Review and Analysis of Tyre Related Accidents and Incidents – an ACARP[1] Study to Improve Tyre & Rim Maintenance and Operational Safety of Rubber Tyred Earthmover Equipment[2]

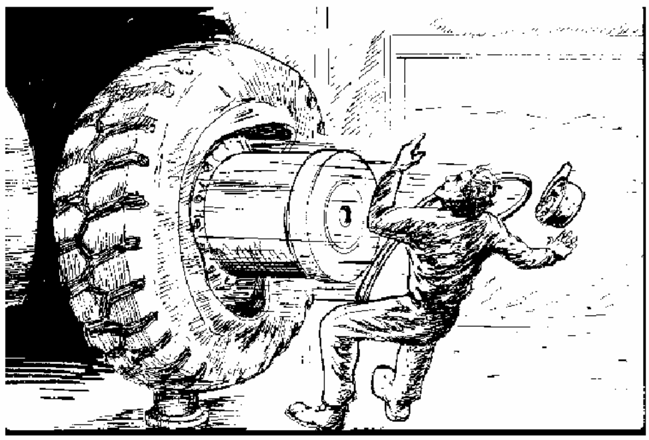
Tilman Rasche[3], & Tom Klinge

Klinge & Co.

Introduction

Earthmover tyre, rims and wheel assemblies are safety critical items which must be maintained and operated correctly to provide a safe working environment.

Unfortunately less than adequate (LTA) awareness of 'off the road' (OTR) tyre and rim related hazards, and lack of application of correct and proven approaches to deal with these hazards, in both the maintenance and operations areas continue to cause tyre and rim related accidents and incidents across the industry, some of them fatal as demonstrated by at least 6 fatalities in the Australasian region over the last few years (e.g. [4-7]). Even near misses, when properly assessed for their true risk potential can often be classified as 'high potential' events. Working with OTR tyres and rims has gained additional significance due to the global earthmover tyre shortage in that tyre owners and managers are required to consider not only higher frequency tyre maintenance (and therefore exposure to tyre and rim related hazards), but also use of 2nd hand, repaired or retreaded tyres, or tyres of untried performance which have created a new set of hazards unknown to most tyre servicemen.



Failure of rim/locking mechanisms during wheel maintenance is one of the highest cause of all tyre maintenance fatalities (sketch from [1])

There are also some fundamental differences between OTR and passenger type tyre assemblies that directly contribute to making working with OTR tyres and rims more hazardous than with any other tyre assembly type.

Apart from physical differences (OTR tyre and rim assemblies can weigh up to 7,400kg (63" tyre plus rim)), such assemblies are in the most part 'multi component' assemblies. As such they consist of the tyre, a rim or wheel base and its components - flange rings, bead seat band, O-ring, and lockring, while passenger and non OTR tyre assemblies are single piece, i.e. consist of a tyre mounted to a single piece rim. Attachment of the OTR assembly to the vehicle is either

[1] ACARP – Australian Coal Association Research Project – this report (C15046) will become available during 2007

[2] Klinge & Co was commissioned by ACARP in 2006 to carry out a comprehensive review of OTR tyre and rim incidents and accidents. The aim of the study was to provide a list of key hazards and recommendations to make work with tyres, and rims safer.

[3] Corresponding Author – Tilman Rasche, Mgr Global Risk & Business Improvement, tilman.rasche@klinge.com.au

achieved through wheel nuts/studs for tyre/wheel assemblies, or cleat type/wedges/ wheel nut systems for rim/ tyre assemblies. OTR rim manufacturers offer several designs all of which, as a critical attribute rely on the correct selection/ matching, fitment of all components in particular the 'lockring' and inflation to considerably higher inflation pressures compared to passenger tyres, to deliver the overall integrity of the assembly 'system'. Given the criticality of correct fitment, and the much higher inflation pressures, working with OTR rim/wheel assembly systems carries much higher risks than working with passenger and truck tyres where risks have largely been 'designed out' through the ongoing evolution and improvement to large volume production passenger and trucking vehicles .

These hazard characteristics and examination of the actual or potential injury outcome supports that OTR tyre and rim related work can result in a disproportionately high incidence, larger than 80% (ref Figure 1), of fatal or potential fatal outcomes for the personnel involved, requiring strict controls at the management and team level, and by the individual carrying out the task.

The risk of sustaining severe or fatal injuries is further amplified in that any damage to OTR tyres and rims can often not be readily identified, which if not observed/corrected, will result in a safety issue. Risks here do not only expose tyre maintenance personnel, but also operations personnel. Operation of a mining vehicle with incorrectly fitted or damaged OTR tyres and rims, and operations outside the tyres design operating envelope is extremely hazardous and will continue to cause incidents and high consequence accidents.

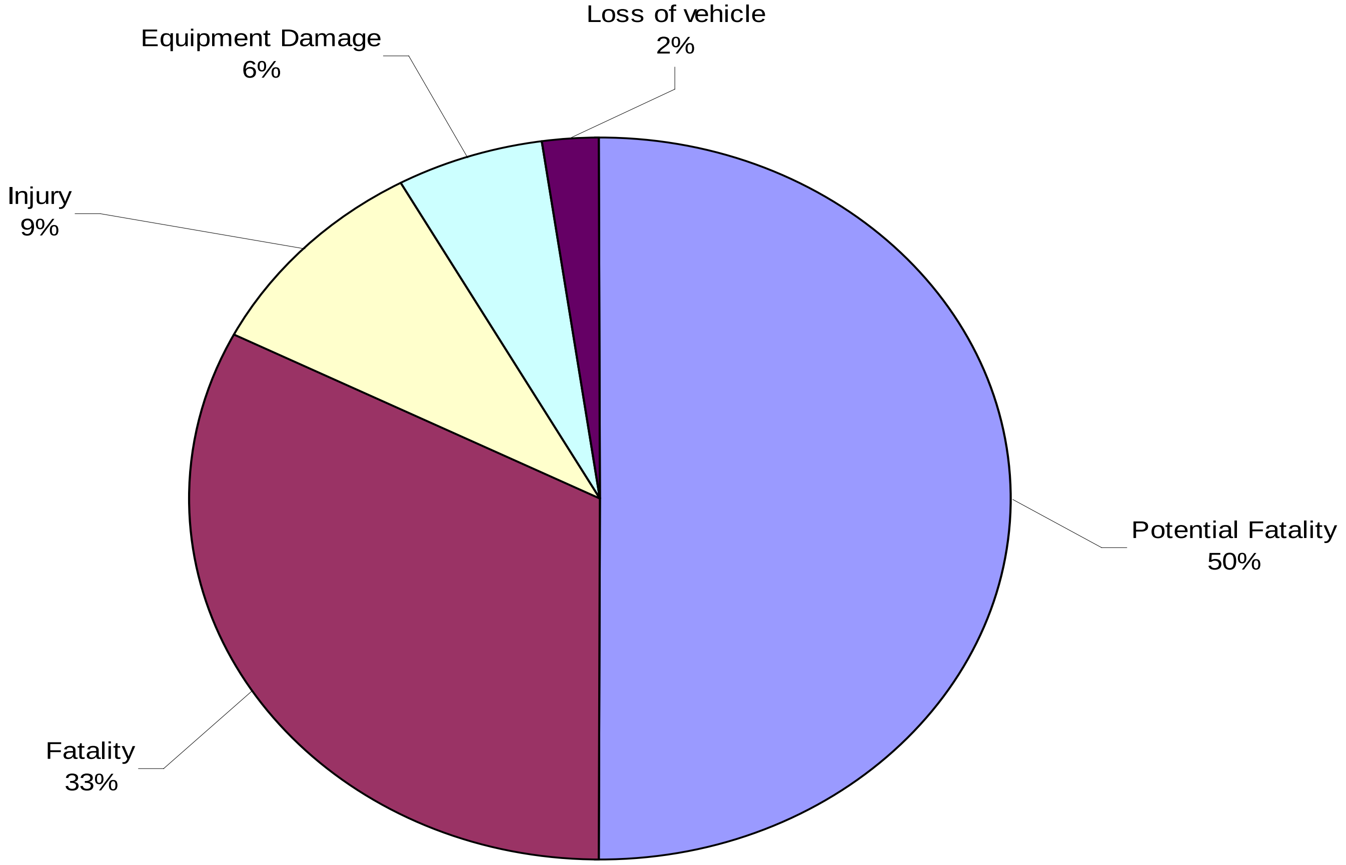
Findings & Recommendations

This review, based on the ICAM investigation methodology, covers 82 incident and accident reports available in the public domain[4].

As shown in Figure 1, 33% of all cases covered by this review resulted in the death of the tyre serviceman or personnel involved in the work. A further 50% of all incidents and accidents were classified as potential fatalities based on their similarity to other fatality cases. The combined percentage of 83% - actual and potential fatal outcomes - clearly suggests that working with tyres and rims in either a maintenance setting, or subsequent operational setting must be strictly controlled through a number of initiatives at a number of levels.

[4] The information was sourced from Queensland Government Department of Mines and Energy, Mineral Resources New South Wales, Department of Industry and Resources Western Australia , Department of Consumer and Employment Protection , Government of Western Australia, National Occupational Health and Safety Commission, conference and workshop publications, Klinge Safety Alerts (available from www.klinge.com.au), United States Department of Labour Mine Safety and Health Administration (MSHA), and Worksafe - British Columbia Canada

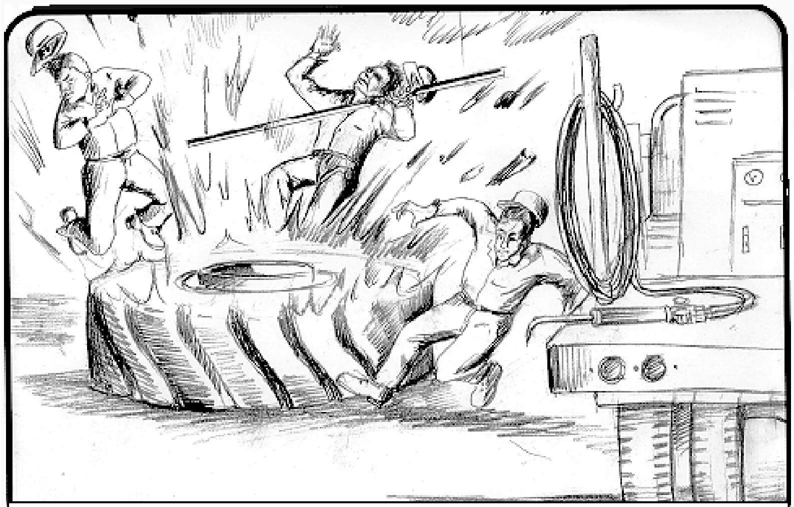
Figure 1 - Actual & Potential Consequences to Tyre & Rim related Incidents & Accidents



A further breakdown as to the underlying acts and conditions leading to the main consequence categories, fatalities and potential fatalities, is shown in the Paretogram in Figure 2.

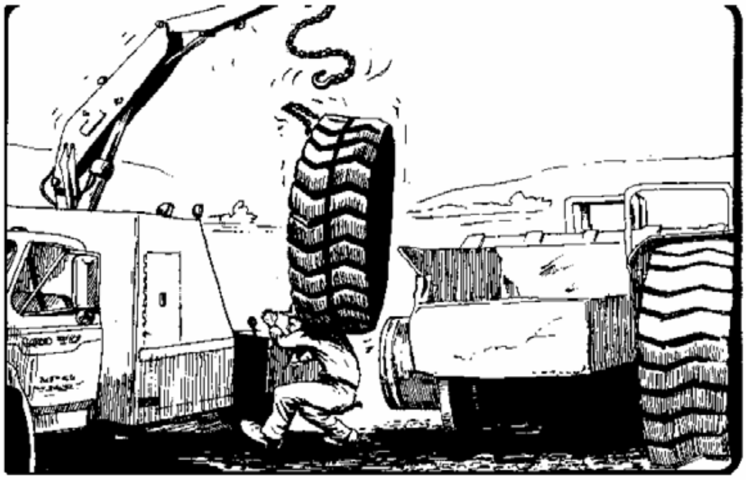
Fatality prevention initiatives must as a minimum cover the following:

- Absent or deficient rim and rim component testing allowing LTA rim integrity must be controlled through rigorous, systematic and reliable rim and rim components testing programs as stipulated by AS4457:1997. Failure to have such systems in place will allow the use of defective rims and rim components which when



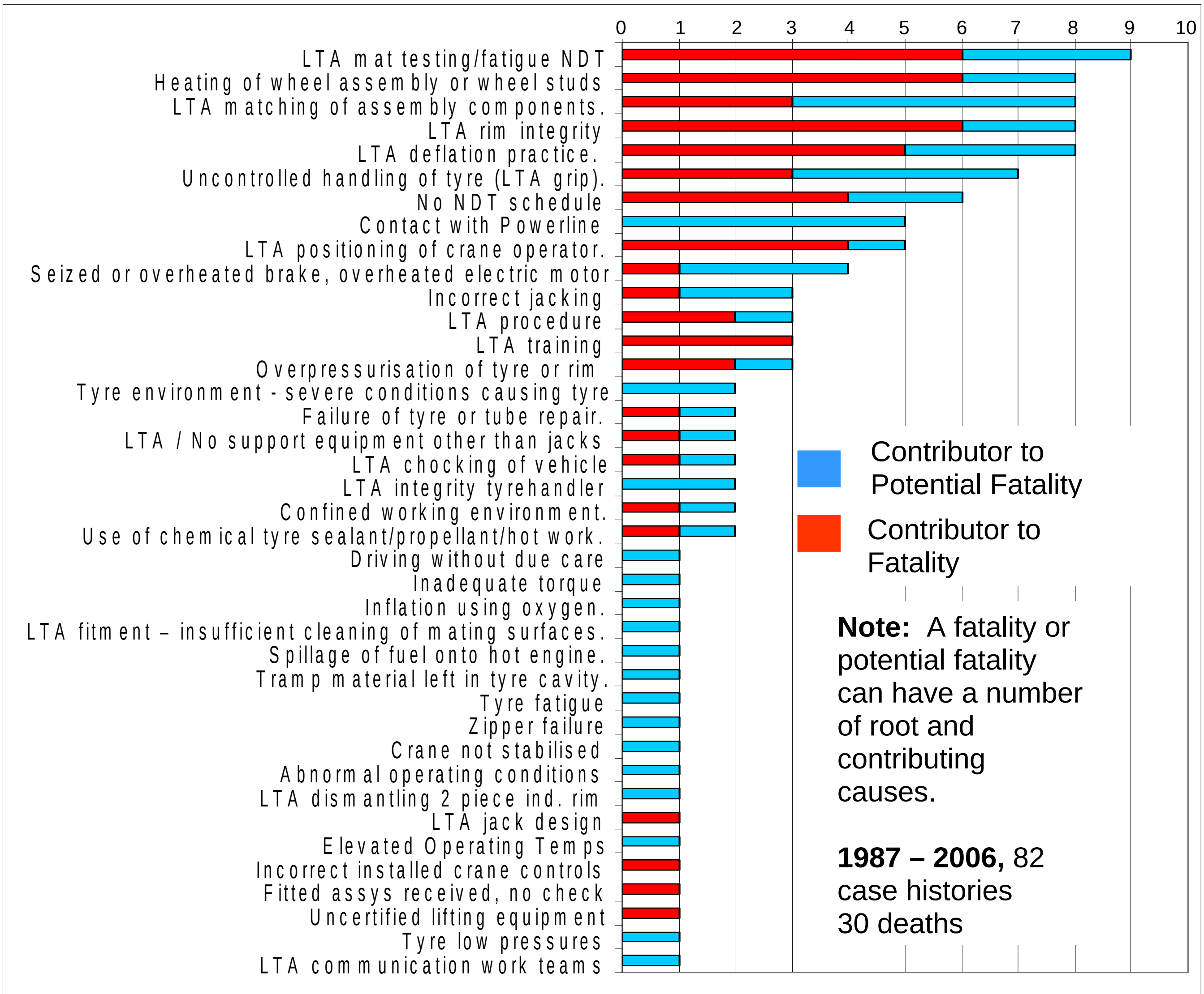
Heating of wheel fastening systems is a key root cause to many tyre and rim related fatalities. This work practise must be eliminated. Sketch from [3].

pressurised can fail dangerously at any time. Such management systems must ensure that the information is readily available at the work interface and personnel are aware of the need to accurately record, track and manage the service and NDT history of each rim base.



Handling of tyres and assemblies must be properly planned before the task is commenced. (sketch from [1]

Figure 2 – Fatalities & Potential Fatalities – Root & Contributing Causes



- Heating of fitted tyre / wheel assemblies using any heat source such as an oxyacetylene flame, to loosen tight or seized corroded wheel fastening system, i.e. nuts and studs, must be eliminated. Such heating may produce pyrolysis in the tyre chamber (even when fully deflated) which is known to escalate into a high energy and violent chemical explosion. Alternative safe methods to loosen wheel nuts or studs, e.g. using hydraulic tools must be sought. Analysis of the incident/accident data has shown that pyrolysis tyre events contribute 21% to the overall incident and accident count and is therefore one of the root sources of harm.
- Poor fitting practises resulting in the mismatching of rims, rim components and tyres will create assemblies that are unsafe and unpredictable throughout the lifecycle of the assembly, i.e. during assembly, inflation, fitment to the vehicle, operation, operational checking and maintenance, and removal. This can only be addressed by providing proven accredited tyre serviceman training and refresher training schemes. Better and more consistent industry wide rim and rim components identifications schemes should also be considered.
- Mandatory deflation/pressure reduction of tyre assemblies prior to removal off any vehicle, as required by AS4457:1997 must be in place, particularly when considering the high frequency of incidents involving LTA integrity of rims, and rim componentry. Both factors combined have caused several fatalities in the last few years in Australia.
- Handling of rims, tyres and fitted assemblies must be reviewed including the suitability and structural integrity of the handling equipment. This assessment must also include a review of operational practises which includes positioning of the person operating the tyre manipulator.
- Operational situations that may result in contact with powerlines must be eliminated. Similarly situations involving lighting strike to rubber tyres vehicles must be considered also and included in a review of vehicle operational and mines rescue practises. The review should also include other scenarios known to cause conditions conducive to tyre fires and pyrolysis events such as seized or overheating of brakes or wheel motors.

Accidental contact with overhead powerlines or electrification by lighting strike is known to cause pyrolysis and subsequent violent explosion of in some or all vehicle tyres. This hazard can be best eliminated by designing roads away from powerlines. (sketch from [2])

While the above highlight some specific actions towards the elimination of potential and actual fatalities, the report also provides other recommendations that will assist in providing underlying systems and processes enabling safe tyre and rim maintenance. These recommendations are ‘pitched’ at several stakeholders and will only have effect if actioned by each group.

At an industry level

1. The industry induction processes should include specific tyre and rim awareness sections that ensure that all personnel within the industry are made aware of the hazards at the beginning and throughout their employment within the mining industry.
2. Tyre awareness sessions, particularly during times of a global OTR tyre shortage should also be promoted through seminars, workshops and conferences.
3. Seek to continuously improve the level of registered training programs.
4. The 'Hierarchy of Control' methodology suggests that most effective safety improvements are best achieved through incorporation of safety features at the design stage.
    a. The design of most OTR rims and wheels in use across the world can be considered 'dated'. In view of the number of incidents and accidents directly associated with issues around rim design and some maintenance practises, designers and manufacturers ought to, as a priority, consider design changes that achieve the following:
        i. Longer rim and rim component fatigue life – this will reduce the exposure to fatigued rims and components.
        ii. Elimination of 'sprung' lockring systems that rely on the 'shape' of the lockring to provide the required integrity of the final assembly. The development of '2 piece lockring' systems appear to have overcome some of the inherent safety concerns associated with sprung lockrings.
        iii. Reduce or eliminate where possible the need to remove wheels/rims from vehicle hubs to effect tyre change, while this issue has successfully been resolved by the development of 'double gutter rim types' more mine sites need to take up this solution.
        iv. Design modifications that require the positive removal of the valve thereby achieving deflation of the assembly, and its dual, before a wheel can be physically removed.
    b. Tyre and rim manufacturers, and rim users ought to consider and implement a consistent Standard to identify rims and rim components which reduces the likelihood of unsafe mismatch. Ideally such guidelines are encapsulated in an International Standard.
    c. Tyre maintenance involves the frequent use of often heavy pneumatic tooling. Effects of whole body vibration on tyre servicemen, as a separate study group should be assessed and where required, tools producing safe levels of vibration should be designed.
    d. Several indents and accidents were caused through fatigue damage of structural components on tyre handlers and manipulators. A non destructive fatigue testing regime ought to be considered which reliably assesses each machine for fatigue damage. Such a regime should be provided as an International Standard and adopted by all owners and users of such equipment.
    e. Given the considerable number of incidents and accidents involving dropped tyres and assemblies, it is suggested to carry out a comprehensive review of all available tyre handler/manipulator designs aiming to improve handling and safety capabilities.
5. Introduce an annual review process of tyre and rim related incidents and accidents, with feedback to the industry. The ongoing data population and analysis ought to remain consistent with this study so that year to year performance changes and priorities can be established.

6. As a project initiative, encourage industry to report all tyre and rim related incidents and accidents, near misses and mishaps as well as operational damage, e.g. 'hot tyres' (as compared to tyre fires) , without exception for inclusion in this database.

At an organisational Level

1. General awareness of tyre and rims must be improved covering areas of maintenance, operations, technical and managerial alike. This should occur during the site induction, and periodically during the employment phase for every person.
2. As most incidents and accidents occur during tyre and rim maintenance, specific accredited training programs and refresher training delivered by registered training organisations (RTOs) must be provided to all personal involved in tyre and rim maintenance.
3. Similar training should also be offered to all supervisory staff to raise their understanding and hazard awareness.
4. Furthermore additional training packages must be tailored aimed at target groups such as operations and mine planning to cover other tyre and rim related aspects so that specific hazards are covered, understood and are addressed by each work group.
5. Implementation of reliable non destructive testing regimes for rims and rim componentry in accordance with relevant standards, such as AS4457:1997 – Earth-moving machinery – Off-highway rims and wheels- Maintenance and repair, must be achieved. These regimes must be backed through reliable rim tracking and reporting systems, ideally electronic, that can provide instant feedback on rim fatigue levels and testing status.
6. Furthermore, these NDT regimes should also include all structural components of tyre manipulating equipment.
7. Workable mine haulage design and operational standards that provide tyre friendly operating conditions must be created.
8. Provision and ongoing maintenance of written vehicle specific safe work procedures that cover safety critical tasks such as isolation, chocking, jacking (incl. supporting) of the vehicle), deflation and safe tyre manipulation practises must be in place.
9. Regularly test the sites emergency preparedness in case of tyre and rim related incidents.

At a maintenance management level

A number of specific maintenance practises must be provided by the tyre and rim maintenance management systems including:

1. Use of heat to loosen wheel fastening systems must be eliminated.
2. Deflation and pressure reduction of tyre/rim assemblies before removal off the vehicle as required by AS4457:1997.
3. Maintenance and upkeep of a reliable NDT testing regime ensuring the ongoing structural integrity of the rim and rim component asset, and tyre manipulation equipment. This must ensure ongoing recording and reporting of NDT status so fatigued rims and rim components do not remain in service.
4. Reliable matching of tyres and rims, and their components to ensure total integrity of final assemblies.

5. Preventative maintenance to eliminate occurrence of hot brakes, or overheating wheel motors must be implemented.

At an operations management level:

1. General awareness of tyre and rims must be provided to all operators, supervisors, and management personnel.
2. Specifically, operational training must be given that provides guidance on tyre friendly operating practises, and on safe actions and protocols required during tyre and rim emergency situations.
3. Mine haulage design standards must be used to provide tyre friendly operations conditions at all times.

Conclusion

The analysis of available incident and accident data has flagged a number of unsafe acts and conditions that must be controlled to effectively guard against the considerable hazard potential presented by working with tyres and rims. Control of these hazards in many instances will continue to rely heavily on the person or team carrying out the work. As the reliance on people presents a recognised vulnerability in terms of 'hierarchy of control', additional industry wide, organisational and departmental safeguards such as recognised training and hardware orientated protocols e.g. NDT regimes must be put in place and managed as a high priority to create highest levels of competency and provide the necessary rigour and support to systematically control tyre and rim maintenance hazards.

The most effective and most reliable safety improvements however can only be achieved by rim and tyre/rim handling equipment manufacturers actively seeking intrinsically safer designs. The review has highlighted that concerted design and hardware improvements aimed at delivering higher levels of rim assembly integrity and better maintainability could drastically reduce the toll of potential and actual fatalities.

Klinge would like to thank ACARP for their support towards this important project.

References

1. *U.S. Department of Labor, Tire and Rim Safety Awareness Program, in Instruction Guide Series, MSHA IG 60. 1996, U.S. Department of Labor, Mine Safety and Health Administration National Mine Health and Safety Academy.*
2. *Worksafe BC, Tire explodes when truck contacts overhead powerline, WorkSafe British Columbia.*
3. *United States Department of Labor Mine Safety and Health Administration, Metal and Nonmetal Mine Safety and Health Accident Investigation Report Surface Nonmetal Mine (Limestone) Fatal Explosion of Vessel Under Pressure Hunter Plant Colorado Materials Incorporated New Braunfels, Comal County, Texas I.D. No. 41-03430 April 22, 1998. 1998.*
4. *Mineral Resources New South Wales, Safety Alert - Queensland fatality - Prime Mover Rim Assembly Failure. 2005.*
5. *Queensland Government Natural Resources and Mines, Safety Alert No.136 Fatal Injury to Prime Mover Operator as Rim Assembly Fails. 2002.*
6. *Mineral Resources New South Wales, Safety Alert - Operator Killed Changing Tyre. 2004.*
7. *Mineral Resources New South Wales, Queensland Fatality During Wheel Removal. 2004.*

***