OPTIMIZING TRUCK TYRE PRESSURES
WITH
CENTRAL TYRE INFLATION

Developing the Ultimate Tyre Pressure Management system

WHITE PAPER

Chet Cline, AIR CTI Managing Director

Julian Taylor B.E. (Hons)., B.Acc., B.Comm.(Economics)., B.A. (Mathematics)

EVERYTHING THAT HAPPENS WITH A VEHICLE INVOLVES ITS TYRES

AND

EVERYTHING THAT INVOLVES TYRES INVOLVES AIR PRESSURE*

*Ancient Australian proverb
anonymous

Foreword by Chet Cline

I grew up with an old army jeep playing in Missouri mud and snow, on my grandfather's farm. I learned to drive there. Australia seemed like a good idea back in 1968, where I drove a tip truck hauling mining samples back to a heavy medium concentrating plant in out back South Australia. Back in the city, I did lots of night school and an apprenticeship in 'turning and fitting'. Night school continued with arc welding, oxy, auto mechanics, truck mechanics, pneumatics, hydraulics, and business/ marketing.

I've worked in many areas, from welding on the Longford Gas Plant, to a truck mechanic for Woods and Reeves, as well as running my own businesses. I've owned a truck for half my life.

Throughout that time, I've argued with almost everyone over tyre pressures. I always ran less than others, whether in my 4x4, my truck, or motorcycles. And no one beat us in the hard going.

Twenty years ago, a chance conversation with a good friend got me interested in Central Tyre Inflation. Logging trucks had the little orange hoses going to their CTI. I contacted and visited a local contractor that happened to drive by in the middle of our conversation. He took me out and showed me his drive tyres on the Kenworth. "Look at how smooth these tyres are, no cuts, no rips, they're as smooth as a babies bum." He was totally stoked. And the CTI cost him $14,000!

That conversation fascinated me. Research was next. I spent two years researching and developing a new CTI system. I visited every truckie that I could find that used CTI to find out what went wrong, and what was good. I covered the breadth of Australia, from Eden in the east, to Bunbury in the west, along with Kalgoorlie and Mt Gambier.

This experience, combined with my background, and my research, pointed in one direction alone. We, in the transport industry, have totally ignored the tyre manufacturer's recommendations. We waste money, safety, people, tyres, machinery, infrastructure, and damage the only world we have.

If any other industry ignored the manufacturer's recommendations, the legal ramifications would be tremendous. Liability would ruin businesses. The legal fraternity would think it was Christmas.

Yet, we continue to blindly follow our predecessors, that existed pre radial tyres, in a totally different world. Even our governments don't understand optimal tyre pressures.

It's so simple, yet...

Chet Cline

What is the Truck Driver’s Ultimate Job?

Drive The Truck?
Or to make Money for the Owner..

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OUR PEOPLE ARE OUR BUSINESS

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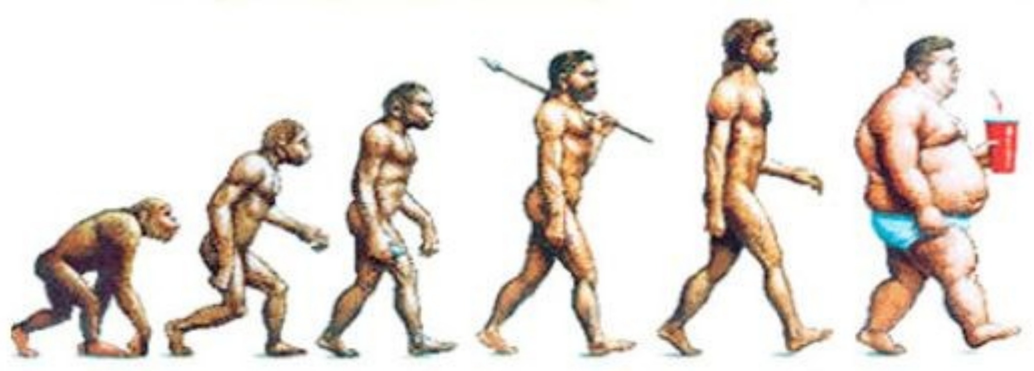


INTRODUCTION

Throughout human history information and knowledge has been passed from generation to generation. It was an efficient system that worked very well when the world was a much simpler place and the outlook of individuals was limited. With the world becoming more integrated and with the globalisation of knowledge technological changes occur so rapidly that one needs to be open to new ideas or fall behind.

One such example is truck tyre technology. It is just over one hundred years since the first practical pneumatic tyre was patented and look at the technology of the product now manufactured. Yet many in the transport industry have not progressed. We are relying on the work practices of earlier generations rather than challenge our thinking to adopt better technology.

In short, a serious problem now affects much of the trucking industry. Transport operators simply do not use the tyre manufacturer's recommended tyre pressures. That is, many of the improvements in tyre technology have been missed or at worse ignored by the industry. The human, economic and environmental costs are astronomical.

Radial tyre construction has revolutionized pneumatic tyre performance, improving every aspect, despite antiquated tyre pressure knowledge and operation. It is time the benefits of research undertaken and new technology were acknowledged, embraced and acted upon. The longer best practice is ignored, the greater are the losses incurred by the owners of our transport infrastructure, our people, and our world.

The current proposal of the EPA states that the optimisation of all transport operation is a legal responsibility and requirement. The Chain of Responsibility laws mean that failure to adhere to this requirement will lead to financial redress and penalties.

There now exists the opportunity to rectify this situation. As society becomes more aware of its responsibility to the driver, to the community as a whole and to the environment specifically, this report puts forward best practice in tyre pressure management.

This white paper has been written to address, explain and correct erroneous traditional practices that are not rational, safe, tolerable or affordable in our modern competitive, safety conscious, and environmental civilization. The biggest challenge to the industry now is to accept the responsibility to change.

TYRE HISTORY

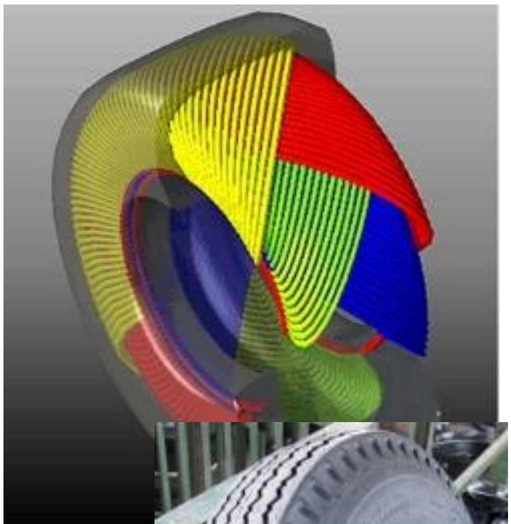
TYRE HISTORY:

EARLY '**CONVENTIONAL' TYRE**: Something was required to protect the wheel, as wheels tend to be light weight and relatively fragile. Wheels were originally made of wood, and protected by an iron strap, called a tyre. Iron provided very little grip, and even less shock absorption. Hard rubber was trialled, but life was poor. Shock loads would over stress the rubber causing it to delaminate or fall apart. Pneumatic tyres made modern high speed transport possible. The first pneumatic tyre was developed for bicycles, long before the automobile. The air pressure absorbed the impact, allowed a degree of controlled distortion, and was cheap and easy to use. Air pressure could be adjusted to suit the load and tyre size to provide the best, optimal tyre operation.

Rubber provided a good envelope that also had good grip, but required reinforcement to contain the pneumatic pressure, and impact from road interaction. The reinforcement was wrapped diagonally across the tyre side wall, around the tread area, and back to the tyre bead and then did another lap, creating a strong and simple to make, reinforced tyre. This system was called Conventional, Bias, or Cross Ply tyre construction. See the drawing below.

These tyres did a great job, transporting everything that humans required. We got very good at changing tyres back in the 1960's and 1970's before radial tyres became normal .

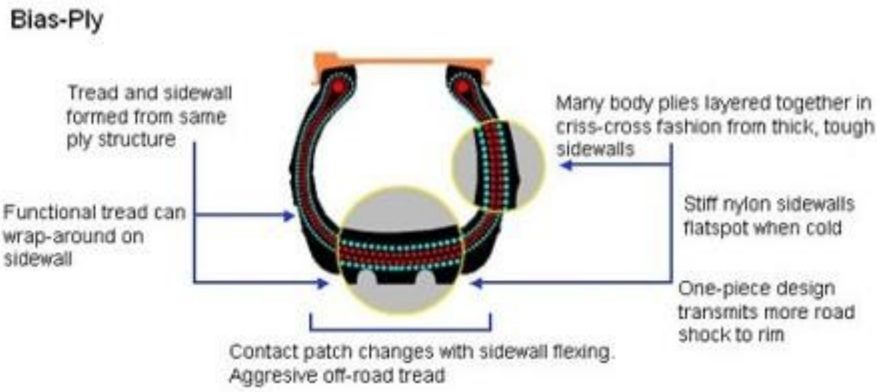
Downside: The reinforcement where it crosses on the side wall creates extra loads and heat when flexing. The footprint cross section balloons outward when over inflated, providing little control of the tread patch. Thus, tyre heat control required high tyre pressures, that distorts the contact patch away from ideal, reducing potential traction. The rolling resistance is highly dependent upon tyre pressures, but is always higher than radial tyres.



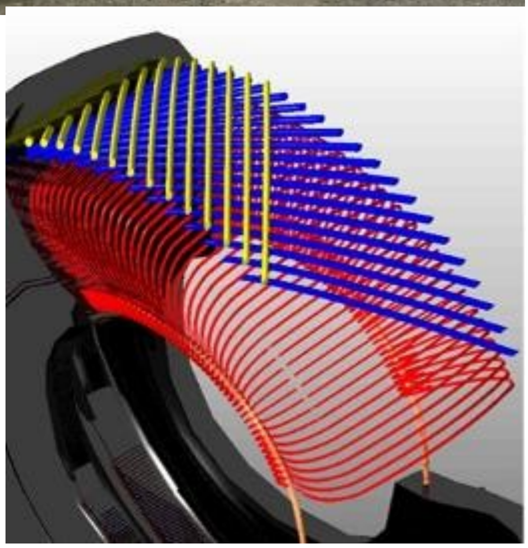
- Higher rolling resistance
- Increased tread squirm
- Increased tread wear
- Reduced lateral traction
- Reduced ride quality
- Increased heat build up
- Poor footprint control
- Tyre rolls laterally under lateral loads

An improvement was a belted bias ply tyre, that used the radial style 'belt' over the conventional cross ply tyre construction. This provided more tread contact patch control.

Typical heavy truck tyre pressure: 100 to 120 psi.



RADIAL TYRE: In the 1940's and 50's, Michelin had a better idea. Michelin ran the reinforcement radially from the bead, around the tread, and back to the bead. A further reinforcement was wound peripherally around the tread area creating a belt, usually of steel fiber, that significantly reinforced the tread area. The radial reinforcement reduced heat build up, while the 'belt' reinforced the tread area creating a far better tyre, with lower rolling resistance, better wear, and better traction, **provided the right tyre pressure is used.** See drawing below.



Radial tyres were first fitted to the Citroen 2CV in 1948. Today, every car uses radial tyres. Virtually every western truck runs on radial tyres also, as does many agriculture vehicles.

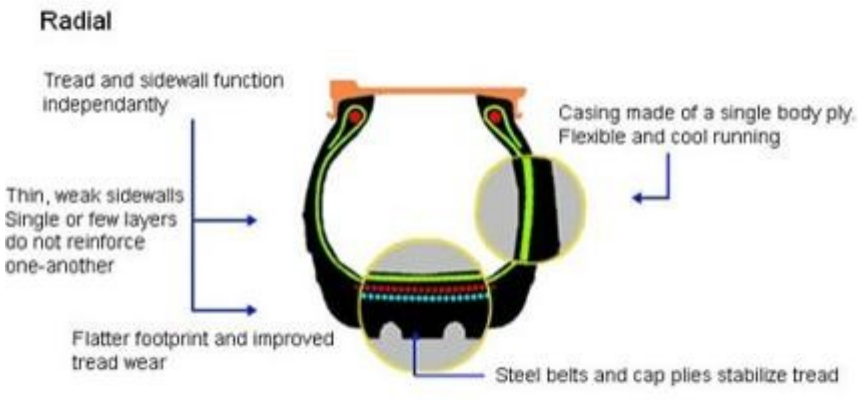
Sidewall flex is not transmitted to the tread. The footprint only changes. The width and profile remain relatively constant. The radial tire has reduced rolling resistance with less tread squirm and wear.

- Lower rolling resistance.
- Lower fuel consumption.
- Improved ride quality.
- Improved traction.
- Reduced slip angle improved driver feel.
- Greater productivity. More of your machines power is actually used.
- Longer tread life
- Reduction in tyre replacement thanks to the longer service life of radial tyres.
- More up time, less down time.

Thanks to the flexibility and strength of the tire, the tire absorbs shocks, impacts and bumps. Provided optimal tyre pressure is used, the result is a better ride, better handling, and better operator comfort.

In fact, modern radial tyres are so reliable and good, that most in transport almost take them for granted.

Typical heavy truck tyre pressure: 100 to 110psi



AIRLESS TYRES: For the last 65 years, designers have tried to eliminate the requirement of pressurized air. The airless tyre structure members are designed to act as a multitude of tiny springs to support the load. If the load changes, the spring rate will be wrong, and either flex too much, or too little. These airless tyres have found some uses in specialized areas, but not on trucks. The concept simply can not work when the load on the tyre varies.

How much does the load on a heavy truck tyre vary? An empty semi trailer supported by 8 or 12 tyres may only weigh 4,000 kilograms, or 8,000 pounds. 4,000/8 = 500 kg each. Each tyre will support less than most car tyres, that are far smaller and lighter. 2000/4 = 500 kg each.

Heavily loaded, those trailer tyres will support more than the total weight of a typical SUV each, or 6 times the empty load.

So, what does the pressurized air do? Why is it so necessary?

The air pressure supports the load. Remove the pressurized air, and the tyre is flat. It doesn't matter what size or vehicle, the pressurized air supports the load.

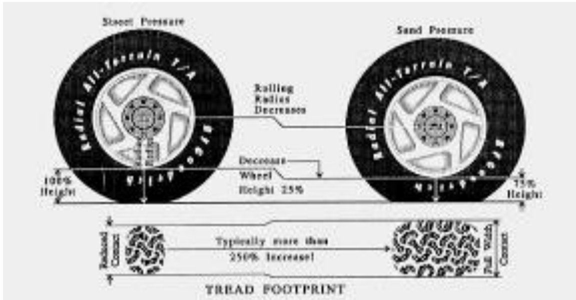
The tyre provides the envelope and the traction surface but it is the air pressure within that envelope that supports the load. The air pressure also works as a spring and damper - an excellent one provided the pressure is at its optimal level. The key is, that, to be effective, the pressure must be at the optimal level having been adjusted to suit the load carried. A high floatation tyre may operate at 3 psi whereas racing bicycles often exceed 150 psi (which explains why they sometimes skid transversely out of races) while a very heavy truck may need 120 psi.

The size of the tyre contact patch, often called the 'footprint', depends upon the load, and the tyre air pressure. Increase the load, and the footprint will increase. Increase the pressure, and the footprint will shrink. For each tyre, there is one optimal footprint, that provides the best compromise between tyre life, tread life, rolling resistance, traction, ride, and vehicle control for that road surface.

Any other footprint will degrade most of the above.

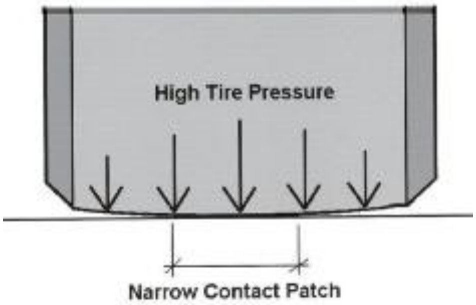
TYRE PRESSURE AND TYRE COSTS

TYRE THEORY:



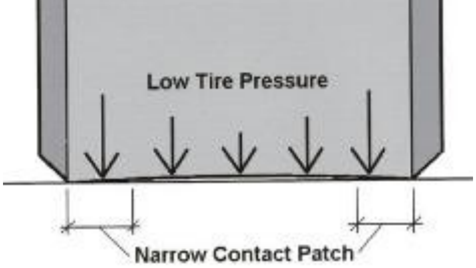
Tyres are basically a toroid, a ring shaped hollow envelope joined to a rigid wheel. The rubber and other materials used, provide a flexible, robust, ring shaped envelope that contains the air pressure, with a thickened rough ribbed periphery to grip the road, provide a wear surface, and displace water. The air pressure supports the load, while adding some lateral stability.

FOOT PRINT The tyre road interface produces all the forces and moments used to alter the vehicle state through cruising, accelerating, braking and cornering. The footprint or contact patch, the area directly in contact with the road surface, provides the traction required. The ideal footprint will have almost identical pressure on all points, limiting tread squirm while providing the best traction and tread life. To obtain the ideal footprint, the air pressure must balance the load correctly.



OVER INFLATION: If the pressure is too high for the load, the footprint area will reduce, and the load distribution will be concentrated toward the center of the tyre, reducing pressure nearing the edge, further reducing tread life. Tyre radial deflection will reduce, reducing absorption of impact, increasing vibration and shock transferral to the suspension and the rest of the truck. Impact from sharp stones or edges are much higher, increasing punctures, cuts, and staking.

- Results in a smaller contact patch with the road. This causes the load distribution to be concentrated toward the center of the tyre and reduces the pressure near the edge of the footprint.
- Tyre radial deflection will reduce, reducing absorption of impact, increasing vibration and shock load transferral. Therefore impact from roads roughness is increased dramatically.
- Increases stopping distances.
- Increases tyre wear — usually with associated uneven wear patterns.
- Increases punctures, staking
- Increases impact damage to roads.
- Increases Whole Body Vibration impact on drivers and passengers.



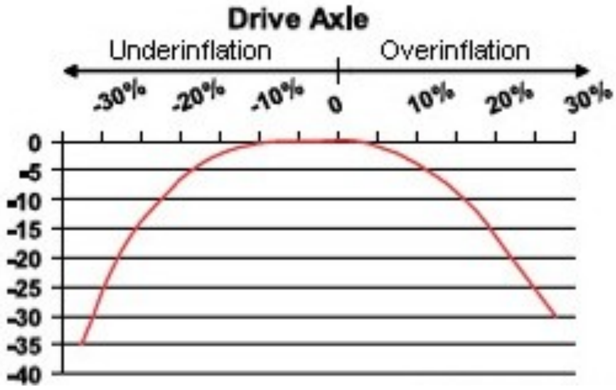
UNDER INFLATION: If the tyre pressure is too low for the load, the footprint area will increase, the footprint will get longer, and the load distribution will be concentrated out toward the tyre edge, reducing tread life. The increased side wall flex will increase heat build up that can lead to delaminating and or blow outs. Tyre radial deflection increases, which improves absorption of impacts, improving ride quality while reducing vibration and shock transferral to suspension components and the truck.

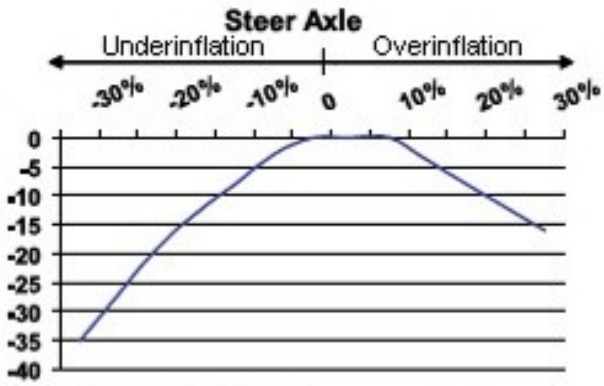
- Under inflated tyres have a greater contact area (footprint) with the road.
- This can increase rolling resistance, tire squirm and sidewall flex.
- Increased rolling resistance is bad for overall efficiency with increased fuel consumption

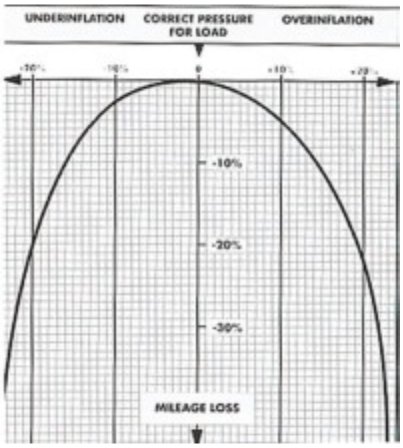
- Will create greater tyre wear and adversely affect performance. The shape of under inflated tyres means that often the shoulder of the tread wears faster.
- Put extra stress on the casing and reduces tyre life.
- Can effect braking performance.
- Can permanently damages tyre structure.
- Increased heat can lead to blowouts.

Footprint increases as tyre pressure reduces (SUV shown).

CORRECT/OPTIMIZED TYRE INFLATION: The Optimal tyre pressure for highway service provides the best tyre tread life. This footprint load distribution will be as even as engineering can provide, reducing tread squirm and wear. The Optimal tyre pressure is also the best compromise between traction, rolling resistance, inherent heat build up, handling, and ride quality. Expected tread life is lost if the tyre is over inflated or under inflated.







The above charts are for typical American roads, which are smoother than other country's roads. The coarse chip bitumen roads used in Australia suffer even more tread loss on drive tyres as shown in the chart on the right.

Tyre inflation pressures are a tool that will improve safety, financial returns, operational efficiency, and the environmental impact. Most heavy trucks waste at least one tyre in four because of incorrect tyre pressures.

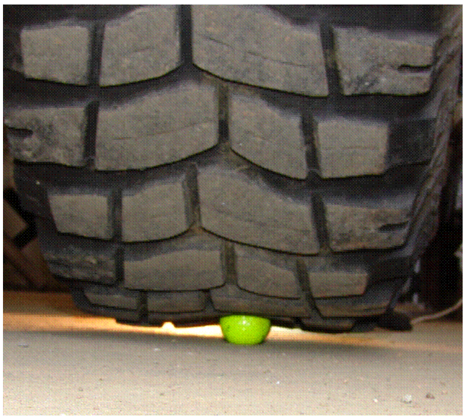
Optimal tyre inflation pressures depend upon the surface travelled on, and the speed.

ROAD PREFERENCES:

Water on the roads must be displaced by the tyre tread. A higher contact pressure will displace more water, increasing the critical aquaplaning speed. Increasing the tyre pressure by 25% significantly increases wet road traction and safety. Velocity(kph)=4.86 x square root of the tyre Pressure (psi) or V (mph)=7.8 x sq rt P (psi)

Water displaced by a tyre

Unimproved roads require reduced tyre pressures. Typically, optimal gravel road tyre pressures are 60% of optimal highway pressures at reduced speeds. Traction, vehicle control, stopping ability, ride quality, safety, and environmental impact are all significantly improved. Over inflated tyres don't conform to the surface, as shown by this tyre 'sitting' on a golf ball. Reducing pressures allows the tyre to conform to the surface, improving traction, while the increased surface area or footprint increases floatation, reducing rolling resistance. Punctures and stone damage also reduces considerably.



Over inflated tyre supported by a golf ball

Off road or hazardous conditions also benefit from reducing tyre inflation pressures. Traction and vehicle control improve on snow, ice, mud, rock, or sand with reduced pressures. Improvements depend upon the surface, with traction improvements of one to two percent on ice, up to a hundred percent improvement in mud, sand, or rock. Access is simply amazing. Ride quality also improves significantly improving driver health and control, while reducing vehicle breakage, damage, and wear and tear.

Bee truck operating in sand.

THE PROBLEM;

Trucks are designed to carry a load. When the load varies, as required by the job, the load on each tyre will change. The steer tyre load usually does not change much, as the engine and cab are integral. The load on the other tyres, including drive and trailer tyres, change regularly. Very few trucks operate at the same load all the time, except for cranes, and other specialized vehicles.

Many trucks operate loaded one direction, and empty the other, like tankers, agitators, and tip (dump) trucks.

For most of the last century, it was impractical to change tyre pressures every time the load changes. The only choice was to run one high pressure.

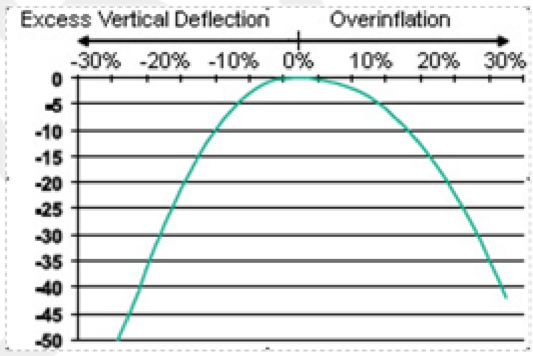
Unfortunately, transport still runs one high pressure, that was established as the norm some 50 years ago when only conventional bias ply tyres existed. This pressure has not changed even though tyre construction and performance has improved substantially.

Therefore, virtually every load carrying truck tyre is significantly over inflated all the time, and extremely over inflated some of the time.

The waste is unacceptable. The impact on health and safety is unacceptable. The impact on our infrastructure and environment is unacceptable.

HOW BAD IS THE PROBLEM?

TYRE WASTE;



Pressure effects on Casing Life

- Tyres are the second biggest cost in heavy transport. Traditional tyre pressures are 25% over inflated, when fully laden, reducing drive tyre tread life by 25%, and trailer tread life by 15%. When empty, or unladen, unnecessary tyre wear increases more.

- Casing life reduces when over inflated too. As retreading is a proven method of reducing costs, casing life is important. Traditional over inflated tyre use increases tyre costs even further.

- Dual tyres suffer a major design fault. Various factors increase the running temperature on one tyre more than the other, yet both are firmly bolted together and must rotate at the same speed. Any discrepancy in tyre diameters and or pressures causes one tyre to attempt to travel farther than the other.
  - Any difference in tyre size will increase wear.
  - Any difference in tyre inflation pressure will increase wear
  - The inner tyre runs hotter because of radiated brake heat, increasing the tyre pressure, increasing the load carried, increases heat....
  - Any road camber will cause the inside tyre to carry more load, increasing wear
  - Any axle deflection will cause the inside tyre to carry more load, increasing wear.

  All the above occurs on every dual tyre assembly. Special air manifolds balance the inner and outer tyres, suggesting tyre savings up to 25%.

A **B** **C** **D** **E** **F** **G** **H**
excessive inflation | under inflation | toe or camber | toe | wheel bearing or balance | internal tyre stress
Tyre scrub from sharp turns | loose suspension, shocks

Over inflated tyres aggravate any other tyre problems that cause uneven wear. A, B, and C are direct tyre pressure problems. E, F, G, and H are amplified by over inflation.

Incorrect tyre pressure increases tread wear, uneven wear, and blow outs, which wastes one tyre out of 3, or 30% minimum. Suspension wear increases, driver stress increases, Whole Body Vibration damages the driver's health, road and infrastructure damage increases, as does accident rates. And the environment is damaged unnecessarily by increased oil, energy, and material use, and by the millions of dead tyres that need disposal.

All because tyre inflation is universally incorrect.

Australian Tyre Council reports that 30 million tyres were imported, at a value of $2.5 billion.

IF YOUR DRIVER DOESN’T COME HOME.......

TYRE PRESSURE AND ROAD SAFETY

TYRE IMPACT ON ROAD SAFETY

All properties of a tyre are influenced by its pressure, e.g. the vertical stiffness, the handling performance, ride comfort, rolling resistance, speed at which aquaplaning occurs, etc. With the correct inflation pressure, the vehicle and the tyres will achieve their optimum performance.

An optimally inflated tyre improves safety, reduces wear and decreases fuel consumption by reducing rolling resistance.

Under inflation reduces lateral grip, increases aqua planing, and increases fuel consumption.

Extreme under-inflation of a tyre leads to large deflections that causes excessive heat build-up and internal structural damage that will eventually lead to tyre failure, often catastrophic.

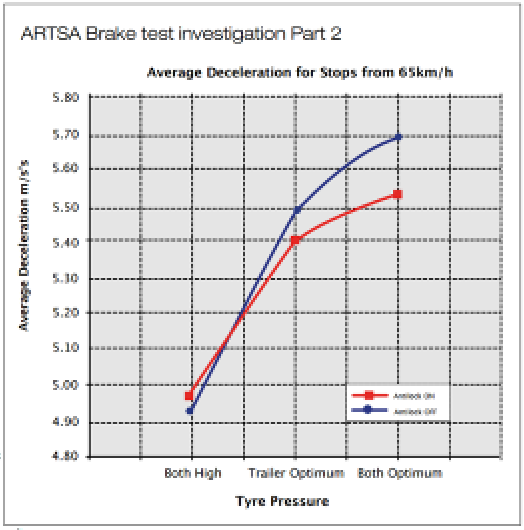
Over-inflation increases stopping distance, reduces traction, cornering grip, vibration and driver stress.

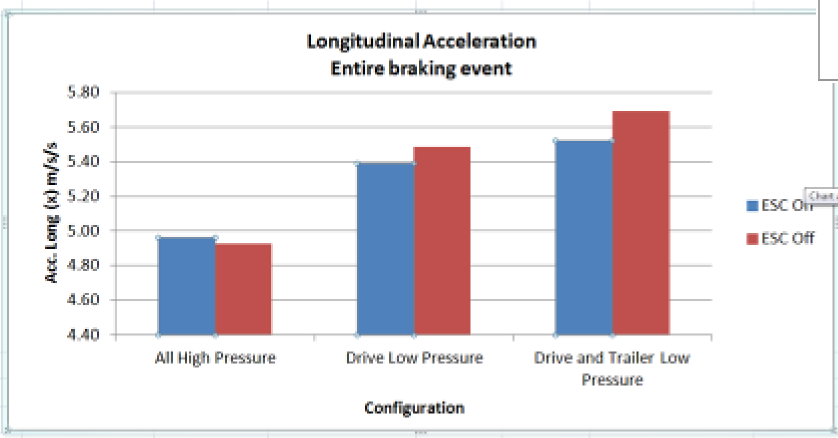
Tyre impact on road safety has two main influences;

Tyre grip is defined as the maximum horizontal force that can be transmitted between the tyre and road surface. A higher level of grip allows the driver to stop quicker, avoid accidents and reduce the chance of losing control over the vehicle. An increase in tyre grip improves the steering and braking potential of vehicles. This assists in avoiding accidents or, if involved in an accident, enabling the driver to reduce speed before the collision to achieve a lower impact speed. A lower impact speed reduces the risk of injury or fatality, for car occupants and for pedestrians respectively. Additionally with increased tyre grip the risk of directional vehicle instability during steering and braking manoeuvres is reduced, leading to further reduction of accidents.

Lightly loaded or empty semi trailers are considered to be the most dangerous, by insurance company reports, with jack knifes a regular occurrence. Tyre inflations in these conditions are severely over inflated, reducing the tyre footprint to 25% or the correct footprint. Stopping distance was reduced by at least 15% with optimal tyre pressures in tests done by ARTSA in 2013.

The vehicle with optimum tyre pressure achieves about a 15 % higher average deceleration than the vehicle with high tyre pressure.



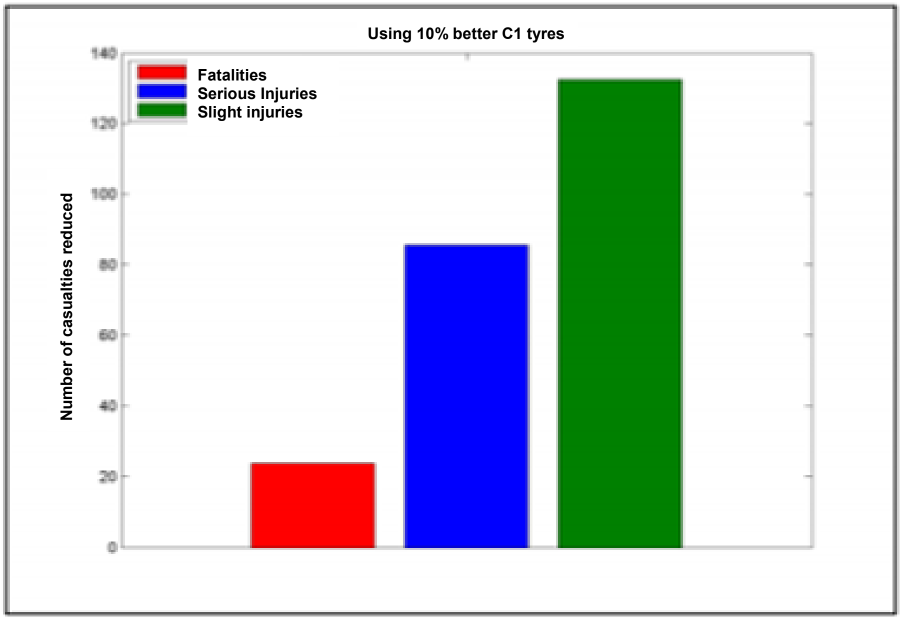


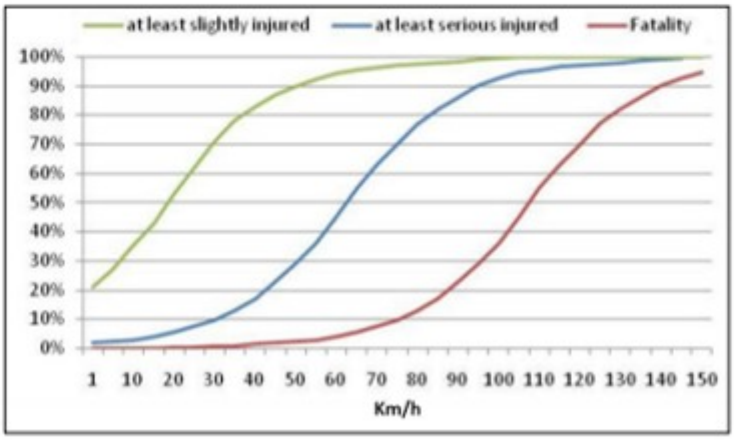
Stopping ability is vital for safe roads. Stopping straight and in control in the shortest distance saves lives. The optimal tyre pressure is essential for safe truck operations.

TYRE PRESSURE IMPACT ON ROAD SAFETY

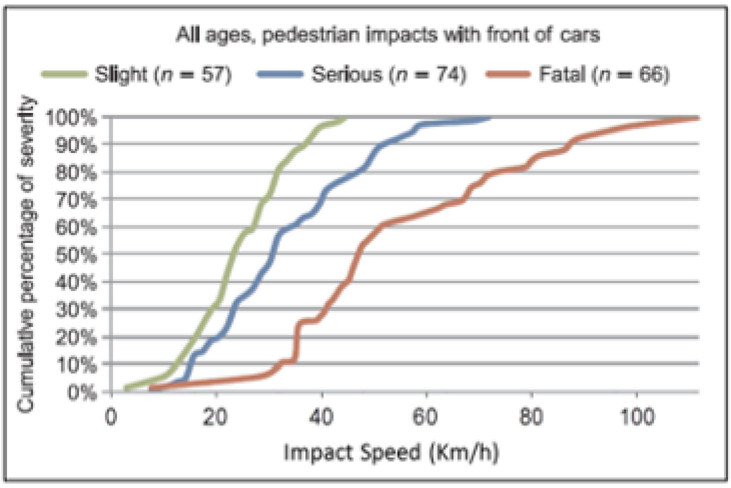
An analysis has been done on the impact of grip level using accident statistics in The Netherlands. The Figure below shows the potential reduction of traffic fatalities and injuries when a 10% increase in tyre grip is assumed. The reduced number of traffic fatalities is a significant 3-4% of the total number in The Netherlands.

Potential reduction in causalities with 10% improved grip using accident statistics from the Netherlands.
This amply demonstrates the importance of optimizing tyre pressure.



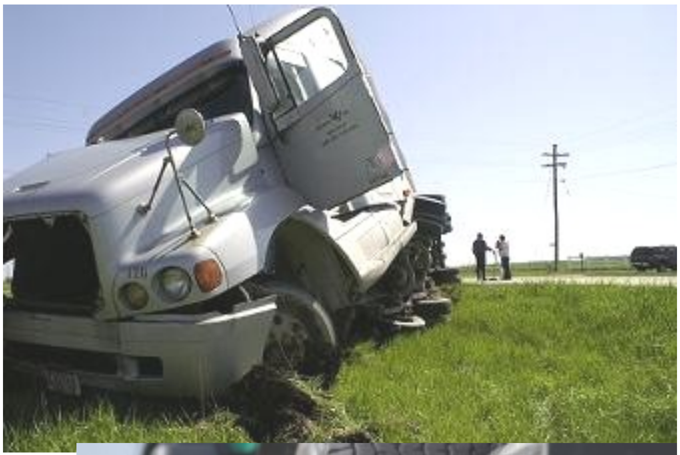


Injury risk of passenger occupants depending on impact speed



Injury risk of passenger pedestrians depending on impact speed

BLOW OUTS



A sudden delamination results in rapid air loss. This is often called a blowout.

A tyre blowout can pose a direct threat as the driver can lose control of the vehicle. This may result in fatalities. Even if a vehicle just loses stability, surrounding persons/cars may be injured directly by the vehicle or indirectly by the debris from the tyre. Further, debris on the road may damage other vehicles. Often, the vehicle with the tyre blowout cannot be stopped at a safe place next to the road resulting in further disruptions.

A study of French accident data over the period 1996-2002 [4] mentions that in 6.7% of the vehicle crashes, the vehicle has a blown tyre. Tyre blowout mostly results in a crash for vehicles with only four wheels as the vehicle stability is directly affected. Vehicles with more tyres have a higher intrinsic stability, but typically have larger tyres. Larger tyres also result in more dangerous debris on the road. Heavy truck steer tyres are still difficult to control.

Apart from damage by (sharp) objects, tyre blowout occurs typically due to overheating of the tyre caused by punctures or slow leaks. Heat is generated by deflection of the tyre because under-inflated tyres result in larger deflections and thus an increased risk of tyre failure.

Secondly, tyre ageing can be a significant factor due to reduced heat resistance of the tyre as well as the diminished structural integrity that result in lower obstacle impact resistance.

An estimated 663 people were injured by a crash precipitated by a truck tyre blowout in the US between 1995 and 1997.

Steer blowouts are the most hazardous.
- Driver side blowouts tend to cause multiple vehicle crashes.
- Passenger side blowouts tend to be single vehicle run offs.

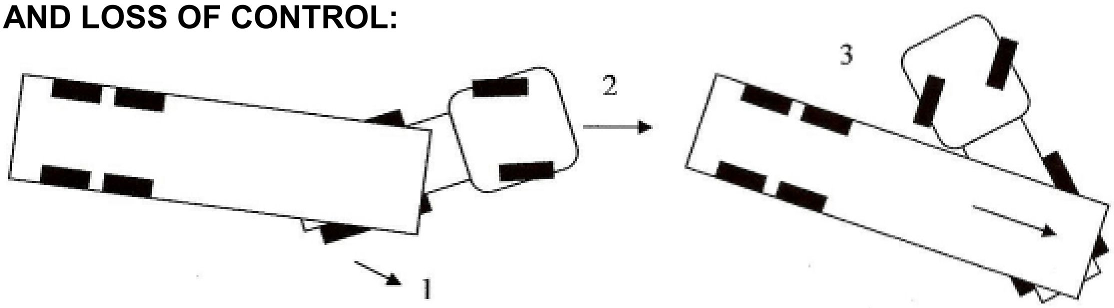
Many steer tyres are under inflated all of the time. With front under run protection and the extra weight of pollution equipment, steer axle weights have increased substantially. Many steer tyres are under inflated at our traditional 100 to 110 psi, while being the heaviest loaded tyre on modern trucks, aggravating this problem. Underinflated tyres increase the risk of blowouts.

Drive and trailer blowouts and delaminations are less of a risk problem for the driver, but create serious risk to other drivers, both at the time of the blowout and from the large rubber pieces, often called ‘alligators’ left on the road.

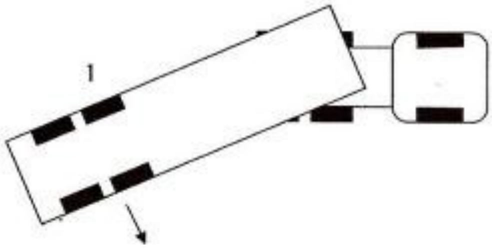
Almost all blowouts can be prevented by tyre pressure maintenance systems.

JACK KNIFES AND LOSS OF CONTROL:

Jack Knife



Jack Knifes happen when the drive tyres lose traction and the trailer pushes them off line.



Trailer Swing happens when the trailer tyres lose traction and slide outwards.

Both conditions happen when the truck is braking heavily, or when the traction level is low. Loss of traction of one set of tyres is the underlying cause. Bad brake balance, that over brakes one or the other set of tyres and or poor loading are the main causes. Over inflated tyres increase the risk.

An example of poor loading is a tip or dump truck towing a plant trailer with an excavator. A Heavy trailer, with no weight on the over inflated truck drive tyres, is a common site on most roads, and is a recipe for disaster.

Similar problems happen to trucks with other style trailers, like dog, pig, or road trains.

Almost all cases happen on empty trucks, where braking is over powering, on severely over inflated tyres, that provide minimal grip or traction. Poor conditions make life even riskier.

Because of the heavy weight and long lengths of semi trailer rigs, the potential damage is enormous.

Modern electronic braking systems virtually eliminate these accidents, although stopping distances increase considerably.

Optimal tyre pressure would substantially improve both cases, while reducing stopping distances.

OVERALL TYRE COSTS add up rapidly. Traditional transport practices waste one tyre in three, while driving maintenance costs and down time up. A truck off the road doesn't earn any money. Accidents cost even more. Safety is paramount to any successful enterprise.

No industry or business can afford to waste so much money, time, and people.

EVEN A DONKEY WON’T SPOIL HIS HOME

TYRE PRESSURES AND THE ENVIRONMENT

TYRES AND THE ENVIRONMENT

THE DAMAGE DONE TO OUR FRAGILE ENVIRONMENT BY THE WASTE OF TYRES

Synthetic rubber is manmade from petrochemical feedstock. Crude oil is the primary raw material. According to the Rubber Manufacturers Association (USA), it takes “approximately seven gallons (26 litres)” of oil to produce a single **car** tyre. “Five gallons are used as feedstock (from which the substances that combine to form synthetic rubber are derived), while two gallons supply the energy necessary for the manufacturing process.”

The US-based Tyre Retread & Repair Information Bureau states that it takes 22 gallons (83 litres) of oil to make one average size **truck** tyre. To have a truck tyre retreaded takes about 7 gallons (26 litres).

Further, these figures do not include the fuel used for transporting these tyres from China, France etc to the place of supply and then to the end user, or the time and trouble to eliminate the dead tyres.

RESOURCE WASTAGE

Research has shown that a reduction of at least 15-30% of the number of tyres produced could be saved by adopting optimal tyre pressures. Measure this in terms of oil, greenhouse gases and energy and one can easily see the waste of resources that could be avoided.

Now extrapolate further; consider the materials used in the manufacture of tyres:

- Natural rubber, or polyisoprene is the basic elastomer used in tyre making.
- Styrene-butadiene co-polymer (SBR) is a synthetic rubber which is often substituted in part for natural rubber based on the comparative raw materials cost.
- Polybutadiene is used in combination with other rubbers because of its low heat-buildup properties.
- Halobutyl rubber is used for the tubeless inner liner compounds, because of its low air permeability. The halogen atoms provide a bond with the carcass compounds which are mainly natural rubber. Both chlorinated (chlorobutyl) and brominated (bromobutyl) versions of halobutyl are commercially available. Although Bromobutyl is superior to chlorobutyl, it is more expensive.
- Carbon Black, forms a high percentage of the rubber compound. This gives reinforcement and abrasion resistance as well as assisting in protecting the tyre from UV and ozone attack.
- Silica, used together with carbon black in high performance tyres, as a low heat build-up reinforcement.
- Sulphur cross links the rubber molecules in the vulcanization process.
- Vulcanizing Accelerators are complex organic compounds that speed up the vulcanization
- Activators assist the vulcanization. The main one is zinc oxide.
- Antioxidants and antiozonants prevent sidewall cracking due to the action of sunlight and ozone.
- Textile fabric and steel reinforces the carcass of the tyre.

Note: Some of these ingredients are in short supply or are currently being sourced from the more “temperamental” areas of the world.

In the Manufacturing process several carcinogenic substances are formed during the manufacturing of rubber tyres, including nitrosamines and dibenzopyrenes.

8.1.3 RUBBER PARTICLES

In our modern cities, roads make up about one-fifth of the urban land area, and about half of the impervious surfaces. On these roads, we have driven our cars and trucks with inflatable rubber tyres for over a century. These rubber tyres wear, and have to be regularly replaced.

Sometimes the rubber comes off in a dramatic cloud of smoke when the car skids on the road. Sometimes the road surface is sharp and slices fragments out of the rubber. However, most of the time, as the rubber compresses and expands, tiny cracks develop and spread in the tread — and tiny particles of rubber flake off.

Consequently every time a tyre rotates it loses a layer of rubber about a billionth of a metre thick. A busy road with 25,000 vehicles travelling on it each day will generate around nine kilograms of tyre dust per kilometre. In the USA, about 600,000 tonnes of tyre dust comes off vehicles every year. Although the tyre dust can travel most of it will settle around the road.

From here some of the tyre dust gets mashed into the road. Most of it gets blown off away from the road by the air turbulence of the vehicles but a significant amount actually gets trapped in the bitumen. The first rain after a dry spell lifts these particles washes the rubber dust off the road into the nearest waterways where it ends up as sediment on the bottom of creeks, ponds and wetlands. Many will say it is the oil and grease that makes roads slippery after a rain – actually it is the rubber particles that have been displaced causing this effect. Any oil/grease dropped by cars is broken down and dispersed whereas the rubber does not.

Further, tyre dust contains two main classes of chemicals — organic and inorganic.

These organic chemicals are especially toxic to aquatic creatures (such as fish and frogs), and depending on the levels, can cause mutations, or even death. In test tube laboratory experiments, **these organic chemicals have been shown to damage human DNA**.

Some of the inorganic chemicals in tyre dust are heavy metals (such as lead and zinc). You may remember that eating from lead plates gradually poisoned Roman soldiers.

THESE ARE THE CHEMICALS WE ARE INGESTING EVERY DAY. They damage DNA as well as poisoning us! How much of these poisons do Truck Drivers expose themselves to every day?

8.1.4 EFFECTS ON HEALTH OVER TIME

But there's another dark side to rubber dust — particles. The organic and inorganic chemicals are carried as, or on, particles. In general, the smaller the particles, the more deeply they can penetrate into your lungs. PM_{10} stands for particulate matter that is smaller than 10 microns in size. (A micron is a millionth of a metre, e.g. a human hair is about 70 microns thick). $PM_{2.5}$ particles are smaller than 2.5 microns – and are even more dangerous.

On average, about 80 per cent of all PM_{10} in cities comes from road transport. Tyre and brake wear causes about three to seven per cent of this component. Each year in the UK, PM_{10}'s of all types are blamed for an extra 10,000 deaths, due to heart and lung disease.

In Europe each year, the normal wearing of tyres releases some 40,000 tonnes of PAHs (polycyclic aromatic hydrocarbons), mostly as PM_{10}. PAHs are a component of the heavy oils used to make tyres. They accumulate in living tissue and are implicated in various cancers.

California is notorious for its heavy smog pollution — which can vary from day to day. One study showed very strong links between $PM_{2.5}$ particles, and the daily death rate in six Californian counties. When the $PM_{2.5}$ count was high, so was the death rate.

ALL THE MONEY IN THE WORLD
IS USELESS
IF YOU’RE NOT HEALTHY

8.2 TYRE PRESSURES AND DRIVER HEALTH [OCCUPATIONAL] WHOLE BODY VIBRATION

TYRES AND DRIVER HEALTH; [OCCUPATIONAL] WHOLE BODY VIBRATIONS

DRIVER HEALTH IN TRANSPORT

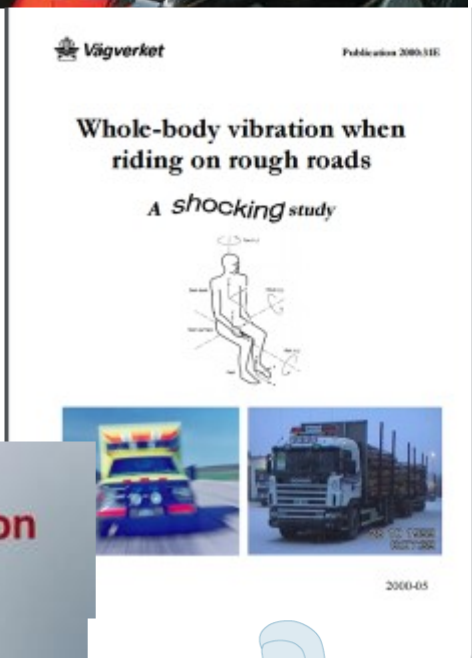
For many reasons truck driver life expectancy is typically of the order of 10 or more years less than other industries,

DOT's Truck Driver Life Expectancy quotes “16 years shorter than the norm.”

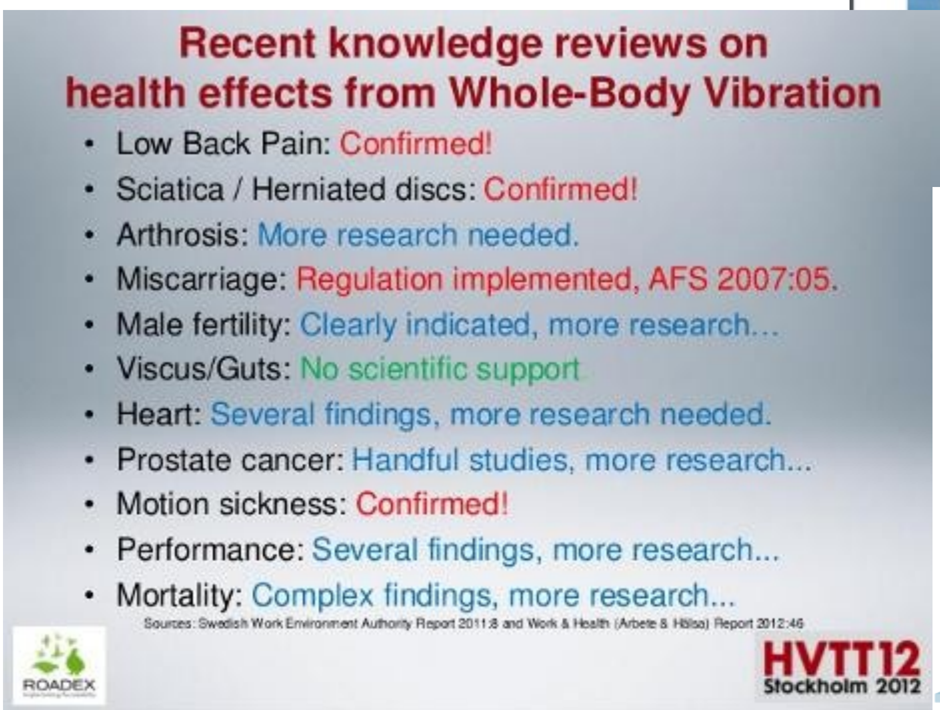
The March 2008 edition of the Roemer Report, which cites a study by Toronto researcher Dr. Martin Moore-Ede. Roemer said the study found “that truck drivers have a 10- to 15-year lower life expectancy than the average ... ”

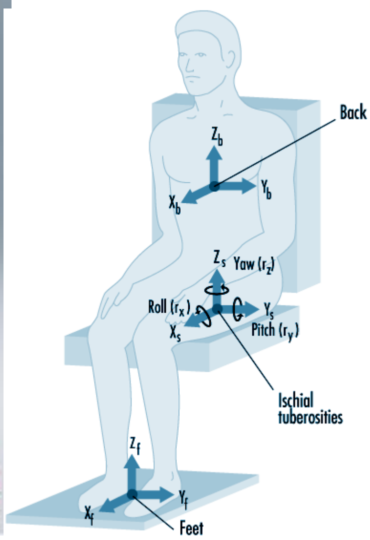
A 2003 conference on truck driver occupational safety and health quoted John Siebert of the Owner-Operator Independent Drivers Association reporting on data that suggests that the average age of death for its members is 55.7 years - over 20 years less than the average.

Regardless of the variation it is clear that the health of truck drivers is seriously below that of the general population. Whereas this was put down to traditionally poor diets, minimal exercise and long hours it has come to the attention of the industry in the last ten years that Whole Body Vibrations, as stated below, has now been recognised as a major contributor to the problem.



Truck drivers are exposed to high vibration levels from the notoriously rough Australian roads for long periods of time and this is making them ill. The result is a premature end to their working life, an end to a quality of life and premature death.





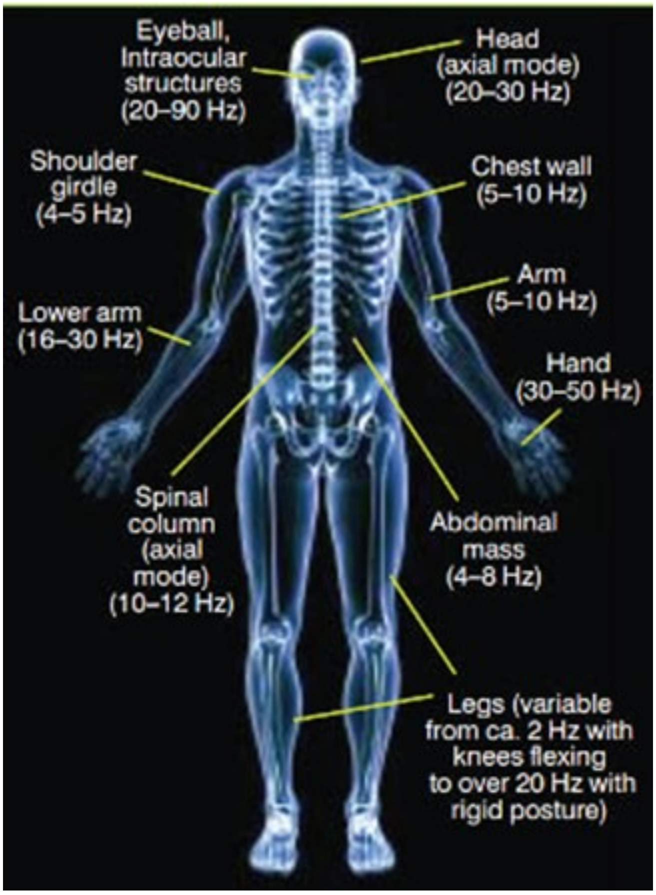
8.2.3 WHOLE BODY VIBRATION — BACKGROUND

Whole-body vibration (WBV) comprises the transfer of relatively low-frequency environmental vibration to the human body through a broad contact area. These frequencies are in the range of 0.5 to 80 Hz (ISO, 1997; ANSI, 2002). Motion sickness is associated with frequencies below 1 Hz (Mansfield, 2005)[15] and specifically from 0.1 to 0.5 Hz (ISO, 1997; ANSI, 2002). The relevant frequency range for hand-arm vibration is 5 to 1500 Hz (Bruce, Bommer & Moritz, 2003)[7].

Transmission occurs through the feet when standing, the buttocks when sitting (most common scenario) or the entire body length when reclining in contact with the vibrating surface. WBV exposures exist in many occupational settings. The body as a whole and each individual organ have natural frequencies that can resonate with vibration energy received at those frequencies.

The result is a condition in which the body or a part of the body will vibrate at a magnitude greater than the applied vibratory force. Thus amplifying the damage. In response, muscles will contract in a voluntary or involuntary manner and cause fatigue or a reduction in motor performance capacity (Chaffin & Andersson, 1984)[10].

Resonance of the body or its parts due to WBV causes adverse health effects, especially with chronic exposure. These include interference with or irritation to the lungs, abdomen or bladder (Kroemer & Grandjean, 1997)[14]. Also, ISO/ANSI standards assume WBV adversely affects the digestive, genital/urinary and female reproductive systems (ISO, 1997; ANSI, 2002). Effects of WBV on vision were reported as early as 1965 by Dennis (1965)[13]. A 1994 Australian study by Cross and Walters[12] identified WBV and vehicle jarring as a contributing factor to back pain in the mining industry and as a significant risk to mobile equipment operators.



WHOLE BODY VIBRATION — SUMMARY

[Occupational] Whole body vibration (WBV) is excessive vibrations in occupational settings such as truck driving or hand tool operating.

Occupational WBV exposure, especially for long periods, causes adverse health effects. Chronic exposure, even for short periods, can be extremely detrimental.

Mandatory standards for regulation and monitoring of worker exposure to WBV exist in Europe and many other places. In fact the seriousness of WBV has been recognised in the USA with the Maximum Road Roughness Index being halved in the last few years.

Over inflated tyres amplify every road irregularity, ridge, rock, or bump increasing damage to the driver and the truck.

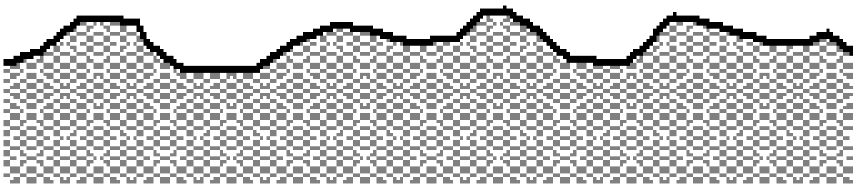
ROUGHNESS OF AUSTRALIAN ROADS

ROAD CONDITIONS AND BRAKE SLIP

The frictional force from the tyre/surface interface depends on the weight or load on the tyre and the tyre-road conditions. That is;

- road roughness. Pavement exhibits three types of roughness, micro-texture (with wavelength less than 0.5 mm), macro-texture (wavelength between 0.5 mm and 50 mm) and mega-texture (wavelength exceeding 50 mm)
- tyre tread wear and grip
- climatic conditions (wet, possible hydroplaning, snow, ice)

Macro- texture are schematically shown in figure below. Macro-texture is related to the overall roughness of the road resulting from the number, type and size of stone chippings. Idealised texture leads to sufficient drainage and significant hysteretic friction (local pressures) at the cost of tyre wear and fuel economy. Tips should preferable be sharp to have good friction even under wet conditions, but that leads to abrasive wear.



Macro-road roughness

Road Roughness is the measure of this unevenness (of the road surface). It describes the condition directly experienced by motorists. It is commonly reported in Australia by either the NAASRA Roughness Measurement (NRM) method, which is measured using the NAASRA Roughness Car, or by the International Roughness Index (IRI), which is calculated by applying an analytical ‘quarter car model’ to road profile data collected via laser profilometer. NRM can be reliably converted to IRI by a linear equation, and vice versa, where required.

Roughness is seen as an important road condition measure right across the world. It is the most widely used condition parameter because roughness data is relatively inexpensive to capture, is an objective measure, correlates well with road user costs, and is accepted as the most relevant measure of the long term functional behaviour of a pavement network.

Due to Australia’s tough environment, the roughness count of this country’s roads indicate that there are twice the number of vibration incidents here than in Europe and the USA. In fact, in a recent report on road quality Australia rated 43rd in the world — virtually at the bottom of all developed countries. This meant the country was ranked below such countries as Namibia, Sri Lanka and Swaziland in terms of roughness and quality.

The vibrations experienced by the driver of a vehicle is directly related to road roughness. The higher the road roughness count the greater the vibration that is transmitted through the vehicle to the driver. This can lead to debilitating, sometimes fatal, long term illness. Literally our roads are shaking drivers into ill health, loss of quality of life and even to premature death. In fact the average life expectancy of a truck driver is in excess of ten years less than the national average.

As a rule of thumb, if a car driver feels a bump or roughness, a truck driver will be suffering from excessive road roughness. Car suspension is far better than a truck’s.

WHAT ARE THE HEALTH EFFECTS OF EXPOSURE TO VIBRATION?

There are two types of vibration: Whole Body Vibration (WBV) and Hand-Arm Vibration (HAV).

WHOLE BODY VIBRATION (WBV) causes or exacerbates other health effects such as:

- Brain and lateral vision damage,
- Impairment of vision, balance or both,
- Varicose veins/heart conditions (variation in blood pressure from vibration),
- Stomach and digestive conditions,
- Respiratory, endocrine and metabolic changes,
- Reproductive organ damage,
- Bone damage
- Lower back pain (damage to vertebrae and discs, ligament attachment damage)
- Motion sickness
- Increased driver stress,
- Increased driver fatigue,
- Sleep apnoea. Only 25% of truck drivers actually know they have the condition.

The report, Occupational Exposure to Whole Body Vibration and Parkinson's Disease, M. Anne Harris*, Stephen A. Marion, John J. Spinelli, Joseph K. C. Tsui and Kay Teschke, American Journal of Epidemiology, Am. J. Epidemiol. (2012) 176 (4): 299307, linked higher-intensity equipment exposure or **Whole Body Vibration as positively associated with Parkinson Disease**.

Further, a case-series analysis [Acta Neurol Scand 1975;51(5):365-379] carried out by Livanainen in 1975 found a **correlation between occupational vibration exposure and diffuse cerebral atrophy*.**

*Cerebral atrophy is a decrement or shrinkage of the brain cells.

Whole-body vibration when riding on rough roads
SNRA Publ. no. 2000:31E

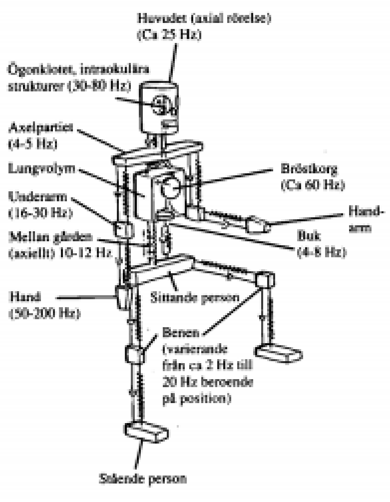


Figure 2 Mechanical model of the human body specifying natural frequencies for a few parts of the body [51]. Observe that the body lacks the female bosom. The natural frequencies refer to vibrations in the axial direction of the body parts (e.g. the spinal column)

The longer a worker is exposed to vibration, the greater the risk of health effects and muscular disorders.

EXTENT OF PROBLEM IN AUSTRALIA

In 2008, National Hazard Exposure Worker Surveillance (NHEWS) gathered self-reported data on exposure of Australian workers to vibration, and data on the provision of control measures for vibration in the workplace.

The aims of the survey were to describe patterns of exposure to vibration in conjunction with patterns of vibration control provisions with respect to industry, occupation and other relevant demographic and employment variables.

Results of the survey are used in the *Vibration exposure and the provision of vibration control measures in Australian Workplaces* report (2010) to make recommendations, where possible, for development of work health and safety and workers' compensation policy and to provide researchers with clear and constructive directions for future research.

The analyses in the report focus on the following national priority industries:

- Manufacturing
- Transport & storage
- Construction
- Agriculture
- Forestry
- Fishing
- Health and community services.

The main findings of the report were:

- Approximately 24% of Australian workers were exposed to vibration in their workplace.
- The industries where workers had the highest likelihood of reporting exposure to vibration were ***Agriculture, Forestry*** *and fishing,* ***Transport****, storage* and *Construction*.
- 43% of vibration-exposed workers were exposed to hand-arm vibration only, 38% were exposed to whole body vibration only and 17% were exposed to both hand-arm and whole body vibration.
- 41% of vibration-exposed workers reported they were exposed for up to a quarter of their time at work, while 21% reported they were exposed for between a quarter and half of their time at work, 15% reported they were exposed for between half and three quarters of their time at work, and 24% reported they were exposed for more than three quarters of their time at work.
- 23% of vibration-exposed workers reported that none of the surveyed control measures were provided in their workplace.
- Only 27% of vibration-exposed workers reported they received training.
- Large percentages of vibration-exposed workers in smaller workplaces reported they were not provided with any vibration control measures.

The report can be downloaded in either word or pdf format from the Safe Work Australia website.

COSTS INCURRED DUE TO OCCUPATIONAL WHOLE BODY VIBRATION (AUSTRALIA)

Between 2000-01 and 2007-08, there were approximately 400 workers' compensation claims per year for injuries or illness that resulted from exposure to vibration. These amounted to approximately $61 million in workers' compensation payments over the eight years and had an estimated total economic cost of $48 million annually (Safe Work Australia 2009).

However, many of the adverse health conditions caused by exposure to vibration have long latency periods (Brammer & Taylor 1982)[6]. For example, the latency period for the 'blanching' stage of vibration white finger can vary from two to 16 years and the 'numbness' stage from two to 12 years (Brammer & Taylor 1982; Contant 2009)[11]. Consequently, workers' compensation data do not adequately capture health conditions with long latency periods. Further, many workers who are self-employed are not covered by workers' compensation data and are therefore not included in the workers' compensation database. Self-employed workers include many tradespersons, farmers and drivers, which are occupations known to be exposed to high levels of vibration. This is supported by the findings of the European Working Conditions Surveys (EWCS) (Parent-Thirion et al. 2007)[16], which found that self-employed persons reported a higher rate of exposure to vibration than employees (27.1% and 23.9%, respectively). Therefore, it is likely that workers' compensation claims significantly underestimate the prevalence of the adverse health effects related to vibration exposure in the workplace.

Echoing this is research undertaken by Bruce, Bommer & Moritz, 2003; ACGIH, 2001 which estimated that about 8 million U.S. workers have occupational vibration exposure. Of these, an estimated 6.8 million are exposed to WBV and the remainder to HAV.

The European Directive 2002/44/EC (Mansfield, 2005) and the CVWR of 2005 set the exposure action value (EAV) at 0.50 m/s^2 and the daily exposure limit value (ELV) at 1.15 m/s^2 (8-hour daily exposure), based on the ISO and British standards. This can be seen in the appendix.

The Roadex III project undertook an accurate assessment of truck driver's exposure to vibration. Measurements were made in a timber logging truck during ten roundtrips of 140 - 170 km, with most time spent on Rd 331 between the Swedish inland forest area and the coast. The results showed that for all measured working days, the daily vibration exposure A(8) was above 0.65 m/s^2 including normal pauses with zero vibration, and that A(8) = 0.76 m/s^2 is a fair estimate for an 8 hour shift on this kind of routes. This is significantly above the EU Action Value of A(8) = 0.5 m/s^2. Thereby employers of truck drivers performing long and bumpy driving in the EU are required to take necessary technical and/or organizational actions to minimize the driver's exposure to vibration.

EU employers are also obliged to perform a special risk assessment for workers exposed to repeated mechanical shock, such as from bumpy rides. The Roadex III case study showed that even when driven at low speeds (below 40 km/h), severe bumps (> 5 cm) exposed the truck driver to an equivalent daily static compression dose S_{ed} over 0.5 MPa. This stress level corresponds to health risk, as per the ISO 2631-5 (2004) standard.

The Roadex III report above shows that the "average" truck driver is exposed to vibration levels above acceptable. If normal is over-exposure, then what are the long distance haulers, the logging trucks being exposed to? As bad as this is, there is a far more damning observation; that many truck drivers feel that Whole Body Vibration injuries are considered part of "life". Drivers are completely unaware that the vibrations they are exposed to on a daily basis are slowly killing them. But WBV not only effects lifespan it also affects quality of life. The latter affecting not only the driver but their families as well.

Early indications are that Occupational Whole Body Vibration will become the next tobacco or asbestos scandal. **This is a time bomb ticking away ready to explode.**

MEETING LEGAL REQUIREMENTS FOR VIBRATION

As a hazard, vibration is covered both under the OHS Act and under Part 3.1 (Manual Handling) of the *Occupational Health and Safety Regulations 2007.* In addition, some of the equipment causing the problem (creating the risk) may be covered under Part 3.5 (Plant) of the regulations.

To comply with the requirements of the Manual Handling Part of the Regulations, the employer must ensure that any task undertaken, or to be undertaken, by an employee involving hazardous manual handling is;

1. Identified,
2. assessed via reviewing
   magnitude
   shocks or jolts
   duration,
3. and has action taken to control the risk either
   at the source of vibration
   along the paths of vibration
   at the position where the vibration enters the worker

Remember also that employers have a general duty under the Victorian *Occupational Health and Safety Act (2004)* to provide and maintain for employees, as far as reasonably practicable, a working environment that is safe and without risks to health. This includes ensuring that the use, transport and handling of plant is safe and without risks to health, providing a safe system of work, information, training, supervision, and where appropriate personal protective equipment.

Also note: Many truck drivers do 12 hour shifts, exposing their bodies to far more stress than the 8 hours mentions previously.

VIBRATION STANDARDS AND EXPOSURE CRITERIA

Basically there are two main criteria currently used in Australia:

Australian Standard AS 2670-2001 *Evaluation of human exposure to whole-body vibration* prescribes methods for the measurement of whole-body vibration.

European Union Vibration Directive 2002.

AUSTRALIAN STANDARD

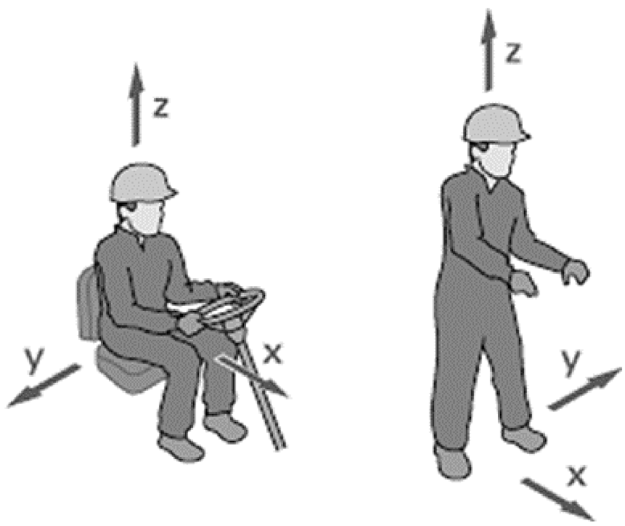
The Australian Standard (AS2670-2001 *Evaluation of human exposure to whole-body vibration*) on whole-body vibration was published in 2001.

It incorporates assessment methods for both steady state (rms) or Daily vibration exposure A(8) and shock/jolt type vibration (VDV).

DAILY VIBRATION EXPOSURE A(8)

Daily vibration exposure A(8) is calculated from the magnitude of vibration expressed as acceleration in m/s^2 and the length of time of exposure. In short the daily vibration exposure A(8) is the amount of vibration exposed to normalised to an eight hour reference period. But, many drivers drive for 12 hours.

Exposure to intermittent WBV (shocks and jolts) is measured using a **VDV [Vibration Dose Value].** The VDV is a cumulative value, which increases with measurement duration. It is assessed using the length of time of the measurement and the total time a worker is exposed to the source of vibration per day.



For WDV the axis with the highest average root mean square is used to calculate A(8). The x-axis and y-axis have a weighting factor of 1.4.

A(8) for a worker carrying out one process or operating one item of plant is calculated by using the following equation;

$$A(8) = a_w \sqrt{\frac{T}{T_o}}$$

See appendage 1 for more information.

This is confirmed by referring to the research conducted in this area.

By reducing tyre inflation pressure a softer and smoother ride can be achieved which improves the comfort of the driver and consequently results in less driver fatigue. The softer ride will also reduce the shock loading that is transmitted to the vehicle, which is potentially damaging to the truck and cargo (Rummer et al., 1990)[8]. Optimally inflated tyres act as an air spring, absorbing small impacts and significantly reduces larger impacts before they can reach the suspension.

Much research has been done on off road trucks over the last 30 years. The ride quality on these rough roads is proven by the following

Adams (2002)[1] conducted tests to evaluate the effect of using Central Tyre Inflation, CTI* to optimize tyre pressures, on the ride quality of a vehicle. He showed that an average ride quality improvement of 99% was achieved when tyres were adjusted using a CTI system to match terrain and speed conditions. At a lower speed, the optimized pressure showed an average ride quality improvement of 177%. Ride quality is quantified by the vibrations the driver experiences through the seat of the vehicle. Sensors were placed on the seat of the vehicle and the vibration levels of the seat are recorded (Adams et. al., 2002)[2]. Similarly to Adams, Altunel (1998)[3] analysed data collected by the US Army Corps of Engineers and the Waterways Experiment Station to evaluate the effect of lowering tyre pressures on a log truck driver's seat using CTI technology. Their analysis concluded that lowering the tyre pressure to match the road surface appear to decrease vibration levels in the driver's seat from 10 to 25%. Almost all drivers involved in the CTI tests commented on the improvement in vehicle ride which resulted in them feeling less fatigued after a day of driving (Brown and Sessions, 1999)[7].

A trial of CTI was initiated by Bradley (1991)[5] to evaluate the impact of optimized tyre pressures on driver comfort. The truck drivers involved in the trial reported reduced vibration and shock loading with reduced inflation of the drive tyres. The driver's opinion was substantiated by comparing the maintenance records of the test vehicle to those of a control fleet of similar trucks. Monthly repair time was reduced by 26%, largely because of fewer vibrations which caused cracks and loosened bolts, and less cab component damage (Bradley, 1993)[6].

A further study conducted in Western Australia with three trucks all with traditional tyre pressure. All three trucks exceeded a half metre vibration limits over 500 times over a 29 km test distance. When one of the vehicles was equipped with a Central Tyre Inflation system and pressures optimized for the load and terrain, the standard vibration limit was only exceeded 13 times over the journey. **This is over 95% improvement.** Other tests in Northern Australia confirmed these results.

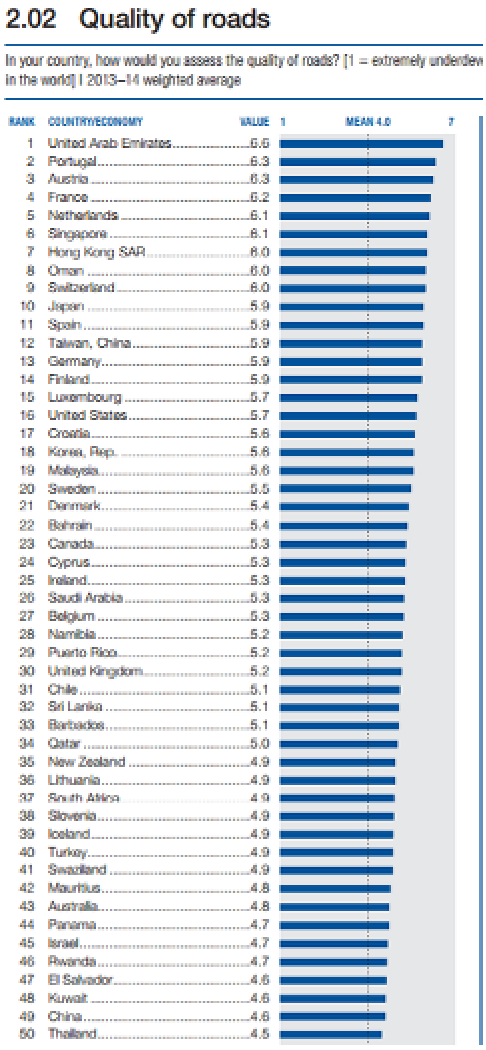
Traditional over inflated tyres actually bounce off road irregularities, amplifying bumps, increasing vibration levels. This high impact vibration increases suspension wear and tear. Strain gauges were installed on log truck drive lines by Goodyear that proved a minimum 30% reduction in drive train loads. The 'softer' tyre could flex axially, to absorb each piston power stroke. This has been confirmed in practice by numerous operator reports of doubling of drive train life.

On better highways, ride quality improvements are still significant, especially on empty and lightly loaded trucks. Empty prime movers (tractors) are notorious for bucking and pitching. Empty semi rigs vibrate almost constantly, with causes ranging from out of balance tyres and wheels, to amplified minor road irregularities that coincide with natural frequencies in the extremely flexible truck chassis. If a bump can be felt in a car, that bump will be at least 10 times worse for the truck driver. Add that to the height above the road, road irregularities and undulating roads do their worst to the poor driver. Optimizing the tyre pressure for the lack of load makes a world of difference to his life.

* CTI refers to Central Tyre Inflation. This involves a device that ensures optimal tyre pressures. Thus in the research above CTI can be read interchangeably with optimal tyre pressures.

TYRE PRESSURES AND VEHICLE INTEGRITY

VEHICLE INTEGRITY:



Roads and Infrastructure throughout the world are falling apart. Most modern governments are struggling to keep up with the worst road maintenance. Many roads are decades old, as are most of the bridges. Our highways are getting worse and worse, and, are literally hammering our trucks, and drivers, to pieces. Today, when a pot hole or rut becomes rough for some car driver, they put up 'rough road' signs. That may cover them for liability, but it sure doesn't help transport operate economically, or safely.

Our roads are rough. 15.6 billion dollars worth of fuel is wasted by USA drivers because of substandard roads in 2013. And US roads are pretty good, compared to many other parts of the world. Australian roads are number 43 in the world.

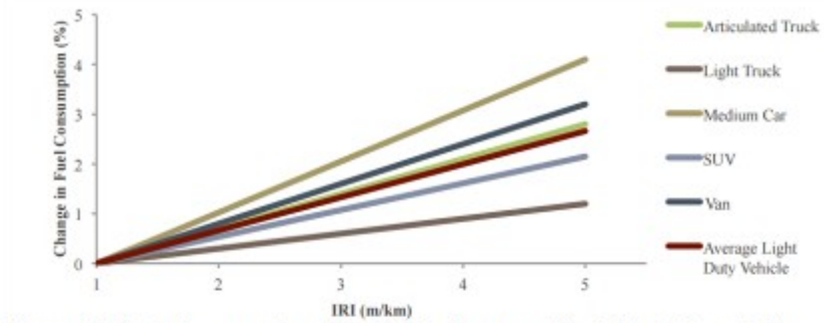


Figure 6. Effect of pavement roughness of fuel consumption (Adapted from Zaabar and Chatti (Zaabar 2010))

How much does our rough roads cost the transport industry. Does over inflated tyres increase this?

A trial by Bradley (1991)[5] to evaluate the impact of optimized tyre pressures, monthly repair time was reduced by 26%, largely because of fewer vibrations which caused cracks and loosened bolts, and less cab component damage (Bradley, 1993)[6].

Anon (2006)[4] performed tests for the United States Forest Service that clearly demonstrates the points above. Two closely matched trucks were operated over identical test courses for an extended period, one with traditional tyre pressures and the other at reduced optimized tyre pressures (the truck was equipped with CTI). Vibration levels were measured and the truck with high inflation pressure recorded six times more vertical energy than the truck with lowered inflation pressure. The high pressure truck exhibited four times the part failures and eight times greater cost of repairs than the truck with lowered tyre pressures.

Traditional over inflated tyres actually bounce off road irregularities, amplifying bumps, increasing vibration levels. This high impact vibration increases suspension wear and tear. Strain gauges were installed on log truck drive lines by Goodyear that proved a minimum 30% reduction in drive train loads. The 'softer' tyre could flex axially, to absorb each piston power stroke. This has been confirmed in practice by numerous operator reports of doubling of drive train life.

A further study conducted in Western Australia with three trucks with traditional tyre pressure. All three trucks exceeded a half metre vibration impacts over 500 times over a 27 km test distance. When one vehicles was equipped with a Central Tyre Inflation and pressures optimized for the load and terrain, the standard vibration limit was only exceeded 13 times over the journey. **This is over 95% improvement.**

Over inflated tyres certainly damage our roads, which then come back and bites transport again, increasing fuel, maintenance costs, and down time.

TYRE PRESSURE AND INFRASTRUCTURE DAMAGE

Over Inflated Tyres are the Hammer to the Anvil called Roads.

INFRASTRUCTURE DAMAGE: Infrastructure, roads, bridges, and highways, are a major problem for most countries. Huge country debts combined with failing infrastructure is becoming critical. High axle loads are the chief enemy, slowly eating away at once sound and smooth structures. Truck loads continue to increase to improve financial rewards, and, theoretically, reduce traffic density. 'Road Friendly' suspensions, most riding on air, were allowed increased axle loads. In practice, this has not worked. Road friendly suspensions only work if all components are in great shape. We have a problem.

Excessive tyre pressure, even on an empty semi, hammers, and hammers, and hammers our roads.

A truck tyre rotates 500 times every mile. A tyre that is a half kilo out of balance is hammering the road with 78 kilograms force 500 times a minute, time and time again. Over inflated tyres amplify each impact, hammering our roads. Potential impact levels are multiplied again and again.

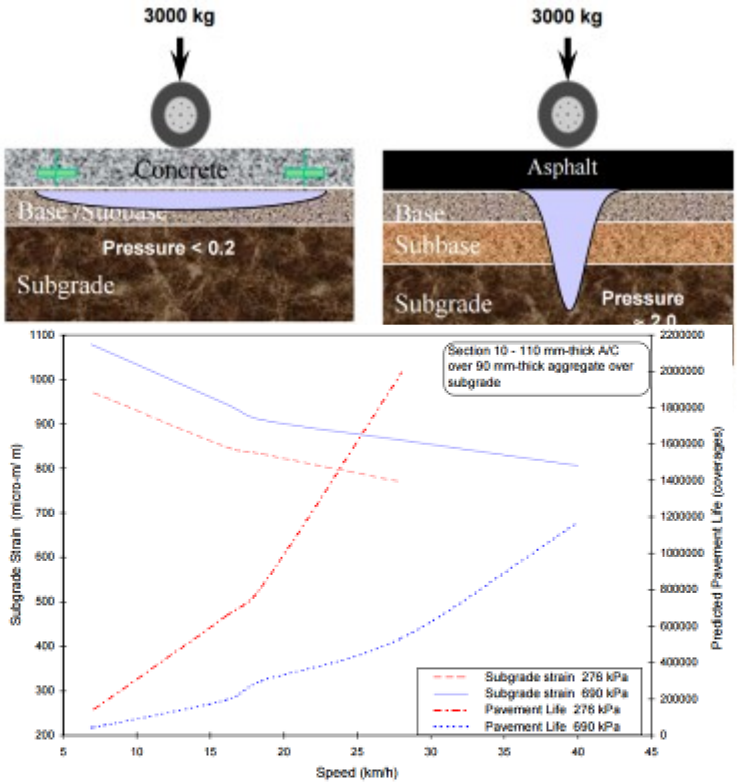


Figure 10. Relationship of speed to subgrade strain and predicted pavement life (*based on subgrade strain data from Table 12, in Smith (1993)*).

Everyone knows that one pot hole will begat another a short distance further on, and then another further on, as the second one develops.

Our roads, that all taxpayers pay for, are being hammered to death simply because 'we have always used 100 to 110 psi in our tyres'.

Our roads are going backwards, yet, we persist, we ignore the manufacturer's tyre pressure recommendations.

Rough roads are more dangerous.

Rough roads cause more accidents.

Rough roads increase the cost of all consumer goods.

Rough roads are killing our drivers.

Yet our governments continue promoting unsafe and wrong heavy truck tyre pressures.

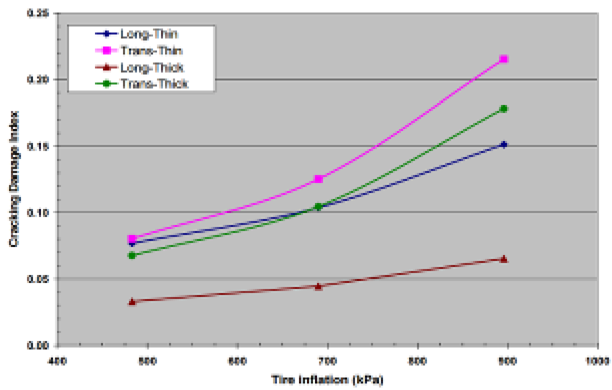


Figure 7. Influence of tire inflation on longitudinal and transverse cracking strains in thin and thick pavements (*Wang and Machemehl 2006*).

Table 5.2: *Summary of Pavement Failure Results from Single-Axle Simulations*

Tire Pressure	690 kPa (100 psi)		550 kPa (80 psi)		410 kPa (60 psi)		345 kPa (50 psi)	
Load Repetitions	*Fatigue*	*Rutting*	*Fatigue*	*Rutting*	*Fatigue*	*Rutting*	*Fatigue*	*Rutting*
Applied Truck Passes	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Passes Allowed by Failure Criteria	78,107	27,538	348,064	28,322	2,209,767	29,746	25,360,598	30,889
Accumulated Damage	1.28	3.68	0.29	3.53	0.02	3.36	0	3.24

Table 5.3: *Summary of Pavement Failure Results from Tandem-Axle Simulations*

Tire Pressure	690 kPa (100 psi)		550 kPa (80 psi)		410 kPa (60 psi)		345 kPa (50 psi)	
Load Repetitions	*Fatigue*	*Rutting*	*Fatigue*	*Rutting*	*Fatigue*	*Rutting*	*Fatigue*	*Rutting*
Applied Truck Passes	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Passes Allowed by Failure Criteria	22,018	427,735	60,338	445,307	268,428	475,898	735,028	492,669
Accumulated Damage	4.54	0.23	1.66	0.22	0.37	0.21	0.14	0.2

WHAT IS THE OPTIMAL TYRE PRESSURE
FOR
HEAVY TRUCK RADIAL TYRES?

OPTIMIZED HEAVY TRUCK TYRE PRESSURE is the single, most ignored and most misunderstood operational practice. Almost without precedent, almost every heavy truck is running the wrong tyre pressure, usually on all tyres.

MOST STEER tyres are underinflated.

ALMOST ALL DRIVE AND TRAILER TYRES are over inflated, by at least 25%, while many are over inflated far worse.

Most tyre retailers don't understand optimized tyre pressures.

Most tyre 'expert's don't understand optimized tyre pressures.

Most government regulators and experts don't understand optimized tyre pressures.

Most magazine articles and most internet articles are incorrect.

MYTHS:

- The pressure stamped into the tyre sidewall is not the optimal tyre pressure. It is the maximum pressure required for that tyre to carry the maximum load as recommended by the manufacturer for that tyre.
- 100 psi is only optimal for one tyre load; 2790 kg or 6138 pounds for single tyres, or 5135 kg, or 11,297 pounds, for a dual assembly with 11R22.5 tyres. That equates to 5580 kg (12,276 lbs) for an axle with only two single tyres, or 10270 kg (22,594 lbs) for an axle with dual tyres on each end.
- 110 psi is only optimal for one tyre load; 5,940 kg (13,068 lbs) axle load for singles tyres, or 10,940 kgs (24,068 bs) for a dual assembly.
- Some experts say that any pressure between the recommended pressure, from 'load to inflation' tables, to the maximum pressure on the side wall is OK. This is wrong. The only optimal pressure for a specified weight is the weight shown in the load to inflation table.
- Some say that the tyre pressure should be higher to allow for natural air pressure loss. Adding 10% isn't going to waste too much money, but why waste any when you can get the best.
- Others say that a higher tyre pressure will improve fuel economy. Yes, this is true, to a point, but, what about the other costs, the additional suspension and chassis maintenance, the increased down time changing more tyres, and the higher accident rate? Michelin states the difference between optimal tyre pressure and severely over inflated is around 1%. Safety first. Then work on reducing the over all costs.

THE OPTIMUM HEAVY TRUCK TYRE INFLATION PRESSURE depends upon the tyre size, the weight on that tyre, and the road surface travelled on. First, we'll deal with improved roads, like those that most trucks work on.

As the load changes, the optimal tyre pressure also changes. Every quality tyre manufacturer provides a load to inflation table. These are readily available on the internet. The US Tire and Rim Association (T&RA) makes a great tyre handbook, that lists every tyre size and every load to inflation table. Typically, Load to Inflation tables minimum pressure listing is 65 psi. They assume that the truck hasn't got Central Tyre Inflation (CTI). Special charts are available from tyre manufacturers or the T&RA that specify tyre pressures down to 25 psi allegedly for those with CTI.

Most countries legislate the maximum loads that can be used on public roads. For instance,

- Australian standard steer axle maximum loads are 6,000 kg., or 3,000 kg per tyre.
- Tandem axle dual tyre groups are 16,500 kg, or 8,250 per axle, or 2062.5 kg per tyre.
- Tri axle dual tyre groups are 20,000 kg, or 6,666.6 kg per axle, or 1,666.7 kg per tyre.

USA typically allows

- 12,000 lbs on the steer, and or 6,000 lbs on each tyre
- 34,000 lbs on the tandem drive, or 4250 lbs per tyre.

DETERMINING CORRECT TYRE PRESSURE

The correct tyre pressure depends on the load.

Consider the following cases;

(i) An Australian Tandem Drive has a maximum legal tyre load of 16.5 tonne on 8 tyres. This is 2063 kg per tyre. Referring to the Bridgestone or Michelin charts below, (See Yellow Squares) this gives the correct cold pressure of 75 psi.

(ii) The front axle load is 6 tonne (6000 kg) - spread over two tyres, ie 3000kg per tyre. Steer axles should have 10% added to account for the increased steering lateral loads and thus the cold steer pressure for a 11R22.5 is 132 psi. (See Orange Squares) In Australia this is illegal and therefore a larger section tyre is needed to support 6 tonne.

The Correct Tyre Pressure depends on the load per tyre and the terrain traversed.
Larger size tyres can carry more weight at similar pressures OR need less pressure for similar loads.

Effective January 2009 **BRIDGESTONE** Load and Inflation Tables

Medium Commercial Truck Radials

RADIAL PLY TIRES FOR TRUCKS, BUSES AND TRAILERS USED IN NORMAL HIGHWAY SERVICE
TIRES MOUNTED ON 15° DROP CENTER RIMS

Tire Size Designation	USAGE	Tire Load Limits (kg/lbs.) at various Cold Inflation Pressures (kPa/psi) Pressure Listed is the Minimum for the Load											
		kPa	480	520	550	590	620	660	690	720	760	790	830
		psi	70	75	80	85	90	95	100	105	110	115	120
10R22.5	DUAL	kg	1750	1830	1910	**2000(E)** $_{132}$	2080	2160	**2240(F)** $_{138}$	2300	2360	**2430(G)** $_{139}$	
		lbs.	3860	4045	4230	**4410(E)**	4585	4760	**4940(F)**	5075	5210	**5355(G)**	
	SINGLE	kg	1850	1940	2030	**2120(E)** $_{134}$	2200	2280	**2360(F)** $_{138}$	2430	2500	**2575(G)** $_{141}$	
		lbs.	4080	4280	4480	**4675(E)**	4850	5025	**5205(F)**	5360	5515	**5675(G)**	
11R22.5	DUAL	kg	1990	2080	2160	2250	**2360(F)** $_{138}$	2460	2560	**2650(G)** $_{142}$	2680	2710	**2725(H)** $_{143}$
		lbs.	4380	4580	4760	4950	**5205(F)**	5415	5625	**5840(G)**	5895	5950	**6005(H)**
	SINGLE	kg	2050	2160	2260	2370	**2500(F)** $_{140}$	2600	2700	**2800(G)** $_{144}$	2870	2940	**3000(H)** $_{146}$
		lbs.	4560	4770	4990	5220	**5510(F)**	5730	5950	**6175(G)**	6320	6465	**6610(H)**

MediumTruck

Medium Truck Tires

Firestone | Truck Tire Data Book | LOAD & INFLATION TABLES

Radial Ply **METRIC** *Tires for Trucks, Buses & Trailers Used in Normal Highway Service*

TIRES MOUNTED ON 15° DROP CENTER RIMS

TIRE SIZE DESIGNATION	USAGE	Tire Load Limits (kg./lb.) at various Cold Inflation Pressures (Pressure Listed is the Minimum for the Load)											
		kPa	550	590	620	660	690	720	760	790	830	860	900
		psi	80	85	90	95	100	105	110	115	120	125	130
315/80R22.5	Dual	kg.	2575	2650	2750	2900	2970	3070	3150	3270	**3450(J)** $_{151}$	3590	**3750(L)** $_{154}$
		lb.	5675	5840	6070	6395	6545	6770	6940	7210	**7610(J)**	7910	**8270(L)**
	Single	kg.	2800	2910	3030	3150	3260	3370	3450	3590	**3750(J)** $_{154}$	3940	**4125(L)** $_{157}$
		lb.	6175	6415	6670	6940	7190	7440	7610	7920	**8270(J)**	8690	**9090(L)**

Note also that the table is titled “used in normal highway service”. It is not referring to gravel or sandy roads.

MICHELIN

S = Single configuration, or 2 tires per axle.
D = Dual configuration, or 4 tires per axle

11R22.5 LRH XZY® 3, XZE2™, XZA3®, XDY-2™, XDY® 3, XDS®, XDN®2, XDE® [illegible]

PSI		75	80	85	90	95	100	105	110	115	120	MAXIMUM LOAD AND PRESSURE ON SIDEWALL				
kPa		520	550	590	620	660	690	720	760	790	830					
LBS	SINGLE	9540	9980	10440	11020	11460	11900	12350	12640	12930	[illegible]	S	6610	LBS at	120	PSI
	DUAL	18320	19040	19800	20820	21660	22500	23360	23580	23800	24020	D	6005	LBS at	120	PSI
KG	SINGLE	4320	4520	4740	5000	5200	5400	5600	5740	5880	6000	S	3000	KG at	830	kPa
	DUAL	8320	8640	9000	9440	9840	10240	10600	10720	10840	10900	D	2725	KG at	830	kPa

295/80R22.5 LRJ X® Coach XZ

PSI		80	85	90	95	100	105	110	115	120	123	MAXIMUM LOAD AND PRESSURE ON SIDEWALL				
kPa		550	590	620	660	690	720	[illegible]	790	830	850					
LBS	SINGLE	10960	11520	12040	12580	13100	[illegible]	[illegible]	14640	15160	15660	S	7830	LBS at	123	PSI
	DUAL	19440	20400	21360	22280	23200	24160	25080	25960	26880	27760	D	6940	LBS at	123	PSI
KG	SINGLE	4960	5260	5460	5740	5960	6160	6440	6640	6900	7100	S	3550	KG at	850	kPa
	DUAL	8800	9320	9680	10200	10560	10920	11400	11760	12240	12600	D	3150	KG at	850	kPa

305/70R22.5 LRL XZU®2, XRV®

PSI		75	80	85	90	95	100	[illegible]	110	115	120	MAXIMUM LOAD AND PRESSURE ON SIDEWALL				
kPa		520	550	590	620	660	690	[illegible]	760	790	830					
LBS	SINGLE	10750	11320	11880	12440	12990	[illegible]	[illegible]	14600	15140	15660	S	7830	LBS at	120	PSI
	DUAL	19060	20060	21060	22060	23020	24000	24940	25900	26840	27760	D	6940	LBS at	120	PSI
KG	SINGLE	4880	5100	5400	5620	5920	6120	6340	6620	6820	7100	S	3550	KG at	830	kPa
	DUAL	8680	9080	9600	9960	10480	10880	11240	11760	12120	12600	D	3150	KG at	830	kPa

315/80R22.5 LRL XZY® 3, [illegible]A2® Energy™, XZA®1, XDY® 3, XDN®2 GRIP

PSI		85	90	95	100	105	110	115	120	125	130	MAXIMUM LOAD AND PRESSURE ON SIDEWALL				
kPa		590	620	[illegible]	690	720	760	790	830	860	900					
LBS	SINGLE	12830	[illegible]	13880	14380	14880	15220	15840	16540	17620	18180	S	9090	LBS at	130	PSI
	DUAL	23360	[illegible]	25580	26180	27080	27760	28840	30440	32040	33080	D	8270	LBS at	130	PSI
KG	SINGLE	5820	6060	6300	6520	6740	6900	7180	7500	7960	8250	S	4125	KG at	900	kPa
	DUAL	10600	11000	11600	11880	12280	12600	13080	13800	14480	15000	D	3750	KG at	900	kPa

The above charts show an example of how the required pressure of a tyre with 6 tonne axle load changes as tyre size increases. NOTE: Steer axles require an additional 10% pressure.

TO DETERMINE THE CORRECT TYRE PRESSURE THE FOLLOWING NEEDS TO BE CONSIDERED,

- Weight on each tyre
- Size of the tyre
- Whether a dual or single configuration
- Steer tyres carry the most weight as well as steering the truck. They therefore should have 10% added,

Weigh each axle of the truck both empty and fully laden. The easiest method is:

- Drive the steer axle or axles onto the weigh bridge. Write down the weight.
- Drive the prime mover or truck onto the weigh bridge. Write down the weight.
- Drive forward until the trailer axles are on the weigh bridge. Write down the weight.
- Subtract the steer axle/s weight from the prime mover or truck weight to get the drive axle's weight.
- You should have the steer axle's weight, the drive axle's weight, and the trailer axle's weight.
- Divide this weight by the number of axles to find the axle weight, or by the number of tyres to find the tyre weight.
- Check the Load to Inflation tables for your tyre size to find the optimized tyre pressures for each axle.

Note: The correct cold pressure is shown in the appropriate load to inflation chart. This allows for natural heat build up to optimized operating temperature and pressures.

Pressions d'utilisation route - *Tire inflation pressures for road service* (bar) **11R22.5**

1 Bar = 14.5 psi
2 Bar = 29 psi

Charge par enveloppe / *Load per tire* (Kg)		Vitesse - *Speed* (Km/h) 130	120	110	100	90	80	65	50	40	30	20	10	0
Nominal route	3150			8,0	8,0	7,9	7,9	7,9	7,7	7,6	7,0	6,2	5,4	4,0
	3000			7,6	7,6	7,5	7,5	7,5	7,3	7,2	6,7	5,8	5,2	3,8
Nominal road conditions	2750			6,9	6,9	6,8	6,8	6,8	6,7	6,5	6,0	5,3	4,7	3,4
	2500			6,2	6,2	6,1	6,1	6,1	6,0	5,9	5,4	4,7	4,2	3,1
	2250			5,5	5,5	5,4	5,4	5,4	5,3	5,2	4,8	4,2	3,7	2,7
	2050			4,9	4,9	4,9	4,9	4,8	4,8	4,7	4,3	3,8	3,3	2,4
	2000			4,8	4,8	4,8	4,7	4,7	4,6	4,5	4,2	3,7	3,2	2,3
	1750			4,1	4,1	4,1	4,0	4,0	4,0	3,9	3,6	3,1	2,7	1,8
	1500			3,4	3,4	3,4	3,4	3,3	3,3	3,2	3,0	2,6	2,2	1,5
	1250			2,7	2,7	2,7	2,7	2,6	2,6	2,5	2,4	2,0	1,6	1,2
	1000			2,0	2,0	2,0	1,8	1,8	1,7	1,7	1,6	1,4	1,2	0,8
Flèche / *Deflection* (mm)				37	37	37,5	37,5	37,5	38	38,5	41	45,5	50	62,5

ALL THE TYRES on the right are severely over inflated.
The only optimally inflated tyre is below on the left.
There must be a footprint that lies flat against the ground.
For an 11R22.5, that footprint should be 240 mm long and 180 mm wide as shown on the next page, life size when printed on standard A4 paper.

OPTIMAL HIGHWAY PRESSURE FLAT AREA

ALL OTHERS ARE SEVERELY OVER INFLATED

IT'S EASY TO

SPOT

OVER INFLATED TYRES!

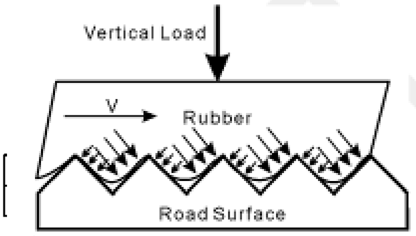

The black tread is the correct footprint
size for a standard 11R22.5
The red footprint below
is the same tyre on an empty truck
WITH 100 PSI TYRE PRESSURE
THIS IS LIFE SIZE
WHEN PRINTED ON A4 PAPER
240 MM X 184 MM.
From Michelin Load tables
AIR CTI 03 51276128

UNMADE ROAD HEAVY TRUCK TYRE PRESSURE RECOMMENDATIONS

On unmade roads, like gravel or dirt roads, reducing the tyre pressure below highway pressures allows the tyre contact patch to deform to mould into and key into the road surface providing numerous benefits.

Notice the loads and pressures recommended for 50 mph, or 80 kph.

Trucks with high tyre pressures slip and slide, especially when empty. As is demonstrated by this tyre sitting on a golf ball, over inflated tyres sit on top of any gravel or stones. By reducing the tyre pressure, the tyre can mould around these, and key into the surface, obtaining substantially more grip.



THE TIRE AND RIM ASSOCIATION, INC.

DESIGN GUIDE
REDUCED INFLATION PRESSURE LIMITS FOR TRUCK TIRES USED OFF HIGHWAY AT REDUCED SPEED
(FOR SINGLE AND DUAL APPLICATIONS)

MAXIMUM SPEED - 50 MPH

TIRE SIZE DESIGNATION	MINIMUM COLD INFLATION PRESSURES (PSI) AT VARIOUS LOADS (LBS.)										
	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
11R22.5	25	25	25	25	26	28	29	31	33	34	36
11R24.5	25	25	25	25	25	25	27	28	30	31	33
12R22.5	25	25	25	25	25	25	26	27	29	30	32
12R24.5	25	25	25	25	25	25	25	25	26	28	29
295/75R22.5	25	25	25	27	28	30	32	34	35	37	39
315/80R22.5	25	25	25	25	25	25	25	26	28	29	30
	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100
11R22.5	38	40	42	44	45	47	50	52	54	56	58
11R24.5	35	36	38	40	41	43	45	47	49	51	53
12R22.5	33	35	37	38	40	42	44	45	47	49	51
12R24.5	31	32	33	35	36	38	40	41	43	45	46
295/75R22.5	41	43	45	47	49	51	53	55	57	59	61
315/80R22.5	32	34	35	37	38	40	41	43	45	46	48
	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200
11R22.5	60	63	65	67	70	72	74	77	80	82	85
11R24.5	55	57	59	61	63	65	67	70	72	74	76
12R22.5	53	55	57	59	61	63	65	67	69	72	74
12R24.5	48	50	52	53	55	57	59	61	63	65	67
295/75R22.5	63	65	67	70	72	74	76	79	81	83	86
315/80R22.5	50	51	53	55	57	58	60	62	64	66	67
	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	6300
11R22.5	87	90	93	95	98	101	104	107	110	113	116
11R24.5	79	81	84	86	89	91	94	96	99	102	104
12R22.5	76	78	81	83	86	88	90	93	96	98	101
12R24.5	61	71	73	75	77	80	82	84	86	89	91
295/75R22.5	88	90	93	95	98	100	103	105	108	110	113
315/80R22.5	69	71	73	75	77	79	81	83	85	87	89

NOTES: 1: The above inflation pressures are applicable for use off highway with vehicles having central tire inflation (CTI) systems. Since these tables define minimum "cold" pressures, additional pressure will be necessary to correct for "hot" conditions. These CTI systems are to be designed so that normal tire pressure build-up is maintained.

IN POOR TRACTION AREAS, USE LOWER PRESSURES.

Lower pressures increase the footprint length, reducing the surface unit pressure providing even better keying, while added floatation. Both effects increase vehicle access.

Traction increases can be up to double, while significantly reducing tyre slip, punctures, ruts, road damage, and silt run off.

Reducing tyre pressures is essential when operating off hard surfaces. The softer the roadway, the softer the tyre needs to be.
NOTE the much larger footprint in this picture.

Page	Rev.	Date
3-36	2	10/24/14

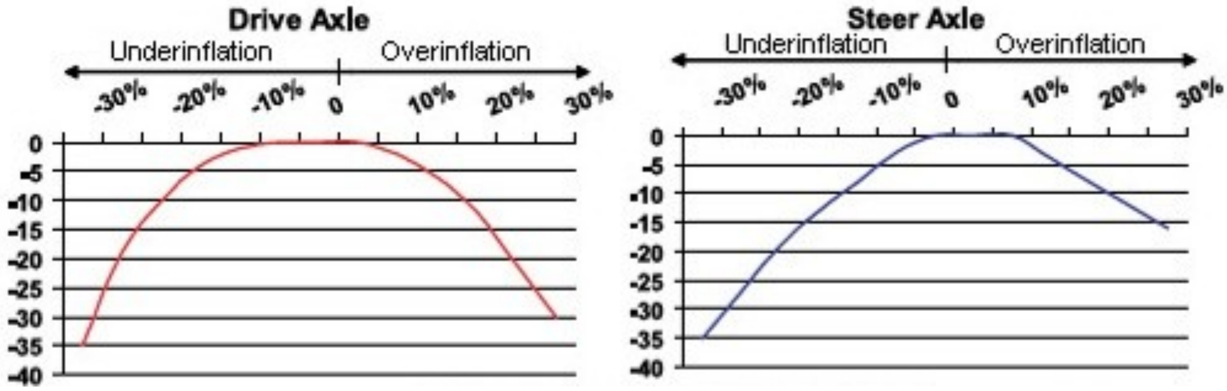
THE TIRE AND RIM ASSOCIATION, I

DESIGN GUIDE
REDUCED INFLATION PRESSURE LIMITS FOR TRUCK TIRES USED OFF HIGHWAY AT REDUCED SPEED (FOR SINGLE AND DUAL APPLICATIONS)

MAXIMUM SPEED 35 MPH

TIRE SIZE DESIGNATION	MINIMUM COLD INFLATION PRESSURES (PSI) AT VARIOUS LOADS (LBS.)										
	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
11R22.5	25	25	25	25	25	25	26	28	29	31	32
11R24.5	25	25	25	25	25	25	25	26	27	28	30
12R22.5	25	25	25	25	25	25	25	25	26	27	29
12R24.5	25	25	25	25	25	25	25	25	25	25	26
295/75R22.5	25	25	25	25	26	27	29	30	32	34	35
315/80R22.5	25	25	25	25	25	25	25	25	25	26	28
425/65R22.5	25	25	25	25	25	25	25	25	25	25	26
445/65R22.5	25	25	25	25	25	25	25	25	25	25	25
	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100
11R22.5	34	36	37	39	41	42	44	46	48	50	52
11R24.5	31	32	34	35	37	39	40	42	43	45	47
12R22.5	30	31	33	34	36	37	39	40	42	44	45
12R24.5	28	29	30	31	33	34	35	37	38	40	41
295/75R22.5	37	39	40	42	44	46	47	49	51	53	55
315/80R22.5	29	30	32	33	35	36	37	39	40	42	43
425/65R22.5	26	27	28	28	29	30	31	31	32	33	34
445/65R22.5	25	26	26	27	27	28	29	29	30	30	31
	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200
11R22.5	54	56	58	60	62	64	66	68	71	73	75
11R24.5	49	50	52	54	56	58	60	62	64	66	68
12R22.5	47	49	51	52	54	56	58	60	62	64	66
12R24.5	43	44	46	48	49	51	53	54	56	58	60
295/75R22.5	57	59	61	63	65	67	69	71	73	75	77
315/80R22.5	45	46	48	49	51	53	54	56	58	59	61
425/65R22.5	34	35	36	37	38	38	39	40	41	42	43
445/65R22.5	32	32	33	34	35	35	36	37	38	38	39
	5300	5400	5500	5600	5700	5800	5900	6000	6100	6200	6300
11R22.5	77	80	82	85	87	90	92	94	97	100	102
11R24.5	70	72	74	76	79	81	83	85	88	90	92
12R22.5	68	70	72	74	76	78	80	82	85	87	89
12R24.5	61	63	65	67	69	71	73	75	77	79	81
295/75R22.5	79	81	84	86	88	90	92	95	97	99	101
315/80R22.5	63	64	66	68	69	71	73	75	76	78	80
425/656R22.5	44	45	46	47	48	48	49	50	52	53	54
445/65R22.5	40	41	42	42	43	44	45	46	47	48	49

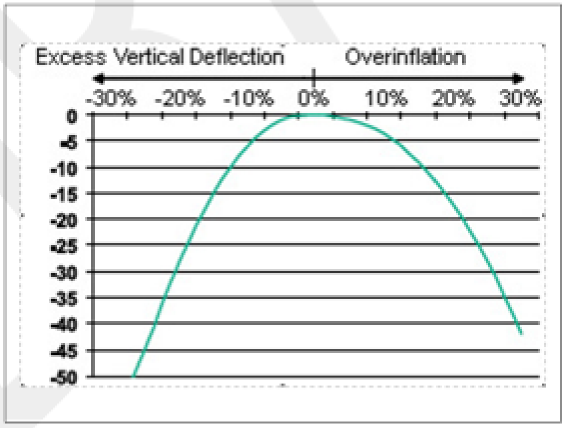
THE FOLLOWING DIAGRAMS DEMONSTRATES CORRECT TYRE PRESSURE INFLUENCE TREAD LIFE, AND CASING LIFE ON AMERICAN ROADS.



Pressure Effects on Tread Life on US roads — per Michelin

TYRE WASTE is ridiculous.

- 100 psi on tandem axles is 25% over inflated when fully laden, losing 20% tyre life and losing 14% of the expected casing life.
- 110 psi on tandem axles is 38% over inflated wasting even more.
- When empty, these tyres are wearing out much faster, wasting even more money, safety, time, drivers, infrastructure, and needlessly damaging our environment.



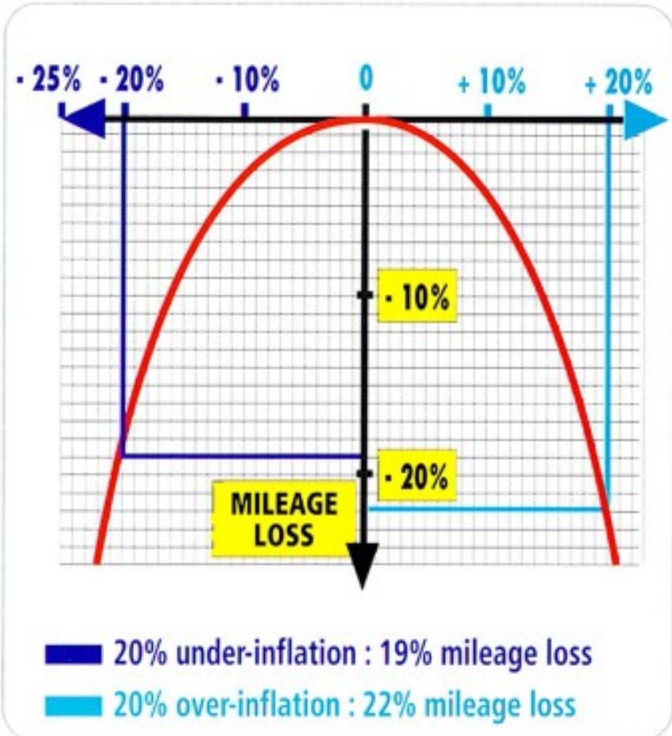
Pressure effects on Casing Life – per Michelin

Australian roads mostly are coarse chip which is rougher than American roads, increasing the wear rate on all tyres.

Loaded B doubles will suffer more wear than single trailers.

The worst case for highway drive tyre wear is an empty tip or dump truck pulling a trailer that is loaded with an excavator or dozer. No weight on the drive tyres, towing a heavy load is a recipe for rapid drive tyre wear. Excessive drive tyre pressure reduces the tyre footprint, causing horrendous wear.

Many trucks operate empty half the time, like many mining trucks, tankers, concrete agitators, bulk haulage trucks. All the power and engine braking are transferred to terra firma through the contact patch. Drive tyre life in these cases is horrible.



OPTIMISING TYRE USE ON/OFF HIGHWAYS, LOADED/UNLOADED

On gravel or dirt roads, the optimal tyre pressure is 60% of the optimal highway pressures, at a reduced speed of 80 kph or 50 mph.

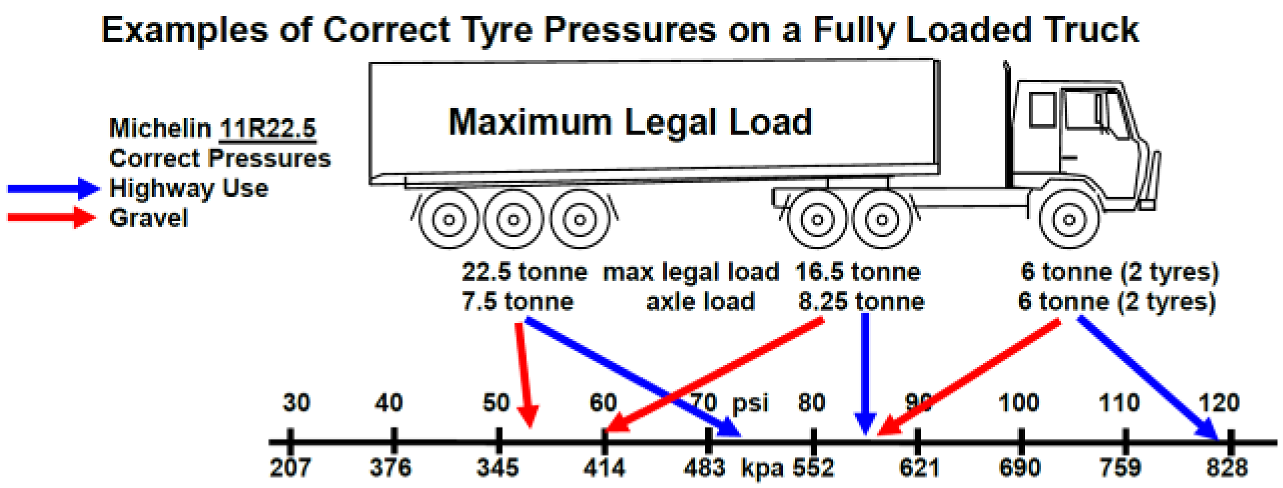
To optimise tyre use, the driver needs to be aware of the load each axle is carrying, and view this information along with the road he is travelling on.

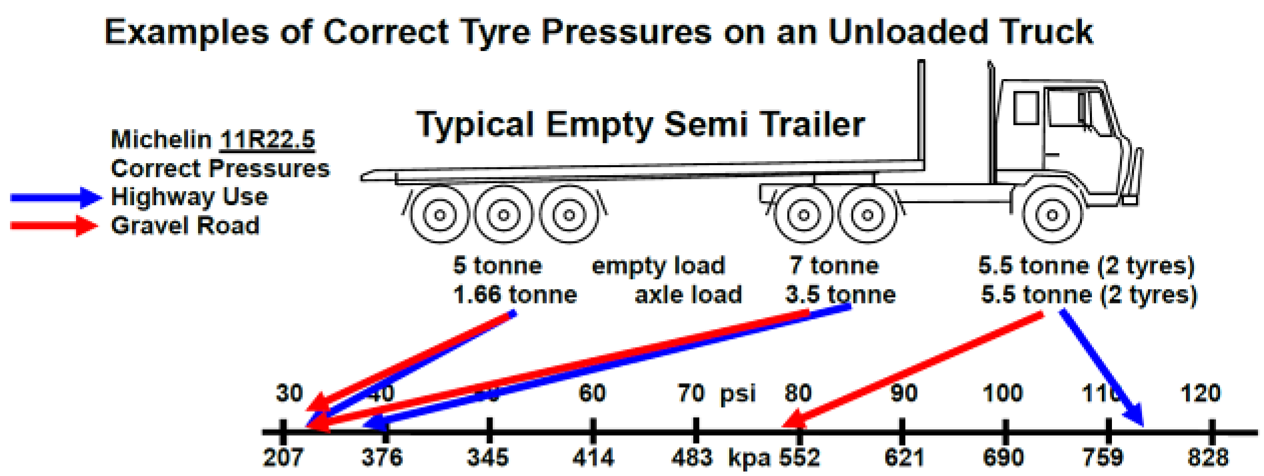
Below are schematics showing how the mentality of “one size” fits all loading/terrain conditions is flawed. Adopting such a mentality will result in enormous unnecessary expense.

Over-inflated tyres reduce the tyre footprint. The contact area is too small to transmit the drive force of the engine since the adhesion or keying of the tyre is not capable of transferring this load to the road. In short, the tyre is unable to grip the road and therefore slips. The engine over-revs without any transmission of energy thereby reducing fuel efficiency. Over-inflated tyres pound the roads causing and then worsening potholes. Over inflated tyres deteriorate faster releasing pollutants into the environment. Over-inflated tyres amplify vibrations to the driver caused by road roughness that lead to debilitating diseases under the umbrella term “Whole Body Vibration”.

Over-inflated tyres cause unnecessary soil compaction, loss of mobility and sedimentation.

Under-inflated tyres increase the potential of a blowout through sidewall damage and poor fuel economy due to increased roll resistance.





OPTIMAL TYRE PRESSURE EXAMPLES OF HEAVY TRUCK TYPES:

To ease understanding of optimal hot operational tyre pressures, a few examples including weight on each group of axles. Tyre size; 11R22.5. Recommended Optimal Pressures were obtained from the Michelin Technical Databook. Steer tyres are increased 10% from recommended to allow for extra lateral loads. All pressures are ***hot pressures***, which are 12 to 15% higher than recommended and ***normal cold*** specifications.

A standard 6 m concrete agitator (3 axles):

	Front Axle/s	Rear Axles	optimal tyre pressure Front	Rear
Empty	4.7 tonne	5 tonne	98 psi	40 psi
Loaded	6 tonne	16.5 tonne	120 psi	96psi

(slightly higher rear pressure because of high CG)

An 8 m twin steer tandem drive agitator (4 axles):

Empty	6.5 tonne	6 tonne	70 psi	45 psi
Loaded	10 tonne	16.5 tonne	100 psi	96 psi

(slightly higher rear pressure because of high CG)

Tandem drive tip truck (3 axles):

Empty	5 tonne	5 tonne	100 psi	30 psi
Loaded	6 tonne	16.5 tonne	120 psi	92 psi

Dog trailer (3 axles):

Empty	2.5 tonne	3.5 tonne	30 psi	30 psi
Loaded	9 tonne	16.5 tonne	105 psi	92 psi

Prime mover/tractor bob tail (3 axles):

Empty	4.5 tonne	3.5 tonne	96 psi	25 psi
Loaded	6 tonne	16.5 tonne	130 psi	92 psi

Tri axle tanker trailer with super singles (3 axles)

Empty	6.3 tonne total	4 tonne	30 psi
Loaded		15 tonne	75 psi

Note: Currently, 385/65/R22.5 super single tyres are restricted to 15 tonne capacity for a tri axle group in Australia.

If a tri axle group of Super Singles could carry 20 tonne as per standard dual assemblies, the optimal loaded tyre pressure would be 105 psi.

WASTE COSTS AND COSTS AND COSTS

8.5 PROBLEM SUMMARY

SUMMARY

The benefits of matching tyre pressure in tyres against weight and terrain conditions is poorly understood within the transport industry. As a result, significant benefits that accrue to the driver, owner, the country, and environment have been overlooked. This is mainly due to antiquated work practices and inter-generational thinking.

The costs of damage to driver's health, the reduction of the safety of vehicles, the lost profitability of the trucking industry, the damage to our infrastructure, and the environmental fallout and damage are substantial yet avoidable.

It is quite clear that the transport industry needs to review and absorb new technological changes that make it possible to improve outcomes for all stakeholders both inside and outside the trucking sector.

Failure to do so will mean that poor economical returns, adverse health and safety issues and environmental damage will remain the norm. This outcome is extremely detrimental to all stakeholders concerned and to the world.

The opportunity exists now to rectify the problem, and everyone within the transport industry needs to make the step from passive observer to active participant.

A solution is clear and easy to adopt. A driver needs to take into consideration the load he is carrying on each axle and then determine the load on each tyre. He needs to consider tyres in individual groups, that is as Steer, Drive or Trailer – each is a separate case – and then relate back to the terrain he is driving on. He can then refer to the manufacturer's recommended load/inflation tables. This recommended tyre pressure is cold pressure and allowance would need to be taken into account when the tyre is at hot pressure. This needs to be done for every change in load conditions and terrain conditions.

Central Tyre Inflation is the OE or aftermarket tool/accessory that makes tyre pressure optimisation easy and affordable.

CENTRAL TYRE INFLATION (CTI) AND OPTIMIZED TYRE PRESSURE CAN ACHIEVE:

- Optimal tyre pressures increase safety significantly. Stopping distances are shorter, and straight. Handling and vehicle control is improved. Ride quality is improved. Accident levels reduce.

- Tyre costs reduce by 30% or more. The use of optimal tyre pressure via a CTI system increases tyre life by at least 30%. By maintaining tyres at correct pressure the contact patch or tyre footprint is at its optimal size. Thus ensuring the best transfer of the engine load through the tyres via contact forces at the road surface. This ensures minimal wear and tear on the tyre.

- 30% less tyres are required, saving large sums of money, while helping reduce a country's balance of payments, improving standard of living in each country.

- Reduce the number of tyres made and we reduce the amount of cancer causing, DNA damaging pollutants that damage our environment.

- Considering that it requires 83 liters, 22 gallons, of oil to produce one truck tyre, optimized tyre pressures reduces the amount of oil, carbon dioxide production and waste that follows from the manufacture and transport of tyres.

- Disposal of old truck tyres is another total headache considerably reduced. Improved case life means more and better retreads, further reducing environmental damage.

- A CTI system automatically maintains optimal tyre pressure. If deflation is excessive the system automatically warns drivers and thus eliminates the prime cause of blowouts and tyre separation, eliminating most dangerous blow outs and road side tyre changes/call outs, further improving safety.

- The use of optimal tyre pressures via a CTI system on vehicles ensures the tyres absorb obstacles and dampen vibrations out so that they are not transmitted through the vehicle to the driver. This will result in enormous reductions in the [Occupational] Whole Body Vibrations the driver is regularly exposed to on a daily basis. Reduced stress reduces driver fatigue improves safety further.

- Optimal tyre pressure reduces damage to infrastructure, reducing road maintenance and replacement costs.

- The use of optimal tyre pressure via a CTI system reduces road damage and road construction costs. Road construction costs reduce, especially on non prime roads, as less road base material is required.

- The use of optimal tyre pressure via a CTI system increase mobility. By maintaining correct tyre pressure vehicles are able to spread their weight over the optimal footprint. A larger footprint and reduced contact pressure combined with increased keying increases traction significantly. This minimises the tendency of tyres digging or trenching themselves into the ground.

- The use of optimal tyre pressure via a CTI system increases fuel economy. Maintaining tyres at the optimal pressure ensures the best adhesion and keying of the tyre to the road surface. This ensures the best transfer of engine load to the tyres, with minimal slippage and sidewall deflection. CTI also balances pressure and therefore loads on dual tyre assemblies minimising the high drag component.

- The use of optimal tyre pressure via a CTI system reduces soil compaction. By maintaining correct tyre pressure vehicles are able to spread their weight over the increased footprint. This reduces excessive surface pressure that causes the collapse of the soil into a compressed, impenetrable barrier. This results in less ruts, less spinning tyres, less potholes, less corrugations and less compaction.

- The use of optimal tyre pressure via a CTI system reduces sedimentation and dust production. Sedimentation of forests is a result of the breaking down of roads. By maintaining optimal tyre pressure the stress transferred through the tyre to the road surface is minimised. Minimising the stress transfer results in less surface damage of the road. This means less surface particles breaking free, less grinding action, less dust and thus less sedimentation of streams.

WORK SMARTER, NOT HARDER

CENTRAL TYRE INFLATION

CENTRAL TYRE INFLATION - HISTORY

During World War II the mobility requirements in Europe were extremely demanding due to poor road and highway quality. Consequently, a considerable effort was made by the USA and Russia to develop systems to improve mobility, including primary suspensions and central tyre inflation systems (Kaczmarek, 1984).

Kaczmarek (1984) stated that "One of the most effective and well proven systems that have been adapted to wheeled tactical vehicles to improve the overall vehicle mobility is CTI." So good were the results that the USA army adopted CTI systems on its front line vehicles from the 1940s.

However, after World War II, no serious consideration of the benefits of CTI occurred outside of the USA army until the 1980s. By this time most of the military tactical vehicles produced in the United States were equipped with CTI (Adams, 2002).

Today the largest application of CTI is in the forestry industry. In actual fact, the logging industry predates the US army in the use of adjusting tyre pressures (although not using an actual CTI system) for their benefit.

It was in the early years of the 20th Century that logging drivers conceived the idea that softer tyres could do much to improve the operation of logging trucks. Specifically in the mid-1920s an attempt was made to provide a softer tyre by first thickening the cross-section of the solid rubber tyre in use at the time and then putting holes through the rubber to produce some give. Logging did improve and increased the demand for softer tyres.

In 1934 Lloyd Christensen, a log trucker who worked in Oregon and Washington and the Goodyear Tire and Rubber Company developed the 14-ply, 10.00 x 20 tire that became the standard in log trucking for many years. In succeeding decades, tires on logging trucks had their pressures increased time and time again due to increased speeds and loads — until the pressure in their tyres reached the 120 psi range. **This is where the deviation from optimal tyre pressure seen today in truck tyres has its roots.** However, and not unexpectedly given today's knowledge, loggers once again started to experience the road damage, traction problems and excessive truck maintenance that they did with early solid tyres. Many loggers now know they can minimise these problems by installing central tire inflation in their logging trucks to ensure they always run at optimal tyre pressure.

Since 1983 the United States Forest Service has been testing the feasibility of Central Tyre Inflation technologies (Altunel and de Hoop, 1998). Brown and Sessions (1999) summarized several of the United States Forest Services sponsored research programs to evaluate the impact of CTI in commercial logging operations on Forest Service

lands. The rough nature of logging roads forces vehicles to slow down in order to limit the vehicle vibrations which negatively impact the vehicle as well as the health of the operators. The results of their research showed that, with CTI, the overall vehicle's speed could be increased as a result of the tyres being optimally suited to the road surface conditions.

While forestry is considered the dominant user of CTI, it is used extensively in other industries namely; military tactical wheeled vehicles, commercial concrete mixer trucks, dump trucks and assorted agricultural vehicles. However, the benefits derived from CTI are common to all industries, these benefits being potential cost savings in road construction and maintenance, lower vehicle maintenance costs, increased vehicle mobility and traction, extended hauling seasons where applicable and improved health and safety for drivers (Greenfield, 1993).

Around the world, CTI has proven it's benefits. Roadex trials has seen logging adopt CTI extensively throughout northern Europe. South African logging uses CTI. Some countries in South America mandate CTI use on all heavy trucks. Canadian Ferric and the USA Forestry Dept proved the many benefits. In Australia and New Zealand, almost all log trucks use CTI. Many forestry areas demand CTI use to lower the environmental impact.

Other transport industries use CTI. Public Utilities require safe access. Country fire services need reliable access. Many out back transport operators know the many benefits, and wouldn't dare venture bush without CTI. Remote motor homes value their vehicles and their lives.

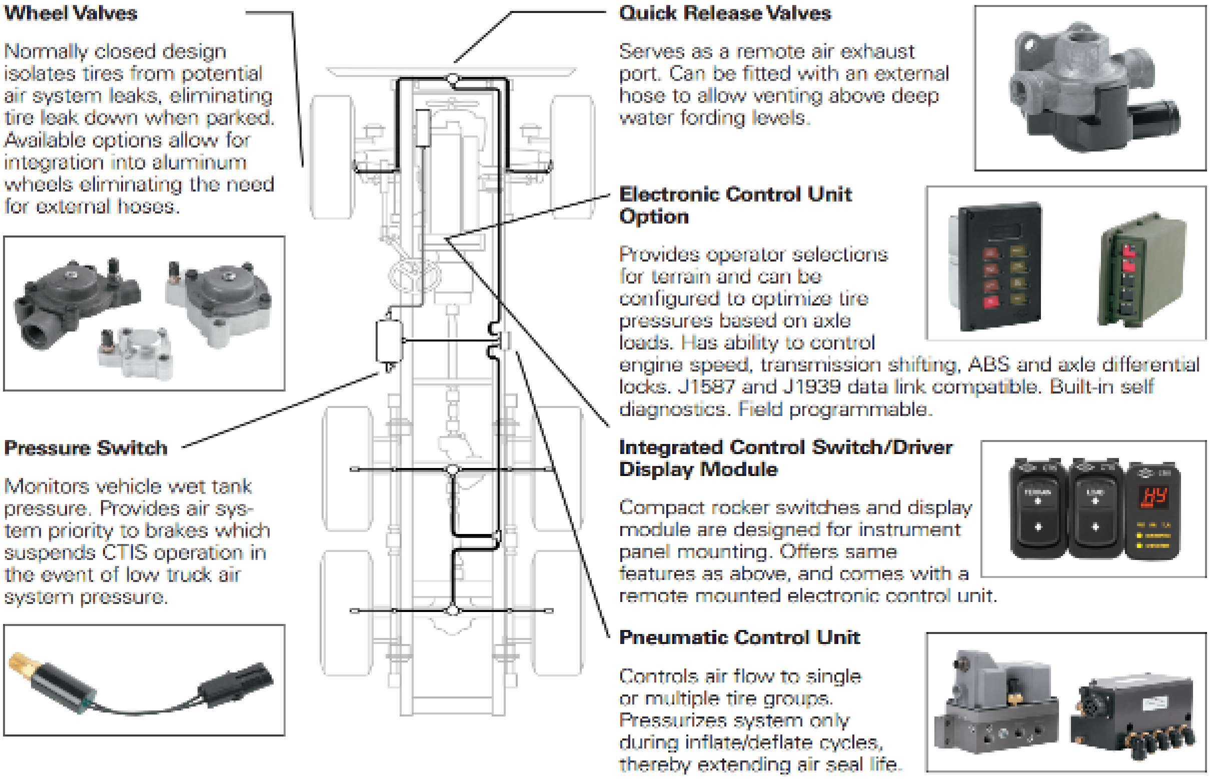
Fuel tankers, tip or dump trucks, agitators, machinery transport, and mining trucks often travel empty half the time. CTI saves them time and money while improving customer service, and reducing their environmental footprint.

70 YEARS,
AND WE’RE STILL NOT USING IT

WHAT IS CENTRAL TYRE INFLATION?

WHAT IS CENTRAL TYRE INFLATION (CTI)

Central Tyre Inflation is an attachment to a truck or trailer that conveys air pressure from an air reservoir to each tyre or a select group of tyres to monitor, maintain, and, often to modify the air pressure as required.



The air reservoir is usually a standard part of heavy trucks. An engine driven compressor maintains approximately 120 psi that is stored in air reservoir/s to operate the truck and trailer brakes. Additionally, many heavy trucks and trailers use air pressure as springs between the axles and the frame. Air springs are often used between the cab and the frame to further improve driver comfort. Air suspended seats are another popular improvement. Air pressure is also used to assist clutch operation, to select gear ratios in the transmission, to operate differential locks, warning horns, engine driven fans, and other accessories.

A control system is required to control the air pressure supplied to the tyres. In it's simplest form, it can be a manually operated tap or valve, an electrically operated valve or solenoid, or an air pressure regulator. A driver control system or automatic operation can be provided.

Manifolding and tubes or pipes distribute the air pressure to each connected wheel tyre assembly.

A flexible tube or hose connects the frame to the axle or wheel, to allow for suspension movement, often called a drop hose or tube.

A rotating gland or union (rotator), that contains the air pressure, connects the stationary hose or axle to the rotating wheel.

A hose connects the rotator to the tyre/s, usually by connecting to the standard tyre Schrader valve.

A warning system warns the driver if a problem exists.

TYPES OF TYRE PRESSURE CONTROL SYSTEMS

MANUAL

The tyres are inflated to the optimal cold pressure for the maximum load the tyres will endure. If the truck is constantly loaded at roughly the same amount, this is a valid first step. This will save at 10% on tyre life. Benefits will depend upon the frequency of adjustment and check ups.

The tyre pressures are adjusted manually to suit the load. Downside: This takes a lot of time and access to compressed air, and does not protect from blow outs, punctures, or inherent dual tyre drag.

TYRE PRESSURE INDICATORS

A variety of special tyre valve caps have indicators built in. One company installed gauges in a truck hub cap. These do make pressure checks easier, but only while actually walking around the truck. No in cab warning. Downside is another fitting that can leak, and no protection from punctures, dual tyre drag, or any means of optimizing tyre pressures.

BALANCE SYSTEMS FOR DUAL TYRES

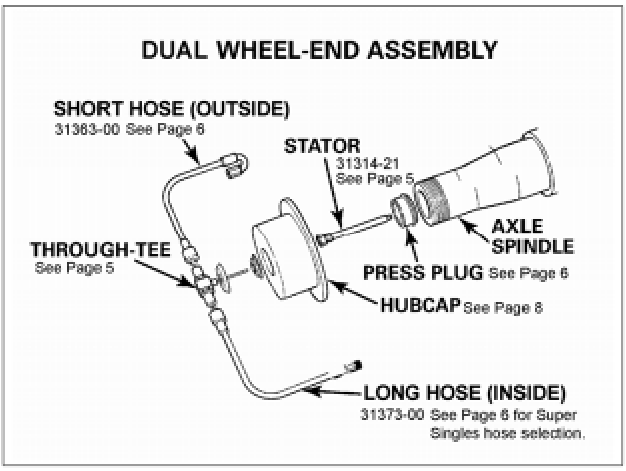
Cat's Eye and Cross Fire attach to both dual tyres, allowing pressures to balance, and provide a visual indication of 'low' pressure. Balancing dual tyre pressures is a definite benefit, improving tyre life. Walk around visual indication has no in cab warning, nor is this set up for optimizing tyre pressures.

TYRE PRESSURE MONITORS (TPMS)

TPMS sensors are mounted on the tyre valve or inside the tyre, and provide via radio signals a dash readout of the pressure. This is a significant improvement, that can warn the driver whilst in motion, of an immanent problem before it becomes dangerous. Most modern cars have a 'low pressure' warning system that is the low cost option of this. The down side is, the driver has to stop and re inflate any punctures, and there is no means to optimize tyre pressures, or to balance the pressures in dual tyre assemblies.

PRESSURE MAINTENANCE SYSTEMS: (also TPMS)

Tyre Pressure Maintenance Systems are used extensively on trailers. They are a type of Central Tyre Inflation, but only maintain a single set pressure. This is another great leap forward. Costs are reasonable, and the returns are good. As trailer tyre maintenance is often poor, this TPMS is a great investment, especially if the trailer is loaded most of the time. A warning light, usually fitted to the front of the trailer, warns the driver if a problem exists. Most trailer axle manufacturers offer a TPMS as do aftermarket suppliers. Unfortunately, most are set an an over inflated pressure, costing tyre life. The down side is no variation of tyre pressure is offered. Pressure maintenance systems are not easy to fit to drive tyres or steer tyres.

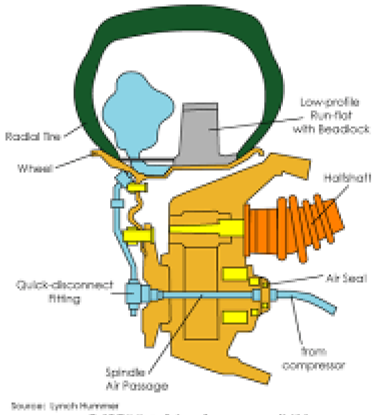


QUICK CONNECT TIRE INFLATION SYSTEM

These systems use a quick connect hose and manifolding to get close to each wheel. The vehicle must be stopped, and the hoses must be attached, and then pressures can be varied at the one time. An alternative is a ‘spider’, which is a hose with several ‘tails’ that connect to each tyre, allowing easier inflation or deflation. Of course, no on board warning system, no dual tyre balancing, and no on the fly adjustment. Blow outs, punctures and driver ‘good luck’ is ignored.

CENTRAL TYRE INFLATION SYSTEM (CTI) or (CTIS)

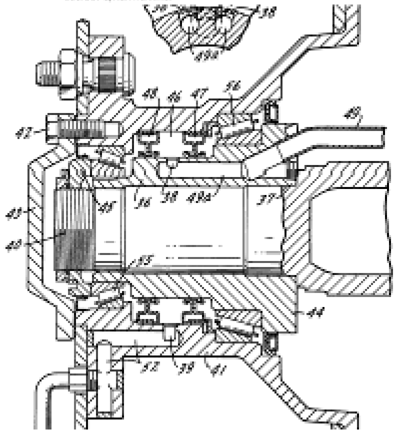
As explained, CTI is an adjustable tyre pressure system. It can be automatic, controlled by the load on the axle via air suspension pressures, or by the driver, as he drives. Most are driver controlled.



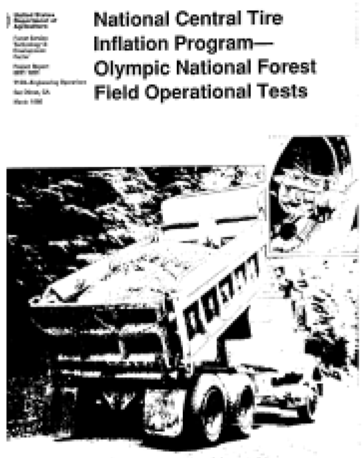
Traditionally, CTI has been used to improve off road access. Front line army vehicles with tyres are fitted universally to aid traction, which it does spectacularly. Most army CTI is fitted internal through the axle. Internal systems are expensive, high maintenance, and short on long term reliability. They are considered much too costly for civilian use.

INTERNAL CTI:

Most heavy duty drive axle manufacturers supply special axles plumbed to allow air pressure to get to the tyres. Portal axles, like those fitted to the American Hummer and Mercedes Unimogs, are relatively easy to fit ‘internal’ CTI. In reality, the rotator is simply bolted to the inside of the live axle. It’s still exposed, just that most don’t look underneath. See above on the right.



Conventional drive axle internal CTI is highly complex as seen in the drawing on the right. Typically a special spacer sleeve slips over the axle tube, requiring a larger internal diameter tapered roller bearings. These bearings do not have the capacity of the original. The air is piped through this sleeve, and out into the hub chamber, where the air is retained by high tech seals, that seal against the inside of the hub, which must be highly polished. These seals are a real problem. The large diameter means high surface or rubbing speeds, hence high wear potential. In fact, *reasonable* seal life is maintained by ‘deflating’ the seals when tyre air pressure checks or adjustment is not needed. Special valving on each wheel controls air flow, when required. Typically, tyre pressure checks only occur once every 20 minutes. One axle supplier has stopped supplying civilian systems to Australia. They simply did not last, and they were very expensive.



NOTE:

It was long considered that CTI was too unreliable and too expensive for civilian use. But, inventors are inventors. External systems appeared.

In the 80’s the USA and Canadian governments wanted to extend the logging season in the spring and autumn, when the tracks were too muddy to log. Extensive tests proved conclusively that CTI and optimized tyre pressures was a fantastic tool. In fact, other than the cost, every test has proven highly positive in every way.

A Canadian company worked with the US and Canadian CTI tests and developed an external system. They have done a lot of marketing with considerable success. Others copied them, and marketed them in the southern hemisphere with success. These very similar systems were good for the time, but time progresses.

EXTERNAL CTI:
External CTI comes from the exposed 'drop' pipes or hoses that connect the rotary gland in the middle of the wheel, to the chassis, on the outside of the truck. These exposed hoses are both the biggest fear, and the best feature. Since this system 'bolts' on, the rest of the truck is totally stock. No undersized bearings, no high maintenance, or added complications.

Just bolt it on, and enjoy the many benefits, while saving money, earning more, safer, and greener.

To optimize the tyre pressure, simply push a button on the dash. Simply look up the Load to Inflation tables to suit your tyre size and load. Easy. The truck rides better, is more comfortable, stops quicker, straighter, and tyre life is extended at least 30%. The driver knows what the tyre pressure is, and all the tyres share equally, safer.

If a puncture occurs, the driver is warned, and the CTI system will automatically re inflate the tyre, up to the capacity of the compressor. Eliminate almost every blow out and road side tyre change. Call outs for tyre problems drop 90% or more.

Maintenance and tyre replacement is reduced. Less downtime means more up time. Lower costs and increased earning means money in the pocket. Everyone wins except the tyre supplier.

Optimal tyre pressures reduces damage to infrastructure, lowering our countries' costs, which should lower our taxes. Less road damage and better traction means less accidents, less suffering and less lost loved ones. Thirty percent less wasted tyres reduces land fill. Healthier drivers, and a less polluted environment mean our people are safer and healthier.

Our natural resources are put to better uses, extending our way of life. Everyone wins.

CTI cost has decreased as the product has matured. Quality, reliability, and ease of operation has also improved and improved. Competition always makes a better product at a more competitive price.

American ingenuity combined with the harsh Australian out back proving ground has revolutionized CTI.

This Aussie competition has reduced costs, reduce frustrations, reduced weight, and increased reliability and robustness.

WHAT MAKES A GREAT CTI SYSTEM

Each component is vital to make any system a success. Every component adds to the complete system.

- **ROTATORS** must do a lot of rotations and miles. Bearings must be protected from mud, dirt, stones, snow ice, and high pressure cleaners. Bearings must be protected by dedicated seals combined with intelligent design, including labyrinth seals. Bearing failure is almost always caused by external dirt ingress.
- **ROTATOR** air seals must be very reliable, and virtually leak free. Carbon seals are the current standard.
- **ROTATOR** bearings should be large for longevity. Large bearings have a higher load capacity, and are inherently stronger.
- **ROTATORS** should be short. The more they protrude, the more exposed to damage.
- **STEEL ARMATURES** rust if they are not plated.
- **ROTATOR MOUNTS** should not weaken the drive train. Replacing axle drive flange studs with bolts reduces torque capacity. Hub female threads become worn and loose when bolts are removed for tyre changes, over time, damaging expensive hubs.
- **TYRE HOSES** must be top quality. Adding another leak point to a tyre Schrader valve increases the opportunity for air to leak. This connection is vital for reliability.
- **TYRE HOSES** must not rub on wheels. Pre made tyre hoses are often too long. Rubbing hoses will rub through while damaging the wheels at the same time.
- **TYRE HOSE QUICK CONNECTS** are convenient and labor saving. Auto stop, quick connect fittings make tyre changing easier, quicker and safer.
- **DROP HOSES** must fit neatly, and not protrude out too much. Flexible hoses are notorious for flapping at speed, often requiring excessive clearance. Australian Design Rules (ADR), as do other countries, allow drop hoses to protrude past the legal limit, but hoses that protrude are easily destroyed by wild animals or tree branches.
- **DROP HOSES** must be tough. Although snagging a hose is rare, it can happen. A super tough, semi flexible, high tech plastic pipe with a rounded, non snag form has been proven to the best option.
- **EASY TYRE CHANGING** is vital. Good systems make tyre changing easy and convenient. Some systems require removal of threaded fittings before removing tyres which encourage leaks. Regular removal causes unnecessary wear.
- **SOME METHOD OF LIMITING AIR LOSS** from good tyre assemblies when another is damaged is important. Typically, air is plumbed through T fittings to each set of tyres. If one is damaged, air pressure can flow from the good tyres to the damaged one. The driver must stop immediately, or he can suffer multiple flat tyres. An automatic isolation valve system is highly recommended as good safe practice, minimizing air loss from other dual assemblies.
- **AIR TRANSFER SIDE TO SIDE** is another potential disaster. When off camber, air will flow from the heavily loaded 'low' side, to the higher side, if not prevented. This will cause the truck to lean further, and possibly roll over. An automatic isolation valve system is required.
- **ELECTRONIC AIR VALVES**, solenoid valves, are used to control air flow. As the compressed air has engine by products, and water vapour, electrolysis is usual if the solenoid plunger is a different material to the guide tube. Stainless steel is recommended for both.
- **TYRES** tend to sluff off small pieces of rubber. These will disable standard solenoid valves if a filter is not provided.
- **A PRESSURE PROTECTION VALVE,** often called a hold back valve, is mandatory. It should be located on the air reservoir, to minimize potential damage. The PPV controls air flow from the air reservoir, ensuring adequate air supply for brake operation, and is a legal requirement for any air operated accessory.
- **DASH MOUNTED MONITORING AND CONTROLS** must automatically re inflate and warn the driver, both audibly and visually, if a tyre pressure drops. A completely manual system that relies solely on the driver's actions is not acceptable, nor is it safe. The controller should be mounted high on the dash where visibility is easy and quick.
- **FUSES OR CIRCUIT BREAKERS** are necessary.
- **SELF DIAGNOSTICS** is highly recommended.
- **MANUAL TAPS OR VALVES** are required for servicing or for isolation of the system if a failure occurs. Taps are usually installed at the air reservoir, and inflate solenoid valve. Each tyre requires a tap to isolate if major tyre or other damage occurs.
- **SPEED SENSING** to warn, or reset tyre pressures if speeds exceed a specified amount can be useful, but in most cases, is not needed.

CURRENT STATE OF THE ART, AIR CTI:

DASH CONTROLLER:

- Must show set pressure and current pressure
- Must show that it is inflating, or deflating
- Audible and visual warnings. Controller beeps every time it inflates. This reminds the driver to check the pressures. Beep, beep, beep, beep if a major leak occurs. Other warnings for tyre valves off, for no air flow, for slow leaks.
- Must be easy to use; high, medium, and low suits most jobs. Just one push of one button.
- Must have adjustability for odd needs. Increase or deflate in one psi increments.
- Auto highest pressure start up, protects against brain fade, or emergency driver
- Self diagnostics is built in
- Compact to make installations easy, to sit high for quick visual checks, and to minimize damage to dash.

OPTIONS include:

- Automatic for highway use
- Gps speed sensing
- Steer & drive, show above
- Two pressure trailer
- Lock out of any controls

PRESSURE PROTECTION VALVE (HOLD BACK VALVE)

A pressure protection valve is mandatory to ensure brake air supply. It should be fitted to the air reservoir if possible

INFLATE SOLENOID AND FILTER ASSEMBLY

Direct acting top quality solenoid valves with stainless internal components, are used throughout. These are extremely reliable. A self draining water trap and filter is standard, as are 11 other stainless filters ensuring reliability.

DEFLATE SOLENOID AND ISOLATOR ASSEMBLY

Dual solenoid valves ensure quicker deflate times.
The Isolator automatically limits air loss from the good duals if one is damaged, and stops air pressure transfer when off camber
The isolator is a fantastic safety feature unavailable elsewhere.
Inflate and deflate solenoids are easy to fit, and easy to maintain.

DROP PIPES

- Drop pipes need to be tough and robust.
- Drop pipes are curved to minimize
- AIR CTI drop pipes are a high tech super tough plastic thick wall pipe, specially extruded and developed for this tough job.
- Pipes are pre loaded to spring out ward to allow typical lateral axle movement, while maintaining minimal clearance
- A short length of push loc hose allows movement and acts as a fuse, protecting the wheel furniture.
- Drop pipes attach with standard Stauff hydraulic clamps which allow easy adjustment and mounting, making chain work easy.
- Drop pipe strength has been proven by over 15 years of service, including millions of miles of logging and out back road train work.
- Drop pipe strength was stretched until failure, at 270 kgs or 600 lbs. The push loc failed as planned. It was reconnected by simply pushing it on by hand. It took 100 kg to pull off the second time. That is strong.

GOOD

BAD

WHEEL FURNITURE:

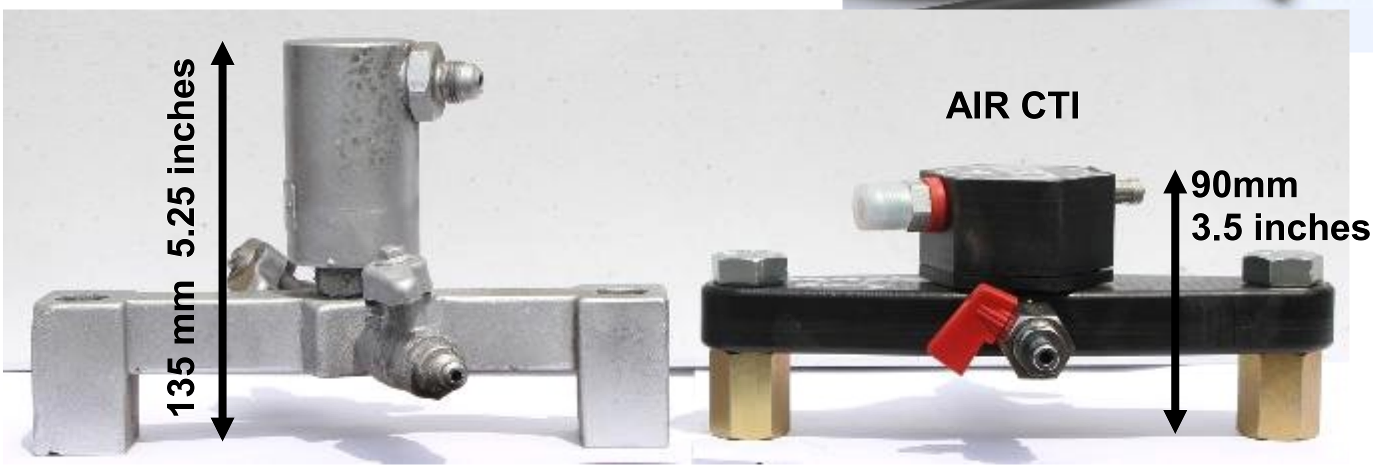
#1. Wheels must be easy to change.
- Quick connect, self sealing tyre hoses save time, minimizing air loss.
- Tyre hose length must be custom fitted to each tyre valve. Hoses must not rub on wheels.
- Rubber sheafed hoses cause less problems than stainless mesh covered hoses, especially after a few years, when they fatigue.
- Each tyre requires a manual tap to isolate the tyres when parking for extended periods, or if a problem occurs.
- Tyre hose quality must be top quality.
- Tyre Schrader valves must be removed, as the depth varies, and they restrict air flow.
- Drive axle flange studs should not be replaced with bolts, as studs provide increased sheer strength.
- Tyres must be fitted with valves 180 degrees apart, for improved balance, and minimal tyre hose lengths and problems.
- Tyres must be wiped clean inside. Some tyre fitters need retraining. Dirt left inside tyres causes damage.

AIR CTI TYRE CHANGE PROCEDURES:
- Push button and remove quick connect tyre hose from rotator.
- Remove two short rotator mount bolts, that screw into long nuts attached to the studs.
- Swing rotator assembly and drop pipe up and out of the way.
- Change tyre.

Internal Trailer Rotator

ROTATORS WORK IN TERRIBLE CONDITIONS:
- Must have superb bearing protection from contamination from, dust, mud, water, snow and salt. Bearing life is the typical failure point.
- Rotators should be short to minimize impact potential.
- Rotators internal components should not rust.
- Larger bearings are better.

Tyre Hoses



35 mm OD bearing **47 mm bearing**

PROBLEMS OR POOR DESIGN:

Look at the mess on this dash!

Some early systems were very complicated, and were fitted in boxes fitted to the chassis of the truck. Complexity always adds cost, weight, and problems.

Some systems used air lines, some even used nylon tube with olives for the drop hoses. These all flop around, and are difficult to fit them neat and close to the tyre, without rubbing.

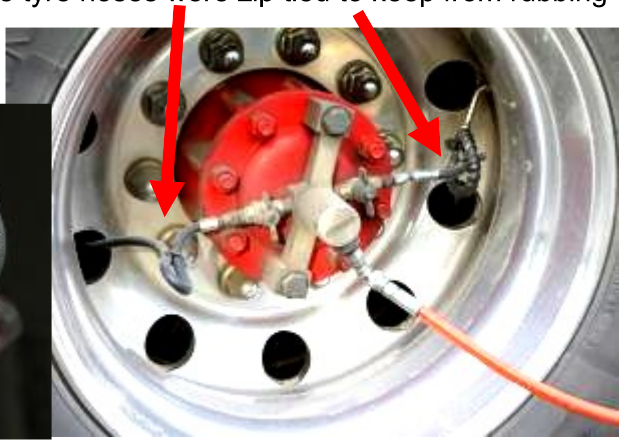
One control system used a toggle switch and a gauge. This is dangerous.

A long rotator hides within this Trailer hub. To change a tyre, Remove all of the plumbing. Simply horrible to work on.

Larger bearings are good

This steel armature rusted closed.

These tyre hoses were zip tied to keep from rubbing



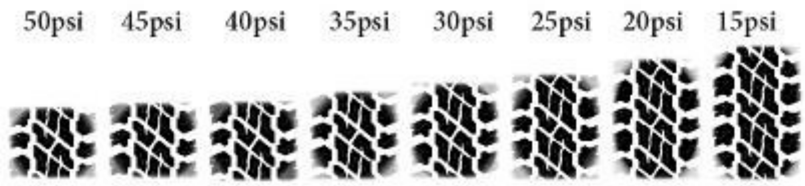
OPTIMIZE FOR PROFITS

IN DEPTH EXPLANATION OF CENTRAL TYRE INFLATION BENEFITS.

OPTIMIZING TYRE USE OFF HIGHWAY ON UNIMPROVED ROADS

A.1 EFFECT OF CTI ON ROAD TRACTION

Vehicle mobility increases with the use of CTI. This is due to the fact that CTI enables tyre pressure to be lowered which results in a larger contact area between the tyre and the ground. Consequently, contact pressure on the ground decreases which improves vehicle traction (Bradley, 1997)[9]. The Figure below illustrates the increase in the length of tyre tread footprint in relation to the drop in tyre inflation pressure on a typical 4-wheel drive tyre.



Tyre footprint with changes in tyre pressure.

Sturos, Brumm and Lehto (1995)[22] from the North Central Forest Experiment Station in Houghton USA conducted a research/demonstration field test to evaluate the effects of lowered tyre pressure on traction. Tests were also conducted on loose sand roadways. The average load that was measured in the rolling resistance tests on loose sand roadway was reduced by 45% when lowered tyre inflation pressures were used (Sturos et al., 1995)[18]. The results concluded that the use of the CTI system significantly increased traction.

Powel and Brunette (1991)[17] from the USDA Forest in Idaho, USA, showed that the use of CTI-equipped trucks can increase the number of operating days due to enhanced vehicle traction and flotation as well as reducing roadway damage such as ruts and corrugations. When wet road conditions reduced traction to the point where operations were unable to continue, the use of CTI systems enabled operations to continue due to the increase in traction that is achievable when using CTI. Tests were conducted by Bradley (1993)[8] to evaluate the tractive benefits of a CTI system. The tractive benefits achievable by reducing the inflation pressure of the drive tyres were quantified through a truck pull test, which found tractive gains up to 39% on loose gravel. The maximum grade climbable by the loaded test truck fitted with CTI was estimated to increase by 8% on gravel surfaces (Bradley, 1993)[8]. In another test conducted by Bradley (1991)[7], it was reported that lowering tyre pressure from 620 kPa (90 psi) to 205 kPa (30 psi) increased tractive effort by 42% on a flat gravel surface.

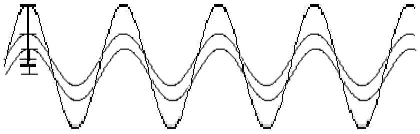
The results were impressive and later independent testing has shown that mobility has effectively doubled. This is because of three reasons, firstly increased traction and secondly, increased floatation (reduced rolling resistance) and thirdly the bow wave is virtually eliminated. All just from using optimal tyre pressure. An in-cabin system that allows the driver to adjust as necessary would contain several benefits.

To explain why this happens it is constructive to look at Newton's Laws. Newton's third law states that for every action there is an equal and opposite reaction. Further, let's consider the surface of the road as a series of little cubes sitting next to each other.

NATURAL TRUCK VIBRATION FREQUENCYS:

- Tyres vibrate at 10Hz, depending upon tyre pressure
- Road friendly suspension below 2 Hz, if it is working correctly.
- Truck Frame natural frequency is 6—9 Hz
- Truck tyre doing 100 kmh if out of balance will naturally vibrate at 8.3 Hz
- A truck that encounters road bumps at 3.5 meter intervals at 100 kph will experience bumps at 8.3 hz
- A half kilogram out of balance on a tyre doing 100 kph has a 78 kgs force vibrating it.

Out of balance on 11R 22.5 at 100 kph

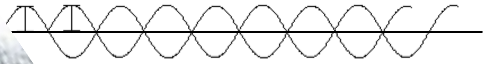


.1 kg @ 100 kph = 15.6 kgs
.25 kg @ 100 kph = 39 kgs force
.5 kg @ 100 kph = 78 kgs force

Given time, a pot hole will give birth to another, a certain distance down the road, depending upon the predominant traffic, and the speed of travel.
As shown above, 100 kph trucks tend to cause damage at 3.5 meters. The Laser scanner picture below shows three bumps over a distance of around 10.5 meters.

Vibrations in phase create a larger vibration.

Vibrations out of phase cancel each other.



High tyre pressures can amplify other vibrations. In worst case scenarios, some trucks can resonate vibrations to the point of being impossible to drive.

VIBRATION DAMAGE ON GRAVEL AND DIRT ROADS

Corrugations or washboards develop on gravel or dirt roads, that severely hinder travel, while literally shaking vehicles to pieces. Corrugations are caused by the natural suspension frequency combined with a tyre frequency that is substantially synchronous. Only over inflated tyres create washboards or corrugations.

The distance between the bumps is governed by the predominant vehicle type and speed. Automobiles create tiny corrugations, while four wheel drives create larger one, and trucks create even larger waves.

Tyre pressure reduction changes the vibration frequency, cancelling the prevailing vibration frequency. Lowering the tyre pressure to the optimal off road pressure for the load will eliminate corrugations or washboards.

One truck will cause corrugations, and damage a track. AIR CTI users have phoned when a new contractor entered their area, providing driver's name, phone number, company that he works for, and the truck type, requesting sales staff sell him CTI.

CTI actually heals roads.

TYRE PRESSURES, FUEL ECONOMY, AND TYRE WEAR FACTORS:

Much is said, and claimed regarding high tyre pressure and fuel economy. But the reality is far different.

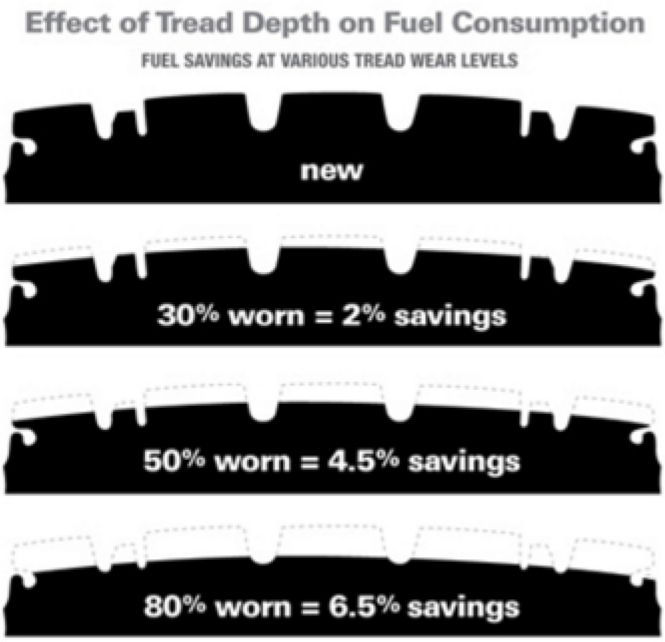
- Swapping safety for a tiny improvement in fuel savings is bad practice.
- Optimal tyre pressure for the load will use less than 1% more fuel, all things being equal.

Yet, the average truck's tyres are not well maintained, costing far more in fuel.

- 19% of tyres in smaller fleets were under inflated by 20 psi or more.
- 3% of all trucks inspected had 4 tyres or more under inflated by 20 psi or more.
- 20% of twin or dual tyres on drive axles varied by more than 20 psi.
- Mis aligned axles increase fuel use.

Hence, typically, CTI improves fuel economy by 2%.

Often, new tyres are fitted when systems are updated. Reduced fuel economy has been blamed on the CTI fitted. As Bridgestone explains below, the difference in fuel economy between new and worn tyres is 6.5%. Other suppliers have reported 8.5% difference.



Tread depth effects

Tread depth has a significant effect on tire fuel economy. Bridgestone tests show that as a tread wears, the fuel efficiency of a tire usually increases.

As tread wear progresses, the fuel efficiency of most tires improves.

So, one of the easiest ways to make a fuel-efficient tire is to cut down on original tread depth. Another way of looking at it is to say that during the last half of its useful tread life, just about every tire is fuel-efficient.

LOW ROLLING RESISTANCE TYRES are a modern ideal. Improvements are possible, but care should be taken. Most LRR tyres have far less tread depth, and usually, shorter life. Traction is often less providing less safety. Lost up time from more frequent tyre changes often eliminates any advantage.

If operating in more aggressive conditions, there is no choice but fit suitable tyres and CTI.

WIDE SINGLE TYRES, like super singles or the very wide 50 series tyres are a major improvement on most trucks and trailers. Tare weight is reduced improving payload, while rolling resistance decreases, because there are half the number of side walls flexing.

CTI is almost mandatory on these vehicles, as any tyre problem stops work immediately. There is no second tyre to limp on. CTI can maintain tyre pressure losses caused by normal punctures, saving the much higher tyre cost. Optimizing these tyre pressures provides even better returns on investment.

**LET'S SQUASH OUR LAND,
KILL ALL THE WORMS
MAKE THE RAIN FLOW OFF
AND RUIN ROOT GROWTH,
AND PAY SOMEONE TO DO IT.**

SOIL COMPACTION AND TYRE PRESSURE

SOIL COMPACTION

INTRODUCTION

Soil compaction is a major problem facing modern agriculture and is usually derived from machinery and trampling of animals. Trucks follow headers regularly, usually with high pressures, damaging soil where ever they travel. Trucks come in to recover hay, or silage. Trucks are used extensively for fertilizer spreading too.

Soil compaction occurs in a wide range of soils and climates and is often seen visually as rutting.

Soil compaction decreases soil physical fertility through decreasing the earth's capacity to store and supply of water and nutrients, leading to decreased production, additional fertiliser requirements and increased production costs. A detrimental sequence then occurs of reduced plant growth leading to lower inputs of fresh organic matter to the soil, reduced nutrient recycling and mineralisation, reduced activities of micro-organisms, and increased wear and tear on cultivation machinery (Hamza and Anderson, 2005)[2].

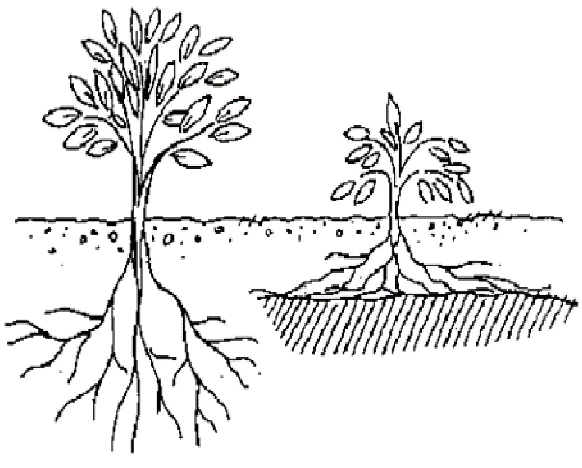
Compacted ground makes it harder for roots to penetrate the soil. This results in reduced plant production. Compacted ground makes rain and irrigation run off rather than penetrating the soil and becoming storage for the roots of plants to access.

Compacted ground has eliminated air access and passage. This results in a lack of nitrogen availability for root bacterial bonding ands assessability to plant roots.

Finally compacted soil form an impenetrable barrier that kills and stops worms, beneficial bacteria and insect passage.

Soil bulk density is the most frequently used parameter to characterise the state of soil compaction. In research undertaken by Hamza and Anderson (2005) it was determined that a way of avoiding or preventing soil compaction was by reducing pressure on soil either by decreasing axle load and/or **increasing the contact area of wheels with the soil**.

Stunted root caused by soil compaction



Diagrammatic representation of stunted root growth

AGRICULTURAL COSTS INCURRED DUE TO INCORRECT TYRE PRESSURES

In a summary of the international soil compaction project, compaction due to axle loads of 10–12 tons reduced yields approximately 15 percent in the first year, decreasing to 3–5 percent 10 years after compaction[4].

The lead researchers suggested that 10 percent of the yield loss in the first year was due to compaction in the topsoil and upper part of the subsoil. The effects of topsoil and upper subsoil compaction disappeared in approximately 5 and 10 years, respectively (Figure 1).

Three to five percent yield loss was apparently due to deep subsoil compaction, which did not disappear during the period in which measurements were taken (12 years for the longest experiments).

The conclusion is that lower subsoil compaction is, practically speaking, permanent and should therefore be avoided by all means, whereas topsoil compaction and upper subsoil compaction are temporary and should be limited as much as possible.

Two other important observations from these studies are;

- surface tillage did not completely alleviate surface compaction
- deep

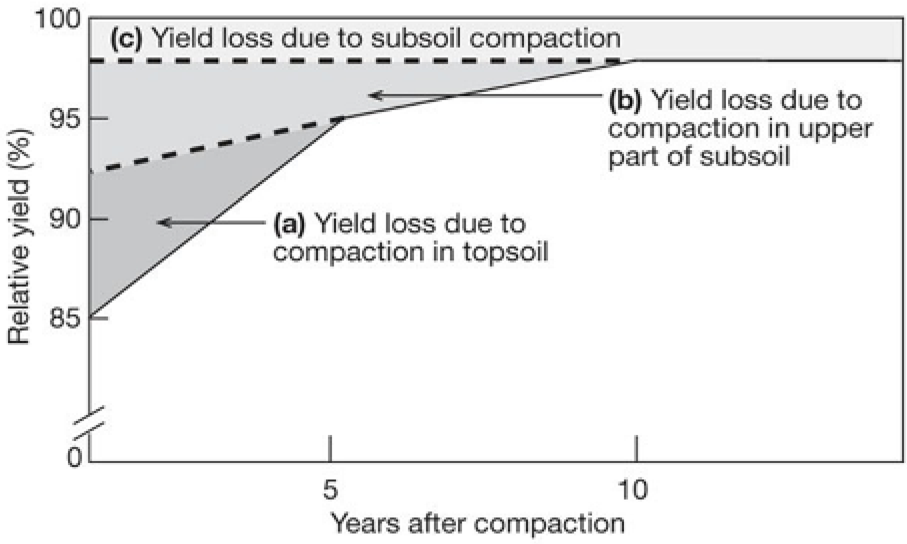


Figure 1. Effects of compaction in the topsoil (a) and upper part of the subsoil (b) are temporary, whereas deep subsoil compaction (c) is virtually permanent.

In another study, soil compaction is estimated to be responsible for the degradation of about 30% of the cropping soils in Australia (Hamza and Anderson, 2005; Tullberg, 2010; Rainbow and Derpsch, 2011)[3]. This runs into the millions of dollars each year.

SOIL COMPACTION

Our knowledge of soil compaction has increased substantially in the past two decades, especially after results of an international project of more than 20 soil compaction experiments in North America and Europe were published.

Based on this work researchers have discovered that;

- compaction in the topsoil is related to ground contact pressure only
- compaction in the upper part of the subsoil is related to both ground contact pressure *and* axle load
- compaction in the lower subsoil is related to axle load only (Figure 2).

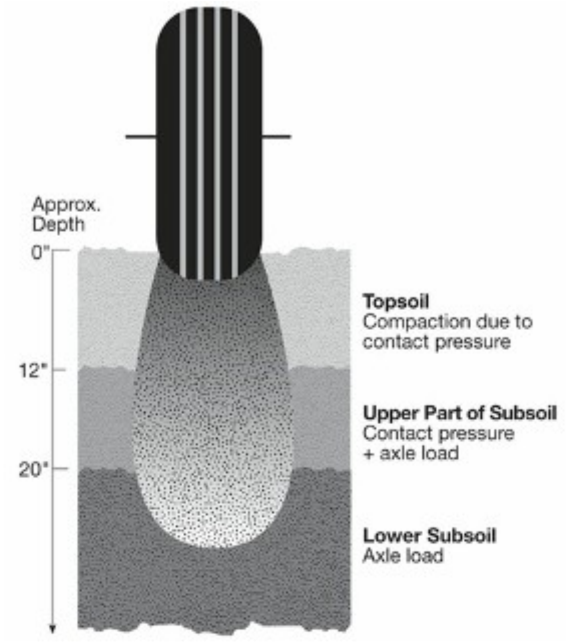


Figure 2. Topsoil compaction is caused by contact pressure, whereas lower subsoil compaction is caused by axle load.

KEYS TO SOIL COMPACTION AVOIDANCE

REDUCE AXLE LOAD

Axle load is the first factor that has to be considered in soil compaction. Axle load is the total load supported by one axle and farm equipment with high axle loads will cause compaction in the top-soil due to its contact pressure and in the subsoil due to the need to carry the load. The key to eliminating deep subsoil compaction is to reduce axle load.

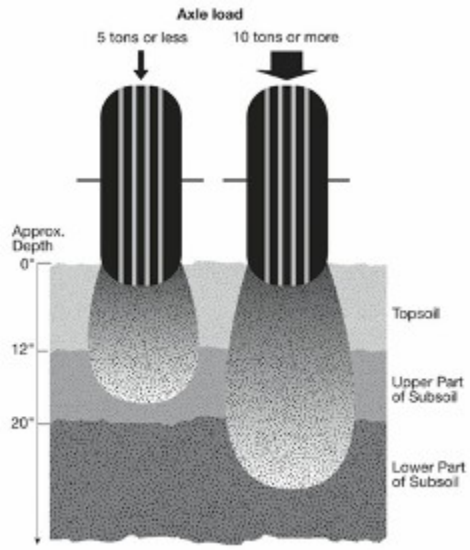


Figure 3. Low axle load causes compaction in the topsoil and upper part of subsoil only, whereas high axle load causes compaction in the lower subsoil as well.

The amount of top- and subsoil compaction caused also depends on the presence of a natural or traffic-induced pan (more on this later in section 8.1 SOIL REPAIR UNDER OPTIMAL TYRE PRESSURE) close to the surface (Figure 4). In a uniform soil, stress will be transmitted from the surface deep down into the soil profile. In a soil with a pan or dense subsoil, soil stress tends to concentrate near the surface.

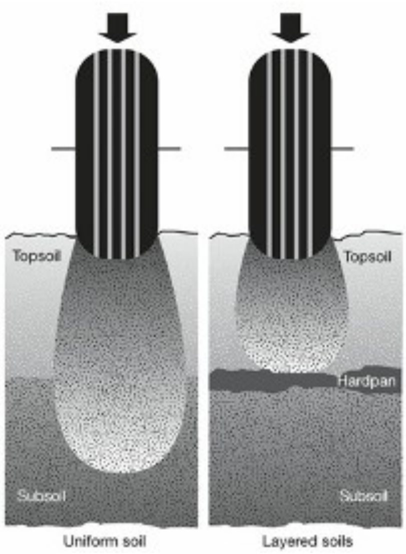


Figure 4. In a uniform soil, compaction is transmitted deep, whereas in a soil with a hardpan, compaction is concentrated above the hardpan.

CONTACT PRESSURE

Contact pressure is the pressure that is exerted by a tyre or track on the soil surface. Reducing contact pressures will cause less topsoil compaction.

NUMBER OF PASSES AND TRAVEL SPEED

Research in tilled soils has shown that approximately 75 percent of the increase in soil density and 90 percent of wheel sinkage is caused during the first pass. However, the compaction caused by subsequent passes may cause as much damage to a crop because the small changes to soil density are now in the high range, which is more likely to be detrimental to root growth.

It has also been shown that the longer the dwelling time of a load on soil, the greater the increase in density.

Therefore, (1) limit the percentage of the field trafficked, (2) concentrate repeated traffic in travel lanes so remedial action can be taken there, and (3) drive faster to shorten the load dwelling time.

A big problem with soil compaction is that it is impossible to cure, and it continues reducing crop growth years.

MOISTURE CONTENT

Monitoring soil moisture content is extremely critical to avoid soil compaction. Most compaction studies are performed at moisture contents near field capacity (approximately 24 hours after soaking rain) to simulate worst-case scenarios. To lessen soil compaction of their fields farmers need to stay off their fields when soils are too wet. Dry soil can sustain high axle loads and high contact pressures without adverse effects. The problem is, however, that factors such as optimum planting or harvest time often dictate that a farmer will be in the field at suboptimum soil moisture conditions for traffic.

Driving on wet soil causes rutting, slipping, and increased deep soil compaction. Dry soil cannot be compressed to as great a density as moist soil. However, at moisture contents above the “plastic limit” soil compaction decreases because all pores are filled with water that cannot be compressed. Driving on agricultural soil that is wetter than the plastic limit has many problems. Rutting and slipping have devastating effects on soil structure that will be difficult to remedy.

Trafficking very wet soil (especially with high loads and tyre pressures) causes a “hydraulic ram” effect. The topsoil is compressed very quickly to saturation. Because water cannot be compressed, surface stresses are now directly transferred to the subsoil. Therefore, driving on very wet soil is very likely to cause subsoil compaction.

AN ADDITIONAL PROBLEM OF RUNNING FARM VEHICLES

There is an additional problem associated with over-inflated tyres. When a vehicle encounters a pothole or bump the tyre moves vertically as well as horizontally. Upon returning to the ground the tyre acts similar to a jack hammer and pounds into the soil, bouncing several times as it travels along the field. Eventually the energy is dissipated and the tyre returns to its median position, however, before this happens the tyre has had time to pound the soil several times. This creates stresses and strains that can be substantially higher than the capacity of the soil particles destroying its structure. Further, and perhaps more importantly, the tyre pounding into the road imposes a force on the soil and the underlying surface. This force causes soil compaction above that from just the weight of the weight as it transverses the field. The rebound is cyclic and compacts the soil is the same pattern. The effect is the same as can be seen in the picture (on bitumen) previously on page XX.

Once this type of compaction is in the field the resulting undulations start to escalate into deeper problems. The pounding on any subsequent run is amplified and the tyres now run uphill upon exit. This can cause slippage and wasted fuel.

Correctly inflated tyres are able to absorb a considerable amount of the energy from the bumps and disperse this energy as heat. Not only is the field saved from compaction pressures but the vibrations are not transferred through the tyre into the vehicle and its occupant(s). When the correctly pressured tyres are used the vehicle components are not exposure to damaging vibrations and the whole body vibration exposure of the occupant(s) are virtually eliminated.

Interestingly rutting is also a side effect of this pounding as it pushes the soil outwards from the impact point.

FUEL ECONOMY

"Tractive efficiency is considered as the most important factor of tractor aggregation, especially in crop production. Research studies indicate that about 20–55% of the energy transferred to the drive tractor wheels is wasted in the tire– soil interaction. Not only is this energy useless or causes soil compaction, but it also may have a devastating effect on crop production [3]. The increasing tractive efficiency means more effective usage of the internal combustion engine's mechanical work. In other words, possibilities of higher efficiency lie in power dissipation reduction. The common speed of a tractor during field operation ranges from 3 kph to 15 kph. Unfortunately, it is the range of the speed where the wheel slip gets its maximal value; therefore, the aim should be focused on reducing the tire slip, which can bring more tractive efficiency. There are two essential ways how to reduce the slip in terramechanics. The first one lies in increasing the tractor's weight by adding ballast. The other possibility is to enlarge the contact area between tires and surface. Enlargement of the tire contact area reduces negative effect of tractor's movement on the field and it restricts physical degradation of soil characteristics (structure damage, compaction, etc.) In addition, a larger contact area makes rolling resistance smaller in soft soil [4,5]. Gaultney et al. [6] found 50% corn yield reductions with severe compaction and 25% yield reductions with moderate compaction." Terramechanica2010

One farm test used a Case 190 hp four wheel drive tractor ploughing identical fields with different tyre pressures. On field was ploughed using traditional pressures as used by farmers in the area. The other field used tyre pressures that provided the least tyre slip. Wheel slip reduces 6-7%. Draw bar pull increased 6-7%. And fuel use reduced by 6-7%.

In effect, the tractor could pull a heavier load, quicker while using less fuel!

When harvest came, the resulting crop was increased 2%. Many farms would be happy with a 2% profit margin.

SOIL COMPACTION

To examine soil compaction it is constructive to review the forces acting on a truck and how these forces are displaced to the road surface. Using Newton's third law, "states that for every action there is an equal and opposite reaction" and viewing the surface of the road as a series of little cubes sitting next to each other.

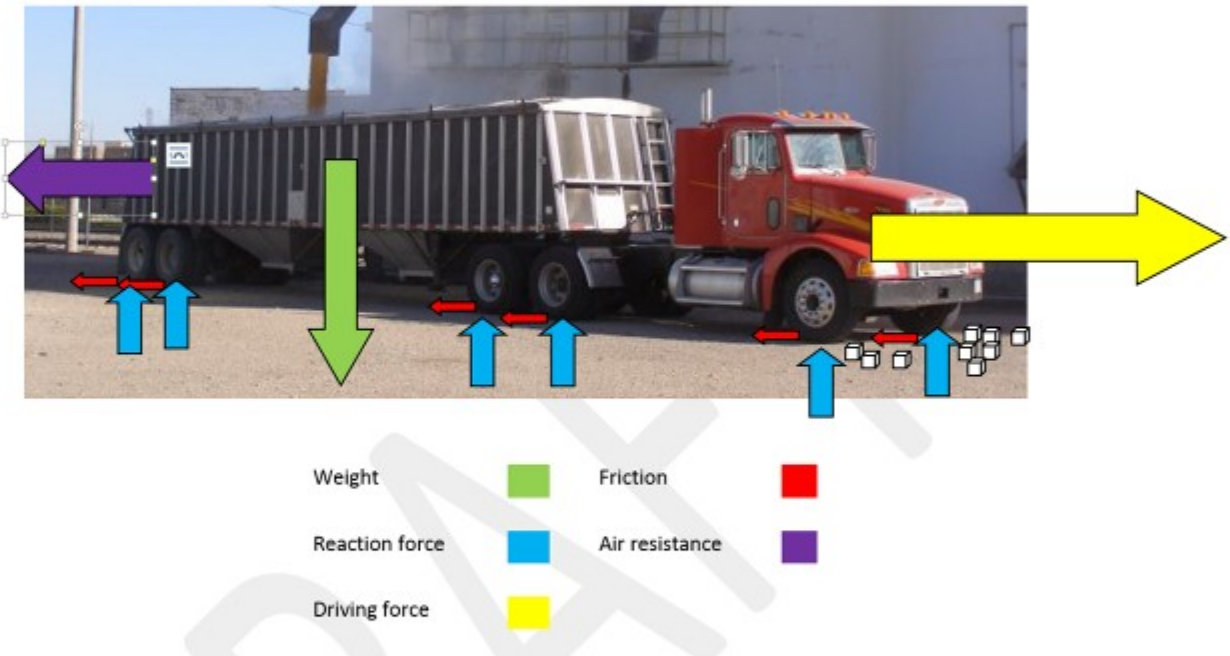
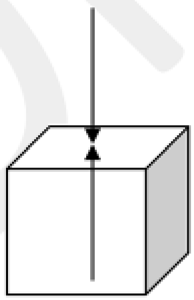


Figure 5. Forces acting on a vehicle

The impact loading of the vehicle (weight divided by the number of tyres) is supported by the road surface (the cubes). This is shown as the reaction force and is distributed evenly over several of the "cubes". Consider one cube; there is an equal and opposite force acting – an action/reaction scenario.



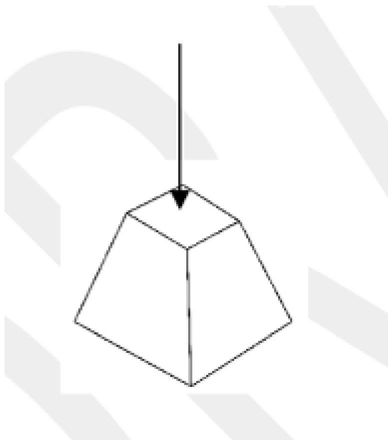
Now the soil particle (one of the cubes) has a finite capacity with which to balance this weight. This is usually described in terms of bearing stress and is measured in N/m^2 (Pascals).

At the tyre contact point the weight (Force) is divided by the tyre footprint (area) to determine the bearing stress $\sigma(bearing) = \frac{Force}{Area}$. If this figure is greater than the capacity of the soil, failure occurs and the soil is compacted, that is, the soil has collapsed. The cohesive bonds between soil particles are broken and the soil collapses onto itself eliminating the air voids between the particles.

This is the cause of the compaction problem faced by farmers when vehicles drive across fields. The problem is visually seen as rutting. The collapsing soil pushes out the air and gives no opportunity for atmospheric nitrogen penetration. It suffocates the nitrogen fixing bacteria and forms impenetrable barriers to plant roots, worms and water. The later either damns or increases surface (and erosion) runoff.

Figure 6. Rutting.
Visual evidence of the collapse of soil.
Notice the damning of water resulting from non-penetration.

As the weight penetrates deeper into the surface the area over which it acts increases in size. Usually we consider a 45^0 spread although the angle, for this analysis, is not crucial.

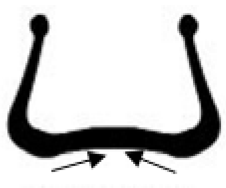


Also, as we go deeper into the soil, the soil particles are held in place by the adjacent particles. The deeper soil particles have more bearing capacity since they are held in place by not only the cohesive forces between adjacent particles but also by the mass of soil above them. Eventually the bearing stress generated by the weight is balanced by the bearing stress capacity of the soil. The soil will continue to compact until the point is reached and it is only at this depth that the soil compaction tapers to zero.

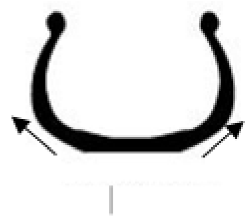
Now two things come into play in this analysis. Firstly the initial weight per unit area is smaller on the low inflation tyre since the footprint is larger. That is the initial bearing is much less. Secondly, the larger the starting footprint the shallower the depth where the bearing stress generated by the weight of the vehicle is balanced by the bearing capacity of the soil. This is because the bearing area spreads out under each condition at the same rate, however the lower pressure tyre has a starting area "advantage".

8.7.6 SOIL REPAIR UNDER OPTIMAL TYRE PRESSURE

However there is one further benefit obtained by using low pressure tyres. When an overinflated tyre creates a rut it pushes the soil outwards and away from the edge thus worsening the problem. On the other hand a soft tyre has 'give' in the middle of the tyre. That is, a lower pressure hollow is formed allowing soil to be pushed inwards therefore compensating for the passage of the tyre.



Soil pushed back inwards under low inflated



Soil pushed away by overinflated tyre

SUMMARY

The benefits of matching tyre pressure in tyres against terrain conditions is poorly understood within the transport industry. As a result significant benefits that can accrual to the driver, owner and environment have been overlooked. This is mainly due to antiquated work practices and inter-generational thinking.

Soil compaction is a major problem facing modern agriculture. It costs billions of dollars in lost production annually — especially in times of increasing population and world uncertainty. It is usually derived from machinery and trampling of animals. Soil compaction occurs in a wide range of soils and climates and is often seen visually as rutting.

Soil compaction decreases soil physical fertility through decreasing storage and supply of water and nutrients, leading to additional fertiliser requirements and increased production costs.

The International Compaction Project has concluded that compaction in the topsoil can be significantly reduced by;

- reducing tyre pressure
- reducing the number of trips over the field
- reducing the total area per acre actually travelled

Further, driving on soil that is wetter than the plastic limit should be avoided at all times.

It is quite clear that the transport industry need to review and absorb new technological changes that make it possible to improve outcomes for all stakeholders both inside and outside the trucking sector. Failure to do so will mean that poor economical returns, adverse health and safety issues and environmental damage will remain the norm. This outcome is extremely detrimental to all stakeholders concerned.

The opportunity exists now to rectify the problem and everyone within the transport industry needs to make the step from passive observer to positive participant.

It seems a solution is clear and easy to adopt. A driver needs to take into consideration the load he is carrying on each axle and then determine the load on each tyre. He needs to consider tyres individually, that is as Steer, Drive or Trailer – each is a separate case – and then relate back to the terrain he is driving on. He can then refer to the manufacturer's recommended load/inflation tables. This recommended tyre pressure is cold pressure and allowance would need to be taken into account when the tyre is at hot pressure. This needs to be done for every change in load conditions and terrain conditions.
Central Tyre Inflation is the OE?? or aftermarket tool/accessory that makes tyre pressure optimisation easy and affordable.

The procedure would be impractical unless the tyre inflation system is in-cabin and can be done "on the run" thereby allowing the driver to continue his journey with minimal inconvenience.

THE SIGN OF SENILITY
IS WHEN YOU KEEP DOING THE SAME,
AND EXPECT SOMETHING DIFFERENT

THE SMART FUTURE

RUNNING THE OPTIMAL TYRE PRESSURE IS THE ONLY CHOICE.

Traditional thinking has it's place in modern society, although knowledge and technology are constantly changing the entire standard business practice. As progress revolutionizes ideals and processes, traditional knowledge can become dangerous, and or unacceptable. For instance, many work practices that were normal when I was young, are no longer tolerated. In fact, many are illegal. Imagine walking steel now. Or wiring your own home. Yet, I did both.

The tyre footprint is the only contact between a truck and the world. Every force and every reaction is transferred through that tyre contact patch, or footprint. Our very incomes, and our lives, depend upon that footprint. In fact, the safety of every road user depends upon this contact patch. If it isn't optimal, everyone's safety is not optimal. **Who would accept a 20% or 30% reduction in safety?**

40 tonnes of steel covering 27 meters per second should not be 20 or 30% impaired.

And who can afford to throw away one tyre out of three, or spend more money and time in some workshop getting repaired.

Our environment and world can not afford the waste. Wasting 80 liters of oil, millions of times is just unacceptable. Disposing of millions of wasted tyres is an environmental nightmare.

We must change.

Just inflating the tyres to the correct 'maximum legal load' pressure would be a start. Tyre pressure monitors at least inform the driver before a tyre disintegrates and becomes another dangerous road obstacle. Tyre Pressure Maintenance systems are sufficient on many trailers, if set at the correct tyre pressure, and if the trailer is always close to the maximum weight.

If we, the industry, the regulators, and the citizens want safety, low costs, higher standards of living, more employment, and a cleaner sustainable world, we must optimize our lives. There is no other choice.

Central Tyre Inflation is the only tool that can optimize tyre performance and operations.

THE SMART FUTURE: The Options

Continuing to use 100 or 110 psi universally on trucks is old fashioned, dangerous, costly, and bad for our world.

Costs everyone in many ways. Simply unaffordable, unacceptable, and unsustainable.

BEGINNING:

Truck and trailer maximum practical working loads, and axle weights, must be accessed. Consult the truck tyre **Load to Inflation tables** for the tyre size used, and establish the optimize the tyre pressure that can carry that load.

This will save some money, as long as tyre pressures are regularly monitored.

This option is valid on low use trucks that don't do many miles, if similar surface roads are used substantially. *Cost savings 5-10%*

BETTER:

Fit **Tyre Pressure Monitors**, and set tyre pressures as above. This will warn the driver if a tyre pressure is low, if he is watching.

This option is valid on low use trucks that don't do many miles, if similar surface roads are used substantially. At least the driver has some warning re pressure loss. *Overall Tyre Cost savings 7-12%*

A BIT BETTER:

Fit **Tyre Pressure Monitors** on the truck, and fit **Tyre Pressure Maintenance Systems** on trailers, set to the above pressures.

This option is valid for moderate use trucks, doing highway work, carting similar loads. *Overall Tyre Cost savings 10-15%*

A LITTLE BIT BETTER:

Fit **Tyre Pressure Monitors** and **Dual Tyre Balance Systems** on the truck, and **Tyre Pressure Maintenance** systems on trailers, set to the above pressures.

This option is valid for moderate use trucks doing highway work, carting similar loads. Tyre balancers save some money, balancing pressures. *Overall Tyre Cost savings 12-17%*

A LOT BETTER:

Fit **Central Tyre Inflation** to the drive tyres, and Tyre Pressure Monitor systems to the trailer, set to the above pressures.

This option is valid for medium use trucks that operate in all conditions. *Overall Tyre Cost savings 14-19%*

Fit **Central Tyre Inflation** to the drive tyre, and **Tyre Pressure Maintenance** system set to the above pressures.

This option is valid for medium use trucks that operate in all conditions, further reducing costs. *Overall Tyre Cost savings 15-20%*

BEST:

Fit **Central Tyre Inflation** to the drive tyres, and to the trailer tyres.

This option is the best possible for any truck, especially suited to high use trucks operating in all conditions. *Overall Tyre Cost savings 25-35%*

THE SMART FUTURE IS CTI

THE SMART FUTURE IS CTI

**Cost savings estimate to provide reference expectations on over all tyre savings. For instance, projected savings for trailer maintenance systems on the trailer only, are averaged out for all tyres on rig.*

LET’S QUANTIFY

LET'S QUANTIFY:

What does a typical semi rig cost to run?

The really important question is how much does down time cost?

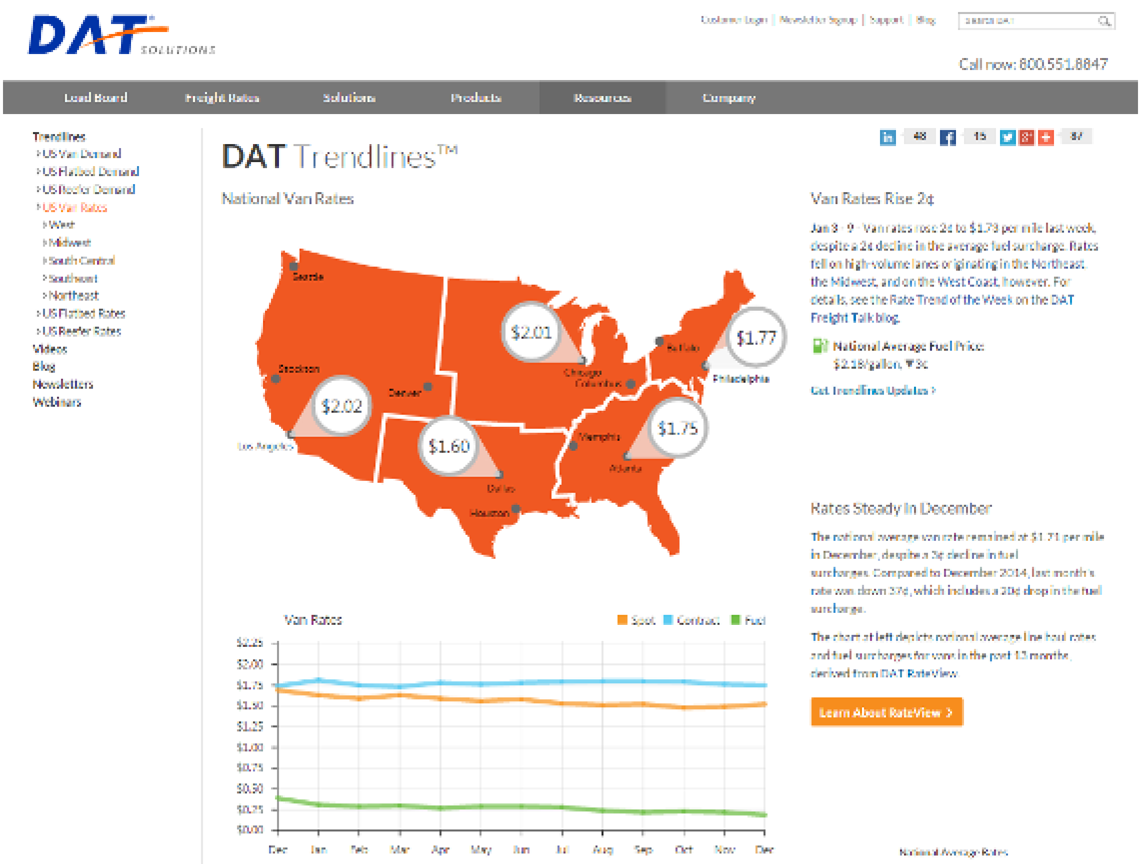
It depends on many factors:

- Fixed costs:
    - The cost of the truck and trailer must be paid for by money earned doing work, up time.
    - Interest on the money borrowed. Don't forget, the entire sum costs money, money that could be working else where.
    - Registration, stamp duty, licenses, and other government charges.
    - Insurance.
    - Overheads
        - Phone
        - Depot or parking area, including insurances
        - Accounting costs, including paying bills, invoicing, and taxes.
        - Office, admin staff, paper, stamps, lighting.
    - Wages, work cover, superannuation, holiday pay (owner drivers have to live too)
- Variable costs:
    - Fuel
    - tyres
    - Maintenance
    - Tolls
    - Wages if driver is on contract.

On the next pages is an example of downtime cost for a sample semi trailer rig.

Below is an example of cost per mile for American trucks.

A sample of 'on line' cost calculators is shown on the following pages.



LET'S QUANTIFY AN EXAMPLE SEMI TRUCK RIG

A typical Australian semi consists of a prime mover (tractor) and a curtain-sider (van) trailer with three axles. Figures are in Australian Dollars (AUD)

Assume a working life of 1,500,000 kms (930,000 miles) and 7 years. In this time, most trucks would have an engine rebuild and transmission or differential work, but, for this exercise, this is ignored.

Prime mover cost:	$220,000
Semi trailer, tri axle curtain sider (van)	$80,000
Total invested, or borrowed	$300,000
Bank interest estimated 8%	x.08
Interest per year	$24,000
Resale or trade in value after 7 years	$100,000
Truck and trailer cost after 7 years	$200,000

Cost of truck plus interest must be covered by operation over 7 years. At the end of the 7 years, the semi rig must be replaced. Therefore the $300,000 investment continues. That $300,000 costs.

$200,000 divided by 7 =	$28,571 per annum to pay the original cost less trade in.
Plus interest	$24,000
Plus registration	$6,678
Plus insurance	$10,000
Minimum cost:	$69,249

A single trailer semi rig costs $69,250 just to sit in your yard per year, ready to work, but without moving.

If the truck works every day for 12 hours, 50 weeks per year, it costs **$198 per day**.
If the truck works 5 days a week, for 50 weeks per year, it costs **$277 per day**.
More typically, it will work 5 days, for 42 weeks, and cost **$330 per day**, allowing for holidays and normal maintenance down time.

Typical yearly costs, including driver, fuel, maintenance, tolls, and over heads will be in excess of $400,000. A ten percent profit, will net only $40,000, for an over all turnover of $440,000. $40,000 divided by 50 weeks $800 per week, or **$160 per day**.

Example: Working 5 days per week, 50 weeks per year. Add the day cost of $277 to the required profit of $160 equals $437 cost. Some would think this is the bottom line cost, but it isn't.

5 days fixed cost plus profit = $2185
If you lose one day from a break down or rain, then:
4 days fixed cost plus profit = $1748, but we lose the cost of the lost day: $1748 less $437=$1311

Lost income for the week is $2185 - $1311 = **$874**

This does not include driver wages. If the driver is employed, he probably still gets paid. If an owner driver, he loses his daily earnings plus the above. 8 x $25 = $200 plus superannuation = $220.
Every day lost costs $1094.... This does not include accounting, taxes, tolls, or any variable costs.

See the chart below for the other working time scenarios from above.

Weeks worked per year	Days worked per week	Cost per day	Cost per day + profit	Cost standard week	Cost week less day less day $	Lost income no driver	Lost income inc driver
50 weeks	7 days	$198	$358	$2506	$1790	**$715**	**$935**
50 weeks	5 days	$277	$437	$2185	$1311	**$874**	**$1094**
42 weeks	5 days	$330	$490	$2450	$1470	**$980**	**$1180**

FINANCIAL RETURN ON AN AIR CTI SYSTEM ON DRIVE TYRES ONLY, in Australia using AUD, using figures from previous pages

Example One: a log truck working in steep rocky terrain, figures from actual transport operator.

Tyre usage before AIR CTI 25,000 km
Tyre usage after AIR CTI 45,000 km

Additional investment cost: $7,550.

This operator would be $200,000 ahead, with a safer vehicle, a happier driver, and a happier owner. His annual profit margin increased by 70%. His return on investment is 3668%.

Over all use and cost for example life of 1,500,000 kms.

Tyre cost	Total Complete Replacements	Tyres Required No CTI	Total Value no CTI	Replacement Required with CTI	Tyres Required with CTI	Total Value with CTI	Tyre Savings with CTI	Days Lost half day per Replacement	Cost no driver	Total Savings
$600	60	480	$288,000	33	264	$158,400	$129,600	13.5	$11,800	$141,399

Over all use and cost for example life of 1,500,000 kms. Continued 25k

Total Direct Savings	Annual Damaged Tyres	Annual Cost	Annual Time Lost	Total Value Damaged Tyres	Maintenance Days Saved	Maintenance cost saved including downtime	Days worked because of extra traction less damage	Improved bottom line total saved
$141,399	4	$2,400	2	$18,548	28	$56,000	70 $61,000	$276,947

Example Two: A log truck operating on rolling hills with sandy base, from an actual operator:

Tyre usage before AIR CTI 95,000 km
Tyre usage after AIR CTI 135,000 km

Additional investment cost for quality CTI is $7,550.

This operator would be $100,000 ahead, with a safer vehicle, a happier driver, and happier owner. His annual profit margin just went up 35%. His return on investment is 1370%.

Over all use and cost for example life of 1,500,000 kms 95 k example

Tyre cost	Total Complete Replacements	Tyres Required No CTI	Total Value no CTI	Replacement Required with CTI	Tyres Required with CTI	Total Value with CTI	Tyre Savings with CTI	Days Lost half day per Replacement	Cost no driver	Total Savings
$600	16	128	$76,800	11	88	$52,800	$24,000	2.5	$2,185	$26,185

Over all use and cost for example life of 1,500,000 kms. Continued 95k

Total Direct Savings	Annual Damaged Tyres	Annual Cost	Annual Time lost	Total Value Damaged Tyres	Maintenance Days Saved Total	Maintenance cost saved including downtime	Days worked because of extra traction less damage	Improved bottom line total saved
$26,185	2	$1,200	1	$14,518	16	$32,000	35 $30,590	$103,293

LET'S QUANTIFY AN EXAMPLE SEMI TRUCK RIG, CONTINUED

Example Three: Milk transport semi rig picking up milk in country area:

Tyre usage before AIR CTI 120,000 km
Tyre usage after AIR CTI 180,000 km

Additional investment cost: $7,550.

This operator would be $48,000 ahead, with a safer vehicle, a happier driver, and a happier owner. His annual profit margin increased by 17%. His return on investment is 640%.

Over all use and cost for example life of 1,500,000 kms 120 k example

Tyre cost	Total Complete Replacements	Tyres Required No CTI	Total Value no CTI	Replacement Required with CTI	Tyres Required with CTI	Total Value with CTI	Tyre Savings with CTI	Days Lost half day per Replacement	Cost no driver	Total Savings
$600	12	96	$57,600	8	64	$38,400	$19,200	2	$1,748	$20,948

Over all use and cost for example life of 1,500,000 kms.Continued 120k

Total Direct Savings	Annual Damaged Tyres	Annual Cost	Annual Time Lost	Total Value Damaged Tyres	Maintenance Days Saved	Maintenance cost saved including downtime	Days worked because of extra traction less damage	Improved bottom line total saved
$20,948	1	$600	1/2	$7259	7	$14,000	7 $6,118	$48,325

Example Four: A semi trailer rig transferring fuel trailer system:

Tyre usage before CTI 250,000 kms.
Tyre usage after CTI 340,000 kms.

Additional investment cost for two pressure trailer CTI on three axles:$7,400

This operator would be $30,000 ahead, with a safer vehicle, almost no call outs, and less break downs. His annual profit margin increased by 10%. His return on investment is 400%.

Over all use and cost for example life of 1,500,000 kms 250 k example

Tyre cost	Total Complete Replacements	Tyres Required No CTI	Total Value no CTI	Replacement Required with CTI	Tyres Required with CTI	Total Value with CTI	Tyre Savings with CTI	Days Lost half day per Replacement	Cost no driver	Total Savings
$500	6	72	$36,000	4	48	$24,000	$12,000	1	$874	$12,874

Over all use and cost for example life of 1,500,000 kms.Continued 250k

Total Direct Savings	Annual Damaged Tyres	Annual Cost	Annual Time Lost	Total Value Damaged Tyres	Maintenance Days Saved	Maintenance cost saved including downtime	Days worked because of extra traction less damage	Improved bottom line total saved
$12,874	2	$1,000	1/2	$10,059	7	$7,000	0 0	$29,933

COST EXAMPLES FOR DISCUSSION PURPOSES

This cost analysis is produced by and available to use at www.freightmetrics.com.au, and provides an idea of costs for Australia for a standard semi rig with a single trailer. It is shown purely as an example for information only.
No taxes are included.

PRINT button can be found at the bottom of the calculator.

Truck Operating Cost Calculator

Country of operation		Australia	*Units:*	*Kilometres, litres, metric tonnes*

Step 1: Fuel

Current Fuel Cost	$	1.40	per Ltr	Australian Institute of Petroleum Fuel Charts National Diesel Average - Click Here
Less Fuel rebate (fuel credit)	$	0.12003	per Ltr	
Fuel Cost including delivery & rebate	$	1.27997	per Ltr	*See ATO for Fuel Credit details- click here*

Step 2: Vehicle Type

Select Type of Truck & Trailer	Curtain Sider - Single	
Net Average Daily Delivery	24	Tonn

Step 3: Fuel Consumption

Average Vehicle Fuel Burn Rate	2.10	Km / Ltr (Kilometres per Litre) = 47.62 ltrs per 100km

Step 4: Distance and Working Days

Distance Travelled per Day	750	Kilometres	(Per working day)
Days per week vehicle works	6	Days per week	
Weeks per year vehicle works	46	(account for driver holidays and service time)	
Vehicle Description / Number			
Route Description From			
Destination			

Step 5: Finance (per vehicle)

Capital Cost - Vehicle (Truck)	$	276,210		
Vehicle Stamp duty	$	8,286	*Based on a rate of 3%*	
Capital Cost - Trailer(s)	$	81,406		
Trailer(s) Stamp duty	$	2,442	*Based on a rate of 3%*	
Miscellaneous costs	$	15,000		
Less Deposit	$	0		
Principle (Loan - Amount Financed)		$383,344		
Balloon	%	25%	Residual	$95,836
Interest Rate	%	9.50%	Paid monthly in arrears	
Loan Period		5.0	Years	

Loan repayments are calculated based on constant payments and a constant interest rate (averaged).
Balloon is the residual lump sum payment payable at the end of the loan (if selected to be used).

Annual Depreciation	$		*Guide to depreciation:*	www.ato.gov.au

Depreciation rates and limits are set by the Tax Office. Speak with your financial advisor for what rate to use.

Step 6: Fixed Costs (per vehicle)

Costs in Step 6 relate only to the costs for a single vehicle

Insurance (Truck & Trailer)	$	13,042	per year	Road Tolls Paid	$	20	per day
Registration (Truck & Trailer)	$	6,555	per year	Mobile Cost	$	120	per month
Accounting / Consultancy	$	500	per year	Telephone Cost	$	295	per month
Depot / Rent for vehicle	$	12,500	per year	Administation Staff	$	1,890	per month
Depot Rates / Insurance	$	1,500	per year	Office Supplies	$	240	per month
Driver Wage (click here to check)	$	278	per day	Miscellaneous	$	82	per day
Workcover/ Workers Insurance		4.70%	(of wage on top of wage)				
Superannuation		9.00%	(of wage on top of wage)				

(Note: The Results Calulation assumes 52 weeks of driver employment for the wages costs).

Step 7: Service / Maintenance

Vehicle Service Cost (Type A)	$	930	per service interval every	18,000	Km
Maintenance Cost (Type B)	$	1,670	per maintenance interval	20,000	Km

(Maintenance includes costs for Brakes / Differential rebuild / Injectors / Alternator / Engine rebuild / Batteries etc.)

Step 8: Tyre Wear

Steer Tyre Cost	$	774	per tyre	Drive and Trailer Tyre Cost	$	700	per tyre
Steer Tyre Quantity		2		Drive and Trailer Quantity		20	
Steer Tyre Life		100,000	Km	Drive and Trailer Tyre Life		160,000	Km

Step 9: Fuel Levy Calculation (only if a base fuel rate is used in contract agreement)

Base Rate Fuel Price (if used) $ 1.00 per Ltr

Base Rate Less Rebate per Step 1 $ **0.87997** per L **Fuel Levy** ***9.66*** %

Using Current Fuel Price of $ 1.4 per Ltr equates to a fuel levy of 9.66% over the base rate fuel price of $ 1 per Ltr

Summary of Estimated Costs - *Click Calculate to Update Figures*

Cost Summary	**Per Annum**	**Per Month**	**Per Work Day**	**Percentage Cost**
Fuel (without fuel rebate included)				***29.98%***
Fuel	126,168.47	10,514.04	457.13	**28.1%**
Finance - Princip	57,501.67	4,791.81	208.34	**12.8%**
Finance - Interest **	24,061.29	2,005.11	87.18	**5.4%**
Depreciation	0.00	0.00	0.00	**0.0%**
Fixed Costs	92,788.56	7,732.38	336.19	**20.7%**
Driver	98,618.83	8,218.24	357.31	**22.0%**
Tyres	21,316.86	1,776.41	77.24	**4.8%**
Maintenance	17,284.50	1,440.38	62.63	**3.9%**
Service	10,695.00	891.25	38.75	**2.4%**
Total Cost Estimate $	448,435.18	37,369.60	1,624.77	**100.0%**

Distance Travelled	207,000	Km per year - (estimated average)
Service Intervals	12	per year (estimated average)
Maintenance Intervals	10	per year (estimated average)

***** Note: Interest amount varies from year to year. Value is the average of the finance period. (See Rule of 78).***

RESULTS - Based on Current Fuel Price in Step 1

Operating Margin **10.0%**

Estimate Charge per Day ***$1,805.29*** *+ GST / Tax (Based on $1.4 per Ltr, less rebate)*

Operating Cost per	*Day*	$	1,624.77	*Est. Charge per Day*	$ 1,805.29	*Margin per Day*	$	180.53
Estimated Cost per	*Tonne*	$	67.70	*Est. Charge per Tonn*	$ 75.22	*Margin per Tonne*	$	7.52
Estimated Cost per	*Km*	$	2.17	*Est. Charge per Km*	$ 2.41	*Margin per Km*	$	0.24

WHO SAYS?

APPENDIX

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IN DEPTH ADDITIONAL INFORMATION

VIBRATION STANDARDS AND EXPOSURE CRITERIA

Basically there are two main criteria currently used in Australia:

Australian Standard AS 2670-2001 *Evaluation of human exposure to whole-body vibration* prescribes methods for the measurement of whole-body vibration.

European Union Vibration Directive 2002.

AUSTRALIAN STANDARD

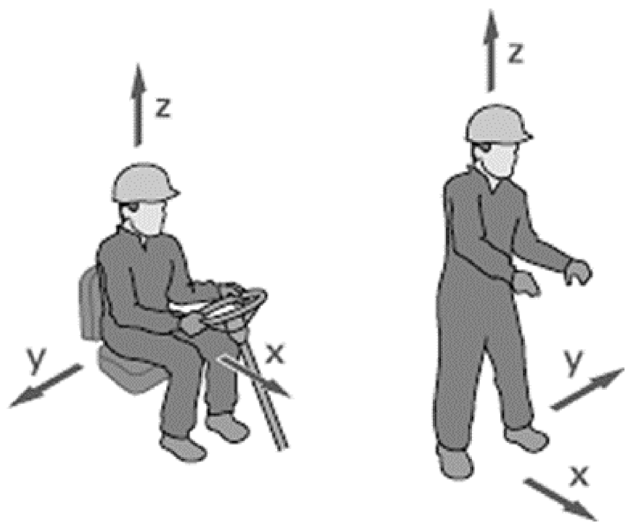
The Australian Standard (AS2670-2001 *Evaluation of human exposure to whole-body vibration*) on whole-body vibration was published in 2001.

It incorporates assessment methods for both steady state (rms) or Daily vibration exposure A(8) and shock/jolt type vibration (VDV).

DAILY VIBRATION EXPOSURE A(8)

Daily vibration exposure A(8) is calculated from the magnitude of vibration expressed as acceleration in m/s^2 and the length of time of exposure. In short the daily vibration exposure A(8) is the amount of vibration exposed to normalised to an eight hour reference period.

Exposure to intermittent WBV (shocks and jolts) is measured using a **VDV [Vibration Dose Value].** The VDV is a cumulative value, which increases with measurement duration. It is assessed using the length of time of the measurement and the total time a worker is exposed to the source of vibration per day.



For WDV the axis with the highest average root mean square is used to calculate A(8). The x-axis and y-axis have a weighting factor of 1.4.

A(8) for a worker carrying out one process or operating one item of plant is calculated by using the following equation;

$$A(8) = a_w \sqrt{\frac{T}{T_o}}$$

Where;

a_w is the vibration magnitude (m/s^2) on the axis which measured highest, including the weighting factor foe the x- and y-axes.

T is the actual duration of exposure to the vibration magnitude a_w.

T_o is the reference duration of eight hours.

The vibration magnitude, a_w ,may come from measured data, manufacturer's information or other sources like online databases.

If a person is exposed to more than one source of WDV then partial vibration exposures are calculated from the magnitude and duration for each source.

The overall daily vibration exposure A(8) can be calculated from the partial vibration exposure using the equation:

$$A(8) = \sqrt{[A_1(8)^2 + A_2(8)^2 + A_3(8)^2 + \ldots]}$$

where $A_1(8)$, $A_2(8)$, etc are the partial vibration exposure values for the different vibration sources.

The daily exposure A(8) is worked out separately for each of the three axes. The total on the highest axis the worker is exposed is then compared to the exposure action value and exposure limit value.

A simple exposure points system can be used to work out the daily vibration exposure A(8). It can then be compared to the exposure action value and exposure limit table (see below).

CALCULATING THE VIBRATION DOSE VALUE

VDV is calculated as the root mean quad (the fourth root) of the acceleration and is more sensitive to peaks in acceleration than the root mean square acceleration. The gives a result m/s1.75. Weighting factors of 1.4 apply on the x and y axes.

VDV is not usually publically available so measurements have to be taken to determine the VDV for each piece of plant.

If VDVs are available, the daily VDV (VDV_{exp}) can be worked out for each axis using the equation:

$$VDV_{exp,x} = 1.4\ VDV_x \left(\frac{T_{exp}}{T_{meas}}\right)^{\frac{1}{4}}$$

Where;

VDV_x is the VDV on the x-axis.

T_{exp} is the daily duration of exposure to the source of WDV

T_{max} he time over which the VDV_x was measured

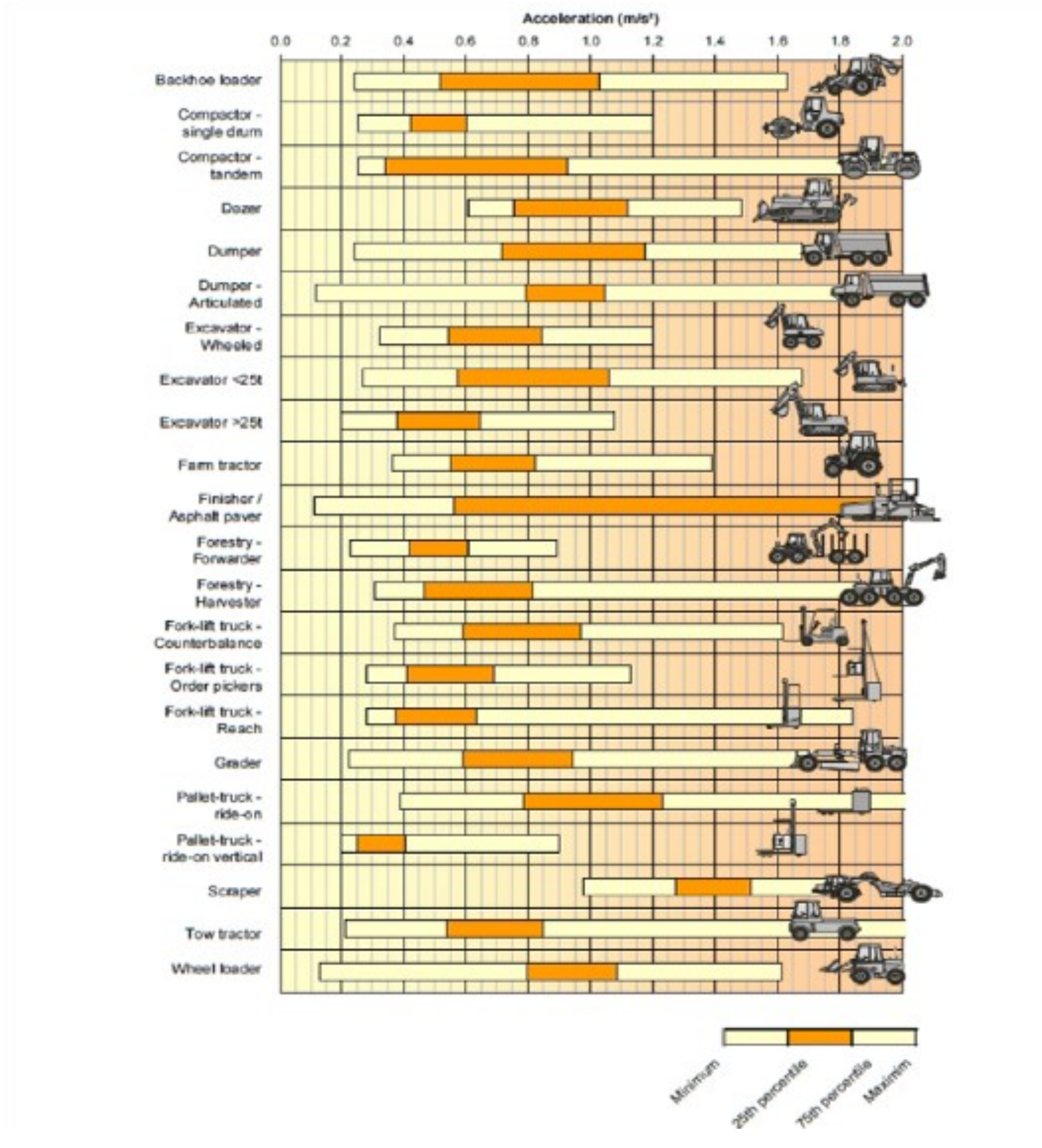
The y-axis has the same factor (1.4) whereas the z-axis does not.

If the worker is exposed to more than one source of WBV and VDVs are available, the total VDV for each axis is calculated using the equation:

$$VDV_x = \sqrt[4]{[VDV_{x1}^4 + VDV_{x2}^4 + VDV_{x3}^4 + \ldots]}$$

where VDV_{x1}, VDV_{x2} etc. are the partial VDVs for each source on the x-axis. The VDV which is highest of the x, y and z axes in the daily VDV.

EXAMPLES OF VIBRATION MAGNITUDE FOR COMMON MOBILE PLANT



DURATION OF EXPOSURE

To estimate the daily vibration exposure A(8) one needs to work out the total daily duration of exposure to the vibration emitted from the plant. Realize that many drivers work 12 hour days.

DAILY VIBRATION EXPOSURE USING THE EXPOSURE POINTS SYSTEM

A simple method for determining daily WBV exposure is the use of a points based system.

The exposure scores corresponding to the exposure action value and exposure limit value are shown in the table below.

Acceleration x k (m/s²) \ Daily Exposure Time	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h	12h
2	50	100	200	400	600	800	1000	1200	1600	2000	2400
1.9	45	90	180	360	540	720	905	1100	1450	1800	2150
1.8	41	81	160	325	485	650	810	970	1300	1600	1950
1.7	36	72	145	290	435	580	725	865	1150	1450	1750
1.6	32	64	130	255	385	510	640	770	1000	1300	1550
1.5	28	56	115	225	340	450	565	675	900	1150	1350
1.4	25	49	98	195	295	390	490	590	785	980	1200
1.3	21	42	85	170	255	340	425	505	675	845	1000
1.2	18	36	72	145	215	290	360	430	575	720	885
1.1	15	30	61	120	180	240	305	365	485	605	725
1	13	25	50	100	150	200	250	300	400	500	600
0.9	10	20	41	81	120	160	205	245	325	405	485
0.8	8	16	32	64	96	130	160	190	255	320	385
0.7	6	12	25	49	74	98	125	145	195	245	295
0.6	5	9	18	36	54	72	90	110	145	180	215
0.5	3	6	13	25	38	50	63	75	100	125	150
0.4	2	4	8	16	24	32	40	48	64	80	96
0.3	1	2	5	9	14	18	23	27	36	45	54
0.2	1	1	2	4	6	8	10	12	16	20	24

Once one has worked out the whole-body vibration acceleration which axis it was determined on and the duration of exposure the worker's total exposure points is calculated.
Where the vibration exposure point is:

- between the exposure action value and the exposure limit values (yellow), monitoring is required to ensure controls remain appropriate so the exposure limit is not passed, and
- greater than the action limit value (red), then controls must be implemented to ensure workers are not exposed under any circumstances.

EXAMPLE USING THE EXPOSURE POINTS SYSTEM

A worker spends:

- One hour driving a grader to repair a dirt road, and
- Then five hours ploughing a paddock

The measured vibration magnitudes were greater on the z-axis.

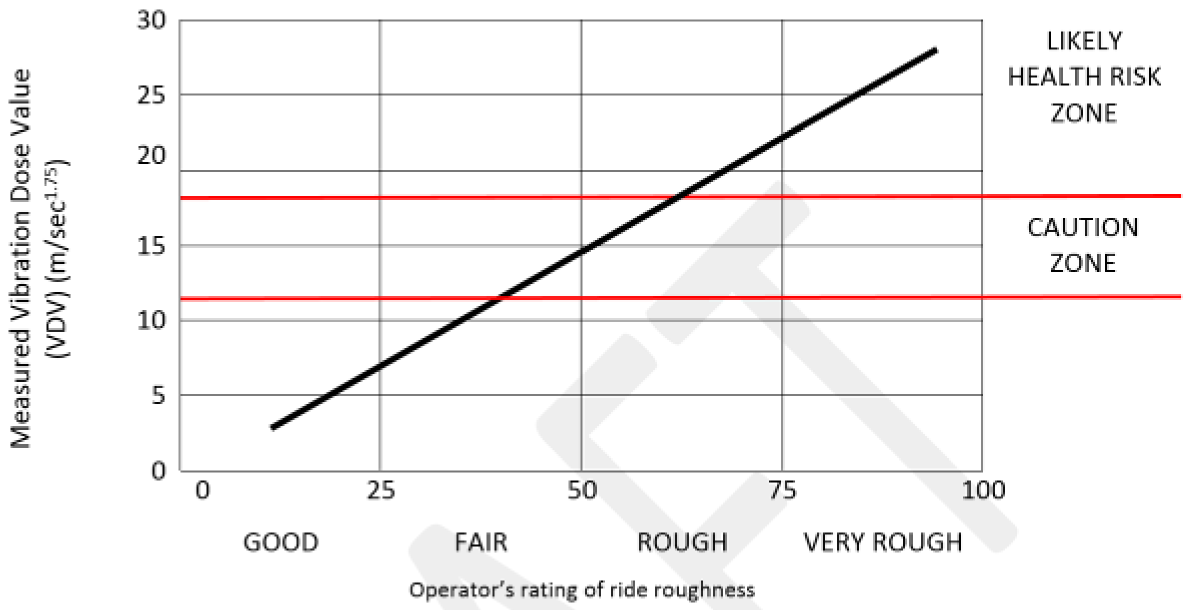
Calculations using the exposure points system

Activity	Measured vibration on highest axis m/s^2	Exposure time (hours)	Exposure Points
Grader — road repair	1.2 (z)	1	72
Tractor — ploughing	0.8 (z)	5	160
TOTAL			232

The worker's total exposure for the day is 232 points. This is above the exposure action value but below the exposure limit value. The business should take action to reduce the worker's exposure.

Surveying opinions of ride roughness

The VDV is also a sensitive indicator of ride roughness and was found to correlate very well with drivers' subjective opinions. For example, a driver who complains that the ride is very rough could be exposed to vibration in the upper half of the Caution Zone or into the Likely Health Risk Zone.



It is generally considered that a noticeable vibration in a car is likely to be 10-50 times worse in a truck.

8.2.10 HOW OPTIMAL TYRE PRESSURE IMPROVES DRIVER COMFORT AND CARGO SAFETY

As a vehicle moves along the road it possesses energy of movement. This energy is called Kinetic Energy, E_K ,and is equal to the mass of the vehicle times the velocity squared.

Mathematically this is; $E_K = \frac{1}{2} mv^2$

If we consider one tyre then the mass includes that wheel and (roughly) half of the axle/springs etc. This is often called the unsprung weight. When the tyre hits a bump in the road the straight line motion is disrupted and the direction of the motion has changed. Instead of straight line parallel to the road we now have motion at an angle to the road. This gives a component vertically and a component horizontally.

The vertical component will cause upward motion of the tyre if it is not removed or dampened out quickly.

That is, the vehicle is now moving upwards as well as forwards. As the vertical kinetic energy reduces – that is the truck slows down vertically the kinetic energy is changed into Potential Energy, E_P.

$$E_p = mgh$$

In this equation, h, is a height and is the amount of distance the wheel moves vertically away from the surface of the road due to the vertical velocity component.

An optimally pressured tyre has 'give' at the contact point between the footprint and the road surface. When a tyre collides with a bump in the road the tyre has the ability to mould around the obstacle and in many cases the potential collision is not transferred to the vehicle. The hysteresis effect of the tyre rubber removes the energy of the deformation as heat to the environment. It thus is not transferred to the chassis and consequently the occupants.

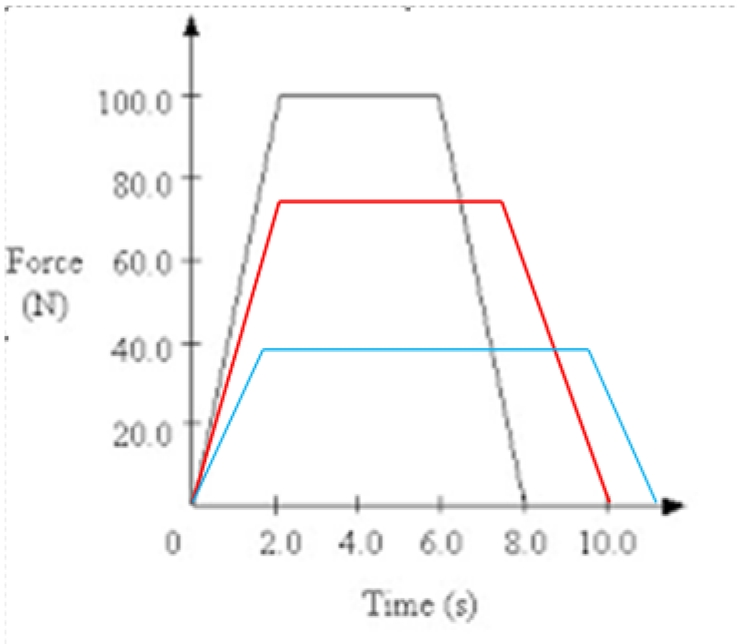
However, it can be that the obstacle is of significant size that the tyre does not mould completely around the obstacle. This collision is sufficiently large to cause the tyre to leave the surface of the road. The goal in this second case is to increase the time of the collision.

This can be examined by considering Impulse, Change of Momentum and Newton's First and Second Laws. A collision is considered to be an impact with a surface obstruction, eg a change of height such as a rock or a sharp change in the roadway. Momentum is a measure of the difficulty of changing a body's motion. It is the multiplication of the velocity (speed) and the mass. When an object (the tyre) is involved in a collision, (in 99.9 % of cases) the momentum before the collision is different to the momentum after the collision [If the system is closed them momentum is always conserved]. This difference is the Change of Momentum and is said to be equal to a quantity called Impulse. Impulse is the Force within the collision multiplied by the Time of the collision.

The equation is a follows, Impulse = $F\Delta t = m\Delta v$ = Change of Momentum.

This means that the magnitude of a quantity called Impulse equals the Force of the Impact multiplied by the Time (duration) of the impact.

Now the Change of Momentum of the object (tyre) does not change, it is a specific value – different for every collision but still a constant for the one in focus. Its value of made up of the multiplication of the two variables, Force and Time. Increase Force then decrease Time or Increase Time then decrease Force.



The area under the above graphs is the same and is equal to the Impulse. Notice that in each case as the collision time increase the force decreases.

An optimally pressured tyre does exactly this – it lengthens the time of the collision and thus the Force transfer to the chassis is lessened. Further, the extended time combined with the hysteresis effect means that considerable energy is removed from the system as heat and thus does not manifest as vibration to the vehicle.

This is the beauty of an optimally pressured radial tyre. Even if the tyre does not wrap completely around a bump or obstacle any deflection is considerably dampened.

An over inflated tyre does not do any of this and transfers the deflection straight to the chassis and then onto the occupants. Now admittedly the shocker absorbers are there to remove some of this vibration from the system but the optimally pressured tyre removes the deflections before it even gets to the shock absorbers as the shock absorbers come into play once the deflection acts on the axle. It is beneficial to remove as much of the vibrations before this happens, that is through the tyre itself. This removal is best achieved by using optimal tyre pressure.

An overinflated tyre has no give in its side walls. The defection is transmitted straight to the axle and the shock absorbers tries to remove this energy from the chassis so that it is not transferred to the driver. This is only marginally successful and considerable vibration is borne by the truck and driver.

Reviewing the Potential Energy equation, $E_P = mgh$. This is the work done against the gravitational force of attraction. Breaking the equation up it can be rewritten as;

$$E_P = mgh = (mg)h = (ma)h$$

Now *ma* is equal to Force, *F*.

$$(ma)h = Fh$$

The Potential Energy (equal to the vertical Kinetic Energy caused by the bump) is proportional to a Force. This is the Force that hammers away at our roads and damages them prematurely - eventually wearing them away. In its early stages this phenomena is the beginning of potholes and corrugations.

Further, look at the Kinetic Energy equation,

$$E_K = \frac{1}{2} mv^2$$

Now the Kinetic Energy equals the Potential Energy – thus both vary as the velocity squared. That is, double the velocity equates to a quadrupling of the energy and thus defection.

Optimally pressured tyres can remove this excess energy from the suspension system via heat dissipated to the atmosphere thereby ensuring it is now not transferred to the truck, its cargo or the driver.

Further, this has removed the transfer of energy to the vehicle and its component parts. The less energy transferred to the truck, the less repairs and maintenance that needs to be done.

This is confirmed by referring to the research conducted in this area.

By reducing tyre inflation pressure a softer and smoother ride can be achieved which improves the comfort of the driver and consequently results in less driver fatigue. The softer ride will also reduce the shock loading that is transmitted to the vehicle, which is potentially damaging to the truck and cargo (Rummer et al., 1990)[8].

Adams (2002)[1] conducted tests to evaluate the effect of using CTI* on the ride quality of a vehicle. He showed that an average ride quality improvement of 99% was achieved when tyres were adjusted using a CTI system to match terrain and speed conditions. At a lower speed, the CTI pressure showed an average ride quality improvement of 177%. Ride quality is quantified by the vibrations the driver experiences through the seat of the vehicle. Sensors were placed on the seat of the vehicle and the vibration levels of the seat are recorded (Adams et. al., 2002)[2]. Similarly to Adams, Altunel (1998)[3] analysed data collected by the US Army Corps of Engineers and the Waterways Experiment Station to evaluate the effect of lowering tyre pressures on a log truck driver's seat using CTI technology. Their analysis concluded that lowering the tyre pressure to match the road surface appear to decrease vibration levels in the driver's seat from 10 to 25%. Almost all drivers involved in the CTI tests commented on the improvement in vehicle ride which resulted in them feeling less fatigued after a day of driving (Brown and Sessions, 1999)[7].

A trial of CTI was initiated by Bradley (1991)[5] to evaluate the impact of CTI on driver comfort. The truck drivers involved in the trial reported reduced vibration and shock loading with reduced inflation of the drive tyres. The driver's opinion was substantiated by comparing the maintenance records of the test vehicle to those of a control fleet of similar trucks. Monthly repair time was reduced by 26%, largely because of fewer vibrations which caused cracks and loosened bolts, and less cab component damage (Bradley, 1993)[6].

Anon (2006)[4] performed tests for the United States Forest Service that clearly demonstrates the points above. Two closely matched trucks were operated over identical test courses for an extended period, one with conventional tyre pressures and the other at reduced tyre pressures (the truck was equipped with CTI). Vibration levels were measured and the truck with high inflation pressure recorded six times more vertical energy than the truck with lowered inflation pressure. The high pressure truck exhibited four times the part failures and eight times greater cost of repairs than the truck with lowered tyre pressures. Industry evidence indicates the doubling of the life of transmissions and differentials are typical outcomes.

A further study conducted in Western Australia with three trucks all with non-optimal tyre pressure. All three trucks exceeded a half metre vibration levels over 500 times over a 27 km test distance. When one of the vehicles was equipped with a Central Tyre Inflation system the standard vibration limit was only exceeded 13 times over the journey. **This is over 95% improvement.**

* CTI refers to Central Tyre Inflation. This involves a device that ensures optimal tyre pressures. Thus in the research above CTI can be read interchangeably with optimal tyre pressures.

**THIS IS ONLY THE BEGINNING.
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