



MINIMISING THE FREQUENCY AND IMPACT OF TYRE FIRES AND EXPLOSIONS



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ABSTRACT

While the frequency of tyre explosions has decreased, there is still sufficient risk to personnel and other assets that occurrence minimisation and hazard management remains important to all mine sites.

Tyre fires are still prevalent and procedures must be installed to deal with them in an efficient and safe manner.

The use of nitrogen as a tyre inflation gas has merit in certain applications, but its use needs to be considered in light of expense and other difficulties.

INTRODUCTION

This paper will review means of reducing the occurrences of tyre fires and explosions and also strategies to minimise their impact.

The WA Mines Department, BHP Iron Ore and Otraco held a seminar on tyre fires and explosions in 1987 at Newman in Western Australia. Parties involved with the seminar believed it was necessary because of the then recent number of serious fires and explosions. The seminar covered, in depth, analysis of specific cases, including speculation of the probable causes and the mechanisms contributing to explosions.

Otraco has done much pioneering work in determining the mechanisms involved in tyre explosions, but discussions with tyre manufacturers indicate that there is little additional research being done to conclusively determine the mechanisms involved. The reason given is the reduction in explosions, and the reasons for this will be covered.

This paper will focus mainly on open pit mines, but many concepts can be transferred to underground mines.

PROPOSAL FOR INDUSTRY STANDARDISATION

All mines develop a common set of parameters for dealing with tyre fires and explosions. Such parameters would include, but not be limited to, values such as:

- Quarantine period
- Standoff distance
- Suitable fire fighting techniques
- Acceptable temperatures in tyres after the occurrence.

This would assist greatly by improving consistency of industry training and work practices between mine sites.



HISTORY OF TYRE FIRES AND EXPLOSIONS

A list of explosions¹ is presented as an attachment to this paper. Tyre fires occur with a frequency too great to report.

To determine the frequency of occurrences in recent times, we contacted the government bodies responsible for investigating these incidents. We found that they had very little information other than what we already knew.

Otraco is currently working on sites in many different parts of the world, and we are in contact with a large number of mines. The lack of occurrences is also in line with our own experience.

We believe the reason for the reduction in events is due to

- For heat related explosions, the saviour has been better awareness of the dangers of welding on or near rims.
- Better site management. For electrification, sites have reduced the possibility of contact with high tension power lines, and the use of circuit breakers and earth leakage devices.
- Different equipment on the mines. All truck designs are mature. Large diesel powered shovels have also replaced many electric drive shovels, such that some sites run without any electric powered equipment.

The reduction in occurrences has also occurred with an ever increasing population of earthmover equipment. Therefore, the industry in general should be applauded for its actions in this field.

¹ This is not an exhaustive list.



DEFINITION OF TERMS FOR THIS PAPER

AUTO-IGNITION

The self-ignition or spontaneous combustion of a substance (usually a fuel) without the help of a spark or flame. With compounds like carbon black, styrene and butadiene, which can be produced in a tyre when heated, the temperature required is around 430°C.

ELECTRIFICATION

The state whereby a piece of equipment has come into contact with an external source of electricity and the piece of plant is providing an earthing path for the current.

FLASH POINT

The temperature at which a substance (usually a fuel) ignites when a test flame is applied under standardised conditions. This is the yardstick by which fuels are classified for safety in storage and handling.

PYROLYSIS:

The decomposition of a substance by heat (usually in the absence of air). In a tyre liner this will commence at about 250°C, and will produce volatile chemicals like carbon black, styrene and butadiene.

TYRE BURST

The destruction of a tyre's pressure retaining capabilities by excessive internal pressures not caused by a chemical explosion. Tyre bursts occur by over inflation² and rock impacts. The pressure retaining capabilities may be reduced by fatigue or other physical damage.

TYRE FIRE

Tyre fires that occur through any means, including the application of external heat or flame such as a vehicular oil fire that burns tyres as collateral damage.

TYRE EXPLOSION

A **chemical** explosion that produces instantaneous pressures inside the tyre up to around 7000kPa. The tyre explodes because its pressure retaining capabilities are destroyed. This tyre of failure causes a sudden and potentially lethal release of extreme internal pressures. Usually associated with such an explosion is an air blast which is capable of killing people, and debris such as pieces of tyre carcass and rim components being propelled large distances with significant velocities.

² Over inflation can be caused by overheating due to separations or running flat.



A TYRE'S STRUCTURAL STRENGTH

A tyre is essentially a flexible pressure vessel to contain the gas required to support the load. It operates at about the same pressure that of the receiver of your shop compressor. However, unlike the shop receiver, which just sits there year after year³, miners subject a tyre to all sorts of abuse, like trying to put rocks through its walls, overloading it and overheating it.

Try overloading a shop receiver by a significant amount, chain it to the back of a dump truck and drag it over rocks and bumps and humps all day, and see how many fitters would feel happy about being next to it during all this abuse.

One point that is often overlooked, is the potential for the maximum strength of the tyre to be significantly reduced before the explosion occurs. A new carcass may have a burst pressure of around 4500 kPa, but a damaged tyre may have the burst pressure reduced to 1000 kPa⁴ or less. This may be caused by fatigue, damage sustained to the tyre in normal operation, such as a casing repair, overloading or running over rocks, or the tyre may have been exposed to excess heat.



Figure 1 - An exploded tyre

³ This is metaphorical, as we realise it must undergo strict tests and inspections.

⁴ See Case Study on Tyre Burst.



WAYS OF INITIATING TYRE FIRES AND EXPLOSIONS

Non Electrical Heat source

- External: The tyre components, particularly the inner liner, are heated by means such as:
 1. Welding on or near the rim base.
 2. Heat being applied to the rim base from a nearby source, such as dragging brakes and or overheating wheel motors
 3. A fire starting at another part of the vehicle.
- Internal: Heat generated within the structure of a tyre, caused by events like tyre separations.

Electrification

Electrification has two usual causes,

- Collision with high voltage power lines, such as those used to power mine equipment and
- Lightning, which can be in the order of millions of volts

Comments On Electrification Explosion Mechanism

The root cause of any electrification event is the high voltage from the source finding its way to the lower potential (zero) by travelling to earth.

In most cases it seems likely that a path of least resistance for the earthing current will be from the rim to the bead section of tyre liner. The current would then travel from the bead area to the crown area directly above the tread/ground contact patch, and then arcing through the casing material and tread rubber to ground.

There have been instances where it has been postulated that the current path was from the rim arcing across to the bead bundle, along the steel body cords to a point directly above the tread/ground contact patch, and then arcing through the tread rubber to the ground. Other evidence indicates on some tyres the current moved along the tyre liner and then through the rubber to the ground.

Paths may have different electrical conductivity, depending on the operating environment. For example, the conductivity at the liner of a dry tyre filled with nitrogen should be significantly less than a tyre filled with compressed air⁵ or one that has tyre sealant inside.

The arcing occurs instantly, but the pyrolysis can progress at a varying rates, sometimes very slowly. This means fires/explosions may happen instantaneously or after many minutes or hours.

⁵ Unless specifically removed with water traps, compressed air will have some water vapour in it.



WAYS OF MINIMISING TYRE FIRES AND EXPLOSIONS

Heat source

Welding :

Welding on, or near, a rim base with an attached tyre is a very dangerous occupation.

It is not safe to weld on a rim base, or to apply heat near a rim base, even if the tyre has been deflated to zero pressure.

We mentioned above that a new tyre's burst pressure is in the vicinity of 4500 kPa and the chemical explosion inside a tyre can produce pressures in the vicinity of 7000kPa. For the carcass to burst, the pressure must exceed the 4500 kPa limit. We know from experience that an explosion inside a tyre WILL cause pressures to rise this high and beyond. Therefore, the inflation pressure of 700 kPa in the tyre is insignificant in the total scheme of things.

An explosion inside a tyre is capable of raising the pressures in a flat tyre by the 4500 kPa needed to burst it.

The only way to safely weld on a rim base is to strip the tyre from the rim.

Other external heat

Good mechanical maintenance, and driver training and feedback, is also important in minimising the likely occurrence of dragging brakes, overheating wheel motors and fires occurring by a fuel coming into contact with a heat source.

Internal⁶

By internal heat source we mean heat generated by operating the tyre.

Running the tyre flat is the most common cause.

Overloading the tyre through excess weight and/or speed can also generate excess heat. Normal operating conditions can also cause overloading if the tyre specification is incorrect for the application. To reduce the effects of heat on a tyre, many operations are using electronic despatching systems⁷ to route trucks on alternative loads, eg two long fast loads - six short loads.

⁶ This is a rare occurrence, but Otraco know of at least four occurrences over the last 10 years.

⁷ Systems include Modular Mining and Wenco.



Electrification

There are two contingencies that should be considered.

The active prevention contingency, obviously, is to ensure that the equipment does not come into contact with the powerlines. However, it is impractical to provide clearance for a truck with an extended tray. Therefore, operator training is very important.

The passive prevention contingency is to provide a system that will eliminate the danger of accidental contact. Systems that provide this type of protection include earth leakage protection and circuit breakers. In order to be effective, these systems must also be maintained.

For lightning strikes, the best way of avoiding them is to know what all golfers know. A 1 iron should be securely fastened, in a vertical position, to a front corner of the vehicle's body. This will ensure the vehicle is not struck by lightning because even God has trouble hitting a 1 iron.

Earthing cables

One suggestion has been to use earthing cables on the vehicle to provide a safe path for the current. However, because of the variability of where on the vehicle electrification may occur, we believe it is difficult to predict the outcome of earthing straps. To our knowledge no one has conducted conclusive test to determine the effectiveness of such a system

Keep oil in tyres to a minimum.

Oil is a fuel and its presence in a tyre is potentially dangerous.

Prevent oil build up in the tyre by :

- Eliminating, or minimising, the use of oil based tyre lubricants.
- Draining compressor receivers⁸ on a regular basis.
- Maintaining compressors to ensuring the rings do not allow excess oil into the receiver.
- Maintain all filters on air delivery systems to ensure optimum performance.

⁸ On mobile and shop compressors.



Fire Suppression Systems.

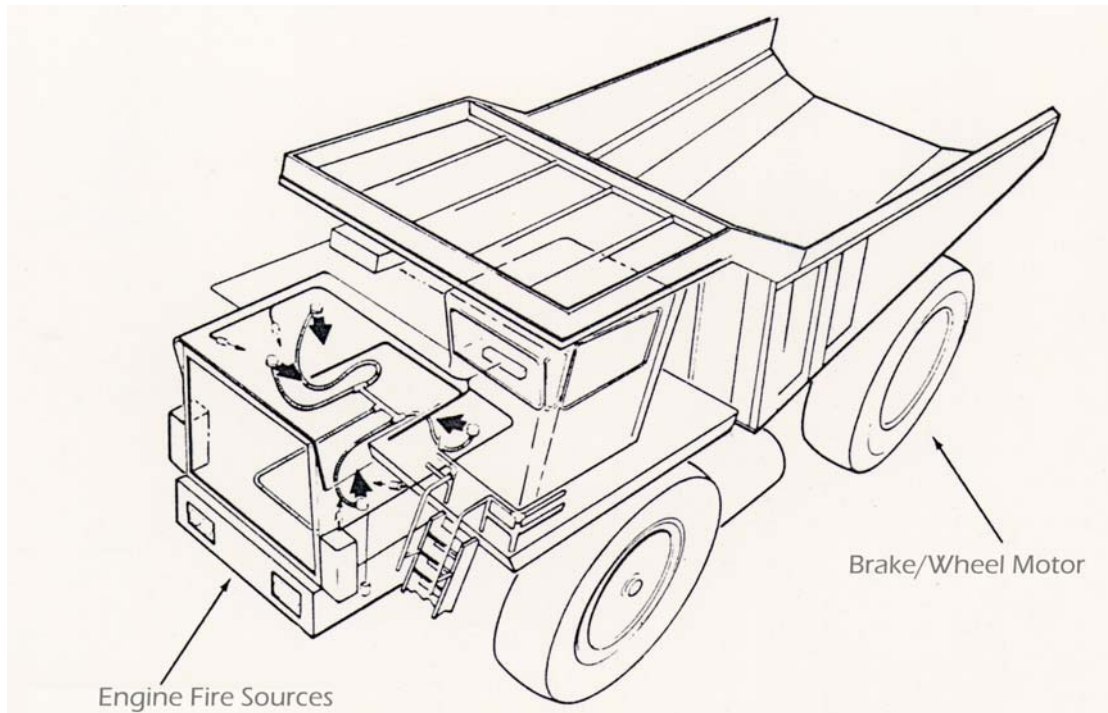


Figure 2 Areas of a haul truck most likely to generate heat.

Most fires on a piece of equipment are serious. Therefore, any system of extinguishing fires has the potential of saving property and lives.

The effectiveness of fire suppression systems have been tested by various organisations. However, Otraco is not expert in this area, and we suggest that interested parties should speak to suppliers for more details.

Solid Tyres (only suitable for smaller tyres in specific applications)

The general description of solid tyres covers product such as segmented tyres, eg Air Boss, to foam filled and solid rubber tyres.

While not suitable for the majority of applications solid tyres will obviously stop all possibilities of explosions.

Other benefits of this tyre type are the reduction in downtime due to punctures and other damage.



NITROGEN AS A TYRE INFLATION MEDIUM

There is still substantial discussion about the benefits of nitrogen for inflating earthmover tyres.

The implied benefits are:

1. Elimination of fires/explosions inside tyres through the lack of sufficient concentrations of oxygen.
2. Reduction/elimination of corrosion of the rim components.
3. Reduction of leakage through the liner, and
4. Tyres running cooler

Elimination of fires/explosions inside tyres through the lack of sufficient concentrations of oxygen

The oxygen content of air is 21%. Less than 5.5%⁹ oxygen will *not* support combustion. Therefore, by using suitable tyre inflation procedures the concentration of oxygen can be lowered to the appropriate safe level.

This may be an overriding criteria for nitrogen use in tyres operating in hazardous environments, such as underground mines.

Reduction/elimination of corrosion of rim components

Oxygen promotes corrosion in metals. Therefore the elimination of oxygen also means corrosion will be eliminated.

If corrosion is the only problem to be solved, other means such as tyre sealants with corrosion inhibitor are equally as effective, and they also prevent some leaks and give indications of where tyres are leaking.

Because of the purity of nitrogen itself, and the reduction in oxidation of the rim components, users should expect virtually no problems with blocked/leaking valves or lines¹⁰.

Tyres running cooler

Otraco has been involved with heat tests comparing tyres running nitrogen and air, and has not found any measurable difference between the two substances. This finding is also supported by one tyre company¹¹ that ran controlled tests.

⁹ There is conjecture as to the actual amount. Some sources say 7% is the minimum concentration.

¹⁰ Most dust in a tyre is there from fitment. A liquid tyre sealant will reduce valve blockage.

¹¹ Bridgestone.



Reduction of leakage through the liner

The permeability¹² of air through a tyre is about 10.6 units and that of nitrogen about 7.2 units. This indicates that nitrogen does in fact reduce the amount of seepage through the liner. However, proper pressure maintenance techniques should obviate the need to rely on the slower dissipation of nitrogen.

It has also been stated that nitrogen will also reduce ageing of the tyre. Most tyres are used relatively quickly, therefore this factor may be of limited value.

The risks of using nitrogen include:

- Having a tyre inflation source that has a delivery capacity of 15,000 kPa. As tyre inflation pressures are normally in the region of 600 kPa to 800kPa, clipping on a chuck and leaving the tyre unattended can produce fatal consequences.
- Filling the tyre with oxygen. Both nitrogen and oxygen bottles and fittings have the same connector specifications. Therefore, an inexperienced fitter could fill the tyre with oxygen, thereby greatly increasing the risk of explosion instead of reducing it. This is unlikely, but still a possibility. One way to eliminate this possibility would be to change the fittings to a type that is unique to nitrogen equipment.

Cost of nitrogen use.

The following tables have been included for completeness only. All pricing should be checked with local suppliers.

Tyre Size	Typical Application	Volume (l)	G Fills¹³
55/80R57	994 class loader	7700	0.87
40.00R57	240 T truck	5600	1.19
50/80-57	994 class loader	5400	1.23
37.00R57	190 T truck	4900	1.36
36.00R57	170 T truck	4300	1.55
33.00R51	150 T truck	3400	1.96
45/65-45	992 class loader	2800	2.38
30.00-51	120 T truck	2700	2.47
27.00R49	85 T truck	2000	3.34

Package	Volume (m³)	Cost/m³
G Cylinder	6.68	\$11.21
E Cylinder	3.18	\$17.14
Cage (16)	106.8	\$6.31

¹² CIG presentation, Newman Seminar 1987.

¹³ One G cylinder provides 6.68m³ at 700kPa and an E cylinder provides 3.18m³ at 700kPa at 25°C.



Other supply methods

For larger users of nitrogen it is possible to get supplies in liquid form and also to produce nitrogen on site, eg with a PSA plant.

The economics of these methods should be discussed with local suppliers.

Inflation procedures with nitrogen

When inflating a tyre with nitrogen it is essential the oxygen level in the tyre is below 5.5 percent by volume (otherwise combustion could occur following, for example, a tyre fire). If unsure about the oxygen level in a tyre it may be checked with an oxygen meter.

If the nitrogen flow rate is too slow to seat the beads of the tyre, initial bead seating must be done with compressed air. If, after seating the beads, the air inflated tyre is reduced to 0 psi gauge (ie. flat), the air seal may be broken (ie. the bead seat band could drop away from the o-ring).

If the air seal is broken, the tyre will require reinflation with a new o-ring but because the beads have already been seated, inflation with nitrogen (even with a slow flow rate) will be possible. If the air seal is frequently broken during the deflation process the tyre should not be fully deflated before being pumped up with nitrogen. If the air is not fully exhausted from the tyre, the nitrogen inflation pressure must be much higher or a double inflation procedure followed (see example below).

The single and double inflation procedures given below are examples only. ***Consult suppliers for suitable methods on your site.***

Single inflation example

If the tyre is inflated from 0 psi (gauge) to 70 psi with 98 percent nitrogen, the oxygen percent by volume will be 5.3%.

Because EM pressure gauges are not always accurate, to ensure the oxygen percent is 5.3% or below, the actual procedure to be followed is:

1. seat beads of tyre with nitrogen or air.
2. if beads were seated with air, remove valve core and fully deflate tyre (ie. reduce pressure to 0 psi). Check valve stem is not plugged by passing a piece of wire through it. If the air seal is broken during deflation, replace the o-ring.
3. inflate tyre with nitrogen to 80 psi.
4. adjust tyre to operating pressure.

Double inflation example

If a tyre inflated with air is inflated from 15 psi (gauge) to 70 psi with 98 percent nitrogen, deflated to 15 psi and then reinflated to 70 psi with nitrogen, the oxygen percent by volume will be 4.3%.

Once a tyre is inflated with nitrogen no oxygen must be introduced through "top ups" with compressed air. Otherwise the oxygen concentration may be raised above the combustion



threshold. *There must be a strict policy of adherence, otherwise the benefits of nitrogen in the tyre will be lost. It may also create a sense of safety, where one does not exist.*

Risk Analysis on nitrogen Fill

Professional risk study analysis on nitrogen fill undertaken following an earthmover tyre explosion on a minesite recommended against the use of nitrogen inflation because it would not prevent tyre explosions altogether. The study suggested that the elimination of conditions which could cause a pyrolysis type tyre fire or explosion is the better method to pursue.

There were two main recommendations arising from that risk analysis.

Temperature Sensing

The study recommended that individual temperature sensing and monitoring of each tyre in the haultruck fleet be undertaken. The information would be transmitted to a central monitoring area. In the event that the internal air temperature of a tyre increased beyond 10 to 15% of its normal operating temperature an alarm would be activated and the respective truck stopped. The reasons for the temperature exceeding normal levels could then be investigated.

Commercial systems are available that will measure tyre temperatures on a moving vehicle. However, they are mainly targeted at improving pressure maintenance, and are difficult to use as indicators of absolute temperatures as they have a "range" where nothing is reported. Because of the variations in ambients¹⁴ at sites, it is difficult to use these systems as definitive warning systems.

Risk Engineering Screening

Because many of the problems on the site where the study was undertaken were the result of truck design problems, the study also recommended that a risk engineering screening process be carried to investigate potential wheel type fire problems associated with truck design.

¹⁴ A change of 10° in ambient temperature can change internal tyre temperatures by anything from 3° to 6°.



Appendix 1 - GENERAL EMERGENCY PROCEDURES

Mine General

- Educate operators and supervisors on the potential dangers of tyre fires and explosions, and train them in procedures to follow if they occur.
- Ensure that adequate height is set for power lines during the design of pit electrical reticulation.

Emergency procedures

Set up formal emergency procedures to deal with a tyre fire, truck electrification or potential tyre explosion. Suggested draft procedures are provided below.

Define an isolation area that provides the following:

- Able to be secured to prevent unauthorised personnel coming closer than 200 m from the vehicle.
- Access for fire fighting equipment to manoeuvre around the vehicle
- Access to the front of the vehicle with a large vehicle if the driver must be evacuated.

Check procedures

Set out check procedures to be carried out following the truck isolation period in the event of a tyre explosion or a truck or tyre fire.

The main points relating to truck electrification are that:

- Currently, there is no way of knowing if or when an explosion will occur.
- There is a possibility that more than one tyre may explode (at different times).
- The truck should be directed to a designated isolation area.
- The fire officer should be notified immediately.
- Crowd control must be initiated immediately.
- Care must be exercised in removing the driver from the truck because of the danger of electrocution, and of injury from an explosion coincident with the driver being evacuated from the truck.
- The truck must remain isolated in a safe area for 24 hours.
- Road blocks must be set up, preferably no closer than 200 metres from the truck during the isolation period.

Check-procedures following isolation period

In the event of a tyre explosion or truck or tyre fire we recommend that certain procedures be carried out following the truck isolation period. These will assist in the analysis of causes and mechanisms.

At the expiry of the 24 hour isolation period, carry out the following procedures:



Tyre Pressure Check

The pressure (and preferably the internal air temperature¹⁵) of **each** of the intact tyres should be checked to determine whether the pressures are normal. In the event that any pressure is found to be more than 20 psi above the tyre's cold pressure setting or if the internal air temperature is more than 35°C above ambient, there should be an investigation to determine the probable reasons for this before releasing the truck from isolation.

Collect Air Samples

Ideally, samples of contained air from **each** of the intact tyres should be collected. The samples should be analysed for the presence of styrene, butadiene or other explosive gases.

Mark Tyre / Rim Position

Mark with paint the orientation of all tyres with respect to the rims on the truck. This may assist in the determination of explosion/failure mechanisms following examination of tyres and rims.

Before allowing the truck to return to work, carry out the following procedures:

Strip and examine tyres and rims

Each tyre should be stripped from its rim and examined for signs of pyrolysis or arcing of the inner liner and any other signs of heat (and in the case of electrification, the passage of electrical current). Rims should similarly be examined for signs of heat or electrical arcing. Deflation and stripping of the tyres will also ensure the dispersal of any explosive gases that may have formed in the tyres' air chamber.

Check all wheel bearings for signs of heat damage

Each wheel bearing should be examined for heat damage, signs of electrical arcing, etc. Bearings showing significant damage should be replaced.

¹⁵ Using a probe thermometer inserted into the valve stem after removing the valve core. A rubber grommet is required around the probe to regulate air flow from the valve until the temperature stabilises and can be read. Otraco has developed a special device for this purpose.



Appendix 2 - EXAMPLES OF STANDING ORDERS

A. WHEEL FIRES / TYRE FIRES

TRUCK DRIVERS

On becoming aware of an active wheel fire or tyre fire, the **Driver** will :

- Notify Production Control by radio immediately.
- Park-up as quickly as possible (in a designated area).
- Park the vehicle so that the water carts will have easy access to the affected wheel.
- Notify Production Control that the vehicle is parked and location of park-up.
- Shutdown the vehicle.
- Vacate the vehicle and remain with the Shift Supervisor or vacate to a safe area of at least 200 metres away ie. nearest road block.
- Not approach the affected wheel nor attempt to extinguish fire with portable extinguishers.

PRODUCTION

Based on current and predicted operations, **Production** will regularly identify and establish strategic 'park-up' areas to enable the immediate park-up and shutdown of any operating earthmover vehicle which is affected by a wheel fire, tyre fire, or vehicle electrification.

*Note : Each area should be sign posted 'EMERGENCY PARK-UP AREA'
The sign should be red background with luminous white lettering.*

In the event of being notified of a wheel fire or tyre fire **Production Control** will :

- Advise the driver of the nearest designated park-up area(s).
- Notify the Shift Supervisor of the situation.
- Notify the Fire Officer.
- Despatch the nearest water cart to the park-up area.
- Advise all plant and vehicles in the vicinity to keep at least 200 metres away from the vehicle.

In the event of a wheel/tyre fire, the **Supervisor** shall :

- If practicable, have the offending vehicle escorted to a designated park-up area.
- Establish adequate road blocks for the area (at a minimum distance of 200 metres for the park-up location). Prohibit all but essential personnel access to the area.
- Ensure the safety of the driver and that the park-up procedures and vehicle shutdown precautions are completed.
- Obtain specific particulars from the Truck Drivers in regard to time frames, strength of flames, heat, sparks and the amount of smoke from tyres etc.



- Assume control of fire fighting and/or cool down operations until the arrival of the Fire Officer.
- Arrange for the transfer of the vehicle to a more remote location (if necessary).
- Ensure that after extinguishment no personnel approach the vehicle for a 24 hour cool down period.

WATER CART DRIVER

- Provide a water service as requested by the Fire Officer.
- Shall back the 'water cart' in onto the affected wheel - at all times shielding the driver's cabin with the body of the truck.

FIRE OFFICER

The **Fire Officer** shall conduct an immediate inspection and assessment of the situation, ascertain the degree of risk and, in conjunction with the Supervisor, take appropriate action to further control the situation and establish safe conditions.

NOTE: Under emergency conditions, the **Supervisor** may direct that the vehicle be removed (driven) from the initial park-up area to a remote location to ensure full protection of personnel and property and to reduce the likelihood of extended disruption to production operations.



B. VEHICLE ELECTRIFICATION

WARNING: A tyre can explode at any moment after vehicle electrification.

TRUCK DRIVERS

On becoming aware of vehicle electrification (eg. from lightning, power lines), the **Driver** will :

- Notify Production Control by radio immediately.
- Park-up as quickly as possible (in a designated area).
- Park the vehicle so that the front can be accessed by a rescue vehicle.
- Notify Production Control that the vehicle is parked and location of park-up.
- Shutdown the vehicle.
- Remain in the vehicle until advised by the Supervisor that it is safe to vacate.

PRODUCTION

Based on current and predicted operations, **Production** will regularly identify and establish strategic 'park-up' areas to enable the immediate park-up and shutdown of any operating earthmover vehicle which is affected by a wheel fire, tyre fire, or vehicle electrification.

*Note : Each area should be sign posted 'EMERGENCY PARK-UP AREA'
The sign should be red background with luminous white lettering.*

In the event of being notified of a vehicle electrification **Production Control** will:

- Advise the driver of the nearest designated park-up area(s).
- Notify the Shift Supervisor of the situation.
- Despatch another truck (of same size/type) to the park-up area to possibly assist with evacuation of driver.
- Notify the Fire Officer.
- Despatch the nearest water cart to the park-up area.
- Advise all plant and vehicles in the vicinity to keep at least 200 metres away from the vehicle.

In the event of a vehicle electrification, the **Supervisor** shall :

- If practicable, have the offending vehicle escorted to a designated park-up area.
- Establish adequate road blocks for the area (at a minimum distance of 200 metres for the park-up location). Prohibit all but essential personnel access to the area.
- Ensure the safety of the driver and that the park-up procedures and vehicle shutdown precautions are completed. Make sure the source of electrification is removed.
- If possible, evacuate the driver safely, eg. by driving a rescue vehicle to the front of the offending vehicle. In the absence of this there are no universally safe guidelines.



While a tyre explosion risk exists, attempting to evacuate the vehicle via the ladder is extremely hazardous, and remaining in the vehicle cannot be guaranteed as safe.

- Obtain specific particulars from the Truck Drivers in regard to time frames, etc.
- Assume control of fire fighting and/or cool down operations (if necessary) until the arrival of the Fire Officer.
- Arrange for the safe transfer of the vehicle to a more remote location (if necessary).
- Ensure that after vehicle electrification no personnel approach the vehicle for a 24 hour cool down period.

RESCUE VEHICLE DRIVER

- Shall provide a driver rescue service as requested by the Supervisor.
- Shall approach the offending vehicle from the front - keeping the cab side away from the offending vehicle while maneuvering as close to it as possible.

WATER CART DRIVER

- Shall be available and ready in case a fire develops and then to provide a water service as requested by the Fire Officer.
- Shall back the 'water cart' in onto the affected wheel - at all times shielding the driver's cabin with the body of the truck.

FIRE OFFICER

The **Fire Officer** shall conduct an immediate inspection and assessment of the situation, ascertain the degree of risk and, in conjunction with the Supervisor, take appropriate action to further control the situation and establish safe conditions.



Appendix 3 - TYRE EXPLOSION CASE STUDY



Figure 1 - Truck after explosion

A Cat 785 haultruck (33.00R51) was carting material from the mine area to a rehabilitation area. While pulling away from the tip point with its body up, the truck contacted 33kv overhead power lines. The driver braked to a stop and was advised to remain in the cab because the truck was still in contact with the power lines. The front left tyre exploded approximately 12 minutes later blowing the tyre and rim components off the truck, causing damage to the truck and minor injuries to the driver.

Examination

The exploded tyre was ruptured in the bead area of the outer sidewall (ie. the sidewall facing out from the truck); the bead bundle had completely sheared. There was no visible damage to the tread area or inner sidewall and bead. The inner liner was tacky from heat and a section of it had pyrolyzed. There was a small hole visible in the pyrolyzed zone. While the other five tyres appeared intact, the right rear tyre had a similar small hole in its liner.

The rim of the exploded tyre was extensively damaged. The truck suffered superficial damage mainly around and to the driver's cab. The left front wheel bearing showed signs of heat damage.



Conclusions

Otraco concluded that the tyre suffered a chemical explosion following the auto-ignition of a mixture of explosive gases which had been created by pyrolysis of a section of the tyre's rubber liner. The pyrolysis was initiated by electrical earthing of the tyre due to the truck contacting 33kv power lines.

Failure Mechanism

The failure mechanism of the exploded tyre was somewhat unusual in that the outer facing bead bundle was completely fractured by the force of the explosion, with the rupture appearing to originate in the bead area. Most earlier tyre explosions, for which Otraco has details, resulted in blow outs in the shoulder area at the edge of the circumferential steel tread breaker belts.

The bead bundle on this tyre is composed of twisted steel cable. One wire of approximately 1.8 mm diameter is wrapped a large number of times (in the order of 250) around a core strand of approximately 4.5 mm diameter. The bead bundle, which is 45 mm in diameter, appeared to have failed in tension with the strand ends exhibited cupping typical of this (tension) failure mechanism. There was no evidence of heat weakening of the steel strands nor of electrical arcing between the fractured ends of the bead bundle.

The force required to cause failure of the bead bundle would have been considerable and would have absorbed a significant amount of the total energy expended by the explosion. It appears likely that if the bead had not been fractured this energy could have been channelled into other areas, eg. additional damage to the truck, or expelling the tyre and rim components over even greater distances.

The point at which the bead fractured was adjacent to the area of liner pyrolysis (the most probable explosion initiation zone). This is also unusual when compared with most explosions where the point of blowout has been almost diametrically opposite the pyrolysis zone (point of initiation).

In those other cases it is hypothesised that the pressure wave moved in both directions around the air chamber away from the initiation point, meeting at a point diametrically opposite (180° from the initiation point) and causing the tyre to blow out at that point. In this case it appears that the two pressure waves met at a point opposite the area of initiation and then reflected secondary pressure waves. The pressure waves converged again near the point of initiation causing bead failure and major rupture in this area. The energy expended when the pressure waves first met may have been absorbed by the bead bundle and casing plies causing weakening of these components immediately prior to their catastrophic failure.



SEQUENCE OF EVENTS

A **33.00R51** tyre running on **Cat 785** haultruck exploded just before 1:00 pm on November 23, 1989 after contacting 33kv overhead power lines near a rehabilitation dumping area.

a. Lead-up to Explosion

The truck had been carting material from the mine area to the rehabilitation area outside the mine's perimeter fencing (refer to the accident map in Appendix I). The truck had just tipped its load and was moving away from the tip area with its body being lowered. The truck body snagged the **33kv overhead power lines**. The driver applied brakes bringing the truck to a standstill approximately 35 metres further on, straddling the power lines.

The driver was advised by the mining manager over the truck's two way radio to remain in the cab, thereby avoiding possible electrocution in the event that the power lines were still live (in fact it was later determined that pole fuses had cut power to two of the lines but not the third).

Approximately **twelve minutes after contact**, with the truck stationary and the driver still in the cab, the position 1 (left front) **tyre exploded** projecting the tyre off its rim and through a steel mesh perimeter fence bordering the road. The tyre landed some 7 metres from the truck while rim components (lock ring, bead seat band and outer flange) were hurled distances of up to 40 metres from the truck. A section of the tyre weighing several kilograms was thrown over 100 metres hitting a transportable hut.

The other five tyres (positions 2 to 6) remained inflated and apparently intact on the truck.

No serious injuries resulted. The truck driver was cut by broken glass. Three observers - the mining manager, a watertruck driver and a dump spotter - were shaken by the explosion.

The spotter later reported having seen sparks emanating from the position 5 or 6 (right rear) tyres. This reportedly occurred after the truck had braked to a standstill but before the explosion.

b. Aftermath to Explosion

The truck driver remained in the truck's cab on instruction from the mining manager until power was cut to the one remaining live wire. The truck was then isolated for a period of approximately 24 hours to avoid injury in the event that another tyre exploded.

Following the isolation period tyre pressures on the remaining tyres were checked and found to be within a few psi of the normal cold settings (100 psi front, 105 psi rear).

A replacement tyre and rim was fitted in situ to position 1 of the truck. The truck was then driven to the workshop for repairs. While in the workshop all tyres were removed for examination.



EXAMINATION

a. Tyres

The tyres that had been running on the truck were the same. Tyre pressures on positions 2 to 6 were checked after the 24 hour isolation period following the explosion and found to be within a few psi of normal cold pressure settings (100 psi front, 105 psi rear). When stripped from their rims all of these tyres still contained some of the liquid sealant¹⁶ that is routinely added to earthmover tyres on site when they are first mounted.

Position 1 Tyre (tyre that exploded)

The majority of tyre damage was sustained by the outer¹⁷ bead and sidewall area. The tyre's tread area, and inner sidewall and bead suffered no external damage. The outer bead bundle (twisted steel cable of approximately 45 mm diameter) was completely sheared. Several large sections of the tyre's bead and adjacent sidewall had been blown outwards, hinging about the tyre's shoulder line but most remaining attached to the body of the tyre. Two large sections (greater than 500 sq. cm surface area) of bead and lower sidewall, and numerous small pieces of liner, bead and sidewall material, were blown off the tyre.

Most of the tyre's inner liner showed evidence of surface heating, being either tacky to the touch or exhibiting a wrinkled texture. A 300 sq cm section of the outer liner layer¹⁸, approximately 1.5 mm thick, was missing (presumably pyrolyzed) from the crown of the liner. The exposed inner layer of the liner was in good condition showing no sign of heat degradation, apart from a small hole of approximately 6mm diameter and 1 mm depth which was apparently the result of electrical arcing. There was no evidence of arcing on the corresponding section of exterior tread crown, which had several small to medium sized rock cuts.

The zone of liner pyrolysis, which encompassed the arcing hole, was in the crown of the liner.

The tyre had an average 47 / 57 mm of tread remaining at the quarter points (42% worn), marginally more tread depth than the other front tyre but less than any of the rear tyres.

¹⁶ The sealant, Seal-A-Wheel, has been certified non-volatile by a chemical analyst.

¹⁷ That is the side of the tyre that was facing out from the truck.

¹⁸ The tyre liner is composed of two layers. The outer layer (bordering the tyre's air chamber) contains a greater proportion of synthetic rubber and is impermeable to air. The inner layer is composed mainly of natural rubber which, while not as impervious to air, acts as a bonding sheet between the outer layer and the tyre's casing material.

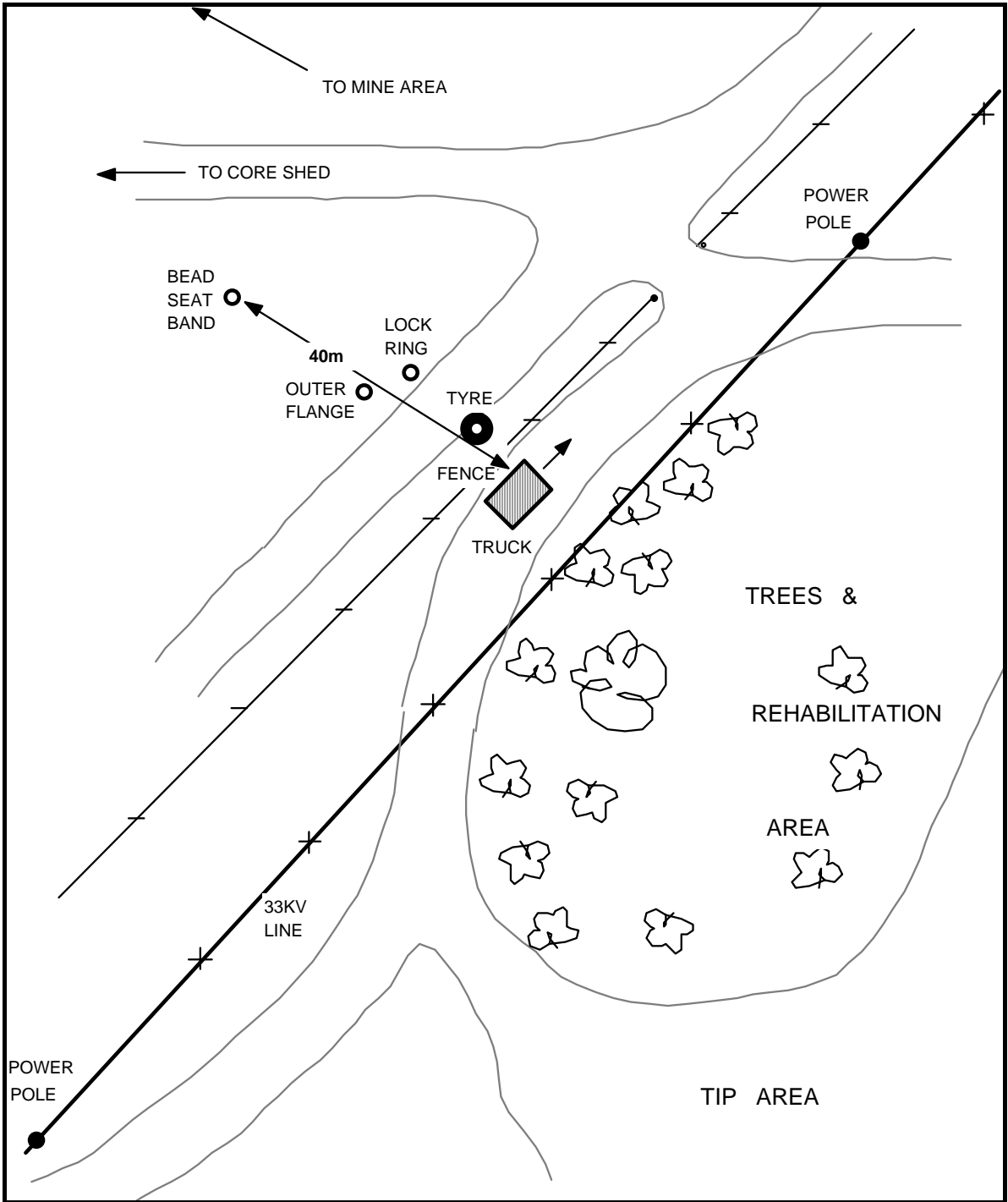


Figure 2 - Accident Location Map



Figure 3 - The Damaged Bead Area



Figure 4 - Internal of tyre showing pyrolyzed area and arcing point.

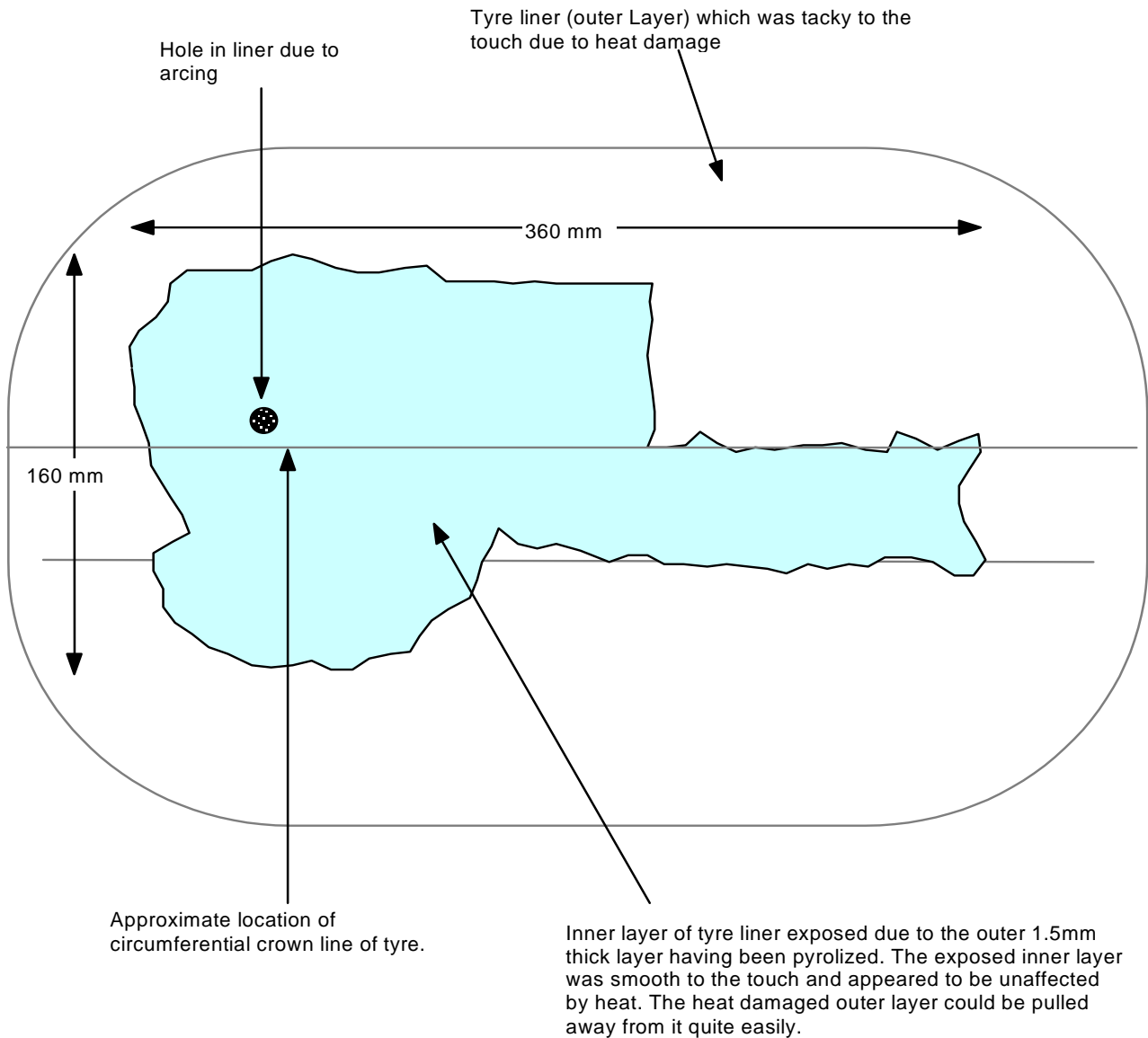


Figure 5 - Crown section of tyre liner Not to Scale

Other Position Tyres (see Figure 6)

The position 6 (right outside rear) tyre had a hole in the crown of the liner similar to the hole observed within the area of pyrolyzed liner of the tyre which had exploded. There was no tackiness around this hole nor any other sign of heat or damage inside the position 6 tyre. The corresponding section on the exterior of the tread had a medium sized rock cut. The tyre had an average 56 / 59 mm of tread remaining (31% worn).

Otraco found no internal damage or signs of heat on other position tyres¹⁹.

¹⁹ There was speculation that the pattern of underlying steel body cords visible on the liner of the position 3 tyre indicated that heating of the cords and/or liner had occurred. However Otraco observed similar patterns on the liners of other tyres removed from the truck and from other trucks. We conclude that this pattern imprint within the liner is a common manifestation of normal operation.



Figure 6 - Arcing hole on Position 6

b. Rims

The rims were original equipment of Goodyear (Motorwheel Corporation) manufacture, incorporating the Cat 785 specification wheel nave.

Position 1 Rim

The force of the tyre explosion had thrown the lock ring, bead seat band and outer flange (along with the tyre) off the rim base. The rim base remained attached to the wheel hub with the back flange remaining on the rim base. The back flange suffered circumferential cracking due to the truck falling onto it when the tyre was blown off. Damage of the other rim components was not as readily apparent. Because of the possibility of cracking, bending and other damage, Otraco recommended that the rim components be sent to Perth for metallurgical and dimensional testing.

In summary the report states that the rim base had a 10mm crack in the flash butt weld of the back lip section and that the nave was 1.2mm out of round. The back (inward facing) flange had a metre long circumferential crack. The front flange and bead seat band were twisted out of round by 20mm and 30mm respectively. The lock ring was sprung out of round as well. The report recommended scrapping the complete rim assembly.

Other Position Rims

The position 4 and 5 (inside rear) rims showed signs of heat where a circular patch of approximately 16 cm diameter around each valve hole (on the tyre side of the rim) was



void of paint. It is unknown if this resulted from electrification of the truck and subsequent arcing through the rims, or if it had occurred previously²⁰.

c. Truck

The truck suffered relatively minor damage. The driver's door, surrounding cab wall, driver side ladder, walkway, fuel tank and exterior fittings were damaged by those sections of tyre sidewall which were blasted outwards and around (hinging about the tyre's shoulder line). The driver's cab glass was shattered. There was minor damage to the position 1 (left front) wheel bearing due to the passage of high current, and to suspension components on this position.

From the indentations in the cab door and fuel tank, it was possible to establish the orientation of the tyre when it exploded.

CONCLUSIONS

a. Explosion Mechanism

Otraco concluded that the tyre suffered a chemical explosion following the auto-ignition of a mixture of explosive gases which had been created by pyrolysis of a section of the tyre's rubber liner. The pyrolysis was initiated by electrical earthing of the tyre due to the truck contacting 33kv power lines.

Detail

We hypothesize the following sequence of events:

1. When the truck contacted the power lines it became electrified (fuses cut power to two of the phase lines, however the third remained live).
2. Presumably, at that instant (although possibly later) there was a sufficient buildup of electrical potential to cause electrical earthing through the position 1 rim and tyre²¹. This resulted in electrical arcing from a point in the crown of the tyre's liner through the tyre's casing and tread to earth. The arcing caused the small hole in the tyre's liner. Similar earthing and arcing occurred in the position 6 tyre (although not necessarily at the same instant) producing a hole in its liner as well. While electrical earthing may have occurred through other tyres on the truck as well, no evidence of arcing was found in these tyres.
3. The arcing in position 1 generated sufficient heat to initiate pyrolysis of the liner (at approximately 250°C), giving off volatile gases including styrene and butadiene vapours²². This did not occur in the position 6 tyre, presumably because the flow of

²⁰ A number of original equipment rims had been subjected to welding and oxy-acetylene cutting by the truck supplier in an effort to install valve protector plates.

²¹ Presumably this path provided least electrical resistance, dependent on factors relating to (among others) wheel bearings, tyre tread depths and rock cuts, and ground contact pressures.

²² Based on analysis conducted following the 1981 Tasmanian tyre explosion (refer Appendix 5).



current was insufficient to generate the heat needed to initiate and sustain pyrolysis.

4. Approximately 12 minutes after the truck hit the power lines, the tyre exploded. Presumably, the two conditions necessary for an explosion prevailed at this time:
 - i. the formation of an explosive mixture of gases due to pyrolysis of a sufficiently large amount of liner material, and
 - ii. a buildup in hot spot temperature within the air chamber equal to or greater than the auto-ignition temperature of this explosive mixture (around 430°C).



Appendix 4 - TYRE BURST CASE STUDY (NOT EXPLOSION)

This is an extract from an Otraco report.

Incident Report

Eye witness reports state that the Wabco 120B truck was brought into the workshop at 1845 hours on 6 February 1989 with low pressure in the position 1 tyre. The tyre was found to have only 35 psi in it, and so inflation was commenced (using the workshop compressor which had a maximum output of approximately 105 psi). At 1910 hours the pressure was checked, found to be 70 psi, and so inflation was continued. At approximately 1915 hours a noise sounding like the truck creeping was heard, and then the tyre burst. The air blast threw three men in the vicinity to the ground, blew out the windows and damaged the door of an adjacent truck. It also threw pieces of rubber over an approximate radius of 30 metres.

Tyre Records: Pressure records show that this particular tyre had been approximately 30 psi underinflated on 3 February and 4 February 1989. The tyre had been inflated to the correct pressure on both occasions although no tyre sealant was available for addition to the tyre (see later for procedure for dealing with leaking tyres). Otraco commenced pressure checking at the mine on 3 February and so no records on this tyre are available prior to this.

The mine records show this tyre to have achieved approximately 2,800 hours.

INSPECTION OF THE TYRE

The tyre was inspected visually and sectioned. The following summarises the findings:

- The tyre was a 28% worn 30.00x51 52 ply bias ply.
- A large carcass fracture was present in the shoulder. This had occurred at the 4 o'clock position (at the time of failure).
- The only sign of external damage near the failure location was a small surface cut. This cut did not extend through to the carcass (ie. it extended through only part of the tread rubber).
- The tyre was sectioned through the sidewall at a point diametrically opposite the failure location. This showed an internal ply separation at approximately one third of the casing thickness in from the inner liner.
- The liner (which forms the sealed air chamber) was broken up considerably.
- There was no indication of pyrolysis (this is the decomposition of rubber by heat of at least 250°C). The ply layer under the liner and parts of the liner itself did, however, show signs of heat damage. The degree of heat damage was consistent with damage that is caused by temperatures much lower than the 250°C necessary for pyrolysis.
- The valve spud on the rim was slightly loose.



CAUSE OF FAILURE

The available pressure records show that the tyre had been running underinflated for at least three days. The ply separation and liner breakup is consistent with the type of damage caused by running a tyre underinflated.

The ply separation shows that the strength of the carcass had been severely weakened. A new tyre of this type is designed and built to have a typical safety factor such that the burst pressure is seven to eight times the maximum allowable base pressure (as defined by the Tyre and Rim Association Standards). This gives a burst pressure for a new 30.00x51 52 ply tyre of at least 600 psi. The underinflation had caused a ply separation and weakened the tyre so that the burst pressure had been reduced to approximately 70 psi. The act of inflating the tyre from 35 psi to 70 psi had been enough to burst the tyre. It failed in the lower half of the tyre because this area had additional stressing from the load of the truck. Failure through the 4 o'clock position indicates this particular location was slightly weaker than any other point in the lower half of the tyre. The cut in the vicinity of failure suggests some additional weakening may have occurred from external damage (eg. hitting a pothole). The heat damage in the liner and adjacent ply layer had been caused by heat generation from underinflation.

The failure was, thus, not a tyre explosion but rather a carcass burst. Tyre explosions require a temperature of at least 250°C at the liner to initiate pyrolysis (which generates explosive gases) and then approximately 430°C to ignite the gases. Such temperatures will only be generated by abnormal conditions such as tyre fires, brake/wheelmotor overheating, vehicle electrocution, or welding/heating on rims/hubs. The explosive pressures can be as high as 1000 psi which is sufficient to send truck and wheel components flying hundreds of metres. Clearly, forces of this magnitude were not present in this incident.

Because of the high rubber content in tyres they do not always fail instantaneously, unlike, for example, a brittle metal. This explains the truck creeping which was heard. The tyre would have expanded in the 4 o'clock region just prior to failure. This expansion would have been sufficient to cause the tread to squirm against the ground, so generating the reported noise.

PROBABILITY OF REOCCURRENCE

There is a strong likelihood that other tyres in the fleet have suffered casing strength reductions from being run underinflated. However, this type of incident is extremely rare. We know of only a few similar incidents in Australia during the last sixteen years. The probability of a tyre being weakened to the point where it doesn't fail in operation, but then fails as it is being inflated is low. Although there is an extremely small risk of a similar incident over the next six months, this risk will decrease to the point of being negligible as a tyre maintenance program is introduced (eg. regular pressure checks and adjustments, addition of tyre sealant, replacement of leaking valve components, corrective action with continuously leaking tyres, etc).



ACTION TO BE TAKEN

The following recommendations are made:

1. A high priority to be placed on maintaining pressure standards at a high level.
2. Regular tyre fleet inspections to be carried out. Any tyres which are considered dangerous (as determined by a qualified person) to be scheduled for change-out.
3. Otraco's policy for dealing with leaking tyres to be introduced:
 - If a tyre is found to be slowly leaking air (and cannot be rectified by repairs or replacement of valve components), tyre sealant is to be added and the pressure to be adjusted.
 - If the tyre is found to be slow leaking at the next pressure check (which for a suspected leaking tyre should be carried out the following day), the addition of tyre sealant and pressure adjustment to be carried out again. If the loss of air is clearly rapid (eg. greater than 15 psi since the previous day's check), the tyre should be changed as soon as possible (particularly in the case of fronts).
 - If the tyre is still leaking at the next pressure check the tyre is to be scheduled for a change (the leak would be most likely due to a damaged O-ring, cracked rim component, or tyre penetration which may be repairable). The urgency of the tyre change is to be dependent on production priorities and the rate of air loss. A tyre with a loss of 10 psi or more per day to be changed as soon as is conveniently possible, although, where possible the change should be scheduled for a non-production day.

NITROGEN INFLATION

Nitrogen inflation would not have prevented this incident from occurring since the failure was a carcass burst, not a tyre explosion.

Nitrogen inflation reduces the risk of tyre explosions by preventing the auto-ignition of combustible gases produced by pyrolysis. So long as the oxygen concentration within a tyre is less than 5.5%, auto-ignition cannot occur since there is insufficient oxygen to support combustion. However, nitrogen does not eliminate the risk of tyre explosions altogether. For example, a tyre can be run flat, which would reduce the nitrogen concentration to near atmospheric. Such a tyre can still be subject to the required heat conditions to cause an explosion.

Six known tyre explosions have occurred in Australia to date. Although rare, the preferable approach at the mine is to minimise the potential risk for a tyre explosion by eliminating the causes rather than using nitrogen. This involves the following:

- Maintaining brakes and wheelmotors in good condition.
- Correct use of brakes by operators.
- Not welding on rims or hubs if there is any possibility of reaching temperatures in excess of 150°C at the tyre.
- Minimising the risk of tyre fires by, for example, adopting safe refuelling practices and avoiding running tyres flat.



Appendix 5 - Examples of Earthmover Tyre Explosions

This list is by no means comprehensive. Numerous other EM tyre explosions have almost certainly occurred. The list represents incidents for which Otraco has received confirmation of at least some of the factors responsible for the explosion and of the consequences of the explosion.

Tasmania

Year: 1981

Tyre: 26.5R25 radial tyre
Position: not applicable (wheel not attached to truck)
Truck: Wigtruck underground haultruck
Source: Oxy-acetylene heat applied to rim

Events

The tyre exploded approximately 10 minutes after heat was applied to frozen wheel nuts using an oxyacetylene torch. The fitter applying heat was killed instantaneously; another was seriously injured.

Otraco conducted an investigation at the request of the mine. It was established that heat being applied to the wheel nuts was transmitted via the rim to the bead of the tyre causing pyrolysis of a section of the tyre's liner near the bead. The released gases exploded a short time later (estimated at around 10 minutes after heating started).

The tyre was ruptured circumferentially around a 90° arc on one shoulder just below the line of the breaker belts. The rupture occurred diametrically opposite the zone of pyrolyzed liner.

Subsequent chemical analysis of the liner rubber established that pyrolysis commences at about 250°C releasing an explosive mixture of styrene and butadiene vapours which auto-ignites at approximately 430°C. Only 20gm of liner material would have needed to pyrolyze to yield an explosion pressure equal to the burst pressure of the tyre (350psi).

Colombia, South America

Year: Uncertain; pre April 1986

Tyre: 36.00x51
Position: Not known
Truck: Not known
Source: A wheel fire initiated by a brake problem

Events

The tyre fire was initiated by a brake problem. The truck was driven into the maintenance area with the wheel on fire and was allowed to continue burning for 20 to 30 minutes before extinguishment. The outside of the tyre was reported to be cool enough to touch when the tyre exploded some 30 to 35 minutes after the fire had been extinguished. Three people were killed.



Hunter Valley, NSW

Year: 1986

Tyre: 33.00R51 radial tyre

Position: 1

Truck: Komatsu HD1200M haultruck

Source: Contact with 33kv overhead power lines

Events

The tyre exploded approximately 10 minutes after the truck contacted a 33kv overhead power line. The truck had tipped its load under a 33kv power line touching the line. The truck earthed via the position 1 tyre, starting a grass fire. The driver, who was unaware that his truck had contacted the line, drove back to the loading point two kilometres away. As he applied his brakes at the loading area, the tyre exploded.

The explosion tore off the truck's access ladder and air cleaner, throwing these items 175-200 metres. The truck cabin door was bulged and the windows blown out. The driver was not hurt.

The tyre was ruptured in a similar manner to the Tasmanian tyre, except that it burst on both shoulders. The rupture occurred through about 90° of arc opposite the area in the crown of the liner where pyrolysis had occurred.

Otraco postulated that electrical earthing occurred through the rim across to the steel bead, via the steel body cords to the crown area corresponding with the ground contact patch, and then through the tread rubber to earth. Michelin, at the 1987 Tyre Fire and Explosion Seminar conducted by Otraco, WA Mines Department and Mt Newman Mining, suggested that the current path was probably from the rim through the tyre liner and then through the casing and tread to earth.

Kalgoorlie, WA

Year: 1987

Tyre: 37.25x35

Position: Not known

Equip: Cat 637 scraper

Source: A tyre fire caused by diesel spillage

Events

The tyre exploded after a diesel spillage caught fire. A man who attempted to put the fire out was injured.



Ipswich, Qld

Year: 1987

Tyre: 27.00R49 radial tyre

Position: Not known

Truck: Cat 777 haultruck

Source: Lightning strike

Events

The tyre exploded after lightning struck the truck.

Leigh Creek, SA

Year: 1987

Tyre: 36.00-51 bias ply tyre

Position: 4

Truck: Terex 33-11 haultruck

Source: Not established (possibly internal heating due to tyre separation)

Events

The tyre exploded after the truck had been parked up for 3.25 hours. The truck had worked the previous shift.

Within 10 minutes of the tyre exploding, it caught fire. The fire could not be extinguished and the truck was completely gutted. The remaining tyres burnt out but did not explode. Tyre fragments were thrown distances of up to 200 metres. No one was injured.

After the examination of numerous possible causes, ETSA (the mine operator) concluded that carbon dust on the tyre's liner may have undergone slow combustion due to a combination of high ambient temperature and localised heating at the site of a cut or ply separation. The combination of rubber pyrolysis and sufficient heat led to the explosion.

Pilbara, WA

Year: 1987

Tyre: 36.00-51 bias ply tyre

Position: 3

Truck: Dresser (Wabco) 190T haultruck

Source: Apparent misuse of service brake combined with broken park brake line

Events

The tyre exploded after catching fire due to a dragging brake. The fire was fuelled by escaping hydraulic oil. The left wheel motor caught fire. The driver stopped and evacuated the truck but did not shut it down. The fire quickly spread to the position 1 and 3 tyres. The position 3 tyre subsequently exploded.

The force of the explosion blew the outer flange off the rim. Tyre fragments were hurled distances of up to 100 metres. The exploded tyre was largely destroyed by fire. No one was injured in the explosion.



Pine Creek, NT

Year: 1989

Tyre: 24.00R35 radial tyre

Position: 1

Truck: Cat 773 haultruck

Source: Lightning strike

Events

According to eyewitnesses, the tyre exploded at the same instant that the truck was struck by lightning. The tyre was reportedly propelled 45 metres from the truck. The bead seat band was thrown 40 metres hitting a Bobcat loader causing sufficient damage to the loader that it was subsequently scrapped. The lock ring was thrown 70 metres imbedding itself in the wall of a transportable hut.

A section of liner, reportedly 90° from the area where the tyre ruptured, was pyrolyzed. The bead bundle of the exploded tyre was completely severed at the point of rupture. There was no visible damage to the tread of the tyre, however the undertread belts were subsequently found to be separated for 60% of the tyres circumference.

Inspection showed that two other tyres, positions 2 and 6, had also suffered pyrolysis of the inner liner.

Kalgoorlie, WA

Year: 1990

Tyre: Bridgestone 24.00R49 radial tyre

Position: 5

Truck: Not known

Source: Contact with 33kv overhead power lines

Events

The tyre exploded 8 minutes after the truck had contacted 33kv overhead power lines.

The tyre was severely damaged by the explosion rendering little evidence of the precise failure mechanism, viz. arcing or pyrolysis. However the position 3 and 4 tyres showed signs of arcing - a hole on the liner, but no pyrolysis of the liner nor any visible evidence of arcing of the external tread.



Nottingham, England

Year: 1990

Tyre: Not known

Position: Not known

Equip: Not known, thought to be a front end loader

Source: Oxy-acetylene heat applied to wheel brakes

Events

The tyre exploded while workmen were using oxy-acetylene cutting equipment on the brakes of the machine in an engineering factory.

The blast tore the roof off a nearby building.

Two men were killed instantaneously; a third died shortly afterwards. Other workers further away were hurled to the ground but escaped serious injury.



Attachment 1

CATEGORIES OF WHEEL/TYRE FIRES

**OTRACO AND MINE. TO DECIDE WHICH CATEGORY APPLIES, AFTER
REVIEW INCLUDING DISCUSSION WITH SUPERVISION AND EYE-WITNESSES**

CATEGORY OF FIRE	IMMEDIATE ACTION & FOLLOWUP
1. Minor - wheelmotor, hub or brake. Smoke or flash, not propagated; includes: <ul style="list-style-type: none"> - Tread separation smoking - Smoke from brakes 	Immediate inspection by Otraco; return to work if check is normal, otherwise hourly inspection until check is normal
2. Obvious hub and wheel involvement with fire, definite flame but not extensive; includes: <ul style="list-style-type: none"> - Tyres run flat - Tyres ignited by Shale - Lightning strikes 	Stand-down then inspection by Otraco after four hours. Recheck hourly until check is normal (<u>Exception:</u> vehicles with tyres set alight by burning shale may return to work <u>straight after</u> inspection provided no evidence of rim heating or scorching is found)
3. Major truck fire with tyre involvement	24 hour stand-down then inspection by Otraco and Emergency Services
4. Power line contact or oxy acetylene work on rim. High danger but internal tyre temps unknown	24 hour stand-down then inspection by Otraco and Emergency Services



Inspection by Otraco includes visual and manual check of exterior, and temperature and pressure check of interior

Check is NORMAL only if ALL the following are true:

- Exterior of tyre appears normal.
- Pressure in tyre is consistent with other tyre pressures on the vehicle.
- Internal air temperature is consistent with tyre surface temperature.
- Internal air temperature found is below 80 °C.
- No smoke issues from P-T gauge during check.

If check is normal, vehicle may return to work immediately

If check is NOT normal, refer to categories above for followup action

THE RISKS ARE THE SAME WHETHER THE TYRE IS INFLATED