

# Bolting rig incident review for NSW underground coal mines

Produced on behalf of NSW Department of Industry, Division of  
Resources and Energy, Mine Safety

By Gearing Engineering and Associates Pty Ltd

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Photo: A worker at an underground bolting rig. Courtesy: Gearing Engineering Associates Pty Ltd

## Disclaimer

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## Executive summary

Based on the work completed by the NSW Mining Workplace Agreed Undertaking – Review of Mobile Roof Bolting Machines Project Report the Department has requested another report focusing on opportunities for improvement in roof bolting. The aim of this report is to focus on end users which includes, understanding the core issues that revolves around current plant, extending on human factors in design and what industry needs to do to consider when implementing a step change approach to manage the risks associated with roof bolting.

### Incidents involving bolting rigs requiring hospitalisation or > 7 days lost time injury

A total of 99 incidents were recorded in this 5.5 year period 01/07/2009 to 16/11/2015.

This compares to a total of 94 recorded in the 6 year period 2007 to 2012.

There are two broad causal categories for bolting rig injuries.

1. Incidents relating to moving equipment.
2. Incidents relating to musculoskeletal disorders, ergonomics, slips, trips and falls.

Other findings included:

- Incidents relating moving equipment have **reduced** around 20% in this review compared to the previous 2012 review.
- Incidents relating human posture and ergonomics have **increased** this same 20% in this review compared to the previous 2012 review.
- Injuries related to bolting underground over recent times continue to remain high.
- There is clear indication that operator entanglement with moving components including roof and rib falls have reduced 20% in recent times. This may be considered largely attributable to the introduction of MDG35.1 (guideline for bolting and drilling plant in mines) in 2010, where 2 handed rig control, additional rib and roof protection systems were required.
- Efforts to curtail the substantial increase in musculoskeletal disorders, ergonomic and human factor related injuries are in great need.

A summary of mine recommendations to prevent recurrence developed from the incident reports is provided in section 5.

### Hydraulic fluid emission involving bolting rigs

There was one fluid injection injury during the 5.5 years to November 2015 with another 83 reported escapes of fluid.

While actual frequency of legitimate injection is low, the high number of reported fluid escapes continues. Drill rig motor hose failures have reduced with the introduction of improved bonded hose sets and guarding in this area. General supply hose failures are now shown to provide the highest frequency of exposure to operators. Hose failures represent a significant production benefit as much a safety benefit. Continued efforts are required to not only prevent, but guard the emission in the event if they do fail.

## Recommendations for reporting protocols

Bolting rig injuries represent a significant 'stand alone' area to be addressed.

Collation and review of the bolting rig injuries required manual searching with the words, "roof\*bolt". Non relevant areas such as multiple gas trips, roof falls, etc, were then manually removed. The process is time consuming and not precise, however it should be noted that the Department as outlined in the Mine Safety Regulatory Reform Incident Prevention Strategy, is currently making changes in the need for quality data, one of the three key foundations of the MSAC fatality review recommendations.

As such, it is recommended a dedicated profile or Performa be developed that outlines base values used in this report. This will serve to better monitor and review ongoing reports within the Department. It should be noted that information needed for these Performa reports may not always be available within the 24 hour report timeframes set by Mine Safety. In this case, the pro forma document should be referenced on the original notification report.

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# 1. Introduction

## 1.1. Forward

The aim of this report is to focus on end users which includes, understanding the core issues that revolves around current plant, extending on human factors in design and what industry needs to do to consider when implementing a step change approach to manage the risks associated with roof bolting

There are 30 underground coal mines in NSW.

The NSW Department of Industry, Division of Resources and Energy, Mine Safety (Mine Safety) has previously investigated and reported bolting rig incidents in these NSW mines, 2007 through to 2012 as reported per the *Coal Mine Health and Safety Regulation 2006*.

Results were not commonly made available to industry, however the report recognised the need for improvement surrounding safety during bolting underground.

A guideline for bolting and drilling plant in mines, MDG35.1 was developed and introduced in 2010.

There has not been a formal review of bolt rig incidents since this period and with continued bolting rig injuries and reportable occurrences, this report aims to draw attention to major causes in recent times with suggested recommendations to reduce these injuries.

The period covered in this review is from 01/07/2009 to 16/11/2015. Source data and criteria is from the same Mine safety COMET incident report data base as the original report in 2013, albeit referenced to the *Work Health and Safety Act 2011* and the *Work health and Safety Regulation 2011* and in addition the *Work health and Safety ( Mines ) Act 2013* and the *Work Health and Safety (Mines) Regulation 2014*.

It should be noted that some comments within the COMET report provided limited information. Where possible, site and departmental interviews and discussions have been carried out to provide additional detail.

It is anticipated this report will be used in conjunction with proposed industry workshops during 2016 to further involve industry and improvement initiatives in this area.

Source data used is provided in the referenced Appendix A. Mine and personal details have been removed.

## 1.2. Legislative considerations

Incident and injury legislation and subsequent notification has changed during the associated years of reports contained within this review.

Duty to notify the same incidents relating the bolting rig equipment has to all intent not changed.

The subsequent mine reports comprise the following from the various Acts and regulations to this time:

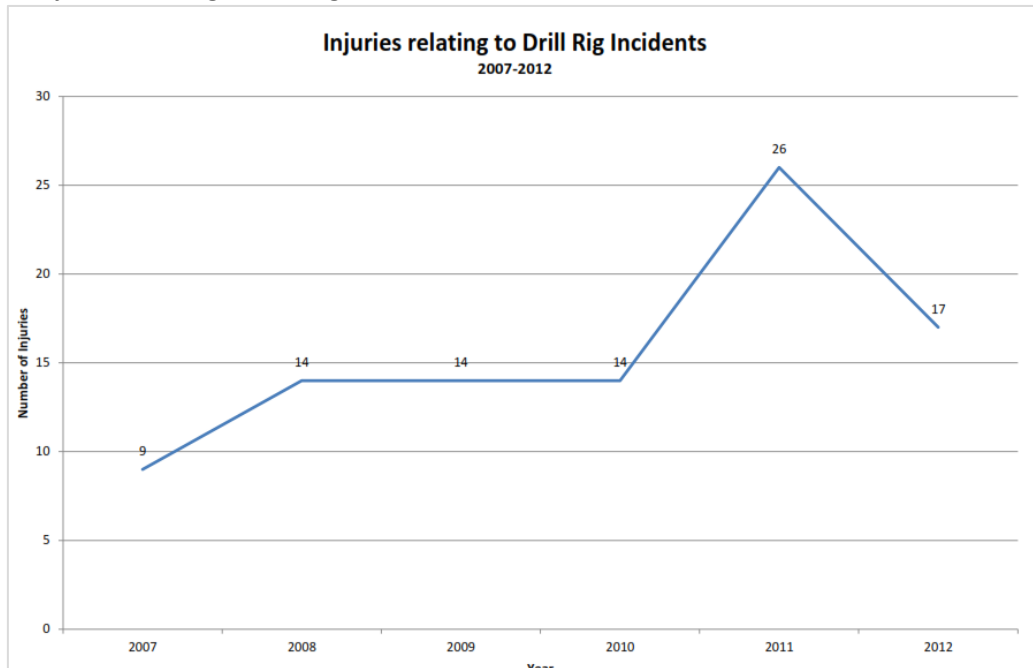
1. Escape of fluid under pressure / Uncontrolled escape of pressurised substance
2. Notifiable injury requiring hospital treatment or loss time injury exceeding 7 days
3. Failure of explosion-protected equipment during service
4. Unintended activation, movement or failure to stop vehicle or machine
5. Failure of strata/slope stability control measures.

## 2. Summary of previous investigation of bolt rig injuries 2007 to 2012

A review of injury statistics in the six calendar years 2007 to 2012 has been previously carried out by the Department in 2013 with the following summary of results.

A total of 94 incident reports relating bolting rigs had been made to department.

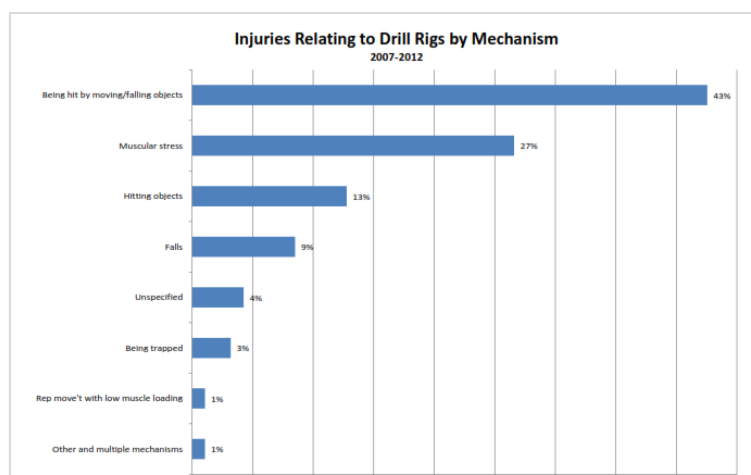
Figure 1: Injuries relating to drill rig incidents.



There was one amputation and one fracture notified, with almost all of the 90 reported injuries resulting in hospital inpatient admission and/or lost time exceeding 7 days.

- The majority of these injuries occurred when using a miner mounted roof bolter (34%), hand held roof bolter (26%) and bolting machine roof bolter (16%).
- The most common causal mechanisms were being hit by moving/falling objects (42%), muscular stress (27%) and hitting objects (13%).
- The most common nature of injury were sprains and strains (26%), contusion (21%) and fractures (19%).
- The part of body most frequently injured was hands/fingers (43%), shoulder (13%) and feet/toes (11%).

Fig 2: Injuries relating to drill rigs by mechanism.



### 3. Incident reports relating to the underground bolting process 2009-2015

There were a total of 216 reported incidents relating roof bolting.

98 requiring hospital treatment OR time off work > 7 days

117 not requiring hospital or any time off.

The 117 not involving hospitalisation or time off include:

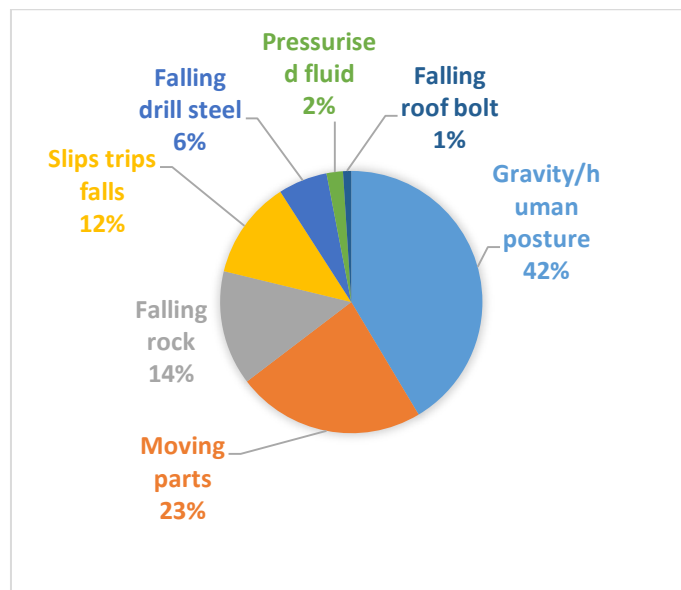
34 unplanned movements

83 escapes of fluid

1 off in service failure of explosion protected equipment. (Found fluorescent light outer tube damage during inspection).

Categories relating to the injury cause of the 98 injured were found to fall within seven areas. These are outlined with the percentage relationships shown below:

Fig 3: Seven areas causing injury.

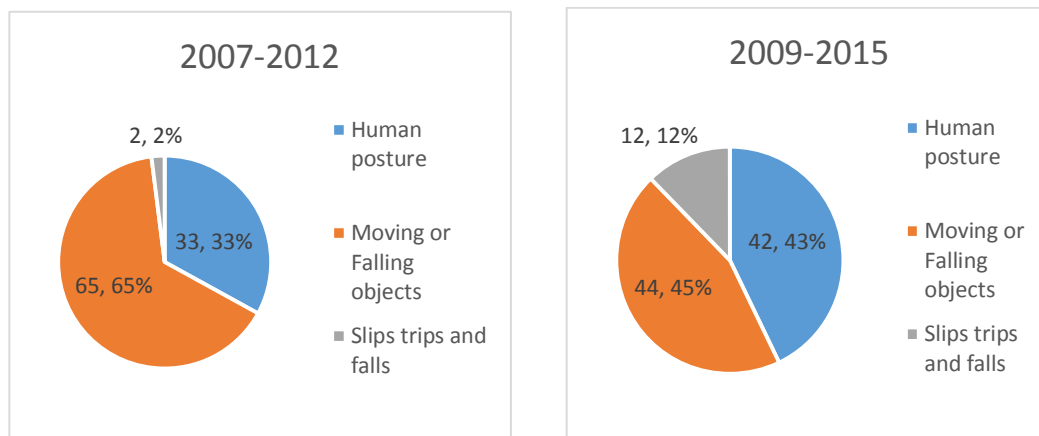


To allow comparison with previous categories in the 2012 report, the falling and moving objects were combined and leave predominantly two higher level categories relating causes of bolting injuries.

Following this normalised approach, the six year period 2007-2012 period investigation compared to the 5.5 year period to November 2015 provides the following results.



Fig 4: Results of 2012 and 2015 reviews.



### 1.3. Comparison on results for the 2012 and 2015 investigation

Slips trips and falls, while scoring low in the 2007-2012 records, can be shown to have been included in the other human posture areas at that time. There is shown to be two distinct causal areas relating injuries during bolting.

1. Incidents relating to moving equipment.
2. Incidents relating to musculoskeletal disorders and ergonomics also resulting in resultant slips, trips and falls.

Incidents relating to moving equipment have **reduced** approximately 20% in this review compared to the previous 2012 review.

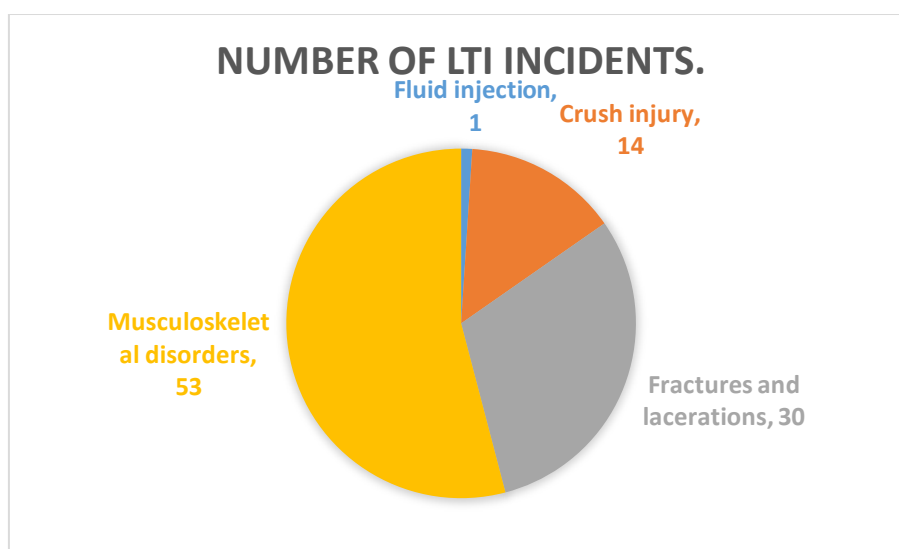
Incidents relating to musculoskeletal disorder and ergonomics have **increased** this same 20% in this review compared to the previous 2012 review.

## 4. Investigation and evaluation of the 2009-2015 incident reports

Further investigation regarding causes, of the 98 persons requiring hospitalisation (and time off > 7 days) provided the following information.

The 98 incidents that lead to a person’s hospitalisation and significant injury were found to be able to be divided into four main categories.

Fig 5: Number of lost time injury incidents.



The greatest occurring injuries in this current 2015 review period relates to musculoskeletal disorders. Note that the terms used on the mine reports nominate slips, trips, sprains and strains. These have been rounded into the generic term musculoskeletal disorders.

Musculoskeletal disorders were also the greatest occurring injury in the 2013 review.

Each injury for each category of the 98 injuries has been systematically analysed with recommendations including the mine's own recommendation to reduce likelihood of a recurrence.

## 1.4. Fluid injection

There was a one off fluid injection in 2013 reported requiring hospitalisation and treatment and lost time > 7 days. During removal of a dolly from the drill motor, an operator was struck with oil pressure just as a hose burst.

Recommendations consistent with mine recommendations to prevent recurrence include:

- Fluid injection hazard awareness and control training for operators and tradesmen.
- Routine testing of hydraulic system for correct operation.
- Review operators and maintenance systematic inspections.
- Review operating procedures and training to reinforce non-contact with moving rig components.

## 1.5. crush injuries

There were 14 crush injuries reported requiring hospitalisation and lost time > 7 days. They all occurred on continuous miners. Two of these incidents were a direct result of geology.

Recommendations which were consistent with the mine recommendations to prevent recurrence include:

1. Review the following design areas in conjunction with the original equipment manufacturer (OEM), areas for consideration include:
  - Potential pinch points.
  - Feed vs speed vs pressure feedback/proportioning systems for varying roof conditions.
  - Hydraulic control valve design consistent with MDG35.1 and 2 handed controls.
  - Check operating and engineering limitations and requirements to maintain design requirements of drill steels and adaptors. Eg: max torque, maximum angles and deflections.
2. Review and, where possible, improve work area for material handling and bolting taking into consideration human factors in design.
3. Review bolting rigs for consistency regards original equipment latest standards.
4. Carry out a bolting risk assessment (MDG35.1 nominates that an operational risk assessment MUST be carried out on bolting plant).
  - Consider all areas involving the bolting process including material handling, roof, rib, flexi and mega bolting.
  - Consider other controls that may be necessary to manage the risk in areas of noncompliance regards MDG35 and MDG41.
  - Consider the need for any power on tasks during the risk assessment. All power on tasks should be accompanied with a safe work procedure and be included in the training. Monitor for effective use.
  - Consider pinch and crush areas involving the entire material handling and bolting process.
  - Consider use of equipment during material handling, roof and rib bolting (including flexi and mega bolts) that reduces the need for manual handling
5. Reinforce the hazard self-assessments such as Take 5, SLAM, etc.
6. Include drill guides and the OEM recommendations into the maintenance inspection regime.
7. Review guards and guard systems at potential crush/pinch points during material loading, roof and rib bolting including any use of mega and flexi bolting.
8. Review bolting procedures. Include the following considerations:

- The various mining environments that may arise. Consider such issues as barring down, Take 5, TARPS etc.
  - Review bolting procedure to preclude interaction with moving parts where possible. Include in training.
  - Include checks for air pressure, spin times, etc. Importance of communication with other operators.
  - Review operating procedures including training related to roof and rib control including mega and flexi bolting and material handling.
9. Review roof control management plans including TARPS and materials and rib shield shown adequate.

## 1.6. Fractures and lacerations

There were 30 incidents resulting in fractures and lacerations requiring hospitalisation and lost time > 7 days.

Recommendations consistent with mine recommendations to prevent recurrence include:

1. Potential to improve bolt platform ergonomics and layout taking into consideration human factors in design.
2. Review and refresh to workforce operating procedures to include:
  - Training related to roof control and hazards including mega and flexi bolting and material handling.
  - Pre-use and operating standard inspections and checks and what is considered unacceptable.
  - Modify bolting procedures to suit various mining conditions (TARPS).
  - Review operational use of butterfly plates. Include considerations of do's and don'ts in the standard operating procedures (SOPs) for bolting.
  - No go zones under all TARP conditions for roof and rib bolting.
  - Disconnection of drill extensions.
  - Include checks for air pressure, spin times, etc, importance of communication and line of fire.
  - Include all procedures into the training.
3. Review training to include:
  - Hazard awareness in and around roof, rib bolting including material handling.
  - Limitations and hazards associated with misaligned dollies and drives.
  - Updated procedures consistent with this report.
  - Review lifting equipment and maintenance training to include roof bolt limitations.
  - Participatory approach focusing on the hierarchy of control to manage hazardous manual tasks.
4. Reinforce self-managed safety risk control measures such as Take 5, SLAM required by the mine. Include 'line of fire' considerations. Include in training and tool box talks and supervisors to monitor this is occurring.
5. Consider what may be required regards rib protection systems.
6. Consider equipment or people rotations to relieve manual handling for extended frequencies and loads.
7. Include feed vs rotation feedback in hydraulic control logic.
8. Investigate alternate mechanical means to locate mesh to reduce personal exposure to environment.
9. Review bolt supply product surface quality finish that eliminates burring and splinter to operators.
10. Provide equipment (additional components) that can reduce manual interaction with mine environment.

## 1.7. Slips, trips, & musculoskeletal disorders

There were 53 incidents related to slips, trips, and musculoskeletal disorders requiring hospitalisation and lost time > 7 days.

Recommendations consistent with mine recommendations to prevent recurrence include:

1. Review operating standards, awareness and training.
2. Review ergonomics and work area available associated with manual handling of materials for bolting and the bolting process itself. Develop and provide procedures associated with the task.
3. Review process to manage pre-existing conditions that provides timely return to normal duties.
4. Carry out a human factors in design review.
  - Consider additional or alteration to equipment/machine that may reduce body stress/ergonomic issues to persons taking into consideration the hierarchy of control.
5. Rotation of persons. Reduction of duration for repetitive hazardous manual tasks.
6. Review operating procedures including training related to roof control and hazards. Include procedures in training and make available to trades.
  - Review bolting procedure that precludes operator interaction with moving parts.
  - Review SOP to include checks for air pressure, spin times, etc. Importance of communication
7. Review isolation and power on task procedures. Include in training.
8. Review hose layout and protection systems.
9. Improve access/egress to bolting rig equipment given 50% injuries on vehicles underground relate to this.
10. Emphasise and reinforce in training hazard self-assessment requirements such as take 5, SLAM, etc.
11. Consider risks, develop and provide/communicate/training SWP for 6' and similarly extended rib bolting systems.
12. Review with original equipment manufacturers operating and engineering limitations and requirements to maintain design requirements of drill steels and adaptors, i.e.: max torque, maximum angles and deflections.
13. Consider use of equipment that reduces the exposure to a hazardous manual task.
14. Consider a participatory approach to reducing the hazardous manual component of the task.
15. Review information provided to workforce regards lifting including training.
16. Consider alternate means of bolting that requires less manual intervention.
17. Consider material handling systems. Bundle sizes, etc.
18. Review existing material handling system for ongoing lift injury potential.

## 1.8. Escape of fluid incident reports

While there was only one case of fluid injection resulting from an escape of fluid and subsequent lost time injury, the highest frequency of incident reports relating bolting rigs is 'escape of fluid under pressure that could place any person at risk'.

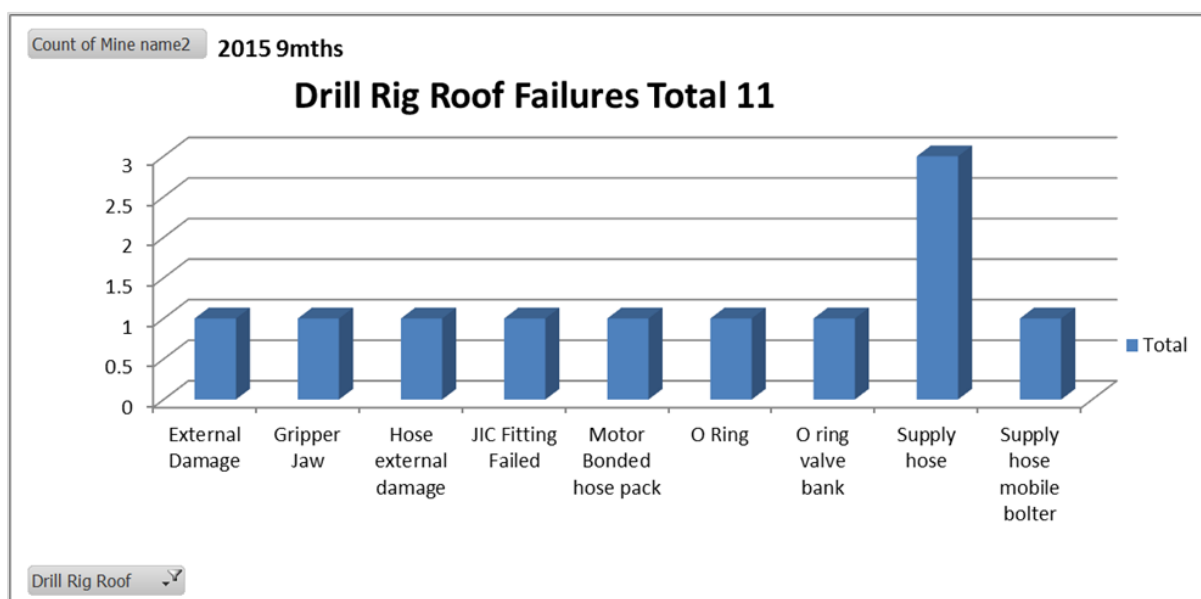
The following information has been provided by the mechanical inspectors that provide additional researched information relating the fluid release reports. The reports highlight the significance, in turn the need to manage the bolting rig hoses. It can be seen that during recent times, the incidents of motor hosing through the use and continued efforts to improve the bonded packs, has reduced.

Fig 6: Years 2007 -2010, 2011, 2012, 2013.

Development Units Drill Rigs (Roof) Failure Cause	2007-10	2011	2012	2013	Total	Percentage
Motor bonded hose pack	39		5	10	54	27.1%
Insufficient information	34		8	1	43	21.6%
Unknown		7	10		17	8.5%
External Damage/Loose		5		11	16	8.0%
Supply hose			5	7	12	6.0%
Other hoses identified	8		3	1	12	6.0%
"O"rings		1		8	9	4.5%
Timber Jack hoses	5		3	3	11	5.5%
Seal on gripper jaw			6	7	13	6.5%
Worn out fatigue		4		1	5	2.5%
Bend Radius		3			3	1.5%
Human Error		1		1	2	1.0%
Corrosion		1			1	0.5%
Hose too short		1			1	0.5%
<b>Total</b>	<b>86</b>	<b>23</b>	<b>40</b>	<b>50</b>	<b>199</b>	<b>100.0%</b>

TOTAL number of escape of fluid reports (including bolting rigs) during this period is= 1189; 185; 209; 193; = 1776

Fig 7: First 9 months of 2015.



There were 83 reported incidents relating to bolting rigs only during the period 2009 to 2015 under investigation. While rig motor hoses were the largest single cause over the six year period, it can be seen from the above information that efforts need to continue in all areas relating to rig hosing.

Recommendations consistent with mine recommendations to prevent recurrence include:

- Review hydraulic hose maintenance and inspection regime particularly in environmental damage prone and known areas of design limitations such as drill motors. Check these areas are also highlighted and controlled as far as practical from operational viewpoints such as park position of rigs and included in training. Review pre-use checks include such inspections.
- Re- enforce the need for operators to report and have rectified damage hoses with the necessary due care taken when a hose is found failed in service.
- Reinforce isolation and out of service standards. Restoration of power checks prior hand over. Include in training.
- Provide redesigned hose pack for rigs with positively retained hose protective covering.
- Include systematic inspections and maintenance replacements for rig hoses.
- Review rotation motor guard design standard to protect both operators and hoses.
- Review adequacy of operator training regards mine site standards.
- Review bolting rig SOP's.
- Review overhaul standards, procedures and training regarding MDG41. Ensure all stakeholders are familiar with requirements.

- Develop in conjunction with OEM operator and maintenance inspections for grippers.
- Review potential fitting and hose failures in vicinity of operators and provide guarding and protection systems as applicable.
- Audit and review hose routes regards rubbing and bend radius for all bolting rigs as applicable. Carry out checks for adequate hose operating clearances for all rig operations and movements on all bolting rigs.
- Review maintenance to production handover, commissioning, and testing protocols are available and effective. Tool box talks to reinforce regards checking and testing prior to placing back into service.
- Request the OE to review and advise industry any maintenance related recommendations that have known reoccurring failures. This has not always occurred with subsequent unnecessary failures.
- Continue to develop and communicate mine equipment and hydraulic standards to tradespersons and operators.
- Review with OE regards isolation and depressurisation procedures and components necessary potential for removal of locked in pressure during gripper component replacement. Advise the OE to provide industry alerts if this condition can occur.
- Review defect management reporting is known and applied for both trades and operators via their respective training to ensure potential hazards are identified and rectified as required.
- Check repair and replacement of components specification are consistent with MDG41. (Fos/burst/rating etc)

## 5. Summary of all injury types and lost time recommendations to prevent recurrence

The total list of prevention measures, developed in conjunction with mine recommendations relating to ALL previous five years of injuries is outlined below:

### Training

1. Review training to include:
  - Fluid injection hazard awareness and control training for operators and tradesmen.
  - Training related to roof control and hazards including mega and flexi bolting and material handling.
  - Include all procedures into the training.
  - Hazard awareness in and around roof, rib bolting including material handling.
  - Limitations and hazards associated with misaligned dollies and drives.
  - Updated procedures consistent with this report.
  - Review lifting equipment and maintenance training to include roof bolt limitations.
  - Include checks for air pressure, spin times, etc. Importance of communication
  - Maintenance persons to receive same training and procedures as operators.
2. Review manual handling procedures, lifting and ensure training takes into consideration a participatory ergonomics approach.

### Equipment design

3. Review the following design areas in conjunction with the OEM.
  - Potential pinch points.
  - Feed vs speed vs pressure feedback/proportioning systems for varying roof conditions.
  - Hydraulic control valve design consistent with MDG35.1 and two-handed controls.
  - Check operating and engineering limitations and requirements to maintain design requirements of drill steels and adaptors. Eg: max torque, maximum angles and deflections.
  - Include feed vs rotation feedback in hydraulic control logic where possible.

- Investigate alternate mechanical means to locate mesh to reduce personal exposure to environment.
- Provide equipment (additional components) that can reduce manual interaction with mine environment.
- Improve access/egress to bolting rig equipment given 50% injuries on vehicles underground relate to this.
- Review with OE, operating and engineering limitations and requirements to maintain design requirements of drill steels and adaptors. I.e.: max torque, maximum angles and deflections.

## Review

4. Review and where possible, improve work area for material handling and bolting regards ergonomics and layout.
5. Review bolting rigs for consistency regards OE latest standards.
6. Review guards and guard systems at potential crush/pinch points during material loading, roof and rib bolting including any use of mega and flexi bolting.
7. Consider equipment or people rotations to relieve the exposure to the hazardous manual tasks for extended frequencies and loads. Reduction of duration for repetitive hazardous manual tasks.
8. Review bolt supply product surface quality finish that eliminates burring and splinter to operators.
9. Review isolation and power on task procedures. Include in training.
10. Carry out a bolting procedure review. Provide additional consideration to:
  - Bolting procedures that precludes operator interaction with moving parts.
  - The various mining environments that may arise. Consider such issues as barring down, Take 5, TARPS etc.
  - Review bolting procedure to preclude interaction with moving parts where possible. Include in training.
  - Include checks for air pressure, spin times, etc. Importance of communication with other operators.
  - Review operating procedures including training related to roof and rib control including mega and flexi bolting and material handling.
  - Consider alternate means of bolting that requires less manual intervention.
  - Consider material handling systems. Bundle sizes, etc.
11. Carry out a material handling and human factors in design review.
  - Consider additional or alteration to equipment/machine that will reduce the exposure to the hazardous manual task.
  - Consider use of equipment that reduces need for manual handling.
  - Review existing material handling system for ongoing lift injury potential.
12. Review roof control management plans including TARPS and materials and rib shield shown adequate.
13. Review potential to improve bolt platform ergonomics and layout.
14. Review ergonomics and work area available associated with hazardous manual tasks of materials for bolting and the bolting process itself. Develop and provide procedures associated with the task.

## **Risk assessments**

15. Carry out a bolting risk assessment (MDG35.1 nominates that an operational risk assessment MUST be carried out on bolting plant).
  - Consider all areas involving the bolting process including material handling, roof, rib, flexi and mega bolting.
  - Consider other controls that may be necessary to manage the risk in areas of noncompliance regards MDG35 and MDG41.
  - Consider the need for any power on tasks during the risk assessment. All power on tasks should be accompanied with a safe work procedure and be included in the training. Monitor for effective use.
  - Consider pinch and crush areas involving the entire material handling and bolting process.
  - Consider use of equipment during material handling, roof and rib bolting (including flexi and mega bolts) that reduces the need for manual handling.
  - Consider what may be required regards rib protection systems.
  - Consider equipment (additional components) that can reduce manual interaction with mine environment.
  - Consider risks, develop and provide/communicate/training SWP for 6' and similarly extended rib bolting systems.
16. Reinforce self-managed safety risk control measures such as Take 5, SLAM required by the mine. Include 'line of fire' considerations. Include in training and TBT's. Monitor.

## **Maintenance**

17. Include drill guides and the OEM recommendations into the maintenance inspection regime.
18. Review hose layout and protection systems that prevent rubbing.
19. Review pre start and daily systematic checks for hose damage on drill rig equipment.

## **Procedures**

20. Review and refresh bolting procedures. Include the following considerations:
  - The various mining environments that may arise. Consider such issues as barring down, Take 5, TARPS, etc.
  - Review bolting procedure to preclude interaction with moving parts where possible. Include in training.
  - Include checks for air pressure, spin times, etc, Importance of communication with other operators.
  - Review operating procedures including training related to roof and rib control including mega and flexi bolting and material handling.
  - Preuse and operating standard inspections and checks and what is considered unacceptable.
  - Modify bolting procedures to suit various mining conditions (TARPS.)
  - Review operational use of butterfly plates. Include considerations of do's and don'ts in the SOP's for bolting.
  - No go zones under all TARP conditions for roof and rib bolting.
  - Disconnection of drill extensions.
  - Include checks for air pressure, spin times, etc, Importance of communication and line of fire.



## 6. What type of roof bolting gives the most injury to people?

By far, the most prevalent type of bolting causing injury is roof bolting on the continuous miner.

Mines should consider how much and what type of bolting is done to assist in establishing control priorities. It is interesting, given their frequency of use, that only a few incidents directly relate to the use of the rib bolters.

There were approximately 20 incidents relating material falling from roof or sides during the bolting time that subsequently caused an incident. Some mines have notoriously bad roof and or ribs and sometimes inconsistent geology.

Given the current technological limitations, the bolting process in potentially poor geotechnical zones relies more heavily on human intervention to effectively support roof and ribs.

The proportion of injuries related to the human and organisational factors at these mines is substantially higher than the mines that have generally good roof and sides.

Fig 8: Photos of underground roof bolting.



Fig 9: Human factors relating the design and environment are the highest cause of bolting rig injuries.

