Addressing Tyre Risks with Critical Control Management – A Collaborative Industry Project

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In February 2015 an experienced tyre fitter was killed and another seriously injured while working on an earthmoving vehicle tyre at a Queensland mine. As with all serious industry events, the incident was reviewed by the Board of the Minerals Council of Australia (MCA) at their March 2015 meeting and they requested that an Tyre Working Group (TWG) representing the industry be formed to answer the questions *“1. Why are tyre related fatalities still occurring for a well understood risk? 2. Do we fully understand the risk landscape and has it changed? 3. Is the current industry approach adequate? 4. What can and should we be doing next?”* Following an initial analysis and progress report in June, the MCA Board supported a recommendation that the TWG apply the *International Council of Mines and Metals (ICMM) Health and safety critical control management: Good practice guide* to systematically and effectively provide answers to these questions.

This paper describes the approach used by the TWG to collect and catalogue incident information, fatality risk analysis and the application of the ICMM critical control management (CCM) process as part of an industry level project to address a specific industry fatality risk. The paper concludes by discussing the outcomes and learnings arising from the work and makes general recommendations about future applications of the CCM process at a collaborative industry level.

Introduction

Ongoing inputs to eliminate workplace injury, including fatalities, are a constant within the Australian Minerals Industry. Over the last two decades, considerable progress in injury reduction has been widely reported, however workplace fatalities continue to occur. The peak Australian industry group is the Minerals Council of Australia (MCA) with a Board comprised of member company CEOs. In 2014 the MCA convened an industry meeting in Brisbane to address an increase in industry fatalities with 16 reported during the year to July 2014. This meeting reconfirmed an industry leadership intent and commitment to eliminate industry fatalities.

In February 2015, an experienced tyre fitter was killed and a trainee was seriously injured while reinstalling a wheel on a Caterpillar 777 Truck at a Queensland mine. This was the tenth tyre related fatality recorded in the Australian minerals industry over the last 20 years including:

- In 2010 a truck driver was killed when he was hit by the percussion shockwave from a coal road train tyre that he was changing (tyre burst)
- In 2007 a freight truck driver was killed when he was crushed by an earth moving tyre (Crushed by tyre or equipment)
- In 2005 a coal train truck driver was killed when he was hit by parts of the wheel assembly he was removing after it catastrophically failed due to a rim wear crack (Rim Failure/ Disassembly)

- In 2004 a tyre fitter died and another was injured while changing the outside rear tyre on a Komatsu 630 Truck when the lock ring off the still inflated inside rear wheel catastrophically disassembled (Rim Failure/ Disassembly)

Also considerable industry attention and effort has been previously directed at improving tyre safety over the last decade including: ACARP funded projects (C13049 [1], C15046 [2], C17032 [3]) used as a basis for TyreGate (http://www.mirmgate.com/index.php?gate=tyregate) an online tyres and rims risk management decision support tool and RISKGATE an online reference of controls that can be applied to managing tyre risks (www.riskgate.org/). Other industry and regulator inputs have included safety alerts, findings and recommendations from arising from state coroner investigations, regulator and specialist tyre service provider standards and guidelines and other within-company initiatives.

In response to the Queensland fatality, in March 2015 the MCA Board requested that an industry Tyre Working Group (TWG), be formed to use a project approach to answer the following questions about the fatality risks of working with or around tyres: *1. Why are tyre related fatalities still occurring for a well understood risk? 2. Do we fully understand the risk landscape and has it changed? 3. Is the current industry approach adequate? 4. What can and should we be doing next?* Progress feedback from the TWG was required for the next MCA Board meeting in June 2015

The MCA OHS Committee secretariat requested nominations and nine MCA member companies provided tyre and risk experts to make up the TWG who met multiple times between March 2014 and June 2015 to undertake project work. The first step was to review and analyse tyre incident information provided by eight mining companies that was combined with databases held by Otraco (a specialist tyre service company). A data set comprised of 155 serious tyre incidents (32 known fatalities) was organised into five incident categories as shown in Table 1.

Table 1: Summary of tyre fatalities and serious injuries from TWG Database

Incident Category	**Australia Fatalities 1980-2015**	**Known International Fatalities 1980-2015**	**Working Group Serious Incidents 2000-2015**
Rim Failure/ Disassembly	4	12	13
Tyre Explosion (pyrolysis)	1	4	3
Crushed (tyre or equipment)	3	6	6
Work Equipment Failure	1	1	1
Tyre Burst	3	3	19
TOTAL	12 (10 since 1996)	26	32

The analysis highlighted that:

- Personnel working with tyres are 10-12 times more likely to be fatally injured than a mine workshop maintenance fitter
- There are five main types of unwanted tyre events – Rim failure/disassembly, tyre explosion (pyrolysis), tyre burst, crushed by tyre or equipment and work equipment failure.

- The causes of the unwanted tyre events are well understood
- Controls have been identified but there are significant gaps in practical understanding, application and verification of controls.
- Australia deploys few hard controls

At the June 2015 MCA Board meeting the TWG progress was reviewed and it was agreed to test the applicability of the ICMM CCM process to help the significant gaps in controls. The ICMM CCM process used was the one documented in the ICMM *Health and safety critical control management: Good practice guide* found at http://hub.icmm.com/document/8570 [4] and shown in Figure 1.

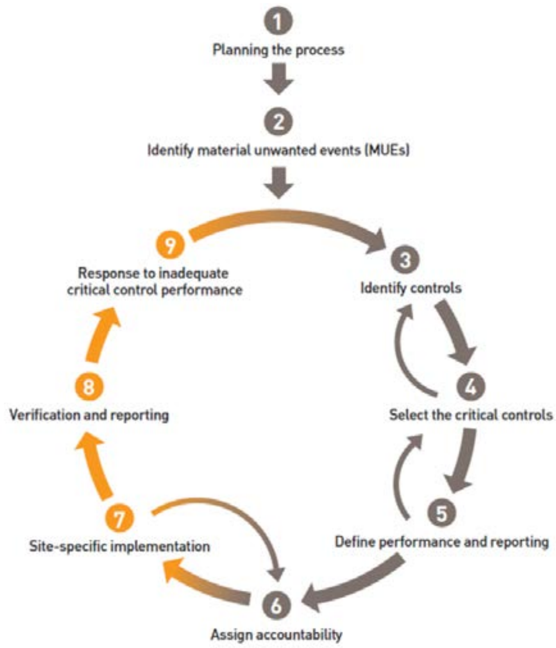

Figure 1: ICMM Critical Control Management process

In August 2015 representatives of the TWG conducted a feasibility workshop with Associate Professor Maureen Hassall to determine if the CCM methodology could produce information that would help the industry eliminate tyre fatalities. The workshop confirmed that applying CCM methodology at an industry level was an efficient way of capturing industry knowledge and experience while challenging existing control assumptions with the new thinking and understanding outlined in the CCM methodology. Following the workshop, a recommendation was made that the CCM approach should be applied to develop bowties and critical control information for tyre related fatality risks across all five incident categories. The MCA accepted the recommendation and further work was funded.

In the next part of this paper we describe how the CCM process was applied at an industry level to reframe control knowledge and experience for a specific fatality risk noting that this paper is intended for practitioners and it provides a ‘work-in-progress’ summary and some answers to the MCA Board questions.

Method

The approach used to apply the CCM process to tyre risks was as follows:

1. The identification of the material unwanted events (step 2 of the ICMM CCM process) used the Incident Categories shown in Table 1.
2. An initial CCM feasibility workshop was held in August 2015
3. This was followed by an early March 2016 workshop to identify controls and develop the bowties for each of the material unwanted events as per step 3 of the CCM process. The identification of controls and development of bowties also followed the guidelines set out in ACARP report C23007 *Methods for selection and optimisation of critical controls* [5] as referenced in the ICMM guide.
4. TWG members reviewed and critiqued the suggested initial controls in their own organisations
5. A second workshop was held in late March 2016 to review and refine the list of controls and to specify control objectives, performance criteria, monitoring requirements, erosion factors, support activities and how their application might be verified.
6. TWG members again reviewed and refined the working control specification information in their own organisations
7. A final one-day review workshop was conducted in June 2016 to review the status of the bowties, control specification information and to do a SWOT (strengths, weaknesses, opportunities and threats) analysis critique of the overall process. As well as the contributing TWG members this meeting was also attended by two MCA Board members.

Results

The representative industry TWG involved 14 people from Glencore, New Hope Group, Downer Mining, Otraco, MCA, Peabody, Thiess, St Barbara, and Yancoal.

Before identifying controls and doing bowtie and critical control analysis, the scope of the risk analysis for the tyre fatality work was confirmed as per Table 2.

Table 2: Scope of tyre activities considered

Descriptor	**In Scope**	**Out Scope**
Scenarios	Fatality related scenarios • Rim failures resulting in catastrophic disassembly and/or failure • Any type of vehicle • All pyrolysis events • Over/under inflation • Casing failure including sidewall failure • Less than adequate tyre quality including impact/damage failures • Failure of retread/repair • Loss of control of tyre, and tyre maintenance equipment and tools	Scenarios: • Resulting from vehicle incidents • Resulting in only damage to assets • Resulting in an injury not death • Resulting in reputation damage • Associated with tyre failure of bomb truck • Associated with being overcome by fumes • Associated with rock ejector failure
Tyres	• 24” and above wheels assemblies on any type of vehicle plus those identified by risk assessment e.g. pyrolysis explosion from heating the rim on any tyre assembly	• Tyres fitted to externally based service providers • Tyres in transit to/from site • Solid tyres

Activity	• Inflation and re-inflation • Fitment, removal and stripping of tyres – a) tyres on rims, b) wheel and rims, c) tyre assembles • Storage and handling of tyres • Use of tyre manipulator/handler, jacks, stand, press and ancillary tools (e.g. bead breaker, pressurised inflation hoses, etc) • Inspection/maintenance of big inflated tyres • During operation	-Activities that that are not known to expose people to fatality risks - Safe parking and Isolation of vehicle
Location	• Tyre workshops, tyre pads, mechanical maintenance • In-the field and in-pit and other areas where vehicle and mine haulage activities occur • Hardstand, offload and tyre storage areas	Offsite locations

A reference set of controls were identified and represented on bowties for all four unwanted events - Rim Failure/disassembly; Tyre Explosion; Tyre burst; Uncontrolled movement of tyre or equipment. The bowties for rim failure/disassembly and tyre burst are shown in Figures 2 and 3 respectively.

Control specification sheets were drafted for the controls shown with green shaded boxes in Figures 2 and 3. An examples is shown in Figures 4.

Discussion

The industry tyre working group was able to describe a more succinct set of controls as a reference for operating sites. This reduction comes from applying the discipline and thinking in CCM to existing knowledge, information and experience. Important CCM methodology concepts include:

- Controls can only be acts, objects or technology systems (combined act and object) that directly prevent or mitigate an unwanted event and controls are specifiable, measurable and auditable
- Control monitoring activities are carried out by front line employees and are a check that controls are present and will work as required when required
- Control erosion factors are the factors that can cause the control to fail
- Support activities are the inputs that prevent erosion factors from causing control failure
- Control verification activities are periodic governance inputs undertaken by management that confirm that both control monitoring is happening at the right time and to an appropriate standard and that the control itself is appropriately effective

As part of the classification step, TWG members drafted example control specification sheets for selected controls to demonstrate how mining companies and specialist tyre service providers might produce their own, taking into account company and site specific information. The TWG members confirmed that producing industry level controls specification sheets with site specific control information was neither appropriate nor practical. However, they did confirm that the controls detailed in the bowties and the example specification sheets can be produced to provide a reference resource for mining companies and specialist tyre service providers to map their existing processes to confirm current control effectiveness.

Feedback from the TWG highlighted that the process of bringing tyre experts together and asking them to identify and classify control information using CCM methodology required different thinking. The discussions and cross industry collaboration was seen as positive and necessary to improve and simplify industry reference controls and control information. However, TWG also provided feedback that the process of having three separate workshops with site homework in between did not work well. Time was lost at the start of each workshop revisiting previous work and reconfirming thinking and assumptions and finding the reflective time back at work necessary to review and test the developing concepts was always difficult. It is therefore recommended that any subsequent industry initiatives work over one intensive week to produce bowties, determine control specifications and confirm erosion factors to a practical and useable reference standard.

It is also important to note that the TWP did not represent the whole industry nor were there contributions from frontline tyre maintainers and supervisors. Also the work to apply the new thinking and CCM processes was undertaken part-time over 15 months by a small committed working group during time of considerable industry change e.g. of the initial TWG members, around 50% are estimated to have left the company that they working for during the life of the project.

The work however takes a significant step forward by proving that the still evolving CCM approach can be applied successfully for industry level project work. However, the final product from this work will recognise the limitations discussed and have a caveat that it is a starting reference that requires review and tailoring before it can provide support for operating sites and this requires a detailed understanding of the site and company erosion factors that can cause control failure.

In adapting the reference information provided by the TWG operating sites and businesses, including specialist tyre service providers, should consider carefully who the intended audience is and how it will complement existing procedures and approached. The authors see that the reference information product as confirming current industry knowledge about control design that can be adapted and applied by mining companies to efficiently and comprehensively review the controls that they have at present to prevent tyre fatalities. As such the primary audience is likely to be the line managers who are accountable for tyre maintenance and other operations where tyre fatalities might occur and its primary use will be for control monitoring and verification. Consideration should also be considered to converting the information to useful prompts and check for front-line maintainers so they know what controls to check and monitor.

Notably the working group decided not to select critical controls (CCM step 4) because the criteria for critical controls varied across companies invalidating any industry critical controls nomination. Instead the working group selected some “important” controls and prepared example specification sheets for these.

Throughout the process the work done was cross checked against TyreGate, RISKGATE and incident data.

To complete the project, further work is required to map the incident data to confirm that all control failures that contributed to fatalities have been identified and also what controls have prevented serious incidents from being fatalities. The work can also be used to update the TyreGate checklists and the RISKGATE bowties so it is available online for industry.

Conclusion

After the incurring another tyre-relating mining fatality in 2015 industry leaders asked four pointed questions. The research described in this paper highlighted that

1. We have a good understanding of the risk landscape and it hasn't it changed. The unwanted tyre events and their causes are well understood and controls have been identified.
2. Tyre related fatalities still occurring for this well understood risk because there are significant gaps in practical understanding, implementation and verification of controls.
3. Using the ICMM CCM approach assists in identifying, understanding and describing the controls and control management activities needed to effectively manage tyre risks.
4. Industry working groups can produce useful reference information but further work is needed to review, tailor and confirm the reference information for company and site controls, erosion factors and control monitoring, verification and support systems.

The process has produced a reference or "set of shelves" that mining companies now need to tailor to their sites and then identify and address any gaps in their current controls and control management systems. The output of the gap analysis work should be implemented controls which are subjected to ongoing monitoring by front line people and ongoing verification by management. Further work should also be done to understand the role the controls are playing in incidents and to update the online industry database information to reflect this updated work.

References:

[1]: Rasche, T.F., C13049 - Tyre Fires and Explosions of Earthmover Tyres, Australian Coal Industry's Research Program - ACARP, 2004: Brisbane

[2]: Rasche, T., & Klinge T., C15046 - Tyre Related Accidents and Incidents - A Study with Recommendations to improve Tyre & Rim Maintenance and Operational Safety of Rubber Tyred Earthmover Equipment, Australian Coal Industry's Research Program - ACARP, 2007: Brisbane

[3]: Kizil, G., & Rasche, T., C17032 - TYREGATE: A "World First" Risk Management Decision Support Tool For Earthmover Tyres and Rims, Australian Coal Industry's Research Program - ACARP, 2007: Brisbane

[4]: ICMM, Health and Safety Critical Control Management: Good Practice Guide, ICMM,2015: London UK

[5]: Hassall M., Joy J., Doran C., & Punch M., C23007 - Selection and Optimisation of Critical Controls, Australian Coal Industry's Research Program - ACARP, 2015: Brisbane

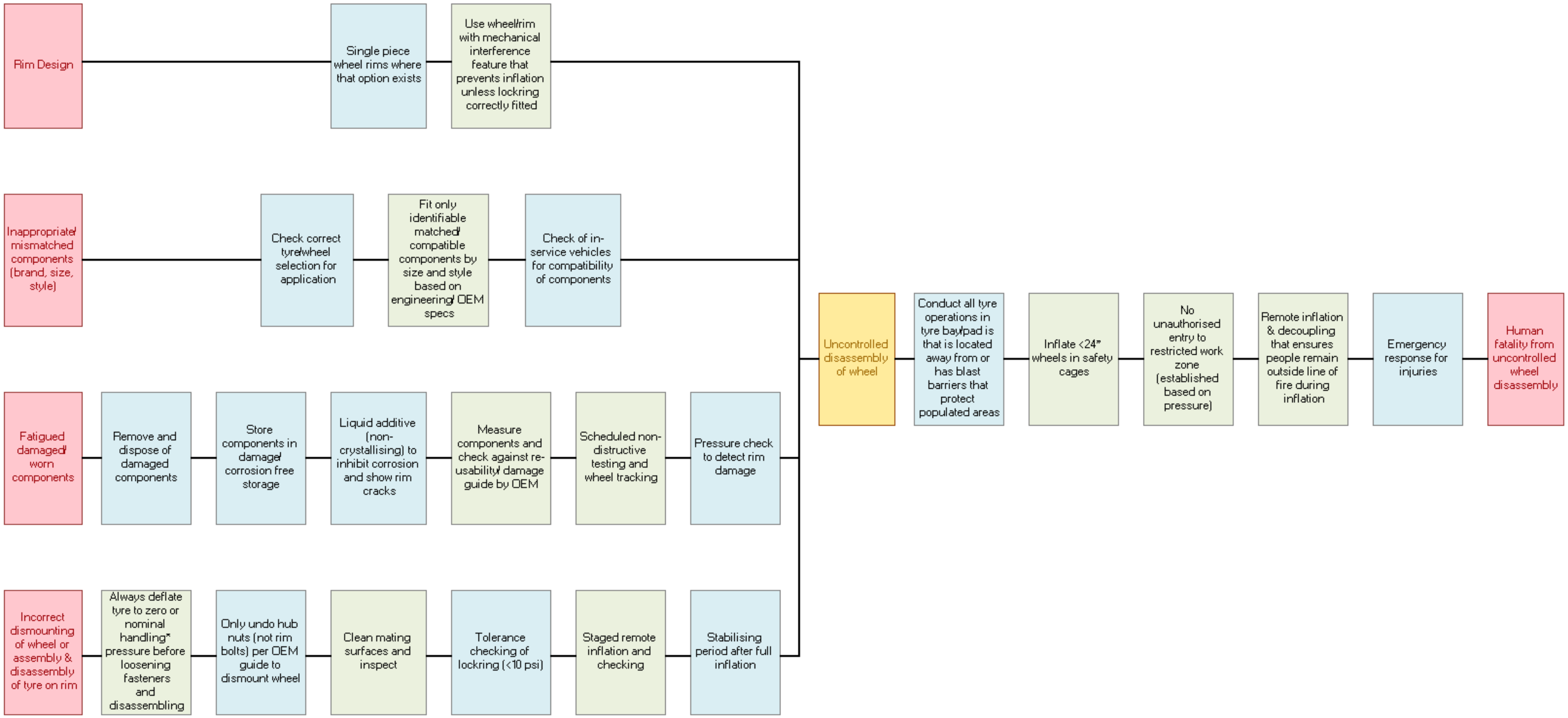

Figure 2: Reference bowtie for rim failure/disassembly

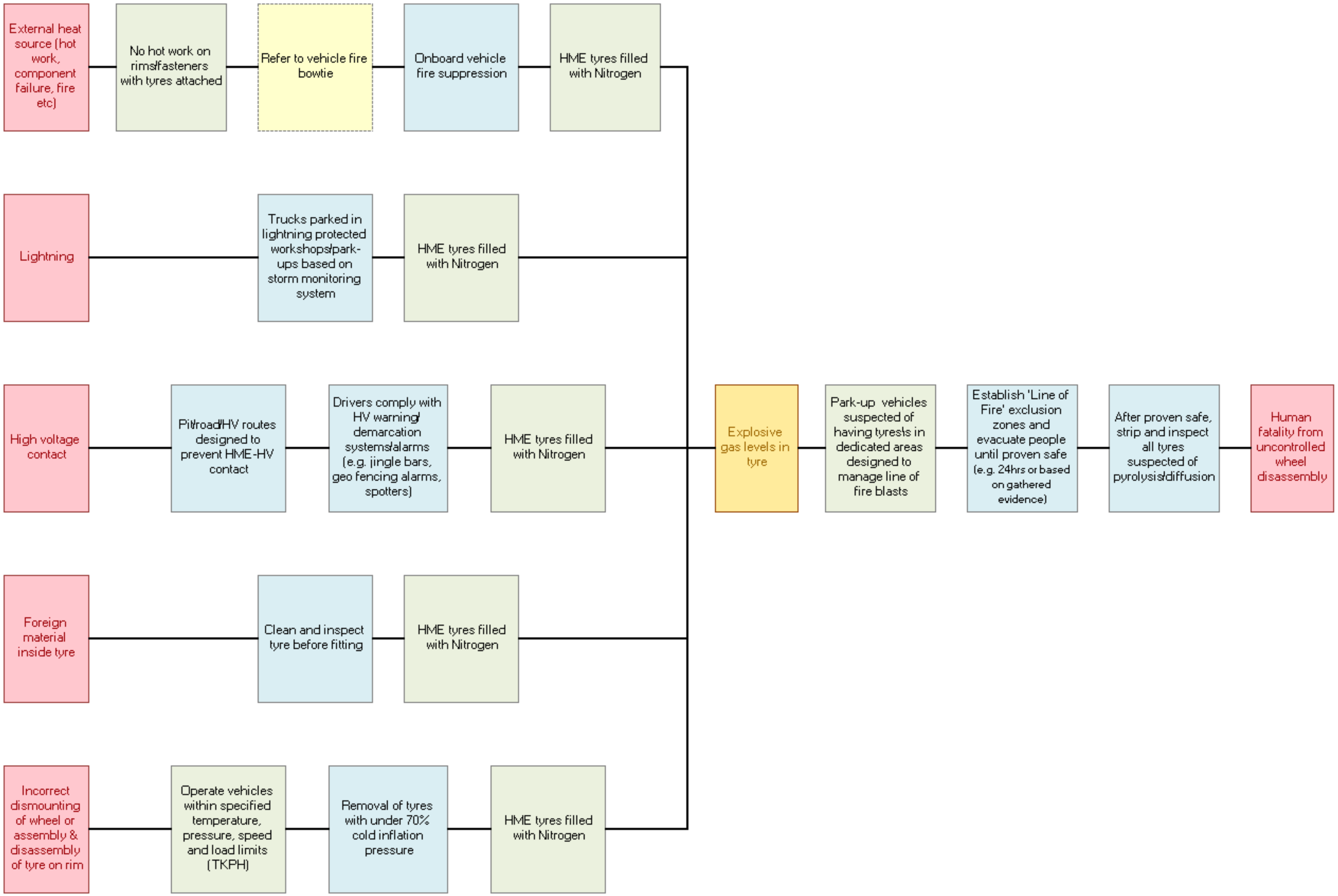

Figure 3: Reference bowtie for tyre explosion (from pyrolysis or diffusion)

CRITICAL CONTROL SPECIFICATION AND VERIFICATION PROFORMA			
1. What is the unwanted event?			
Uncontrolled wheel/rim disassembly			
2. Name of the *example* critical control			
Use wheel/rim with mechanical interference feature that prevents inflation unless lock-ring correctly fitted			
3. What are the specific objectives of the control related to the unwanted event?			
To prevent uncontrolled wheel/rim disassembly caused by incorrectly or insufficiently seated lock rings by having a design feature that creates mechanical interference between the lock ring and bead seat band to prevent tyre inflation if the lock ring is not correctly seated.			
4. Specify the performance required of the control so it meets its objective	**5. What front-line monitoring is needed to check the control is present and will perform as required when required**	**6. Triggers for ok to proceed, follow-up action required, immediate stop work**	**7. What verification activities are needed to check controls are implemented and effective and monitoring activities are being done in a timely manner and to a high standard?**
Only use pre-approved rims with mechanical interference device is incorporated into the design and where design has been verified that it provides sufficient interference to ensure tyre assembly cannot be inflated if the lock ring is incorrectly or insufficiently seated during inflation.	Cross check rim design number/marking against company's list of preapproved rims prior to assembly. BY: Companies to determine [e.g. tyre fitters] WHEN: Companies to determine [e.g. before every assembly]	GO Design marking/number on rim can easily be read and it is on company's list of preapproved rims. ⚠ STOP Removal from service and rim where the design marking/ number is NOT clear or it is NOT on company's list of preapproved rims.	Pre-assembly in-field checking of rim markings against preapproved list and checking of fitters' understanding of process. BY: Companies to determine [e.g. workshop managers] SAMPLE: Companies to determine [e.g Rims on 10% of fleet] WHEN: Companies to determine [e.g. once a month]
8. What are the erosion factors that could cause the control to fail or lessen in its effectiveness over time	**9. What support activities are needed to address the control erosion factors**		**10. What verification activities are needed to check controls erosion factors have been identified and are being actioned**
No/wrong definition of the functional requirements that need to be tested to ensure sufficient interference. No list or list contains designs not tested to ensure it provides sufficient interference to prevent inflation.	Only purchase lockrings that suppliers warrant have been engineered and tested to ensure tyre assembly cannot be inflated if the lock ring is incorrectly or insufficiently seated during inflation. BY: Companies to determine [e.g. tyre procurement person] WHEN: Companies to determine [e.g. before purchasing rims]	GO Checked and confirmed that designs on preapproved list have been validated by the OEM that they meet intended functional outcome*. ⚠ STOP Preapproved list not available or insufficient/no confirmation that designs on preapproved list have been validated by the OEM and meets intended functional outcome*.	Check that - Up-to-date list of preapproved items exists - Items on preapproved list have written confirmation from manufacturers that they have been designed and tested that they meet company requirements - Installed lockrings are on company's pre-approved list BY: Companies to determine [e.g. specialist engineer] SAMPLE: Companies to determine [e.g 5% of lockrings] WHEN: Companies to determine [e.g. once a month]
Mechanical interference feature worn or damaged.	Inspect condition and measure physical parameters key to guaranteeing mechanical interference [companies to specify] and cross-check to ensure within OEM guidelines for wheel/rim reusability tolerances. BY: Companies to determine [e.g. tyre fitters] WHEN: Companies to determine [e.g. before every assembly]	GO Key lockring dimensions measured and checked that they meets manufacturer's guidelines for reuse. ⚠ STOP Removal from service any rim that does not meet manufacturer's guidelines for reuse.	Pre-assembly in-field checking of rim tolerances against OEM guidelines and checking of fitters' understanding/ execution of process. BY: Companies to determine [e.g. workshop supervisor] SAMPLE: Companies to determine [e.g 5 reassemblies] WHEN: Companies to determine [e.g. once a month]
11. Other comments			
Original Equipment Manufacturers (OEM) guidelines lack some detail in some cases and require further development. Current gaps from manufacturers for guidance on maintenance, repair and reusability tolerances of wheel/rim components. * Thiess has done some work around determining functional outcomes and verifying which designs meets these outcomes and provide sufficient interference			

Figure 4: Example control specification information for "Use wheel/rim with mechanical interference feature that prevents inflation unless lock-ring correctly fitted" control