The Wider Application of Poka Yokes (Mistake Proofing) in the Mining Industry

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ABRIDGED CV

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EXECUTIVE SUMMARY

Mines have implemented many different safety initiatives over the past decade, many of them recognising the human factor and its impact on safety. Many of these have been successful, yet the need exists to improve.

No person goes to work thinking that it is a good day to be involved in some incident or even worse to be injured, yet incidents and injuries occur on a daily basis.

Incident causation analysis techniques recognise that people make mistakes and once this is accepted, safety initiatives aimed at making working places, processes and procedures as mistake-proof as possible can be implemented.

This paper explains how the Japanese concept of Poka Yoke (mistake-proofing) can be more widely applied to the mining industry.

Although there are already many examples of Poka Yokes in the mining industry, it is proposed that focussing safety initiatives around identifying Poka Yokes from prioritised risks identified by existing Risk Assessments could yield significant further benefits. Operators that are familiar with the hazards and risks that they are exposed to on a daily basis should be involved in the process of identifying potential Poka Yokes.

This should enhance the Risk Assessment process and ensure that these documents are regularly reviewed when incidents occur.

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1 Introduction

Most successful global companies, acknowledge that human behaviour is pivotal to their success and contributes towards goals such as competitiveness, high quality, improved productivity and a work force committed to safety.

Recognised Incident Causation Analysis Techniques acknowledge that errors (accidental) or violations (deliberate) made in the presence of a hazard can contribute to an event.

It is therefore accepted that humans err.

For example have you ever:

- Driven to work and not remembered it?
- Driven home from work when you meant to stop elsewhere?

Mines without people do not exist. Mistakes will therefore be made resulting in different outcomes.

Poka Yoke is a quality management concept developed by a Matsushita manufacturing engineer Shigeo Shingo to prevent human errors from occurring on the production line. Poka Yoke means “avoiding inadvertent errors”.

The main objective of Poka Yoke is to achieve zero defects and is a component of a Zero Defect Quality Control system aimed at eliminating defective products.

Poka Yoke is more of a concept than a procedure. Thus, its implementation is governed by what people think they can do to prevent errors in their workplace and not by a set of step-by-step instructions on how they should do their job. Poka Yoke is implemented by using simple objects like fixtures, jigs, gadgets, warning devices, paper systems and the like to prevent people from inadvertently making mistakes.

Poka Yokes should be low cost devices that are useable by all workers, simple to install, that do not require continuous attention from operators and provide instantaneous feedback, correction or prevention.

Shingo suggested a solution that became the first Poka Yoke device. In the old method a worker began by taking two springs out of a large parts box and then assembling the switch. In the new approach, a small dish is placed in front of the worker and the worker then takes two springs out of the box and places them on the dish. Then the worker assembles the switch. If any spring remains on the dish, then the worker knows that he or she has forgotten to insert it. The new procedure completely eliminated the problem of missing springs.

There are many Poka Yokes that exist and to which we have been exposed over time without realising what they were, yet they prevented us from making mistakes.

Examples include the following :

- Leaded and lead replacement petrol openings are different sizes (Figure 1).
- Rumble strips on tar roads (Figure 2).
- Male and female plugs commonly used with computers (Figure 3).
- Gears on most automatic vehicles cannot be engaged without the brake pedal being depressed.
- Seat belt warnings (visual and audible).
- Keys on most automatic vehicles cannot be removed from the ignition unless the gear selector is in the Park position.

The purpose of this paper is to define human error, explain how the Poka Yoke concept can help address the problem and how to implement Poka Yoke concepts.

Figure 1. Petrol filler opening

Figure 2. Rumble strips

Figure 3. Computer power cable

2 The Human Factor

Safety in mines is often in the headlines and in many instances, justifiably so. This reflects poorly on the industry, which over the past 10 years has made significant investments in safety and has achieved improved safety records. For the purposes of this discussion I will deal mainly with falls of ground in gold and platinum mines as they remain one of the most significant risks that underground employees in these mines are exposed to. From January 2007 to December 2009, 176 persons have lost their lives in gold and platinum mines due to falls of ground accidents and 2 404 have been injured. These injuries represent 25% of all injuries, while the fatalities represent 42% of all the deaths.

These statistics indicate that there is still significant room for improvement, especially from a fall of ground perspective, but where do we go from here?

During my career in the mining industry, I spent 22 years on mine safety and I investigated many incidents with vastly different outcomes. I also perused many investigations conducted by subordinates and in the majority of these investigations one common denominator was always present and this was the person/ persons involved had done something contrary to their training or had done something considered to be "stupid". In many cases the reasons for these mistakes could never be established and I always believed that once we understand this aspect of human nature we could prevent incidents from occurring.

When I was introduced to the Behaviour Based Safety initiatives I was excited as these addressed some of the causes of incidents from a people perspective. The development and implementation of behaviour-based safety processes was based on an analysis of injury statistics that indicated that 87% of injuries were attributable to at-risk behaviours, 11% of injuries were attributable to at-risk conditions, and 2% of injuries were attributable to other causes.

The gold and platinum mining industries are labour intensive and the risk, based on this analysis, indicated that intervention was required.

The objectives of a behaviour based safety initiative are:

- to eliminate barriers and weaknesses that could cause failure of the process, and
- to intervene in critical areas through effective action plans, coaching, training and streamlining of management systems.

The principles of Ubuntu also form an important cornerstone of the process. Being your brothers' keeper requires you to sound the alarm when at risk behaviours are being performed / observed.

Behaviour based safety initiatives have been introduced in the mining industry over the past 8 years and some significant improvements in safety performance have been recorded by some operations.

In addition to ensuring excellent safety performance amongst the total work force by well planned, dedicated and continuous efforts such as Behaviour Based Safety Initiatives, mining companies have addressed safety through the implementation of safety management systems, operational systems and engineering designs and controls.

2.1 Types of human mistakes

Common human mistakes are as follows:

- Forgetfulness
- Misunderstanding
- Wrong identification
- Lack of experience
- Wilful (ignoring rules or procedures)
- Inadvertent or sloppiness
- Slowness
- Lack of standardization
- Surprise (unexpected machine operation etc.)
- Intentional (sabotage)
- Processing omissions – leaving out one or more process steps
- Processing errors – operation not performed according to standard work procedures
- Error in setting up the work piece – using the wrong tooling or setting machine adjustments incorrectly for the current product
- Missing parts – not all parts included / available
- Processing wrong work piece
- Operations errors – carrying out operation incorrectly
- Adjustment, measurement, dimension errors – errors in machine adjustment, testing measurements or dimensions
- Errors in equipment maintenance – defects caused by incorrect repairs or component replacement
- Error in preparation of consumables – damaged parts, wrong jigs, wrong tools, wrong target etc.

I can think of many examples where I have made mistakes as mentioned above, and I am convinced that the reader can do the same.

2.2 Errors and defects

The differences between errors and defects are:

- humans make errors (cause), defects arise because errors are made (effect)
- an error is any deviation from an intended process
- it is impossible to completely and consistently eliminate errors from tasks being performed by humans
- errors will not turn into defects / non-conformances if suitable feedback and action takes place at the error stage
- errors can occur when any condition necessary for successful processing is improper or absent – incomplete cleaning of footwall prior to the measuring and installation of an elongate
- not all errors result in defects / non-conformances

2.3 Causes of defects / non-conformances

Factors which are responsible for defects or non-conformances are:

- Poor procedures or standards
- Incorrectly spaced / set-up / maintained / operated machines
- Non-conforming material
- Worn tooling
- Mistakes

2.4 Consequences of defects

The optimum utilisation of resources is essential to remain competitive in today's global economy. Any undesired event that impacts on this utilisation can be considered to be a defect or a non-conformance. If one analyses defects or non-conformances that could exist or occur within mining operations, the consequences and costs associated with these could be significant and every effort should be made to eliminate the causes of such defects or non-conformances. The consequences and cost of defects / non-conformances not only impacts on profitability, but can also create the potential for further defects / non-conformances due to increased pressure on business performance. We therefore need to eliminate all potential defects by enforcing a Zero Defect Quality System.

2.5 Zero Defect Quality System (ZDQS)

The characteristics of a ZDQS are:

- A quality concept to manufacture / install ZERO defects and eliminate waste / non-conformance associated with defects. Zero is the goal.

- Based on a discipline that defects are prevented, control the process so that defects are impossible.
- No finger pointing – operators and machines will sometimes make mistakes – we need to find ways to keep mistakes from becoming defects / non-conformances.
- A method for mistake proofing a process – ZDQ assures that a defect / non-conformance is not shipped / delivered to a customer.

The next section explains how Poka Yokes can be used as an important component of a ZDQS.

3 Poka Yoke (Mistake Proofing) Philosophy

People make mistakes, but by the application of the process of Poka Yoke, defects / non-conformances are reduced. Poka Yoke is simply a system designed to prevent inadvertent errors made by workers performing a process from becoming defects / non-conformances and ultimately incidents. The idea is to take over repetitive tasks that rely on memory or vigilance and guard against any lapses in focus. This concept has provided answers to many of the questions that I asked myself during my involvement in safety management. I believe that this concept is the next step in the process of incident prevention and acknowledging that humans make mistakes leading us to ***Mistake proofing – Poka Yoke***.

Mistake proofing is necessary for the following reasons:

- Humans make mistakes
- Errors are unavoidable
- 100% inspections by humans are less than 85% effective
- Products are not always designed for assembly / installation
- Suppliers also make mistakes
- New persons on jobs cannot do error free work
- Machines can make mistakes if they are not properly maintained

3.1 How to achieve ZDQ

ZDQ can be achieved by the following:

- “Poka Yoke” the process
- Errors must never become defects
- No finger pointing
- No mandate to do better next time
- Poke Yokes can be developed by anyone from managers through to line employees

3.2 The outcome of applying Poka Yoke

The implementation of a Poka Yoke results in the following:

- Makes performance of incorrect actions more difficult, or impossible
- Makes it possible to reverse actions – to “undo” them or make it harder to do what cannot be reversed
- Makes it easier to discover the errors that occur
- Makes a mistake obvious at a glance
- Eliminates of set-up errors and improves quality
- Decreases set-up times with associated reduction in lost production time and improved production capacity
- Simplifies and improves housekeeping
- Improves safety – resulting in lower costs
- Lowers skills requirements
- Increases production flexibility
- Improves operator attitudes

3.3 Where Poka Yoke works well

Poka Yokes can be effective when utilised in the following scenarios:

- Manual operations where worker vigilance is needed
- Where teams need common sense tools
- Where training costs and employee turnover are high
- Where mixed model production occurs
- Where mis-positioning can occur
- Where adjustment is required
- Where customers make mistakes and blame the service provider

The above situations apply to the mining industry.

The principle of mistake proofing is that the task can only be performed one way – correctly.

3.4 Reduction of quality defects / non-conformances

In order to reduce quality defects we must:

- understand the process and its relationship to other business processes e.g. the installation of support relative to the other processes of the mining cycle such as drilling, blasting and cleaning.
- identify the inputs and outputs of the process e.g. Inputs relating to support – Codes of Practice, support standards, safe work procedures, selection of support elements, training, installation of support elements, monitoring performance of support elements and system. Outputs relating to support – a support system that will provide the designed support resistance during mining operations in the area.
- identify the suppliers to and customers of the process e.g. suppliers to the process are rock engineers, suppliers of support elements and employees installing the support elements. All employees working underground are customers of the process and are entitled to expect a defect free system that will ensure their safety.

4 Implementation of Poka Yokes

4.1 Source inspections – "Eliminating errors"

Source inspections are intended to keep defects / non-conformances from occurring. Self-checks by operators and successive checks by supervisors provide feedback about the outcomes of the process. Self-checks and successive checks should be used when source inspection cannot be done or when the process is not yet well enough understood to develop source inspection techniques. While successive checks provide rapid feedback, having the person who performs the production operation check their own work provides even faster feedback. Self-checks use Poka Yoke devices such as load indicators to allow workers to assess the quality of their own work. As every unit installed is checked, operators may be able to recognize what conditions changed that caused the last unit to be defective. This insight is used to prevent further defects / non-conformances. Self-checks are preferred to successive checks whenever possible. Successive checks would be done in accordance with the Ubuntu principles.

4.2 Proactive approach

A fully implemented ZDQ system requires Poke Yoke usage at or before the inspection points during the process and Poka Yoke will catch the errors before a defective part is manufactured 100% of the time.

4.3 Detecting errors

- Physical contact – determine whether defects exist based on the presence or absence of physical contact with a sensing device e.g. Limit switches, light beams, FOG lights, closure tell tales.
- Poka Yokes do not have to be high tech. Passive devices such as guide pins or blocks that prevent incorrect seating can be adequate.
- Grouping and counting to prevent errors. A fixed number of parts are allocated and need to be used.
- Sequencing – standard sequencing required – if step has not occurred next step can't take place.

Positive effects are:

- Pushes defect detection up-front
- Cost reduced
- Non-conforming materials are not processed
- Eliminates need for SPC (Statistical Process Control)
- Reduces steps in process

Negative effects are:

- Cost of Poka Yoke devices (often minimal)

4.4 Eliminating errors

Approaches for eliminating errors are:

- Shutdown approach – process shuts down when error occurs (e.g. inadequate light for camera)
- Control approach – Does not depend on operator or assembler. Stops process and in some cases corrects automatically. (e.g. unleaded petrol pipes)
- Warning approach – signals operator to stop process and correct the problem (e.g. seat belts)

Simple objects such as fixtures, jigs, gadgets, warning devices, paper systems and the like are used to prevent people from making mistakes.

Everybody should practice Poka Yoke in the workplace.

The solutions to perceived complex issues can generally be developed by the persons exposed to these issues on a daily basis and are normally not complex solutions. With the necessary guidance, operators involved in the various mining processes are best suited to develop Poka Yokes as they are the ones exposed to the hazards, risks and frustrations on a daily basis.

Poka Yoke devices should have the following characteristics:

- Useable by all workers
- Simple to install
- Does not require continuous attention from operator
- Low-cost
- Provide instantaneous feedback, correction or prevention

4.5 Developing Poka Yokes from Risk Assessments

Potential Poka Yokes can be developed from the risks identified during a risk assessment. The identified and prioritised risks can be used as a basis for the identification of areas where Poka Yokes could and / or should be developed. Teams of empowered employees can develop possible Poka Yokes to address the identified risks. It is possible that not all the potential Poka Yokes can be implemented, especially in the harsh underground environment. It is therefore essential that the process be aimed at the simple solutions rather than complex ones.

4.6 Developing Poka Yokes from incidents

A method for developing Poka Yokes from detected defects is:

- Determine the root cause of the defect / non-conformance. (Existing Risk Assessments have identified many of these).
- Review current standard procedure.
- Identify deviations from standards.
- Identify the Poka Yoke device most likely to effectively eliminate the defect / non-conformance.
- Create and test effectiveness of device and continue modifying until defects are effectively prevented.

4.7 Developing Poka Yokes from identified at risk behaviours

Behaviour Based Safety Initiatives have identified critical safe behaviours and these can also be used in an attempt to develop potential Poka Yokes. Such Poka Yokes could then eliminate some of the critical behaviours.

Good Poka Yokes are generally developed through the empowerment of employees. The person doing the work for 8 hours per day, who is exposed to the challenges and frustrations associated with the tasks to be performed and is exposed to the hazards associated with such tasks can provide valuable input into the process to eliminate mistakes that could result in defects / non-conformances.

Production processes involve the flow of men and material, machining, assembly, packaging, transport and use / installation. All these processes have the potential for defects. Hence all processes offer an opportunity for the elimination of defects and the resultant quality improvement.

5 Examples of Poka Yokes That Already Exist in the Mining Industry

There are many Poka Yokes that exist in the mining industry and in our everyday lives that we have grown accustomed to without realising what they are. These have been put in place over many years in an attempt to eliminate mistakes which could lead to incidents and it would be interesting to know how many incidents have been avoided over the years as a result of these Poka Yokes. Most of these have been developed following defects / non-conformances and in many cases these resulted in injury and / or death.

Examples:

- Station stopping devices that are interlocked with signalling systems to prevent rolling stock from gaining access to shaft compartments when there is no conveyance at that point in the shaft. (Deebar) (Figure 4).
- Rolling stock coupling devices have been changed over time and have handles to prevent hands from coming between couplings during the coupling process (Figure 5).
- Winder safety interlock for artisans performing maintenance. Each person locks out independently and ensures safety during maintenance processes that have varying time spans. (Deebar) (Figure 6).

Figure 4. Stopping device

Figure 5. Coupling device

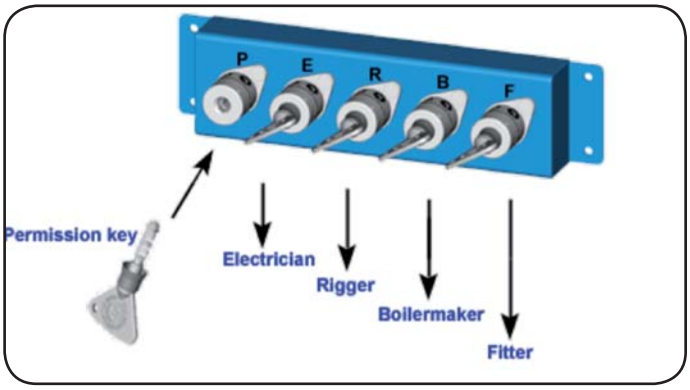

Figure 6. Winder safety interlock

6 New Concept Mining Case Study

New Concept Mining is a leading supplier of Mine Support products and has incorporated a number of Poka Yokes into its Jackpot Elongate Pre-stressing Unit, Hydrabolt expandable roofbolt and associated pumping systems. Some of these Poka Yokes were identified by analysing the Risk Assessment Guidelines for these products.

6.1 Risk Assessment Example

A risk assessment done on Jackpot pre-stressing units has identified the following potential Poka Yokes, some of which have been implemented.

Risk	Potential Poka Yoke
Load loss in units due to creep.	Load indicators will indicate whether re-pumping is required and which units need to be re-pumped.
Rust in unused units can snag valves.	A rust prevention fluid could be pumped into units in an attempt to eliminate this problem.
Over-pressurising of Jackpots due to incorrect pump being used.	Colour coding of pumps and hoses and different shaped nozzles.
Incorrect pressure delivered by pump.	Daily check with pressure gauge and load indicators.
Fall of ground during pumping.	Extension nozzles ensure that installation can be done safely from a distance.
Failure of units during pumping.	Stringent quality control including Poka Yokes during manufacture ensures a Zero Quality Defect product.
Units falling during transport.	Attach carrying handles and limiting bundle sizes.
Incorrect pressures.	Pressure release valves ensure that units are not over or under pressure.
Pressurised water leaking at seal.	Remote pumping and use of eye protection during pumping.
Over-inflation of PSU.	Indicator on PSU that will be exposed if unit is over-inflated.

6.2 Product Examples

- Colour coding of numerous systems. The yellow pump (low pressure for a Jackpots) and blue pump (high pressure for Hydrabolts and Jackpots) (Figure 7).

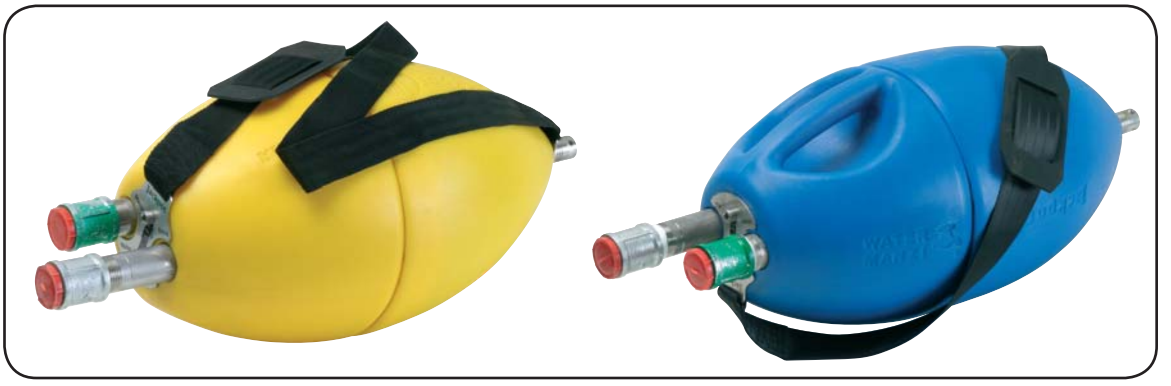

Figure 7. Jackpot Pumps

- Pressure Relief Valves (Figure 8). The Safety Pistol and Combi-Nozzle Pressure Relief Valves (PRVs) (Figure 9), which prevent products from being over-pressurised and indicate correct pressure by dumping water from the PRV when at the correct pressure.

Figure 8. Pressure Relief Valves

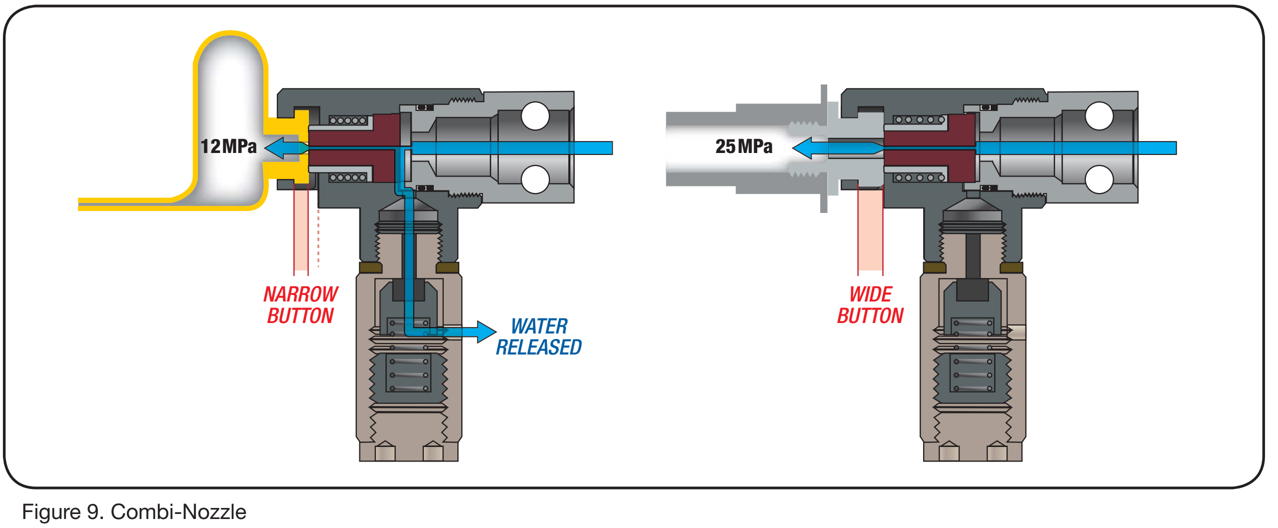

Figure 9. Combi-Nozzle

- A load indicator card showing colours per length and Hydrabolt vs X-Pandabolt (Figure 10).
- Two holes machined into the back of the NC8 Safety Pistol to indicate that this is a NC8 pistol and not a NW6 pistol. NC8 is used on high pressure pumps, NW6 is the fitting most used on low pressure pumps. It's important that pumping systems are only assembled correctly so that the products are inflated to correct pressure (Figure 11).
- A NC8 hose end showing the 3 rings machined into the outer diameter and the blue collar indicating NC8 fitting and not NW6 (Figure 12).
- Load indicators on Hydrabolts in pressurised and un-pressurised position (Figure 13).

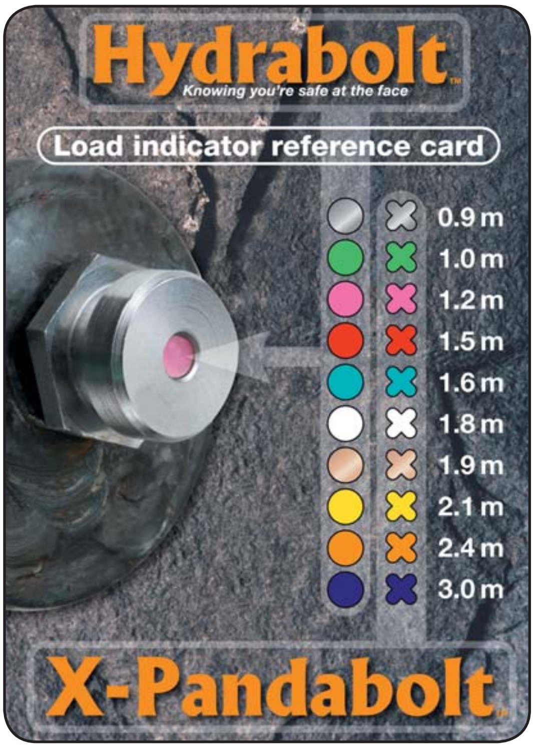

Figure 10. Indicator Card

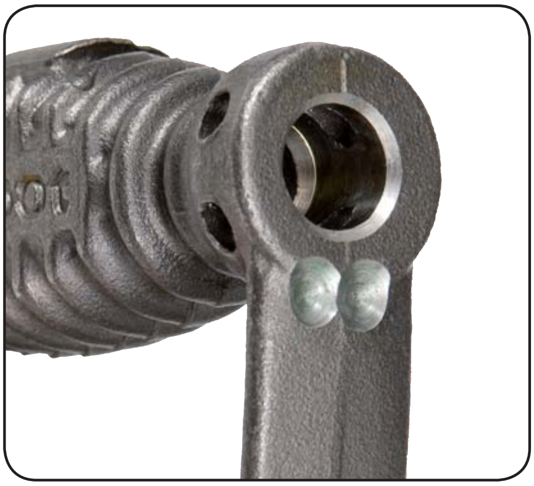
Figure 11. Safety Pistol

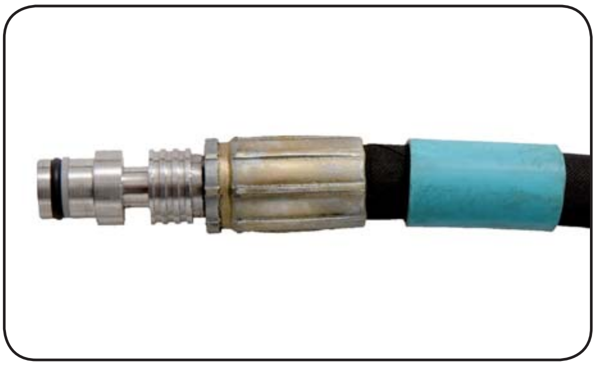
Figure 12. NC8 Hose End

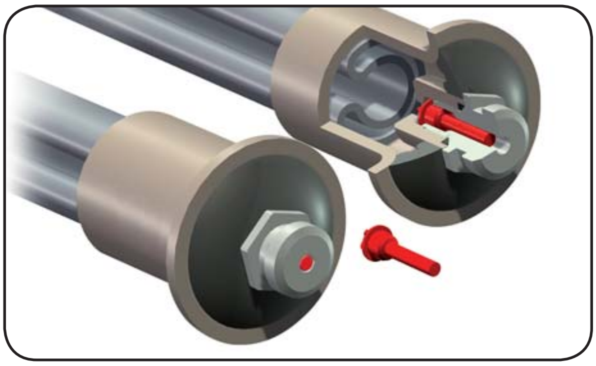
Figure 13. Hydrabolt Load Indicator

- Load monitoring Jackpot that continuously monitors and indicates the pressure by means of a load indicating pin (Figure 14).
- Self auditing Jackpot with button indicating required pressure (Figure 15).

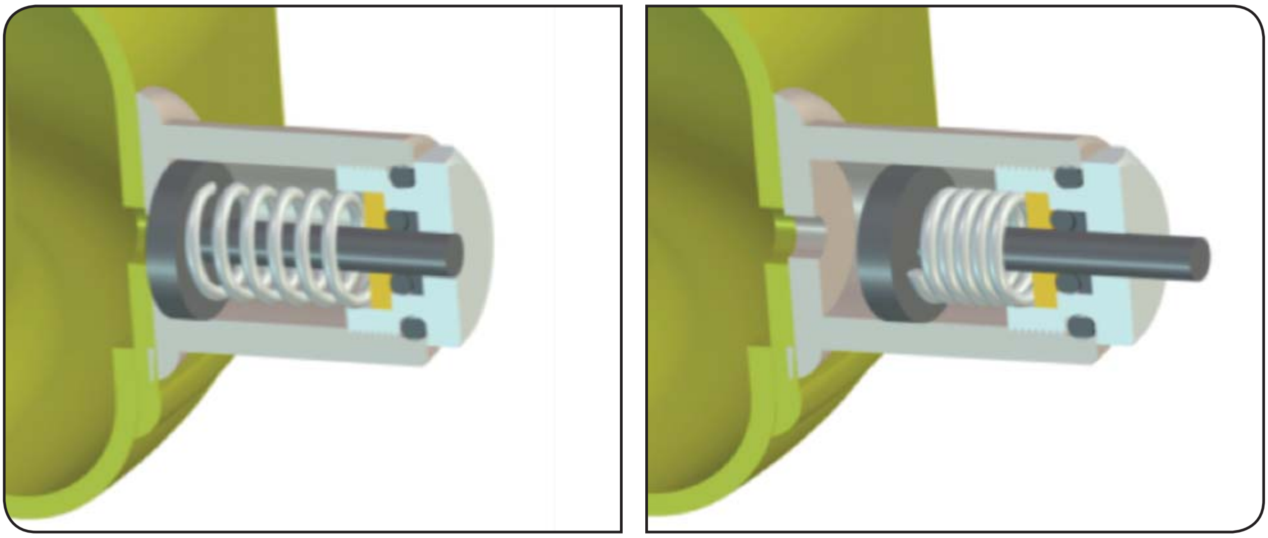

Figure 14. Jackpot Load Monitor

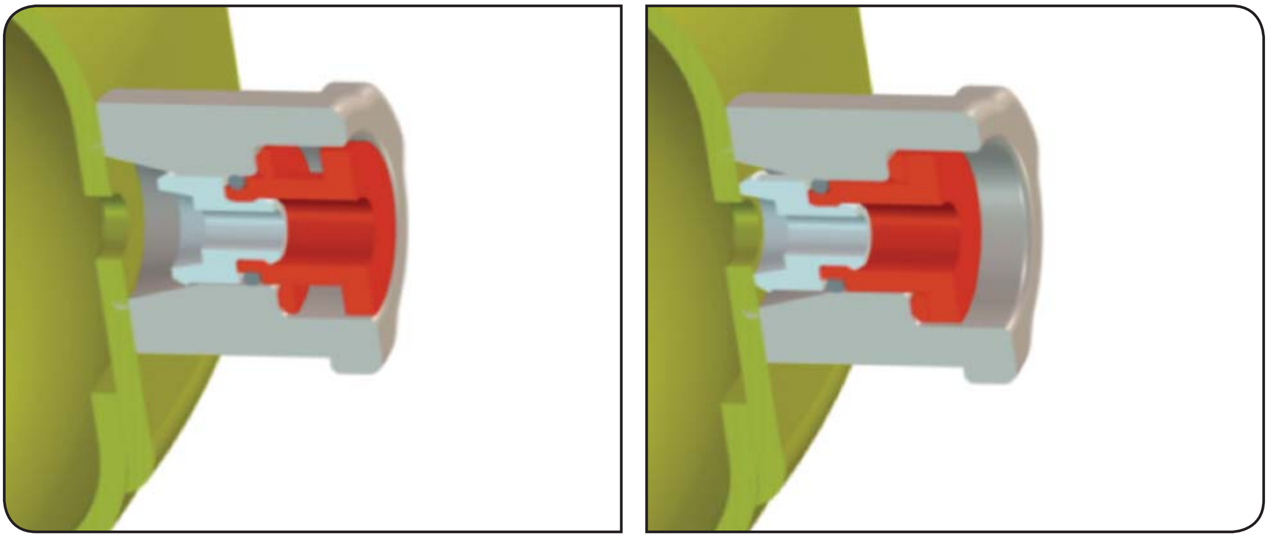

Figure 15. Jackpot Filling Pressure Indicator

7 Poka Yoke in Practise to Prevent Falls of Ground

Falls of ground are common incidents in both gold and platinum mines and account for a significant percentage of injuries and deaths. All underground employees are exposed to the risks associated with falls of ground and the successful reduction of this type of incident can result in significant improvements in industry injuries and fatalities. If we consider the processes associated with the prevention of falls of ground, they include the compilation of Codes of Practice, the development of equipment and support standards, the selection and installation of equipment and support elements that combine to form a system. The Codes of Practice and standards generally pass any scrutiny. The equipment and support elements are also subjected to QC systems and regular testing. In the event of an incident, the issues are, in most cases, associated with the application of mining processes underground (i.e. support installation, drilling, blasting and cleaning). Undetected defects / non-conformances associated with these mining processes can result in defects / non-conformances such as ineffective support elements and blasted out support elements that can impact on the integrity of the support system and lead to failure with resultant falls of ground. The initial defect / non-conformance could then result in injury or death with resultant production delays, section, shaft or mine closure with significant cost implications.

One factor that is often ignored is that the underground workings are dynamic environments that change after every blast as opposed to a relatively static environment of a processing plant. This implies that greater vigilance is required from every underground employee and the need to Poka Yoke the processes is essential if we are to be successful in reducing the number of fall of ground incidents.

Using the existing risk assessments as a basis, the risks should be re-evaluated from a Poka Yoke perspective and this would most probably result in some novel Poka Yokes being developed which could include simple and inexpensive visual prompts that prevent the defect occurring.

8 Conclusion

Behaviour based safety addresses the critical safety behaviours associated with tasks being performed. These behaviours can be identified by the risk assessments and employees become each others' keepers in the application of the process. The investigative processes into incidents recognises that mistakes are made. Poka Yoke is therefore clearly an enhancement to the Behaviour Based Safety Initiatives that can assist in addressing the individual and / or team actions that contributed or caused the event by means of errors (accidental) or violations (deliberate) made in the presence of a hazard. Through the process of determining root causes, Poka Yokes can be identified that could effectively ensure that the critical behaviours are continuously safe.

One factor that is often ignored is that the underground workings are a dynamic environment that change after every blast as opposed to a relatively static environment of a processing plant. This implies that greater vigilance is required from every underground employee and the need to Poka Yoke the processes is essential if we are to be successful in reducing the number of fall of ground incidents.

Poka Yoke has been applied successfully in many industrial environments throughout the world and is an effective method of limiting human errors. Poka Yoke is a process that is aimed at eliminating mistakes by means of low-cost, simple devices that are useable by all workers in environments where worker vigilance is required in an environment where manual operations are performed, where teams need common sense tools and where training costs and employee turnover are high. These attributes make Poka Yoke suited to the South African mining industry.

Mistakes can result in defects / non-conformances and therefore need to be eliminated as far as possible. The potential cost of defects / non-conformances in the mining industry is astronomical and could include injuries, deaths, section, shaft or mine closures and the resultant business disruption.

The process of Poka Yoke can enhance the existing processes of safety management and is the logical next step in closing the loop on existing "shortcomings". The logical starting point in this process is the existing risk assessments, the identified risks should be analysed from a Poka Yoke perspective and through the proper empowerment of employees, Poka Yokes can be developed that could assist in reducing the number of undesired events.

9 Acknowledgements

1 New Concept Mining for allowing me to present this paper and for providing examples of Poka Yokes that they have already introduced. *www.ncm.co.za*.

2 The examples found at *www.mistakeproofing.com* and *pokayoke.wikispaces.com*. (Please consider forwarding other examples of Poka Yokes to *pokayoke.wikispaces.com*. This website allows anyone to add examples and edit existing ones (just like wikipedia does).

You may also be interested in a mistake-proofing exercise/case study available at *http://www.campbell.berry.edu/faculty/jgrout/exercise/index.html*.

3 Deebar Mining Division for providing photographs of the station stopping device and the winder safety interlock. *www.deebar.co.za*.

4 Information obtained from *www.siliconfareast.com/pokayoke.htm*.