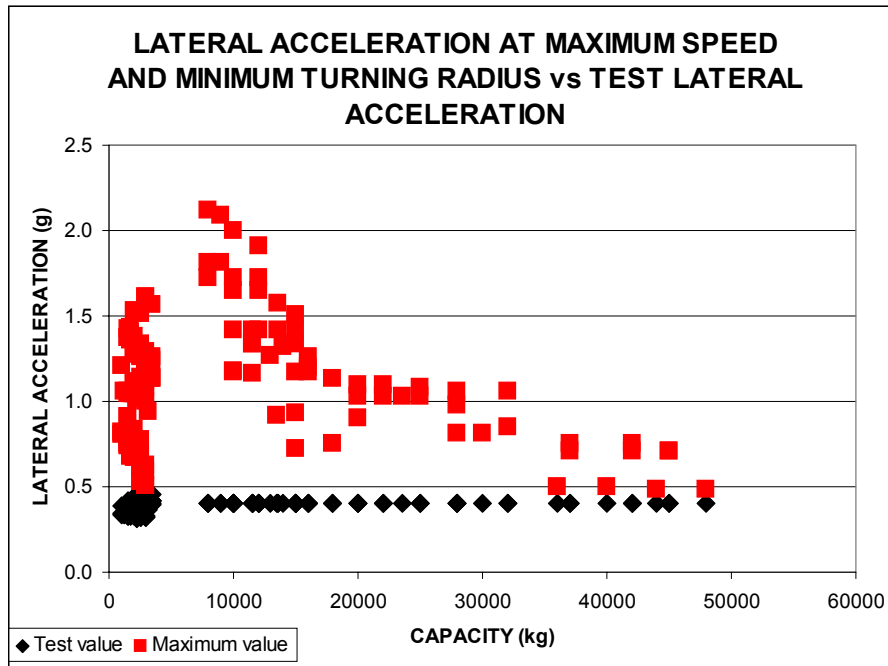
The principal factors affecting side tipover are the centre of mass of the empty forklift, the speed of the forklift, and the radius of a turn.

Forklifts are designed to be very manoeuvrable and so have tight minimum turning circles. Unfortunately this dramatically increases the chance of side tipping.

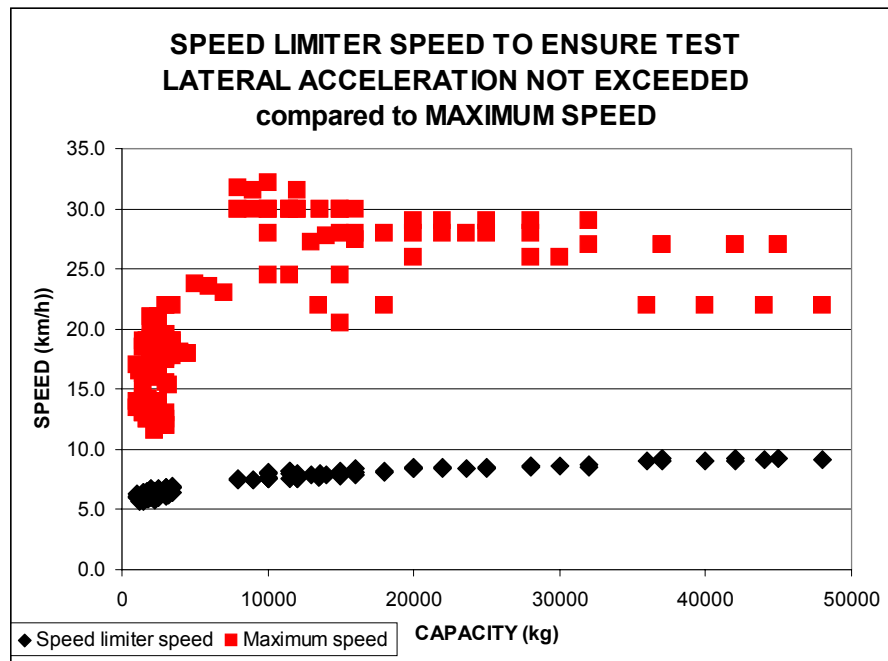
Stability test 4 ensures that the forklift ALONE has a minimum level of side tip resistance.

The graph below shows the lateral acceleration to which the forklift alone will be tested versus the lateral acceleration possible at full speed and minimum turning radii.

It is obvious that the test falls far below the levels of lateral acceleration that are achievable.



It is possible to reduce the levels of lateral acceleration dramatically by limiting the forklift's speed. Modelling this scenario is shown in the figure below.



On average speeds need to be reduced to about one third of maximum, with the common small forklifts of up to 5 tonnes capacity reduced to around 6 km/h.

These figures may be somewhat conservative as Test 4 may not be the limiting test. For the only make of forklift for which centre of mass figures were available, the side stability was about 35% higher than the minimum required under Test 4. If this were indicative of all forklifts, then it would allow the speed limiter setting of small forklifts to be increased to around 8 km/h.

The addition of dual tyres increases stability by about 20% or a little more. As stability is related to the square of the speed, this would allow a 10% increase in speeds to around 9 km/h.

This would eliminate most of the 75% of side tipovers that occur when the forklift is empty.

It is recommended that to eliminate most side tipovers when the forklift is empty that single tyred forklift speeds be limited to 8 km/h and dual tyred forklifts to 9 km/h. Two possible exceptions to this are:

- Where forklift manufacturers can provide stability figures to prove that empty forklifts are safe at higher speeds then those higher speeds may be adopted,
- Or where different work environments justify a different speed limit (for example, an uneven operating surface could require a lower limit).

AS and ISO standards - counterbalance forklift stability tests – other side tipovers

As noted previously, adding load with the forklifts down increases stability in respect of side tipover.

However raising the load rapidly negates that increased stability. Hence the strong message to forklift drivers to not travel or turn with the load raised.

Note that when the forklift is tipping over sideways the load does not tend to fall off the forks until it is too late because the side forces are at right angles to the fork direction.

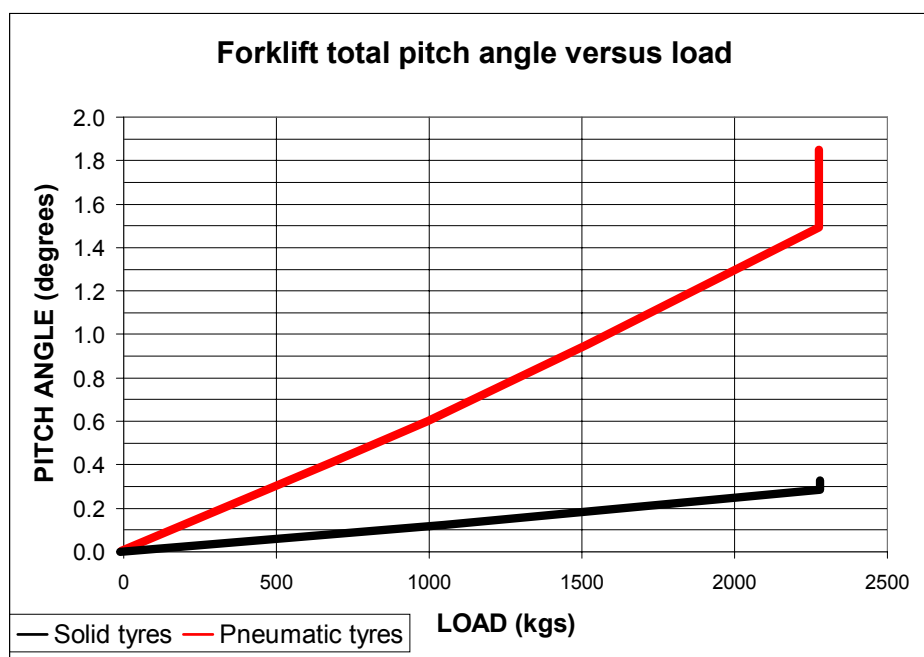
Given that forklift manoeuvrability is essential when loading into racks, the only option is to have an intelligent speed limiter.

It is recommended that forklift manufacturers or others develop an intelligent speed limiter that reduces maximum speed depending on the load, its height, and the turning radius defined by the steering wheel position. This unit would have to be conservative re speeds once the load is raised say a metre because increasing steering angle with the same speed will rapidly lead to a high risk of side tipping situation.

Dynamic effects on stability – tyre types

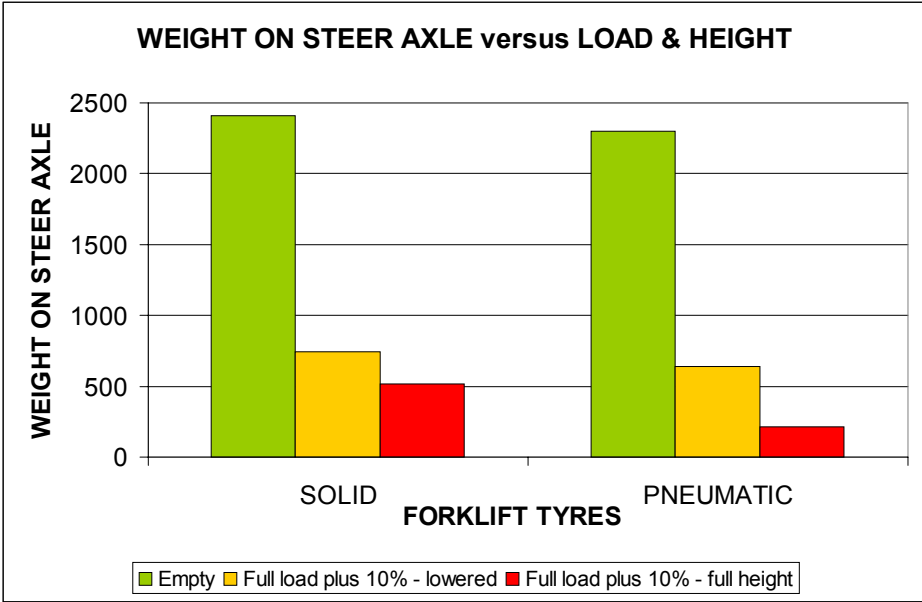
Available tyre types range from pneumatic tyres to cushion tyres to hard rubber tyres. These tyre types have decreasing deflections under load.

To check the effects of tyre flex, tests were undertaken with two forklifts of around 2.7 to 2.9 tonne capacity, with lift heights around 4500 mm. The results of those tests are shown below.



As can be seen the solid tyred forklift only pitches forward about 0.33 degrees while the pneumatic tyred unit tips forward 1,86 degrees or 5.6 times as much. At 4500 mm lift height this results in the load moving forward around 146 mm with the pneumatic tyres, and only 26 mm with the solid tyres.

To check on the impact of that scenario on stability, further testes were done with the results below.



As can be seen when empty there are similar loads on the steer axles. Given that the weight of packaging is often overlooked when estimating the weight of goods on pallets, a test load of the rated load plus 10% was chosen.

When loaded to the rated load plus 10% steer axle loads were still similar.

However when the loads are raised to full height with the mast initially vertical, the situation changes. The solid tyred forklift still has more than 500 kg load on the steer axle at a lift height of 4775 mm. The pneumatic tyred forklift only has 210 kg load even though it has only been lifted to 4300 mm.

With the load at full height, braking or reversing backwards that generated an acceleration of 0.043 g would initiate tipover of the solid tyred forklift while the acceleration required to tip over the pneumatic unit would be only 0.021 g.

Based on the above, and allowing for the fact that pneumatic tyre pressures may not always be at design levels, it is recommended that pneumatic tyres be the tyre of last resort for forklifts designed primarily for use on flat smooth surfaces. On these forklifts pneumatic tyres significantly erode safety margins in the dynamic situation.

It is further recommended that an education campaign be undertaken explaining that pneumatic tyres and uneven operating surfaces like gravel yards are a dangerous combination.

Note that these comments do not necessarily apply to rough terrain forklifts

Dynamic effects on stability – computer simulation of certain manoeuvres

The project team appreciated that in forklift operation significant dynamic forces are generated including those resulting from braking, acceleration, turning, and bounce.

It was decided to set up a computer simulation model to estimate the impact of these dynamic loads on stability. RMIT offered to undertake this work.

A number of simulations were undertaken.

Dynamic effects on stability – computer simulation of braking & turning

RMIT personnel undertook simulation of simultaneous braking and turning.

While it was expected that this would aggravate instability this was not found to be the case.

Analysis showed that as lateral forces due to cornering are proportional to the square of the speed, the reduction in speed under braking reduces these lateral forces very rapidly so that on balance stability is not adversely affected.

However heavy braking can exacerbate side tipover situations where the steer wheels lift off the ground. In this situation any lateral forces spinning the forklift to one side will generate high side loads at the drive tyres and cause the forklift to be “tripped up”.

Dynamic effects on stability – computer simulation of uneven floors

For typical small single drive tyred forklifts, the test side slope required in test 3 with the load at full height is 6%. For small forklifts (up to a little more than 3 tonnes nominal capacity for Australia) this is equivalent to a variation in the height of single drive tyres of around 60 mm (53 – 64 mm). Hence the forklifts would be “safe” in a static situation with this difference.

Modelling was undertaken by RMIT of a forklift moving forward slowly to place a rated load onto a rack at maximum height. The design speed chosen was 3 km/h and the drop was a sharp drop as might be experienced where the edge of a slab has dropped or the edge has broken away at a joint. Lift height was about 4500 mm.

That simulation showed the side tipover stability limit was reached at a 40 mm height difference assuming that:

- The floor was flat and level
- The load was central on the forks,
- The forks were central on the carriage,
- The rated load had not been exceeded,
- All pneumatic tyres were at proper pressures, et cetera

Further, given that there is a practice of double stacking pallets weighing about half the rated load each as a way of getting extra storage volume, this was also simulated. It showed the stability limit was reached at 30 mm with the load at full height, making the assumptions detailed above.

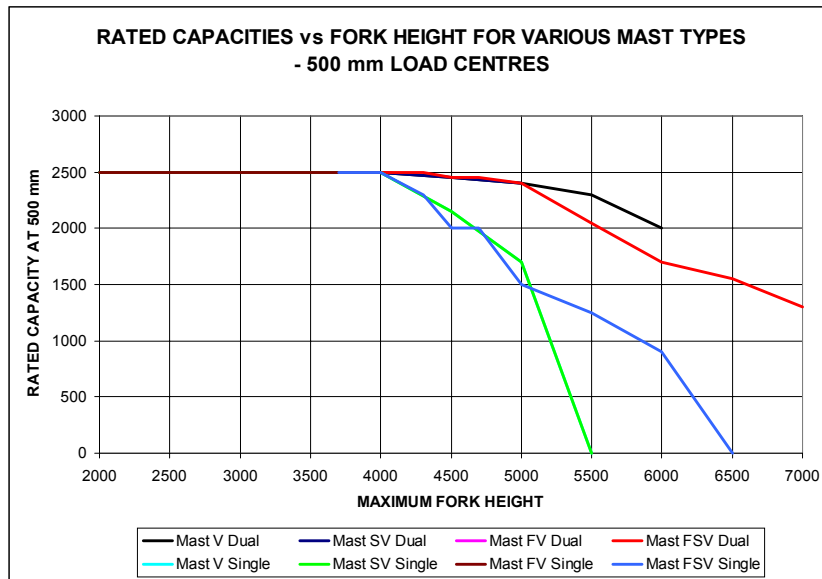
Calculations at Monash showed that if the load was offset 100 – 150 mm by a combination of off centre loads and slight general floor slope then the stability limit would be reduced a further 10 mm to 12 mm.

Hence it is recommended that in areas where loads will be raised to full height (in aisles between racks for instance), any floor imperfection exceeding 20 mm in depth and of a size and shape that would enable a forklift tyre to fit be repaired as a matter of urgency.

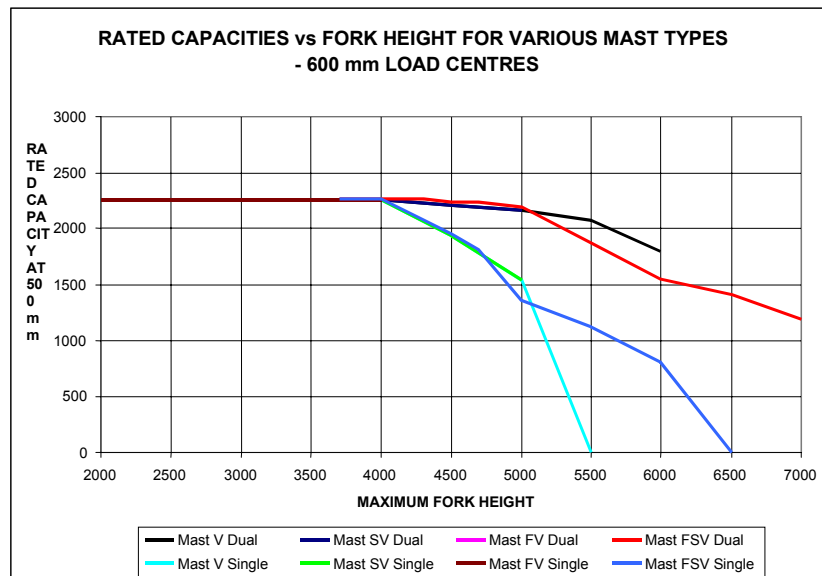
Forklift capacity versus lift height

For the same forklift, capacities can vary dramatically with the mast design, the maximum lift height and with the drive tyre set up – single or dual tyres.

The graphs below show manufacturers’ capacities for a current model forklift at the international standard of 500 mm load centre.



Monash has used this data to estimate capacities at the Australian 600 mm load centre – these are shown below.



As can be seen there is a dramatic loss of capacity at maximum lift:

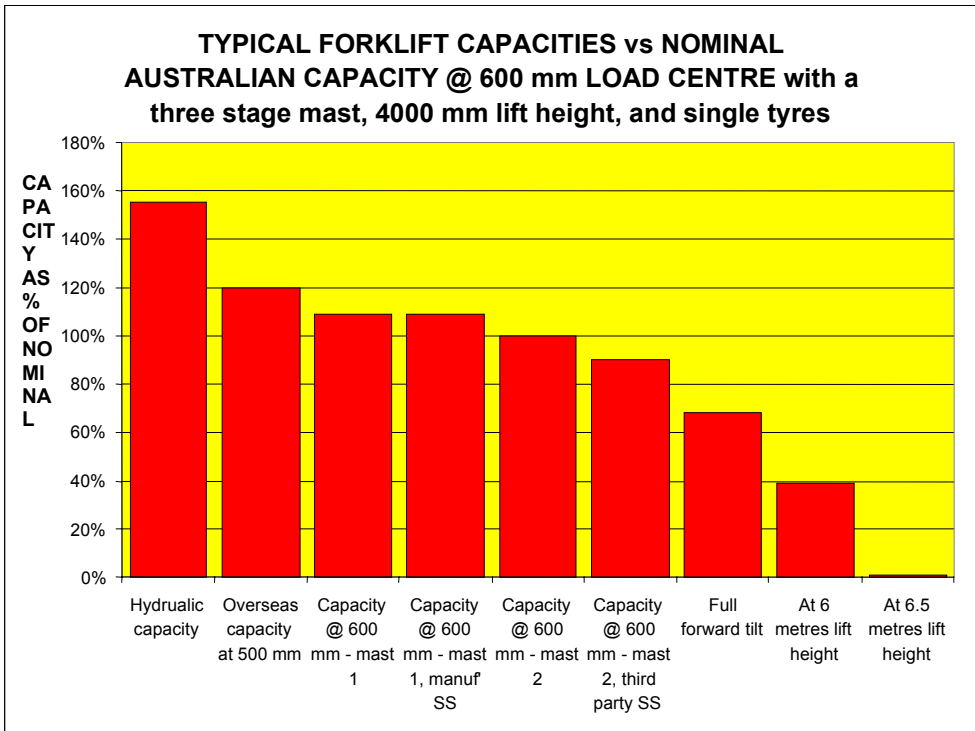
- for the single tyred forklift once lift height exceeds 4000 mm; and
- for the dual tyred forklift once capacity exceeds 5000 mm.

However the hydraulic cylinder of the forklift will still lift 2.5 tonnes or more (see later).

Hence it is recommended that in the absence of proof of additional safety systems that limit the risk of side tipping, small single drive tyred forklifts be limited to lifts of around 4000 – 4500 mm, and small dual tyred forklifts be limited to lifts of around 5000 – 5500 mm

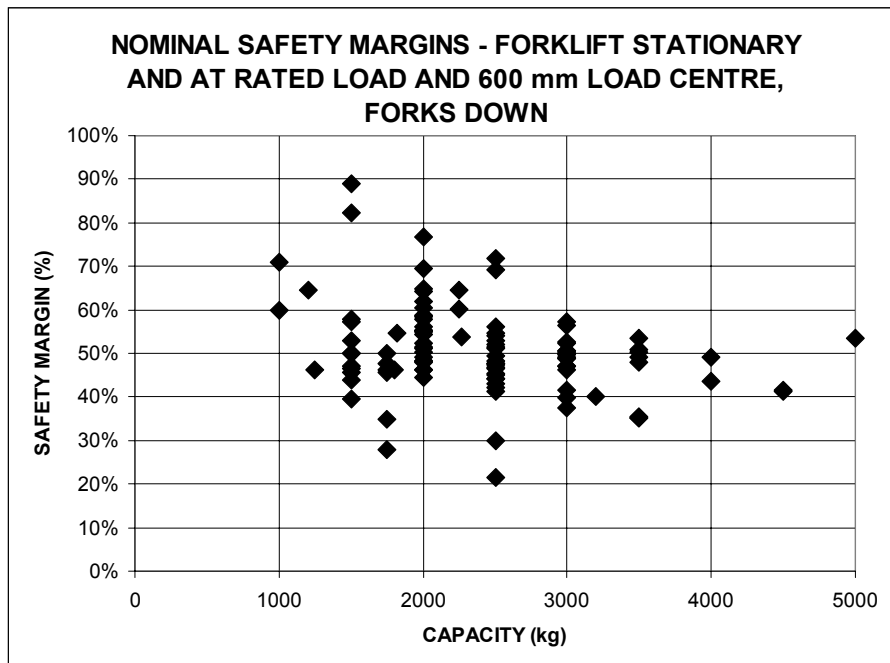
Forklift hydraulic lift capacity versus rated capacity in Australia

The graph below shows the various capacities of a current small forklift.



Capacities range from 155% of nominal Australian capacity to 0% of that capacity.

The forklift's hydraulic system will often physically lift about 155% of rated nominal capacity because for small forklifts the static safety margin often exceeds 55% as shown in the graph below.



From a risk perspective this could create a situation where there was serious risk of the forklift tipping over. Typically this would be where an operator lifted a load whose weight they did not know, and went to place it at full lift height onto a rack.

It is possible that the load could be 300% - 400% greater than the safe load.

The obvious safety initiative would be to reduce the maximum hydraulic pressure to more closely match the forklifts rating – say maximum rated load for that forklift with its permanent

attachments and with its mast design and maximum lift height plus 10%. This could be achieved with a high performance pilot operated pressure relief valve or similar.

It is recommended that the purchasers of forklifts arrange for the maximum hydraulic pressure to the mast cylinders to be set at about 110% of the maximum rated load of each forklift at full height, mast vertical

Stability when mast at forward tilt

Mast forward tilt is primarily required to pick up loads on the tray of trucks where the ground may not be completely level and or the coaming rail on the tray requires tilt to insert the fork tyres. Typically forward tilt is limited to about 6 degrees (10.5% slope) for this purpose.

To place or pick-up pallets on racks, given that the floor should have a slope of no more than 2%, a forward tilt of 1.2 – 2.0 degrees (2% - 3.5% slope) is adequate

Some specialist applications require greater forward tilt. For example to split steel plate without gouging the plate below the split point requires a tilt of 12 – 15 degrees (21% - 27% slope).

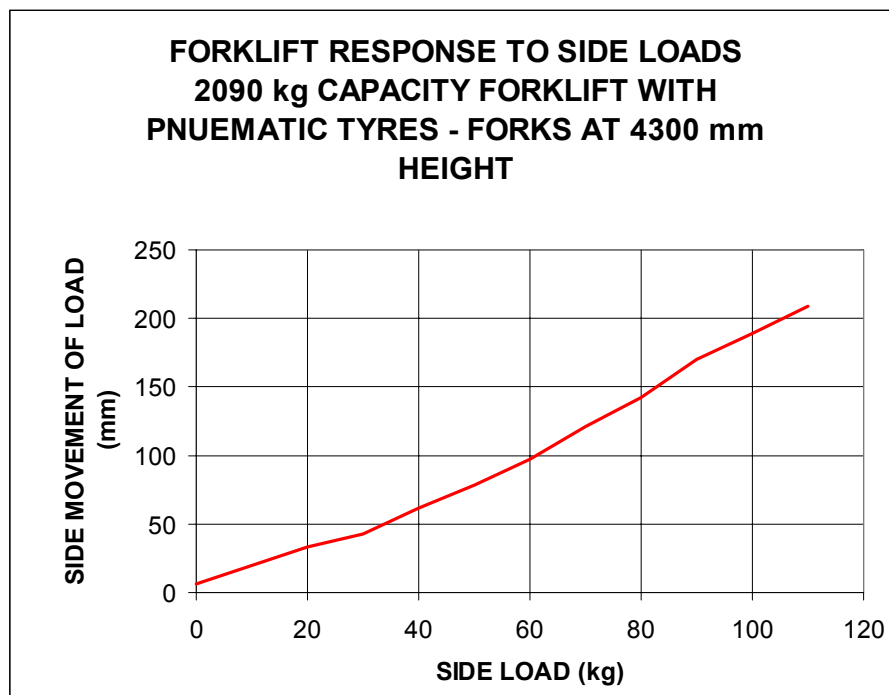
However the rated load at full forward tilt reduces with fork tyne height. At lifts of 4300 to 4800 mm the capacity is reduced to 65% - 80% of the vertical capacity for tilts of 6 degrees. For 15 degrees tilt the capacity is reduced to 50% at 4000 mm.

It is recommended that only forklifts that have a system to prevent full forward tilt above about 1600 – 2000 mm lift be purchased. The system should require the mast to be brought back to a tilt of no more that 2 degrees above this height.

Limits to safety when using tarpaulin spreaders or similar items

Tests were undertaken at Monash University on side loads on forklift tyres.

For a pneumatic tyred forklift with a rated capacity of 2090 kg, a side load of 110 kg resulted in the centre of the mass of the load moving 208 mm sideways, equivalent to a forklift tilt of 4.8%. While this was less than the 6% tested under the standard, at this deflection the most heavily loaded tyre had deformed to the degree that it had difficulty in resisting dynamic effects of the loading, so the test was stopped.



Tarpaulin spreaders are devices that consist of frame with a 3-4 metre long arm extending sideways. The tarpaulin, which may weigh up to 110 kg, is prepared as a roll and the arm inserted into the centre of the roll. End ropes are attached to the vehicle and the forklift driven forward so that the tarpaulin is spread over the load. Alternately the tarpaulin is spread behind the truck and then attached to the spreader and dragged up over the load.

This means the truck driver is not exposed to the risk of working at heights. For the highest loads the spreader may have to operate with forks at 4300 mm or a little higher.

When new ropes used on tarpaulins have breaking strengths of 400 kg – 900 kg.

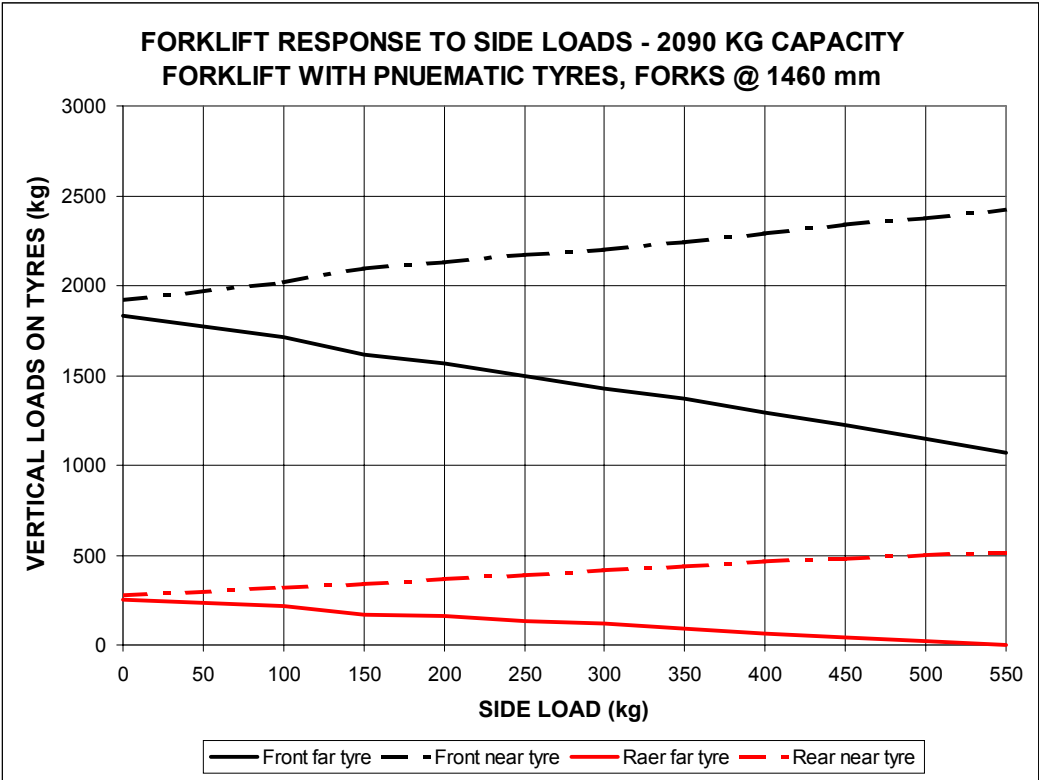
Given the test above, any situation where the tarpaulin “catches” represents great risk of dragging the forklift over.

In addition the mast and the fork attachments are not designed to take the forces that may be generated by the twisting moment applied to them, and may be damaged or fail.

For this reason it is recommended small single drive tyred forklifts not be used for tarpaulin spreading. And a risk analysis needs to be undertaken for larger dual drive tyred forklifts including consideration of the fitting of a “breakaway” device that will minimise the maximum forces applied to the forklift.

Limits to safety when a truck being loaded drives off while the forklift is placing a load

In the tests undertaken at Monash University on side loads on forklift tynes, one test was undertaken at 1460 mm fork height, similar to the height of forks when placing a load on the tray of a truck. The results are shown below.



At a side load of 550 kg the rear far side tyre commenced lifting off the ground and the test was stopped. And the load on the far side front tyre had reduced by 42%.

Calculations suggest the far side front drive tyre would have lifted off at around 1300 kg side force.

Australian Design Rules for heavy vehicles require them to be able to start on a slope of 13%. Hence any truck of 10000 kg or heavier could pull a “two tonne” forklift with single tyres over provided the load caught on previously placed parts of the load or the truck body structure.

Incidents of this happening are not common but do occur.

Hence it is recommended that any safe system of work related to loading or unloading trucks provide for the keys of the prime mover to be taken out of the truck and placed with the forklift driver or other responsible person.

Forklift marking

There is a practice under which forklift model numbers are related to the overseas forklift rating at 500 mm with standard forks.

As result of this practice, a forklift with the numbers 25 on the side tends to be referred to as a 2.5 tonne forklift.

However as shown above, such a forklift may have a capacity less than half that rating if fitted with sideshift and/or a high lift mast.

A preferred practice is recommended to place numbers on the counterbalance of the truck that represents its actual capacity or capacities. And model numbers on plates preferably would not include figures indicative of the international capacity.

9. SUMMARY OF STABILITY ISSUES AND MEANS TO REDUCE RISK

Forklifts designed to comply with Australian and ISO standards are inherently unstable. As a result operators have to moderate their braking, accelerating and other behaviours to compensate for this inherent instability. Requiring forklift operators to change their driving behaviour to compensate for such instability problems is not the most effective method of hazard control- the most effective method is to design the hazard out of the system.

Note that manufacturers do not normally provide operators with instruments or other devices to guide them in regard to appropriate forklift driving behaviour.

As a means of reducing forklift stability related risk in the workplace, the following recommendations are made:

1. The Victorian WorkCover Authority with the assistance of experts continues to work with the Standards Association to have Australian standards produced which provide a higher level of safety in respect of stability
2. That manufacturers provide customers with information as to the stability test defined in those standards that determined a forklift's capacity.
3. That the stability tests defined in the standards be undertaken for the worst case scenario – for instance with the side shift in its worst position, and that tilting of the forklift so that the body of the forklift is supporting the unit be considered a failed test. This will have the effect of de-rating some current models.

4. To ensure stopping distances are not degraded, it is recommended that manufacturers or others develop intelligent speed limiters that reduce forklift speed as the load being carried is increased. Such systems could be further enhanced by incorporating variations in load height into the design.
5. To eliminate most side tipovers when the forklift is empty, that single tyred forklift speeds be limited to 8 km/h and dual tyred forklifts to 9 km/h - except that where forklift manufacturers can provide stability figures and analysis to prove that empty forklifts are safe at higher speeds, those higher speeds may be adopted.
6. That forklift manufacturers or others develop an intelligent speed limiter that reduces maximum speed depending on the load, its height, and the turning radius defined by the steering wheel position. This unit would have to be conservative in regard to speeds once the load is raised above about a metre because increasing steering angle with the same speed will rapidly lead to a high risk situation.
7. That pneumatic tyres be the tyre of last resort for forklifts designed primarily for use on flat smooth surfaces because they significantly erode safety margins in the dynamic situation. In particular, education needs to be provided that these forklifts operating in gravel yards represent a high risk operation. Note that this comment does not necessarily apply to rough terrain forklifts.
8. That in areas where loads will be raised to full height (in aisles between racks for instance), any floor imperfection exceeding 20 mm in depth and of a size and shape that would enable a forklift tyre to fit be repaired as a matter of urgency.
9. That in the absence of proof of additional safety systems that limit the risk of side tipover, small single drive tyred forklifts be limited to lifts of around 4000 – 4500 mm, and small dual tyred forklifts be limited to lifts of around 5000 – 5500 mm
10. That the purchasers of forklifts arrange for the maximum hydraulic pressure to the mast cylinders of each forklift to be set at about 110% of the rated load at full height and with the mast vertical.
11. That only forklifts that have a system to prevent full forward tilt above about 1600 – 2000 mm lift be purchased. The system should require the mast to be brought back to a tilt of no more than 2 degrees above this height
12. That small single drive tyred forklifts not be used for tarpaulin spreading. And a risk analysis needs to be undertaken for larger dual drive tyred forklifts undertaking this and similar tasks, including consideration of “breakaway” devices to limit forces applied to the mast.
13. That any safe system of work related to loading or unloading trucks provide for the keys of the prime mover to be taken out of the truck and placed with the forklift driver or other responsible person.
14. That existing model numbers of the style where 25 = 2.5 tonnes be removed and replaced by numbers on the counterbalance of the forklift that represents its actual capacity or capacities as supplied for use in Australia.