

IMPROVED SAFETY AND EFFICIENCY OF TRUCKS



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Abstract

The article focuses on new safety systems for trucks and a new energy saving system to reduce fuel consumption. This first article using Mathers' technology looks at tipper roll over safety, hoist safety and safety around overhead power wires.

Fuel savings occur by retracting the vanes of the secondary power steering pump when not required. This system eliminates parasitic power losses by not pumping oil through the hydraulic circuit when the pump is not required

Introduction

Since the first invention of the horseless carriage, motor vehicles have undergone a long progressive change. In particular, trucks have also been subject to this extreme transformation. The progression to make trucks wider, longer, higher, faster, safer and more powerful has slowed in recent years. As there is an upper limit to the dimensions that vehicles can have and since axle load limits are applied to prevent pavement damage, the required power of vehicle engines have a practical upper limit.

The modern trend has been to make truck engines more fuel efficient together with fewer exhaust emissions. Truck safety remains on the agenda.

To discuss all truck innovations that have occurred over the past century would require a number of volumes of publications. This first article will focus on the following problem areas and offer a solution to each one — fuel saving by power steering pump management, tipper roll over safety, hoist safety and tipper safety around overhead power wires. Subsequent articles will explore productivity improvements through computer technology, weight and site management, power regeneration, noise reduction and braking.

Fuel saving by power steering pump management

Early trucks were relatively slow compared to passenger cars. Their road speed was limited by a number of factors including engine power, tyre technology and the ability to safely steer and brake the vehicle. Steering systems were entirely manual in operation with high steering gearbox ratios. Steering wheel diameters tended to be large as well to allow the driver to exert extra torque into the steering box. A necessary requirement for truck drivers of yesteryear were strong brawny arms.

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The introduction of power steering to trucks, saw steering box ratios approximately halve and steering wheel diameters reduced in size. These changes allowed trucks to safely attain higher speeds while still allowing the truck to be sufficiently agile to manoeuvre amongst modern high speed traffic.

During low speed urban travelling, a truck requires high response in its steering with large turn angles expected from its front steer wheels. At the same time the engine revolutions are not high. A highly responsive steering system requires a high oil volume flow rate to its power steering and this must be achieved with low engine revolutions. Hence a high volume output steering pump is required.

Conversely, at highway speeds only small movements of the steering system are required. Also at highway speeds the engine revolutions are considerably higher than low speed urban running. Hence for highway speeds only a low volume of power steering oil is required.

From a conservation of energy aspect, the pumping of large power steering oil flows even at low open circuit pressures can equate to significant fuel wastage. Truck designers have attempted to skirt around this issue by installing a number of power steering pumps. Using various techniques the required volume of power steering oil is supplied on demand. The problem with these systems, large volumes of oil are continuously pumped around in a circuit at low pressures achieving nothing except expending energy.

A new Australian design of power steering pump called a fuel saving vane pump² (FSV) has been developed where its output can be switched to zero (Figure 1), and importantly, without attracting the parasitic losses normally experienced by standard power steering pumps. The feature has been added to the Eaton/Vickers style medium and heavy duty vane pumps to improve efficiency, reduce noise and fuel consumption and reduce greenhouse gas emissions. This innovative pump design won the Engineers Australia (Queensland), Engineering Excellence Award for Sustainability in 2007. It is one of a number of other Australian inventions that have contributed to the transport industry worldwide.



Figure 1.
Left – vanes restrained in the standby energy saving position
Right – standard vane pump operation position

The system works by having a primary and secondary vane pump driven by a common drive line connected to the steering circuit in parallel. At low speeds both pumps combine to deliver the large volume of oil needed for a highly responsive steering system. As the engine speed increases the secondary pump is deactivated. Studies have shown that a vehicle engine spends 90% of its life over 1300 rpm. With this new system, the secondary steering pump is deactivated at 1200 rpm. It can be seen from Figure 2 how power is saved using this method.

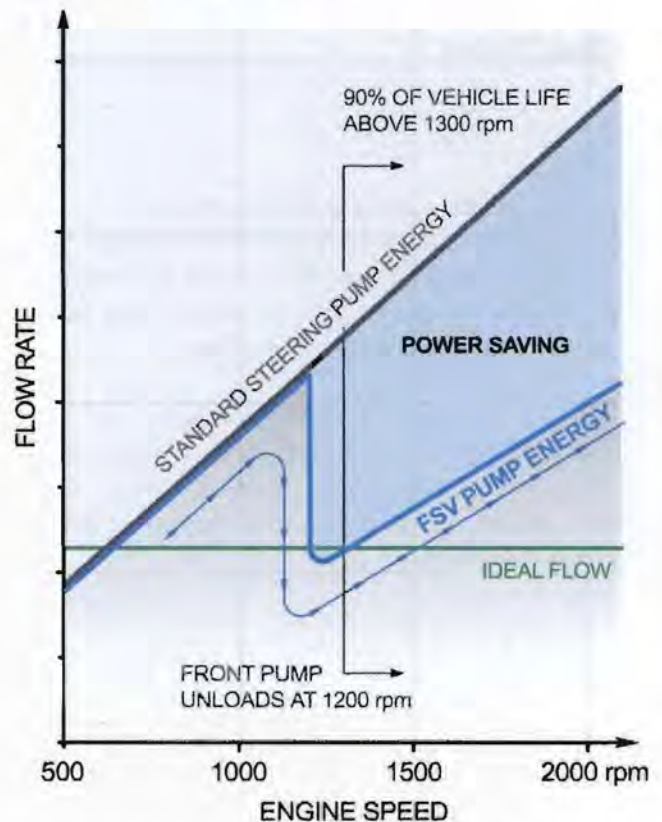
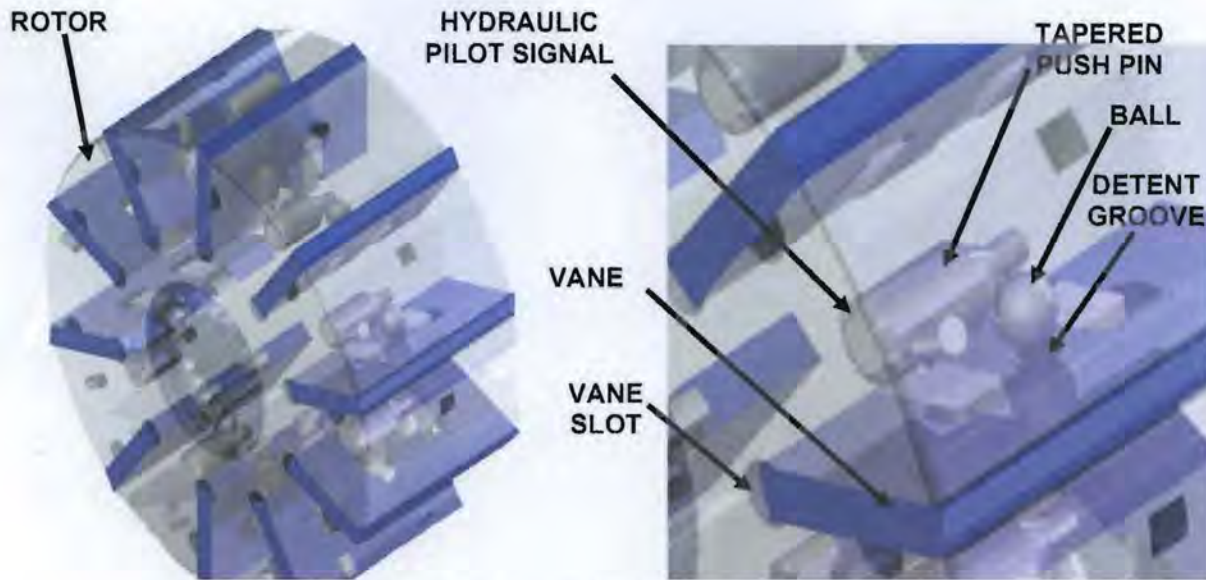


Figure 2. Comparison of a FSV pump to a standard pump

² Harry F Vickers (1898 – 1977) was an American industrialist and inventor of the balance vane pump. He founded Vickers Manufacturing Co. which later became Vickers Inc.



**Figure 3. Left – vanes restrained in deactivated position
Right – Ball forced into a detent in a vane by a tapered piston**

With reference to Figure 3, a hydraulic pilot signal is applied to the square end of a cylindrical piston which had a tapered pin formed into the opposite end. The tapered pin forces the steel ball into a detent groove in each vane as they are retracting. As the ball fully enters the detent groove, the vane is retracted further into the rotor slot and retained. This deactivation process occurs while the pump is running. As long as a hydraulic pilot signal exerts a force on the pistons, the vanes are held in the retracted position despite being acted on by a centrifugal force. In this position the pump does not pump any oil and therefore is not subject to power losses.

When the pilot signal is removed, the centrifugal force acting on the vane and ball push the pin away, releasing the vanes to operate as a normal vane pump. Eaton Laboratories USA measured the on/off actuation times at less than 100ms.

When installed on a long haul truck, the pump can save up to 0.5 litres per hour in typical quarry to city working conditions. While this saving is not extraordinarily large it is just one component part of a suite of measures that when combined make significant savings to a truck fleet operator. In addition this secondary pump can be used for other hydraulic applications on the vehicle. This in itself is an additional saving, as often these auxiliary pumps have intermittent use (and parasitic losses) such as operating a body tipping hoist.

The current trend toward constant drive engine driven power take offs (PTO) removes the need for conventional transmission PTOs with clutches and associated gear clashing issues. Conventional PTOs are heavy and bulky and take up valuable space. Their operation can also cause gear shifting issues with automatic mechanical transmissions. Hence the use of constant drive hydraulic pumps makes the fitting of the FSV pumps a necessity for power saving. The use of FSV pumps will assume greater importance when used in conjunction with power regeneration systems which will feature in a future article.

Tip truck rollover

World-wide each year, many truck rollovers go largely unreported. Truck and/or trailer rollover is a major safety issue and concern for truck fleet owners. In addition to potential injury to drivers and bystanders, the costs of repair and down time of the vehicles are significant with an average of \$33,000 for repair and 4.2 weeks down time per incident.

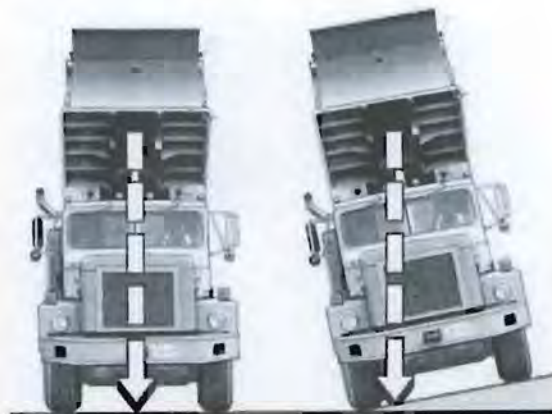


Figure 4. Tip truck rollover (1)

There are several causes, which can contribute to the trailers tipping to one side including:

- The tipper may be unloading on uneven, uncompacted or inclined ground (Figure 4)
- The load in the tipper may be sticky or lumpy and not slide out evenly from the tailgate when the body is raised. This situation can cause the driver to raise the tipper body higher, raising the centre of gravity of the tipper and making it unstable
- The tipper ram may lift the tipper body dangerously due to poor maintenance. If the centre of gravity of the load does not align with the trailer it can cause a sideways tipping movement
- Tyres on one side may be under-inflated causing the body to tilt slightly to one side
- High wind gusts acting sideways on the raised body
- The tipper body may be over loaded.

Tipper trucks and trailers are designed with a very narrow margin of stability. Even a slight incline in the land contour poses a risk that the vehicle could roll sideways. This risk is further increased by factors such as a high centre of gravity of the load, and poor maintenance of the tipper body lifting mechanism.



Figure 5. Grain truck rollover

During the tipping operation, the truck body's centre of gravity is raised above the chassis. If the truck is not laterally level, the centre of gravity increasingly moves away from the centreline of the truck. When this occurs, unequal forces are exerted on the vehicle suspension, tyres and chassis. These unequal forces cause differing amounts of deflection and tend to amplify further the amount of sideways tipping effect. Because heavy vehicle chassis' are deliberately made of torsionally flexible channel section, the prime mover can only exert a limited restraining torque to the sideways moving tipper body. When the point of instability is exceeded, rollover occurs. Figure 5 shows a grain truck rollover while unloading.

To reduce the likelihood of rollover, an innovative system has been developed which senses a number of parameters during tipping. This system is comprised of the following key equipment items:

1. Load cells are mounted on either side and underneath the hoist trunnions (Figure 6). These measure body load and side load
2. A safety valve is mounted directly to hoist. This valve controls the double stage lower section of the hoist, is a fail safe in case of hose failure and it maintains a positive hydraulic pressure in the hoist (Figure 6)
3. Truck tipping hoists are typically single acting. Figures 6 & 7 show a double acting stage in the lower part of the hoist with single acting stages above that
4. Body pivot point load cells to monitor body load (Figure 8)
5. A dual axis inclinometer is mounted to the tipping body to measure tipping angle and transverse body angle (Figure 8).
6. An onboard control computer is used to manage and respond to the various parameters.

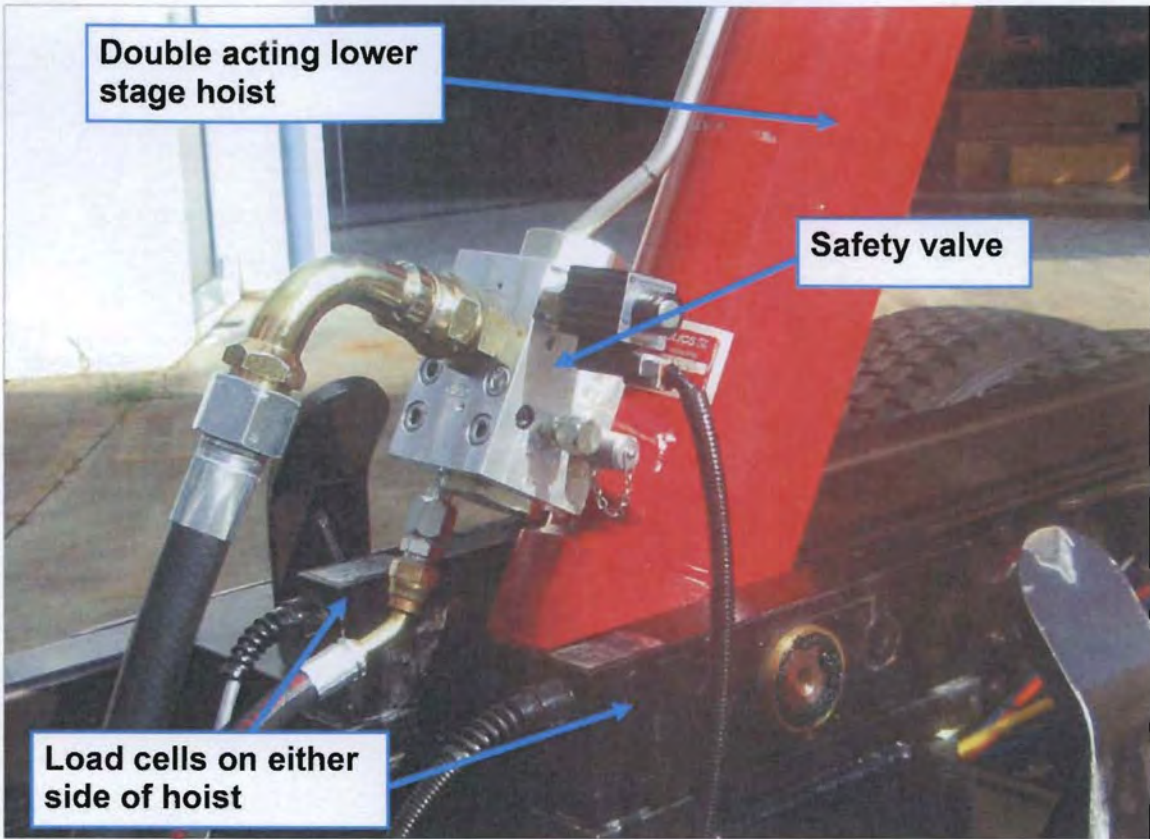


Figure 6. Truck hoist



Figure 7. Lower red stage of the hoist is double acting

The onboard computer system senses a number of parameters and can detect potential instability and sideways momentum of the tipping body. This rapid response system will greatly reduce the risk of roll over accidents. The electronic system reacts much faster than an operator can and more than likely before the operator realises there is a stability problem. When instability is detected, depending on the level and condition, the system will either:

- Automatically lower the hoist
- Respond by either electro-hydraulically vibrating the body to free sticking loads
- Stop tipping operations until the load has had a chance to clear.

The hoist load cells serve two functions. By comparing the load on either side of the hoist, an indication is given to the extent of lateral side load or bending moment that is being placed on the hoist. If a truck is about to tip, there can be a high lateral bending load placed on the hoist. The load cells also play a part in the body weighing system which will feature more fully in a future article.

Load cells are fitted inside the two body pivot pins at the rear of the body measure body load (Figure 8). These rear pivot pin load cells are not required for the stability system but are a part of the body weighing system.

A dual-axis inclinometer mounted to the tipping body (Figure 8) is used to confirm if the ground is suitable for tipping in the transverse direction and to monitor the body tipping angle in the longitudinal direction. When tipping, if the load is not reducing on the trunnion load cells as the body tips, instability can result. The system detects this and takes preventative measures. In addition, the inclinometer helps prevent end of stroke shock by stopping the hoist prior to the end of stroke. It also prevents the pump pressure needlessly reaching its maximum with the associated energy loss through operation of the pressure relief valve.

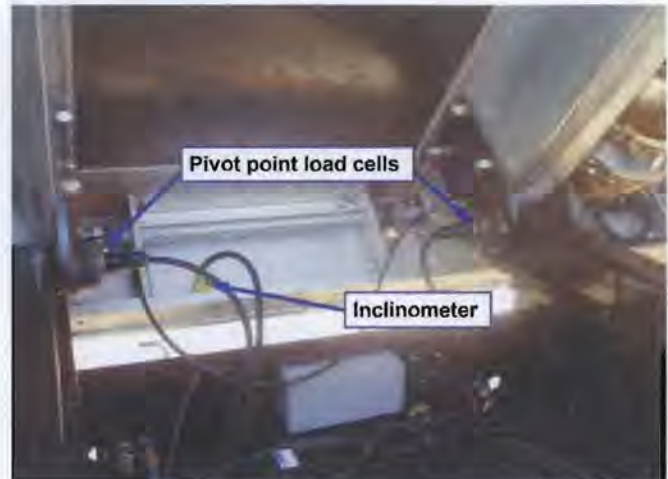


Figure 8. Instrumentation in and adjacent to the truck body pivot pin

Telescoping hoist safety

The hoist safety valve shown in Figure 6 serves a number of different functions.

Hose failure - If the main hydraulic pressure hose immediately prior to the hoist were to burst while tipping, the body would fall rapidly and create a safety issue for the driver and surrounding personnel. The safety valve is mounted directly to the hoist with no connecting hoses. To counter the effects of a burst hydraulic hose, an excess flow valve has been fitted inside the safety valve. If hydraulic hose failure occurs, the excess flow valve instantly prevents further lowering. If this situation arises, the hoist would still need to be lowered in a safe fashion but now under the full control of the driver. The safety valve does this electrically by remote operation from the safety of the vehicle cab. A slow descent speed is controlled by the safety valve.

Double acting lower stage - When tipping a truck body, large extended lengths of hoists are required. To do this hydraulic truck hoists are made with telescoping sections. Each successive section is smaller in diameter and retracts inside the section below it. These hoists are single acting which means they can only exert a hydraulic force in one direction. They rely entirely on the body weight to collapse the hoist once hydraulic pressure is released and the oil is redirected back to the oil reservoir.

Often circumstances arise where the body weight is insufficient to retract the hoist. By constructing a double acting lower stage, the hoist can be retracted by hydraulic force by one full stage height. This achieves two important things - it allows more body weight to be transferred from the rear pivot pins to the hoist and allows the body to lower and/or increases the stability of the truck so that it can be moved with a partially raised body, if circumstances make it necessary. Generally lowering by one stage is sufficient to transfer sufficient weight to the hoist so that it retracts satisfactorily. As both the double acting lower stage and the single acting upper stages retract simultaneously, the hoist retract time is reduced significantly. This improves productivity especially around congested load dumping areas shared by multiple tip trucks and construction plant.

Hoist binding - Front mounted tipper hoists as shown in Figure 7 are the industry norm. Uneven ground conditions during tipping operations places a transverse load on the hoist. Problems with hoists binding are usually noticed when the body is empty in the raised position and with the majority of the body weight acting through the rear body pivot pins (Figure 8). When a side load acts on a hoist, it can bind with sufficient friction and not permit the body to lower under its own weight. Under these circumstances, if the truck driver persists in lowering the body, oil has been known to drain out of the single acting hoist back to the oil reservoir.

These are a dangerous set of circumstances - the body is raised, the hoist is jammed and a large proportion of oil has drained from the hoist. When the hoist eventually becomes free of the bind, it can freefall under its own weight with dangerous and damaging results.

The safety valve in Figure 6 overcomes this issue by always keeping a positive pressure of 0.5 bar in the hoist. This prevents oil draining from the hoist. In the event of a hoist jamming, the driver or computer control can activate the lower double acting hoist stage. This pulls the body down with a hydraulic force and therefore does not rely on body weight to retract the hoist. Where this procedure still does not free the hoist, the truck can be moved slowly forward to a more level surface.

Overhead power lines

Fatalities have occurred worldwide where construction equipment such as cranes, excavators and tip trucks, have accidentally come into contact with overhead power lines. There are two basic scenarios for tip trucks hitting overhead power lines:

- Raising the body directly into the overhead power line while tipping a load
- Reversing or travelling forward with a fully or partially raised body and running into the overhead power line.

Mathers Hydraulics has fitted power line detection systems to tip trucks to improve safety when trucks are required to work in close proximity to overhead power lines. The power line detector's sensor head is typically mounted on the uppermost part of the body's headboard. When the power line sensor is at a set distance from overhead power wires the operator is alerted. When the sensor technology is integrated with a double acting lower stage hoist, once a power line alert is given, the system is designed to stop raising the body and then immediately power down using the double acting lower stage and upper single stages. This system responds very quickly and automatically reducing the possibility of short-circuiting the overhead power line. With modern truck engine management systems and electric shift transmissions, the sensor system is capable of preventing a truck from moving into a dangerous situation.

Summary

This article has addressed just a few of the many new technologies that will improve the safety and efficiency of the large trucks. These technologies currently exist and are planned for full release later in 2011 and 2012. It is hoped that fleet owners will see that while these new technologies may have a cost impost in the short term they will prove to be a cost saving in the longer term.

Subsequent articles will explore productivity improvements through computer technology, weight and site management, power regeneration, noise reduction and braking technology.

References

1. *Tipper trucks and trailers*. Hazard Alert HA 41, WorkCover ACT Government. October 2007