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'FIT FOR PURPOSE' TYRE MAINTENANCE EQUIPMENT AND MANAGEMENT PRACTISES FOR NON-EARTHMOVER MINING VEHICLES

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'Fit for purpose' tyre maintenance equipment and management practises for non-earthmover mining vehicles

A study to improve tyre safety

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Executive Summary

Tyres, rims and wheel assemblies are safety critical items which must be maintained and used correctly to achieve levels of acceptable risk. Inadequate tyre and rim maintenance carries considerable inherent risks of personal injury and death, as tragically confirmed through several tyre and rim related fatalities in the Australasian region over the last few years, including some involving non-earthmoving equipment.

As such this project report aims to identify tyre maintenance safety issues around non-earthmoving vehicles and mobile equipment, and demonstrate effective solutions such as better tooling, improved maintenance equipment, improved safe work practises, and other recommendations for safer work.

Principle findings of the report are as follows:

1. Australian mining industry relies heavily on rubber tyred equipment.
2. In field observations suggest that there is a diverse range of non-earthmoving rubber tyred type equipment being used in Australian mines. This equipment can often be found in frontline applications such as long distance coal haulage. In some instances more than 50% of all rubber tyred equipment is non-earthmoving type equipment.
3. Typical management of tyres, rims and wheels at mine sites is focussed largely around earthmover type tyres, rims and wheels. This bias seems to be driven by AS4457:2007-Part 1 which defines earthmoving machinery rim and wheel assemblies as units of ‘not less than 24” (600 mm) in outside diameter’.
4. There is no Australian or international standard providing any guidance (operational or maintenance) for rims and wheels of less than 24” (600mm) nominal diameter, i.e. those rims and wheels used for much of the non-earthmover ancillary rubber tyred equipment. Many of the company internal documents also seem to favour this distinction.
5. Non-earthmover tyre and rim management receives much less management attention despite representing well over 50% of rubber tyred assets at some operations, and having been involved in several fatalities in the last few years

6. The design of non-earth moving equipment remains production focussed with less thought put into the maintainability of the equipment,
7. Tyre maintenance relies heavily on standard type of tooling despite the increased frequency and therefore exposure to typical tyre maintenance hazards including considerable manual task hazards.
8. Knowledge of sound solutions towards safer non-earthmover tyre maintenance is not consistently applied across industry.

Considering the above the following recommendations are made:

1. All mine sites that utilise non-earthmoving type of equipment should review their risk assessments in light of this report; in particular sites should check and verify current controls for their effectiveness. Relevant procedures and processes must be amended where found wanting.
2. Similarly sites should review tyre awareness and tyre maintenance training programmes for all mines personnel including contractors.
3. The Australian Standard AS4457 should be amended to cover non-earthmoving tyres. This could be achieved through a general amendment of the '24 inch or 600 mm' outside diameter rule incorporating the standards other requirements, or through a separate standard covering specific sections (as applicable to non-earthmoving tyre equipment) such as:
    - Tyre and rim selection - to suit local haulage parameters
    - Management of repaired tyres
    - Pressure maintenance regimes
    - Tyre and rim identification
    - Training requirements
    - Non-destructive testing of rims and wheels (refer to [9])
4. Further research should be conducted in the area of design of mobile vehicle support systems - jacks and stands. The design must take into account the elimination of manual task hazards and resultant risks of placement and retrieval of jacks and stands from under the vehicle, including those created by a person's proximity to potentially damaged tyres and rims during that process. The design of' low profile lift and lock jacks' is encouraged to eliminate the need to place support stands.

5. Research should also be carried out into developing a low profile jacking platform permanently placed into the laneway of the tyre maintenance bay.
6. Designers of trailers should consider external jacking points to limit the requirement of manually placing jacks and stands under vehicles. Alternatively vehicle/trailer designers should consider inclusion of hydraulic or pneumatic jacks into the actual frame/chassis of the vehicle/trailer so they become self elevating without the need to place a jack/stand under the vehicle.
7. All mine sites utilising non-earthmoving type of equipment should review tyre pressure recording, reporting/analysis and maintenance regimes. The use of independent tyre pressure monitoring and reporting systems is encouraged.

To provide easy integration of the reports findings and recommendations, the document will be structured using the Nertney wheels main components – ‘fit for purpose’ equipment, procedures, skilled people, in a controlled working environment, as shown in Figure 1.

Figure 1 - Nertney Wheel

The author would like to thank ACARP and the projects monitor, Matthew Sheather, for the ongoing support and assistance.

Thanks also goes to Anglo Americans’ Foxleigh and Capcoal mines, and Peabodys’ Burton mine staff, particularly LCR and Toll contractor haulage personnel for their help during the mine visits.

Thanks also to ACARPS’ Keith Smith for looking after the administrational aspects of the project.

Introduction

Over the past few years, many safety aspects of earthmover tyre maintenance activities have seen considerable improvements. These have been brought about by the recognition that earthmover tyre maintenance is a hazardous activity which if not controlled effectively, will lead to serious injury or death of the persons involved.

C13049 and C17032, two of the authors' previous research projects on earthmover tyre maintenance safety has shown that, in terms of consequence, less than adequate tyre maintenance is known to result in single or multiple fatalities in one third of all tyre maintenance incidents and accidents, with potential fatality outcomes accounting approximately half for the same incident and accident sample data [1, 2].

Simple improvements in basic earthmover tyre maintenance approaches such as deflation and inflation protocols, enhancements of tyre handling and maintenance equipment, improved rim designs, formal training requirements and introduction of comprehensive tyre management systems have had a positive and measurable impact on tyre maintenance safety.

Some recent incidents and accidents however suggest that the advances in earthmover tyre safety may be offset by the increased utilisation of contractor owned and managed on-road mobile equipment – tip-trucks, semitrailer-type and road-train configuration trucks brought into the harsh mining environment to assist with a variety of haulage aspects.

What has not been considered is that the much harsher duty increases the frequency of tyre maintenance, which while relying on on-road maintenance approaches and tooling will considerably increase the risks for those carrying out the tyre maintenance.

This study aims to accelerate the level of knowledge of causes and controls towards safer, 'fit for purpose' tyre changing tools and equipment, better training and education, and management for those engaged in tyre maintenance of non-earthmoving vehicles used at a mine.

While this report is based on the authors observations at three large open cut coal mines, many if not all aspects and recommendations can equally be applied to any other mining environment, including underground.

Causes and Consequences of tyre related accidents and incidents

TYREgate, a web based database and reporting tool developed by the author [3, 4] as part of a previous ACARP project suggests that in terms of consequences over 80% of incidents and accidents result in either potential or actual fatality, as shown in Figure 3.

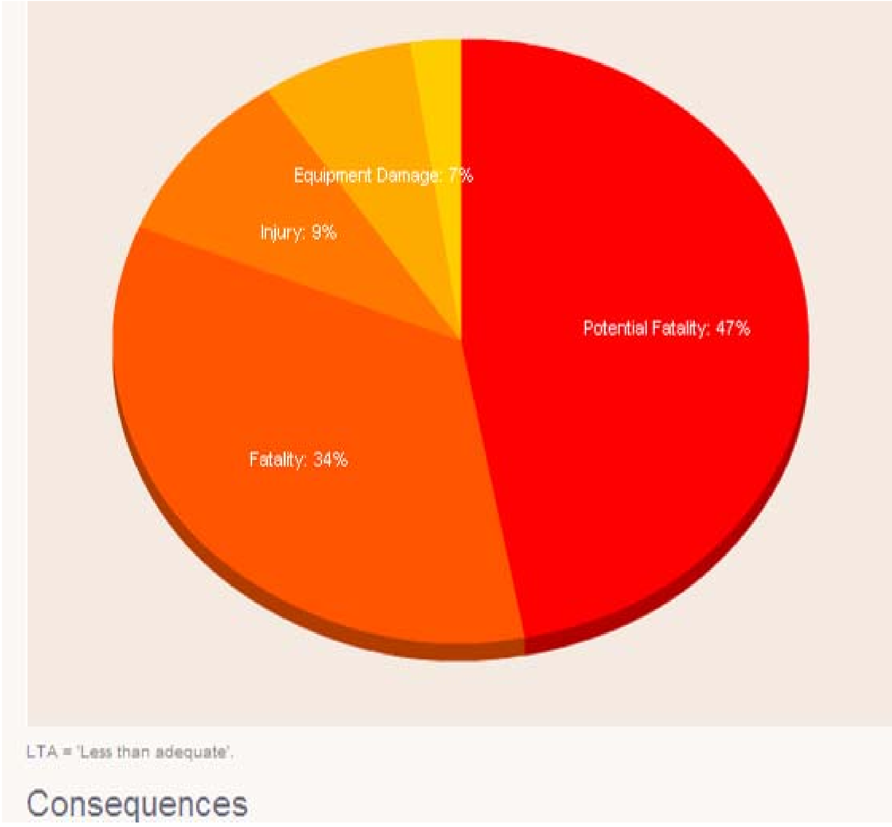

Figure 2 - TYREgate - Consequence of tyre and rim related incidents and accidents

While TYREgates' database covers mainly earthmover tyre and rim accidents and incidents, underlying root causes (see Figure 2) could also be extrapolated to non-earthmoving type tyre and rim applications, based on observations of two fatalities that occurred in Queensland in previous years.

The accompanying safety alert issued by the Qld Department of Mines [5] describes the incident scenario for the first fatality (2005) as follows:

> *While removing a tyre and rim assembly from a drive axle bogey of an off-highway coal transport prime mover the operator suffered fatal injuries when the inner rim assembly failed and blew the outer wheel and mounting jewellery of the inner assembly off the drive axle.*

The incident scenario for the second fatality (2010) reads [6]:

> *While replacing a wheel on a bulk coal transport trailer, the driver was killed by the air blast shock wave when the tyre ruptured.*

The safety alert goes on to say:

> *This has highlighted a 'sleeper' risk well known in the trucking industry, but having previously rarely caused injury in mining, it receives little attention. It concerns tyres up to 25" diameter on highway style prime mover and mining style trailers (double or triple).*

Both safety alerts suggest an oversight regarding the underlying hazards of inflated tyres and mounted wheel assemblies, highlighting the need for a concerted management strategy covering non-earthmover tyres and rims.

Figure 3 – Root causes for tyre and rim related incidents and accidents (refer to Tyregate for more information)

What is ‘earthmover’ equipment, and what is not?

AS4457-2007 Part 1, Page 4 defines rubber tyred earthmoving equipment as equipment with ‘rims or wheels greater than 24 inches (600 mm) in outside diameter’.

This infers that any equipment with a lesser rim or wheel diameter is not seen as (true) earthmover equipment.

Non-earthmover equipment would therefore include vehicles such as smaller tiptrucks, semitrailers of various configurations, backhoe loaders, utility vehicles, in field servicing vehicles, lubrication and refuelling trucks, smaller watertrucks, cranes, work platforms, lighting plants, tractors, skid steer bobcats, forklifts, light vehicles, driftrunners and buses for personnel transport.

Figure 4 - Typical non-earthmover equipment

Figure 5 - Non-earthmover equipment used to haul coal

At one of the opencut mines visited the split was about 60% Light vehicles, light trucks and ancillary equipment versus 40% of equipment with a rim size above 24 inch (600 mm, i.e. earthmover type equipment). This suggests a considerable exposure.

Figure 6 – Non earthmoving equipment used to haul coal

Figure 7 - 'Cowcatcher' on coal haulage trailer

Some typical non-earthmoving equipment viewed during the site visits are shown in Figure 4, Figure 5 and Figure 6.

Typically, many of these vehicles are on-the-road type vehicles used ‘as built’, or modified for particular mining service applications as refuelling trucks. Other vehicles and trailers are custom built, however none appeared to consider the increased need for better maintainability e.g. tyre maintenance access as part of their design.

For instance, ‘cowcatchers’ at the front of trailer bogies designed to push large lumps of coal away from the trailer tyres (thereby reducing tyre damage) also made access to the vehicles front axle jacking points difficult (see Figure 7).

Review of AS4457 Earthmoving machinery – off the road wheels, rims and tyres – maintenance and repair

AS4457 currently exists as a two part standard [7, 8], namely

- AS4457:1 2007 Earthmoving Machinery – Off the road wheels, rims and tyres – Maintenance and repair Part 1: Wheel assemblies and rim assemblies.

- AS4457:2 2008 Earthmoving Machinery – Off the road wheels, rims and tyres – Maintenance and repair Part 2: Tyres.

Because standards such as AS4457 are considered ‘quasi legislation’ under the Queensland legislative framework, they naturally attract more management attention and compliance.

It follows that equipment not covered by a standard could attract less (management) attention, even if the underlying hazard and risk management requirements are similar or identical. Taking this one step further, this implies that at one mine, 60% of vehicle tyres and rims could fall outside of management surveillance.

Following a spate of tyre and rim related fatalities the AS4457:1997 was reviewed and reissued in 2007. In its current version, AS4457:2007 – Part 1, it offers stricter guidance on maintenance practises of wheel and rim assemblies that were seen wanting or ‘less than adequate’ (lta) based on the fatality investigations. However, as mentioned AS4457:2007 only offer guidance on wheels and rims of greater than 24” (600mm) outside diameter, i.e. is silent on wheel, rim and tyre management below that size.

It should be noted that in 2008, Part 2 was written and issued covering specific aspects of tyres; in particular identification, inspection, repair, retreading and maintenance of off the road tyres for earthmoving equipment.

Given the identical match of hazards and resultant risks between earthmoving and non-earthmoving equipment, it is recommended that AS 4457 be amended to cover non-earthmoving tyres.

This could be achieved through a general amendment of the ’24 inch or 600 mm’ outside diameter rule, or through specific sections applicable to non-earthmoving type equipment covering issues such as:

- Tyre and rim selection
- Management of repaired tyres
- Pressure maintenance regimes
- Tyre and rim identification
- Training requirements
- Non-destructive testing of rims and wheels (refer to [9])

Fit for Purpose Equipment

Tooling and tyre change equipment

To achieve safe tyre maintenance, people carrying out these tasks must be equipped with fit for purpose (FFP) tooling, refer to Figure 8.

Figure 8 - Nertney Wheel – FFP Tooling

Not being 'fit for purpose' may inadvertently lead the operators to situations where the process of changing a tyre will put them and their peers at risk from injury or death.

This section introduces the reader to basic but necessary 'tools' and systems for safe tyre maintenance.

Retention tags

What is the Hazard?

Rims and wheels are attached to the vehicles hubs using a system of wheel studs and nuts, sometimes in conjunction with cleats, and spacers depending on the design. As the mounting system depends on the interaction of screw threads and close fitting/mating of other surfaces on the hub, initial installation must be done using the right tools – Torque wrenches or hydraulic torque tools, in accordance with manufacturers tortue settings and procedures. If these processes are not

Figure 9 – Typical tyre maintenance tags including retention tag

followed, wheels could become loose, damage the hub, or come off the vehicle causing a highly dangerous situation for the driver – he could loose control resulting in a vehicle crash or rollover.

Control

To ensure wheel attachment systems - nuts, studs, rims, wheels, spacers etc. are checked for their safety and integrity after they have been fitted initially, simple retention tags should be used to alert operators and maintainers. Ideally these checks are also captured in a vehicle maintenance management system. Naturally all operators should as a routine, check all wheels for unsafe conditions, prior to using the vehicle (i.e. prestart check). Typical retention tags are shown in Figure 9.

Calibrated torque wrench or torque gun - Torqueing and torque tools

What is the Hazard?

As mentioned above, incorrectly torqued wheel attachment systems may cause the wheel to come loose, damage the hub or at worst cause the assembly to come off the vehicle creating a dangerous situation for the operator.

Figure 10 – Trolley holding tyre maintenance tooling, note the torque chart attached to side of trolley

Control

Torqueing and retorqueing, where required, must form part of any sound tyre maintenance process. Torque wrenches and guns must be calibrated as per OEM requirements, and calibration certificates must be readily available; ideally they are kept with the torque tool itself. Torqueing must be conducted in accordance with OEM procedures, and special attention must be given to checking if lubrication of stud/nut threads is a requirement.

Torque tools whose calibration has lapsed must not be used.

Because of the weight of most torque tools and hosing etc, they should be carried in customised baskets such as shown in Figure 10.

Specific torque reference charts, as shown in Figure 11 must be available in the workplace to ensure wheel studs and nuts are torqued and retorqued to the right original equipment manufacturer (OEM) nominated value. The charts should form part of the sites quality system.

Figure 11 – Inflation pressure and Torque specification charts

Housekeeping - Tyre Racking, Consumable Storage and Tyre Handling Equipment

What is the Hazard?

Untidy and disorganised storage of tyres and rim components are a housekeeping issue and could result in trips and slips, manual handling injuries, exposure to a potential tyre storage fire, general stock control and productivity issues.

Control

Because of the potentially large number of tyres – new, used, (repaired) and discarded, mines should institute a sound and easily maintained regime of tyre storage. This will also assist with stock control and general efficiency of a tyre management program.

Figure 12 – Tyre racking system

As mounted tyre/rim assemblies can be weighty, care must be taken to minimise manual handling issues, and or tyres rolling away/toppling during handling causing injury or damage. Tyres, wheels, rims and assemblies are best stored in customised racks such as shown in Figure 12.

Tyres for disposal should be bundled and clearly marked to avoid accidental reintroduction in to the tyre stock – refer Figure 13 .

A similar basic standard of housekeeping ought to be applied for tools and consumables, such as shown in Figure 14.

Figure 13 - Tyre bundled and ready for offsite disposal

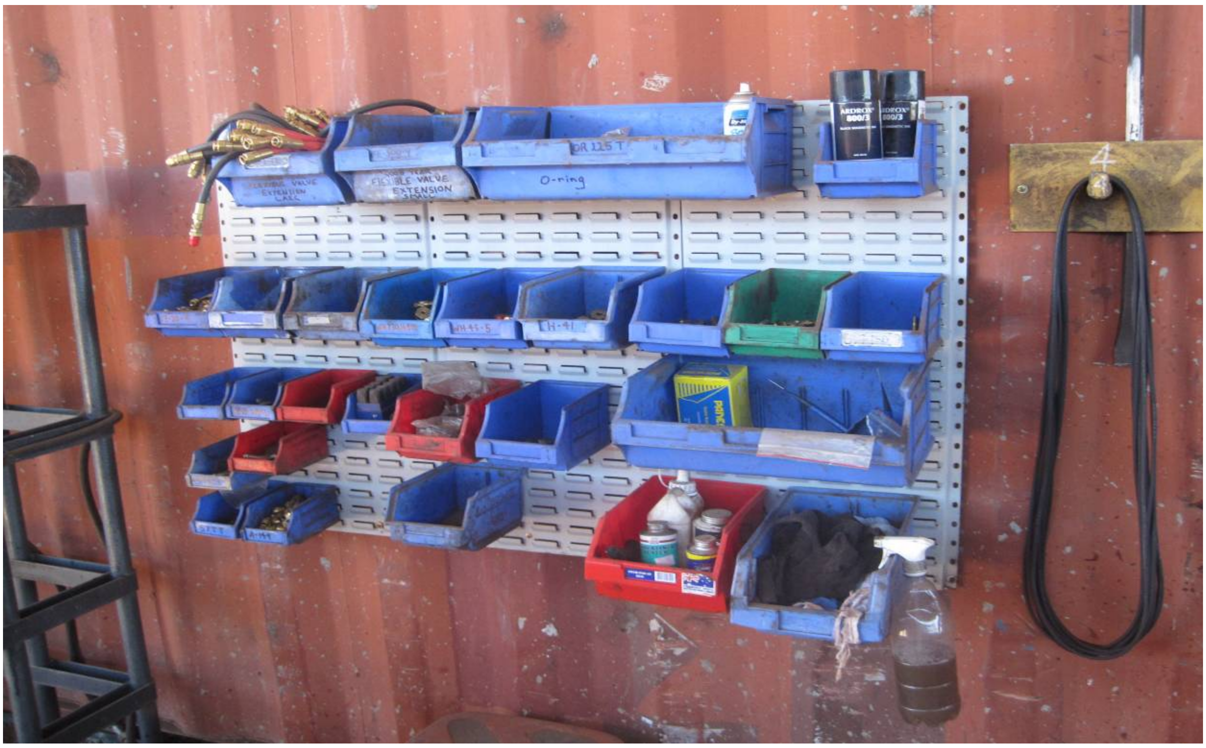

Figure 14 – Tyrebay consumables storage

Figure 15 – Tailgate designed to lift/lower tyres and wheel assemblies onto service vehicle reducing manual handling

Naturally any chemicals used should be supported by readily available MSDS sheets.

To reduce manual handling, tyre delivery trucks ought to be fitted with lifting aids such as the rear gate shown in Figure 15, it can be used to safely lift tyres on and off the truck tray.

For smaller tyres, tyre handling dolleys as shown in Figure 16 should also be considered as they assist in reducing manual task load when removing and fitting assemblies on or off the hub of a truck.

Figure 16 - Tyre Handling dolleys

Tyre handling equipment such as tyre handlers or forklifts must be fit for purpose. Structural integrity and serviceability of tyre handling equipment can be achieved through initial selection, appropriate inspections, structural examinations and preventative maintenance by competent maintenance personnel.

Better education and specialised training of tyre servicemen in the use of tyre handling equipment will also assist in reducing tyre handling accidents e.g. dropped tyres, rims and assemblies.

Tyre Maintenance Tooling – Wheel Chocks, Jacks and Stands

Wheel Chocks - making the vehicle fundamentally stable

What is the Hazard?

Vehicles while undergoing tyre maintenance must be stable. If the vehicle was allowed to move, supports such as jacks and stands could fail causing the vehicle to fall onto tyre service personnel resulting in serious injury or death.

Control - Wheel chocks

All vehicles should be equipped with appropriately sized wheel chocks; additional wheel chocks should be available in the tyre fitting area – refer **Error! Reference source not found.**.

Vehicle Stands - making the vehicle fundamentally stable

What is the Hazard?

Any vehicle, once raised off the ground can become unstable. A number of fatalities have occurred from improper support of a vehicle while undergoing tyre maintenance - stands of insufficient safe working load (SWL) can fail with the vehicle falling onto tyre service personnel resulting in serious injury or death.

Control - Vehicle stands

Unless lift and lock jacks are used, all vehicles must be supported by engineered and certified vehicle stands capable of supporting the vehicles under maintenance.

To assist with placement and reduce manual handling exposure and prevent pinch injuries, such stands should be designed with handles, and where possible wheels to better manoeuvre them under the vehicles axles, such as shown in Figure 17. Placement and retrieval should be possible without a person having to climb under the vehicle.

Figure 17 – Vehicle stands

A number of variable height stands should be available so that all vehicles in all circumstances and locations can be safely supported, and to avoid the dangerous use of timbers or other unsuitable materials or practises to extend the height of vehicle stands.

Like all other load carrying equipment, stands ought to undergo an inspection regime and be tagged safe for use as shown in Figure 18.

Lifting jacks - making the vehicle fundamentally stable

Vehicle Lifting Jacks

What is the Hazard?

One of the key maintenance tools is the vehicle jack. A number of fatalities have occurred because incorrect jacks or lifting practises were used – jacks of insufficient safe working load (SWL) can fail with the vehicle falling onto tyre service personnel resulting in serious injury or death.

Control - Vehicle Lifting Jacks

Because of possible in the field tyre changes, jacks generally must be short enough to fit under the vehicle/support point. Lifting using other means, e.g. using a front end loader and its loader bucket is unsafe, and must not be done.

All jacks must be inspected prior to use, and of sufficient SWL to support the vehicle; support dollies must be shaped to safely support and engage the vehicle axles without slipping.

Caution must be applied that the recommended type and number of extension dollies are used to ensure maximum stability while the vehicle is lifted.

Figure 18 – Engineered and tested vehicle stands, note the SWL on the stand

Consideration must be given what sort of jack is being used; for instance, a bottle jack requires the person to position himself under the shadow/under the equipment making him vulnerable to a number of hazards while placing, raising, lowering and retrieval of the jack. One of the fatalities mentioned earlier most likely occurred when the operator performing the tyre change was lowering or retrieving the bottle jack from under the vehicle [6].

Where possible, lift and lock type jacks should be used which eliminate the requirement to use a separate vehicle support stand. Unless lift and lock jacks are used, jacking and supporting of vehicle must done in conjunction with suitable vehicle stands, supporting a vehicle using a jack alone must not be done.

To avoid working under the vehicle, it is recommended that trolley jacks are used with a long enough handle so that the jack can be placed and operated well away for the vehicle. Examples are shown in Figure 19 and Figure 20.

All vehicles must be supported under the OEM recommended support points, supporting the vehicle in other (non OEM nominated) points may lead to the vehicle slipping off its jack/support injuring or killing the tyre service personnel.

Figure 19 – Trolley jack – note the difficulty with placement under the vehicle

Figure 20 - Extendable trolley jack, there are no manual task issues with safely placing the jack under the vehicle compared to the previous scenario

Alternative vehicle jacking and support points

What is the Hazard?

Where jack placement under the vehicle axle is difficult, operators may seek to support the vehicle in another location e.g. the bogey chassis, as shown in Figure 21.

Should the vehicle slip off the jack, injury or death may occur to the tyre serviceperson.

Figure 21 – The axle is raised off the ground by supporting the bogey chassis. Note: this should only be done if the OEM nominates the chassis as a safe lifting/support point.

Figure 22 – Tyre inflation cage

Control

While this may be an option, alternative support points should only be used after consultation with the trailer OEM.

Inflation tools

Inflation cage

What is the Hazard?

Tyres that have burst during inflation have injured and killed bystanders.

Control

Tyre inflation should be detailed in the site's procedures and occur in an engineered and certified tyre-inflation cage with inflation controls mounted to the outside, or remotely to the cage.

Where inflation in a cage is not practicable (e.g. on vehicle pressure adjustment) the tyre-inflation equipment should enable the tyre-service personnel to stand well clear and to the side of the tyre, controlling the inflation through a remote shutoff valve and pressure-gauge attachment.

Figure 23 – Inflation Line

Figure 24 – Inflation trolley

As shown in Figure 23, an inflation lead should consist of the attachment chuck (quick detach type), minimum 3 m inflation lead, an in-line filter, valving to control the airflow and calibrated pressure gauge. Consideration should also be given how to dump air quickly from the inflation hose and attached tyre assembly.

Inflation could further be assisted through custom-made trolleys carrying the inflation equipment and other tools such as shown in Figure 24.

Master pressure gauge, handheld gauges

Any tyre pressure gauge used on site should be crosschecked for accuracy against a master pressure gauge.

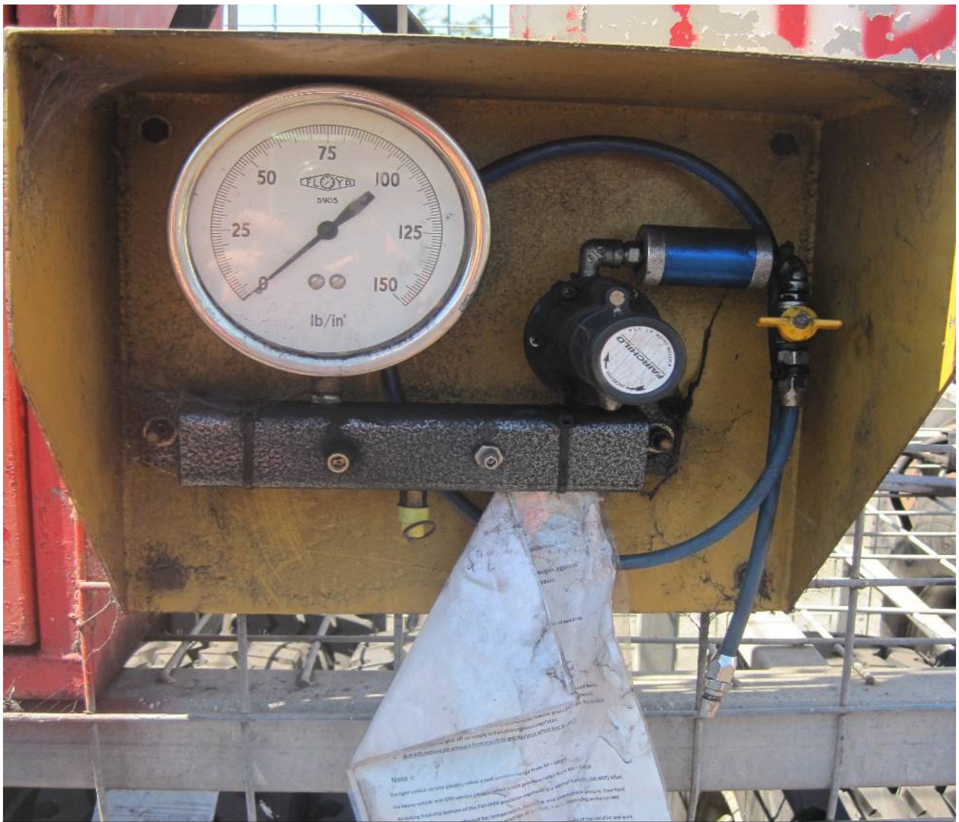

Figure 25 - Master pressure gauge

Handheld gauges must be checked against the master pressure gauge before each use, and check readings recorded. Faulty gauges must be replaced.

Tyre Pressure monitoring systems on board, in cabin, in tyre
What is the Hazard?

A tyres inflation pressure can be compared to a persons blood pressure - too high or too low blood pressure flags certain health conditions and if untreated can result in illness or death of the person.

Similarly incorrect tyre inflation pressure will reduce tyre life and may trigger unsafe conditions during the operation of the vehicle, e.g. tyres may burst or become hot resulting in a tyre fire. Unseen to the eye, underinflated radial tyres will also suffer structural damage which may make them unsafe should they be repaired and reintroduced into service. So called ‘zipper failures’ have injured and killed people, as was the case in the last Qld tyre related fatality.

Figure 27 - Automated pressure monitoring system, and valve stem securing system

Figure 26– on wheel pressure monitoring system

Control
Monitoring tyre pressures and taking corrective action is paramount in ensuring tyre safety.

To reduce the amount of time taken, several pressure monitoring systems had been installed at the mines to assist operators and tyre servicemen with this task.

One system used a small gauge like display connecting both valve extensions. This system also serves to equalise the pressure between the inner and out tyre.

Another tyre pressure monitoring system used screw on pressure measurement transmitters and an in-cabin display enabling the operator to remotely check pressures on all positions. This system works by continuously monitoring the air pressure on a tyre and wirelessly transmitting data through RF signals from large bore valve-stem mounted tyre pressure sensors to a digital display mounted in the cab of the equipment.

Compressor Facility

What is the hazard?
Tyres that are not correctly inflated will suffer higher wear or can result in hazardous tyre conditions such as tyre bursts and hot tyres that have resulted in fatalities.

Control
To ensure all tyres are inflated to the correct recommended inflation pressure, the mine site including any field maintenance vehicles must be equipped with compressor facilities that will deliver the required air pressure, and necessary flow volume. These facilities should be equipped also water drainage take-offs to ensure inflation air is dry.

Selection of new tyres into service

What is the Hazard?

The key to safe tyre performance is the correct selection of tyres. In consultation with the tyre manufacturer, it is vital to choose tyres that suit the operating conditions at the mine. Incorrect selection of the tyre for the intended haulage duty will not only result in premature tyre failure, but will also give rise to a number of unsafe tyre conditions that could result in injury and death of tyre service personnel and operators alike.

Control

The safe operation envelope of the tyre in terms of payload and vehicle speed must be established through weight and cycle time studies. Mine road conditions, gradients and curves, particularly for semitrailer type applications, must also be considered in the selection process.

Vehicle tyres must not be operated outside of those tyre payload and allowable speed recommendations — exceeding these will create unsafe tyre conditions, such as heating and/or mechanical degradation of the tyre.

Introduction of other tyres must invoke the sites change management process with particular considerations of the capabilities of the new tyre.

Repaired tyres

What is the Hazard?

Repair of tyres and use of repaired tyres is common in the haulage industry.

The safety alert describing the 2011 fatality quotes …*Investigation of the fatality described above found the driver had followed the set procedure. The almost new tyre / wheel assembly was taken from the rack, fitted to the axle, pressurised and the lifting jack lowered. The (fatigued) tyre then ruptured in a typical 'zipper failure'; a radial cord breaks overloading the two adjacent cords, which then break and so on. Air blast from sudden ruptures may injure people, or as in this case, prove fatal.*

Importantly the alert goes on …

It is likely the 'almost new' replacement tyre had previously operated at low pressure. It had a puncture repair indicating it had probably been 'run flat'. The Zipper rupture will occur at the place where the plies have been weakened the most and is independent of the puncture repair location

Control

The re-introduction of repaired tyres must be effectively managed through the sites 'management of change' process and should only be done in consultation with tyre specialists before such tyres are introduced into the operation - importantly, previous service and repair history must be known to ensure safety integrity of the tyre. Each tyre must be inspected by a competent tyre specialist that can assess the integrity of the tyre.

If any doubt as to the tyre history, tyres should not be repaired to avoid introduction of potentially unsafe tyres into the fleet.

Such tyres should be bundled up and disposed off as per sites policy (ref Figure 13).

Such tyres must not be sold offsite to re-enter the supply chain elsewhere.

Figure 28 – Zipper failure

Safe Work Practises

What is the Hazard?

Figure 29 - Nertney Wheel – safe work practises

Most tyre maintenance involves dealing with compressed air, inflating tyres or handling inflated assemblies, in a range of workplace settings. The potential energy contained in a tyre assembly is considerable and one of the key hazards of tyre maintenance, see Figure 3.

The uncontrolled release of the inflation pressure has injured and killed a number of tyre service personnel and operators. It is therefore critical that all work practises and documented procedures consider effective controls dealing with inflation pressure management.

While inflation pressure is the driving energy agent, assembly failures can also be induced through other mechanisms such as damaged or fatigued rim/wheel components, and corresponding LTA operational controls and work procedures.

Minimum concepts are described below:

Control

Work procedures To comply with the legislative requirement to ensure that risk to workers is at an acceptable level, the mines safety and health management system (SHMS) must ensure that any maintenance activity involving tyre and rim assemblies are appropriately captured in risk based site specific work procedures, and are carried out only by authorised personnel competent in approved training programs.

Figure 31 Unique rim identification number on a non-earthmoving wheel

As highlighted by the two safety alerts quoted earlier, particular emphasis must be given to deflation and pressure reduction of tyre and rim assemblies in accordance with AS4457:1 2007.

Figure 30 – Unique rim identification number on a non-earthmoving wheel

The disintegration of pressurised tyre and rim assemblies is often the main mechanism of fatalities to tyre servicemen, typical root causes and prevention include:

All rims undergo punishing dynamic loading cycles during their operation that can result in metal fatigue and general deterioration of the assembly. The combination of compromised rim integrity, through fatigue or damage of components, and failure to deflate the tyre prior to removing the assembly has led to several fatalities. At one of the mines, a piece of rim shrapnel shown in Figure 32 was found, this suggests either accidental or accumulated fatigue damage of the rim or wheel involved.

While not explicitly stated for non-earthmover equipment, implementation of a reliable non-destructive testing regime to identify fatigue and other deterioration in rims and rim components, and deflation protocol, as detailed in AS4457:1 2007 should also be incorporated into the sites SHMS. This includes stamping of rims such as shown in Figure 31 and Figure 30.

Mismatch and subsequent disintegration of rim components has led to several deaths.

Figure 32 – Piece of shrapnel from a disintegrating wheel or rim

Clear and unique identification of rim components must be achieved to minimise incorrect assembly of components that can lead to compromised rim integrity.

Similarly, it is also necessary to check the integrity of light vehicle rim systems including sprung lockring systems and 'split rims' fitted to personnel carriers, site ambulances and other non earthmoving equipment.

Damage and material fatigue of tyres – the maintenance management system ought to ensure that tyre wear and condition are assessed regularly by competent tyre service personnel so that safe use criteria as specified by tyre manufacturers are not compromised. Individual branding of tyres as shown in Figure 33 could assist in establishing 'operating hours' of any tyre.

Inflation pressure management

What is the Hazard?

As described in a previous section, tyre pressure management is vital to the safety of all tyres. Under or over inflated tyres will result in premature tyre failures, and will give rise to unsafe conditions, such as tyre bursts or hot tyres. Underinflated tyres carry the risk of creating dangerous 'zipper' type' failures on reinflation'

Control

To ensure all tyres are in a safe and serviceable condition, and inflated to recommended pressure, sites must have a system for checking, adjusting and recording of tyre pressures.

Where tyres are mounted as duals, the inner valve stem must be easily accessible so that pressure readings can be obtained for analysis. If inside tyre pressures cannot be checked, underinflated or run flat tyres are not detected which could introduce serious safety issues. Also, it follows that the outside tyre will carry more load creating other tyre performance issues.

Tyres must always be inflated to the manufacturer's recommended inflation pressure because both under-inflation and over-inflation are dangerous.

As described, under-inflation in particular, will result in the weakening of a radial tyre's steel belting structure causing the tyre to burst violently. This failure mode is known as a zipper failure (refer Figure 28), characterised by its zipper-like appearance across the broken steel cords. AS4457.1 - 2007, while written for earthmover tyres suggests that any tyre found with less than 70% of its cold inflation pressure should be removed from service, as 'reinflation may result in a serious or dangerous occurrence' (ref AS4457.1- 2007, Appendix A2, initial action).

Correct tyre pressures can only be achieved by using high-quality tyre pressure inflation gauges that are calibrated and systematically crosschecked against a calibrated master gauge before use (refer Figure 25).

The practise of using a small hammer to tap a tyre cannot be recommended as a reliable means of verifying that tyres are inflated correctly.

The frequency of pressure checks needs to be decided based on haulage severity and tyre damage occurrence, but should take place at least weekly. The condition of each tyre assembly should be visually assessed after each load - in a well designed well lit checking station, allowing the operator good walk around safety including good lighting as shown in Figure 38.

Record Keeping

What is the Hazard?

Records allow the analysis of say tyre inflation pressure. If records are not kept and analysed/used then the opportunity to intervene and remedy unsafe situations is lost. Also, records must be kept as part of a documented SHMS.

Figure 33 – Individual 'branding' with site specific identification number

Control

If tyre pressures are recorded and analysed systematically, leaking or damaged tyres can be readily identified and removed before they become a hazard. Tyres with slow leaks for instance can be identified and removed (permanently) from service.

This process should also serve to check ready accessibility to the inner valve stem, and therefore pressure readings of the inner positions. Ideally all pressure readings are time stamped, record vehicle details, individual wheel positions, tyre and rim serial or branded numbers (refer Figure 30 Figure 31, Figure 33,) and details of the person taking the records.

Also, it is important to check the actual process of pressure check and recording, the author is aware of some instances where pressure record sheets are completed without a physical check actually having been conducted. This highly unsafe practise becomes apparent when the same pressure reading is entered for every wheel position.

Selection of wheels/rims and mounting systems

What is the Hazard?

Mines should be aware that some tyre assembly vehicle attachment designs deliver greater safety while undergoing tyre maintenance.

For instance dual mounted tyre/rim assemblies where both rims are held in place with a set of cleats require extra caution during maintenance. Before assemblies are to be removed, both tyres must be fully deflated. The removal of pressure in both assemblies prevents the outer tyre/rim assembly being violently pushed off the hub onto the tyre serviceman (often with fatal results) should the inside rim be cracked or structurally unsound.

Control

A much higher level of safety can be obtained through the introduction of wheels (not rims) where the assembly is attached to the hub using independent studs and nuts.

Discussion at one of the mines also highlighted significant improvements through the introduction of a tyre/wheel combination specifically designed for the more severe duty cycles on some non-earthmover equipment with the principal benefit in reduced tyre damage

Safe and Competent People

What is the Hazard?

In most situations hands-on tyre change tasks are done by the truck operators themselves. Increased frequency of tyre maintenance combined with possibly inadequate levels of skilling in tyre maintenance puts operators at increased risk from tyre related mishaps and accidents during the tyre change process

Figure 34 - Nertney Wheel – Competent people

Control

Training and refresher training for onsite tyre servicemen and line supervision is required and should only be provided by registered training organisations experienced in tyre and rim maintenance using approved training packages i.e. RIISAM210A Remove and fit wheel assemblies, and/or RIISAM211A Remove, repair and refit tyres and tubes (refer [10]).

Providers of tyre and rim maintenance and service to the minerals industry offsite ought to be trained to the same standard i.e. RIISAM210A Remove and fit wheel assemblies, and/or RIISAM211A Remove, repair and refit tyres and tubes.

Non-mine personnel, such as operators and maintenance personnel (e.g. fitters) who work on and around mobile equipment, should also receive awareness training in basic tyre hazards from an experienced provider, as their work is often in the direct vicinity of equipment-mounted tyres. Training and education for this group of people should focus on identifying tyre and rim hazards and taking precautions.

Working Environment

What is the Hazard?

Less than adequate (LTA) road design and maintenance practises will shorten tyre life and give rise to a variety of serious safety issues, e.g. hot tyres, tyre damage, tyre burst etc., on site.

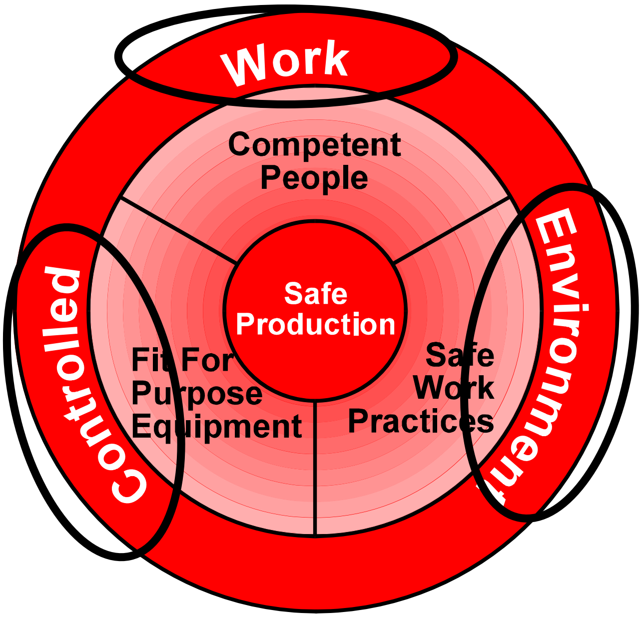

Figure 35 - Nertney Wheel – Controlled work environment

Control

Road maintenance and road surfacing

Road design including selection of road surface materials should follow established engineering practises and standards.

Road maintenance – removal of spillage, grading and watering must be in place to ensure a fit for purpose road surface. Roadside delineation must be installed and maintained so that all vehicles are guided and remain on the road and do not drift off onto the shoulders where rocks could cause tyre damage.

Dump loop and dump station layout

Traffic in and out of dumping stations should minimise loaded travel through bends and corners. Ideally loaded trucks should proceed straight into any dumpstation, tip and then return to their loading area through a wide loop. This not only reduces tyre wear, but also reduces that chance of vehicle rollover. During the site visits it was observed that some loaded trucks were required to travel through loops and corners to reach the dump stations.

Regular dump station inspections should be carried out to ensure that underfloor conditions are free of cut hazards such as steel plates or other damaged steel work, refer Figure 36.

Once a truck has delivered its load, or completed its duty, all wheel positions ought to be inspected by the trained operator. Ideally this is done in purpose designed and built inspection stations, refer Figure 37.

Suitable lighting must be supplied to assist with a thorough inspection, refer Figure 38 .

Figure 36 - A well maintained dumpstation is free of tyre damaging conditions such as loose steel-work or rocks

Figure 37 – Vehicle, tyre and rim checking station - note the use of the wheel chocks.

Figure 38 – Vehicle, tyre and rim checking station – note solar lighting

Maintenance facilities

What is the Hazard?

Any maintenance including tyre maintenance carried out away or outside of designated (tyre) maintenance facilities exposes the persons involved to a number of safety and health hazards - exposure to sun and often high temperatures increases the risk of heatstroke, uneven ground gives rise to slip and trips, and may cause instability of jacked/raised vehicles.

Control

Dedicated fit for purpose workshop facilities such as shown in Figure 39 should be provided to allow workmen to work under cover, with required tooling and services readily available. Conditions should be that jacks and stands can safely be used; ideally the facility offers a full length concrete floor.

Operation of tyres outside their specification

What is the hazard?

Operation of a tyre outside its design envelope must be avoided. Driving above the recommended speed and operating above the payload recommendation will cause tyre damage and create unsafe tyre conditions

Figure 39 – Dedicated fit for purpose tyre maintenance facilities /workshop

Control

A number of electronic 'surveillance' systems such as shown in Figure 40 were identified that alert the vehicle operator as well as supervisors of unsafe driving practises. Combined with payload controls this will reduce the likelihood that tyres are operated outside their design envelope.

Figure 40 – electronic vehicle surveillance system display screen

The Future - Design Improvements/Suggestions for Safer Raising of Vehicles

One of the key tasks in tyre maintenance is the safe jacking and support of the vehicle.

While long handled trolley jacks or lift and lock jacks are recommended, actual design improvements on the vehicle itself or the tyre bay environment could be considered.

Self Jacking Vehicle

Vehicle self jacking systems could include built-in pneumatic or hydraulic jacks to raise the vehicle chassis; however discussions with one trailer manufacturer raised some concerns over the placement of these. Ideally, each axle required its own jacks, and considerable jack / ram travel may be required to overcome the sag of the suspension system. Installation of such a system may also incur weight penalties and would add to the maintenance load of any mine site.

External Jacking Points

At one mine site, a trolley jack was used to lift the trailer chassis frame itself to allow removal of wheel assemblies (refer Figure 21).

Additional external jacking points, i.e. jacking points external to the underside of the chassis might be an option to eliminate the requirement for personnel to enter or go under the footprint of vehicle. Discussions with one trailer manufacturer highlighted that the chassis need to be raised a considerable distance to compensate for suspension sag – this could create issues of instability and damaging chassis twist and deformation.

As observed the practise cannot be recommended unless the jacking locations are confirmed as 'safe' by the trailer OEM. Furthermore, care needs to be taken in selecting a fit for purpose jack, given the considerable distance required to lift the chassis. The same would apply to the selection of a suitable fit for purpose (FFP) 'chassis' stand.

Tyrebay lifting/support systems

To eliminate exposure to people when placing jacks under any vehicle, tyrebay vehicle jacking and support systems may be an option. Envisaged is a flat jacking system, integrated into the floor of the tyre bay. To remove a wheel assembly, the vehicle would be driven into the tyrebay and stopped with the respective axle positioned over the jacking system. Once shutdown, chocked and isolated, the system could then be used to raise the axle.

For in field emergency tyre maintenance, the above system could be made portable for temporary installation at a dumpstation or similar.

Conclusion

Substantial improvements in tyre life and tyre safety can be achieved through a combination of sound management principles — based on dedicated inspections, preventive actions, good operating conditions, improved operator awareness and practices, and management of tyre performance.

Adopting such principles and implementing the recommendations contained in AS4457 Part 1 and 2 into a mine's SHMS — combined with effective communication with all stakeholders — will result in a safer workplace for all.

Research Team

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Recently submitted his PhD thesis covering safety and risk engineering aspects of earthmover tyres. Over 20 years experience in Australian mining industry, as engineer, supervisor and Superintendent of production and maintenance.

Substantial experience in developing programmes in Health & Safety, risk assessments, catastrophic risk management, operations and business improvement, training and quality assurance.

Part-time lecturer in Risk Analysis at the University of Queensland.

Two years as a research assistant at MISHC, and further 5 years as consultant with the last 4 years as Manager Global Risk & Business Improvement - Klinge & Co, a Brisbane based earthmover tyre and rim management business.

ACARP research project leader or contributor in a number of previous and current ACARP projects on tyre fires and explosions, establishment of TYREgate, ISOLgate, COLLISIONgate and currently ACARPs' landmark project 'RISKGATE'.

This project is an indirect continuation of several previous studies by the author around the issue of tyre usage and maintenance in the mining industry. These included:

1. C13049 - Tyre Fires and Explosions of Earthmover Tyres, published September 2004

2. C15046 - Tyre Related Accidents and Incidents - A Study with Recommendations to improve Tyre & Rim Maintenance and Operational Safety of Rubber Tyred Earthmover Equipment - published May 2007

3. C17032 - TYREgate: A “World First” Risk Management Decision Support Tool for Earthmover Tyres and Rims - published June 2009

Appendix 1 - Checklist

Non-Earthmover Tyre Maintenance Checklist (Note this list is indicative only)		Compiled by:		Date of Check	
Checkpoint	Prompt	Response	Required Action, effective control	Assigned to?	Action by?
Retention tags	Are they available, and are the used?				
Calibrated torque wrench or torque gun	Are they available and are they currently 'in calibration'?				
Torque charts	Are they available and do they cover all equipment?				
Inflation pressure charts	Are they available and do they cover all tyre/ types and equipment? Are the pressures OEM given/recommended pressures?				
Housekeeping - Tyre and rim racking	Are tyres and rims safely stored?				
Housekeeping - Consumable Storage	Are there sufficient consumables? Everything has a place and there is a place for everything.				
Tyre Maintenance Tooling – Vehicle support Stands	Are stands of sufficient SWL available for the different types of vehicles?				
Tyre and rim handling Equipment	Is it FFP, are users trained and authorised to use it?				
Wheel chocks	Are chocks available, do they suit the different tyre sizes?				
Vehicle Lifting Jacks	Are jacks of sufficient SWL available for the different types/weights of vehicles?				
Alternative vehicle jacking and support points	Confirm that only OEM nominated jacking points are used.				
Inflation tools – fit for purpose	Is there a FFP 3 m inflation tool in use, incl valving and pressure gauge? Is it used?				
Inflation cage	Is a cage available and is it used?				
Calibrated Master pressure gauge	Is there a master pressure gauge, is it in calibration and it is used to measure handheld gauges?				
Handheld pressure gauges	Are handheld pressure gauges checked against the master pressure gauge? Are records kept?				

Non-Earthmover Tyre Maintenance Checklist (Note this list is indicative only)		Compiled by:			Date of Check
Checkpoint	Prompt	Response	Required Action, effective control	Assigned to?	Action by?
Tyre Pressure monitoring – manual, systems on board, in cabin, in tyre etc	How are tyre pressure checks performed and how is the information recorded? How is the information analysed?				
Selection of new tyres, wheels, rims and mounting into service	What is the process used to select new tyres into the service? Are load/haul and weight studies performed? When purchasing equipment, do you consider wheel/rim attachment systems for safety?				
Selection of new tyres into service	Are OEM tyre factsheets and recommendations readily available, and how are the recommendations reflected in operations manuals, or tyre maintenance information e.g. pressure charts?				
Repaired tyres	How is the safe use of repaired tyres assured?				
Safe Work Practises	Are copies of AS4457:1 2007 Earthmoving Machinery – Off the road wheels, rims and tyres – Maintenance and repair Part 1: Wheel assemblies and rim assemblies readily available?				
Safe Work Practises	Is the standards content understood and applied, and incorporated into documented work procedures e.g. rim/wheel identification system, NDT testing etc.				
Safe Work Practises	Are copies of AS4457:2 2008 Earthmoving Machinery – Off the road wheels, rims and tyres – Maintenance and repair Part 2: Tyres readily available?				
Safe Work Practises	Are the standards content understood and applied, and incorporated into documented safe work procedures?				

Non-Earthmover Tyre Maintenance Checklist (Note this list is indicative only)		Compiled by:		Date of Check	
Checkpoint	Prompt	Response	Required Action, effective control	Assigned to?	Action by?
Safe Work Practises	Is the site specific tyre management plan based on a risk assessment? Is it available, how old it is and when was it reviewed? Are the controls effective?				
Safe Work Practises	Do you have a risk assessment based site specific tyre and rim procurement process? Is it available, how old it is and when was it due for review? Does it cover all tyres currently in use on site? Are the controls effective?				
Safe Work Practises	Do you have a risk assessment based site specific tyre removal and disposal process? Is it available, how old it is and when was it due for review? Does it cover the ain hazards of inflation pressure and lta rim integrity? Are the controls effective?				
Safe Work Practises	Do you have risk assessment based specific procedures dealing with Tyre and rim selection Management of repaired tyres Pressure maintenance regimes Tyre and rim identification Training requirements Are the suggested controls effective?				
Safe Work Practises	Do you have risk assessment based site specific work procedures? Do these procedures cover all equipment, and situations e.g. tyre maintenance away from the tyrebay (in field)? Are the controls effective?				

Non-Earthmover Tyre Maintenance Checklist (Note this list is indicative only)		Compiled by:		Date of Check	
Checkpoint	Prompt	Response	Required Action, effective control	Assigned to?	Action by?
Safe Work Practises	Do you have risk assessment based site specific work procedures dealing with deflation and pressure reduction of tyre and rim assemblies in accordance with AS4457:1 2007? Are the controls effective?				
Safe Work Practises	Have you considered, by risk assessment, non-destructive testing regime to identify fatigue and other deterioration in rims and rim components, of non earthmover equipment wheels and rims?				
Safe Work Practises	Have you considered, by risk assessment, clear and unique identification of rim components to minimise incorrect assembly of components that can lead to compromised rim integrity?				
Safe Work Practises	Have you considered, by risk assessment, how damage and material fatigue of tyres and rims are assessed? Are the controls effective?				
Safe Work Practises	Have you detailed tyre removal reasons, based on manufacturer recommendations? As part of these guidelines, have you considered at what pressure an underinflated tyre is to be removed from service?				
Safe Work Practises	Have you considered, by risk assessment, safe use criteria as specified by tyre manufacturers? Are the controls effective?				
Safe Work Practises	Have you considered, by risk assessment, Individual branding of tyres to assist in establishing 'operating hours' of any tyre? Are the controls effective?				

Non-Earthmover Tyre Maintenance Checklist (Note this list is indicative only)		Compiled by:			Date of Check
Checkpoint	Prompt	Response	Required Action, effective control	Assigned to?	Action by?
Inflation pressure management	Do you have risk assessment based Site specific work procedures dealing with inflation pressure management? Are the controls effective?				
Record Keeping	Is there an effective process in place to maintain tyre maintenance records? How are work requests scheduled and closed out effectively?				
Safe and Competent People	Are (all) your tyre service personnel trained to national competency standards?				
Safe and Competent People	How have you checked that providers of tyre and rim maintenance and service offsite are trained to the same standard i.e. RIISAM210A Remove and fit wheel assemblies, and/or RIISAM211A Remove, repair and refit tyres and tubes.				
Safe and Competent People	Is there an effective process in place ensuring that Non-mine personnel, such as operators and maintenance personnel (e.g. fitters) who work on and around mobile equipment are well aware of basic tyre hazards? Training and education for this group of people should focus on identifying tyre and rim hazards and taking appropriate safe actions.				
Working Environment - Road Maintenance and Road surfacing	Road design including selection of road surface materials should follow established engineering practises and standards.				
Dump loop and dump station layout	Is the layout tyre damaging or tyre friendly? How often are inspections carried out? Are the controls effective?				
Maintenance facilities	Are they fit for purpose and by design assist the safety of tyre service personnel? Are the controls effective?				

Non-Earthmover Tyre Maintenance Checklist (Note this list is indicative only)		Compiled by:			Date of Check
Checkpoint	Prompt	Response	Required Action, effective control	Assigned to?	Action by?
Design Improvements suggestions	External Jacking Points/ Homemade tools/stands etc – are these approved for safety?				

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