



**Midland Institute of Mining Engineers**

## **13<sup>th</sup> Safety Seminar**

### **“Safely Managing the Challenge of Change”**

**Holiday Inn Royal Victoria  
Victoria Station Road  
Sheffield, S4 7YE  
Friday 20<sup>th</sup> April 2018**



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Doosan Babcock	Martin Oldroyd	
Health & Safety Authority	Jim Holmes	
Health & Safety Executive	Simon Coldrick	
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PBE Europe Ltd	Adrian Barratt	
TFL	Mark Thompson	
Trox	Matthew Evans	
3D Laser Mapping	Dr Neil Slatcher	

# Welcome Message

On behalf of the Midland Institute of Mining Engineers, I would like to welcome you to this, our 13th Annual Safety Seminar entitled “Safely Managing the Challenge of Change”.

Since the last Seminar held on the 6 April 2017 the Midland Institute has undergone a major change in that we are now an Incorporated Charitable Organisation (ICO) registered with the Charity Commission Reg No 1177100. Charitable objects being “the advancement in the public interest of the engineering, science and the practice of the extraction and processing of natural resources, and the education of those involved in such activities and of the public.”

In compiling today’s programme, we have sought to bring together a range of topical and relevant subjects which will appeal to both operators and equipment suppliers, irrespective of the nature of the mineral being mined.

The day will be split into two sessions with a variety of presentations. Time has been allotted at the end of each presentation for questions and I would encourage you all to take advantage of this opportunity.

As mining engineers, we are highly aware of the challenges which confront us in all aspects of mining, extraction, and processing of natural resources, especially to maintain and uphold high safety standards. As one of the founding objectives of the South Yorkshire Viewers’ Association was the spreading of best practice, especially in relation to mine safety, I feel that events like this continue to meet this objective which is just as relevant today as it was over 160 years ago.

Your presence here today shows the determination of companies, members and individuals to consider the safety aspects and implications of necessary changes and shows continued determination to succeed in a challenging environment.

The Midland Institute of Mining Engineers encourages membership of The Institute of Materials, Minerals and Mining (IOM3) to enhance professional status within the mining and minerals industry. Many events, including this held today, count towards an individual’s Continual Professional Development (CPD) as well as giving an excellent opportunity for networking amongst colleagues within similar spheres of activity.

I encourage you to visit the Midland Institute of Mining Engineers, Institute of Materials, Minerals and Mining and other trade stands during the break periods.

I would like to thank our supporters for their continued involvement in this important event in our calendar. As President, I would also like to thank the speakers for the presentations you will see today, members of the organising committee for their contributions and of course, you the audience for making this Safety Seminar a success.

# Message from Honorary Secretary



## *Steve Straw – Honorary Secretary*

Steve began his career with the then National Coal Board in the South Yorkshire area as a mechanical apprentice in 1977, working at several collieries in the area and progressing from fitter to mechanical shift charge engineer.

Having gained his HND qualification in Mining and Mechanical Engineering he was appointed Deputy Mechanical Engineer at Welbeck Colliery in the Nottinghamshire coalfield. Then upon the announcements of its closure in 2009, he saw out the last six months of production and the closure of the colliery as Mechanical Engineer.

In 2010 Steve took the position of Deputy Mechanical Engineering at Thoresby Colliery in the Nottinghamshire coalfield looking after the production and salvage coal faces with responsibilities for coal face mechanisation projects.

After 38 years in the mining and the complete closure of the industry he finally hung up his boots in July 2015. He now spends his time actively involved with the Midland Institute of Mining Engineers and the local Labour Party of which he is chairman.

Steve is currently the Honorary Secretary of the Midland Institute of Mining Engineers and Fellow of the Institute of Materials Minerals and Mining.



# Programme of Events

TIME	TITLE	NAME	ORGANISATION
8.15 AM	Registration and Coffee		
Morning	Session Chairman	Bob Leeming	Chairman of Safety Seminar Committee
9.00am	Welcome introduction	Charles Rhodes	President MIMinE
9.05am	Focusing on safety in the tunnelling industry and lessons learned from the mining industry	Mark Thompson	Transport for London
9.35am	The use of automated laser scanning in mine safety	Dr Neil Slatcher	3D Laser Mapping
9.55am	A new age of particulate monitoring	Matthew Evans	Trolex
10.30am	Coffee Break		
11.00am	Vehicle fire suppression for mining equipment	Daniel Brunt	Ardent UK
11.30am	Exposure measurement of diesel engine exhaust emissions (DEEE) in mines	Peter Baldwin/ James Forder	HSL
12.00 noon	Mining dimensional stone and controlling major hazards at Hartham Park underground quarry	Steve Ainsworth	Lovell Stone
12.30pm	Benefits of professional membership of the Institute of Materials, Minerals and Mining	Sarah Boad	IOM3
12.40pm	Presentations	Charles Rhodes and Bob Leeming	President MIMinE Chairman of Safety Seminar Committee
12.45pm	Lunch		
Afternoon	Session Chairman	Neil Battison	Vice President MIMinE
1.45pm	Critical task analysis - managing change in high risk environments	Martin Oldroyd	Doosan Babcock
2.10pm	Managing the challenge of change in Irish mines	Jim Holmes	Health & Safety Authority
2.40pm	Modelling for the underground store of explosives	Simon Coldrick	HSL
3.00pm	Closing remarks	Charles Rhodes	President MIMinE

# Aims & Objectives

The Midland Institute of Mining Engineers (MIMinE) was formed toward the end of 1868 and amalgamated with the South Yorkshire Viewers Association (1857) during 1869. The inaugural address of the President, Mr T W Embleton of Methley, was reported to have dealt almost entirely with the problems of safety in the Yorkshire Coalfield and he was quoted as saying;

*“We must try to decide calmly and deliberately under what conditions will it be possible to work the Barnsley coal – the great staple of this district, and on which the prosperity of the neighbourhood mainly depends – with safety and comfort of the men.”*

In this simple phrase Embleton identifies two issues, namely, the economic advantages of working the Barnsley coal, together with the need to consider the health and safety of the workforce whilst doing so. He appears not to view these as two separate issues, but to regard them as being mutually desirable objectives for long term commercial viability.

Organisations and individuals may or may not recognise a connection between business efficiency and health and safety, but there appears to be difficulty in integrating these issues in a meaningful and constructive manner. Health and safety issues appear to be reliant on annual initiatives, do not generally appear to be self-sustaining, and focus on outcomes not procedures (ie: what is done not how it is done).

The purpose of this Safety Seminar is to consider the synergy between health and safety management and business efficiency. Root cause investigation of health and safety incidents invariably highlight deficiencies which are impacting, usually more frequently, upon an organisation's ability to deliver its outputs in a predictable manner. It is therefore the intention of this seminar to consider those matters that link health and safety management and the challenge of changes that are necessary to maintain business efficiency.

The opinions, conclusions and other information expressed in this publication are those of the individual presenters and may not necessarily be those held by the Midland Institute of Mining Engineers.



# Organising Committee

Bob Leeming (Chairman)	HM Chief Inspector of Mines, and Past President, MIMinE
Charles Rhodes	President, MIMinE
Neil Battison	Vice President
Mr Ian Dixon	Past President
Mr Peter Scott	Councillor
Norman E Riley	Honorary Treasurer, MIMinE
Steve Straw	Honorary Secretary, MIMinE
Jane Isaacs Claire Stapleton	Administrators, MIMinE

# About Midlands Institute of Mining Engineers

With a history dating back to 1857, this association of engineers in the extractive energy industry was prompted by a desire to disseminate information and to encourage the development of young persons in engineering. These two primary aims, in tandem with others, are still very much the focus of the MIMinE activities today.

Historically MIMinE has been part of a federation of other mining societies and was then federated to and a branch of the Institute of Mining Engineers with various changes of title over the years. On the formation of the Institute of Materials Minerals and Mining (IOM3) in 2002, the MIMinE became affiliated to IOM3 as a local society mainly operating in the regions of Nottinghamshire, North Derbyshire, and Yorkshire.

The title of Local Society does not fully express the importance of MIMinE, and other similar bodies, because it is through their efforts that members are able to maintain and develop their professional competence. MIMinE assists in the provision of Continual Professional Development (CPD) necessary, in most professions, for the retention of professional accreditation. With specific regard to the MIMinE this is achieved through a programme of lectures, papers, and this annual seminar, all of which lead to peer group discussion.

## Professional accreditation

MIMinE members face many challenges in their employment and from time to time their competences may be questioned. MIMinE has encouraged members to be able to demonstrate their competence and as previously stated is affiliated to IOM3, who hold the licence from the Engineering Council for the awards of professional accreditation such as EngTec, IEng and CEng.

Members of MIMinE are from a broad engineering background and some are regularly co-opted to undertake professional reviews for awarding Engineering Council accreditation. It is vital that these reviews are competently undertaken because the award provides for an international recognition of an individual's level of competence.

## Dissemination of information

Although articles and journals are available through IOM3, an important facet of maintaining knowledge and skill is via peer group discussion. To this end MIMinE engages in the following activities:

MIMinE hosts, monthly from October to May, a programme of speakers who present information on current industrial/engineering activities.

The Presidential address, by the incoming President, is normally held during October and is timed to coincide with the Annual General Meeting.

Annually organises a one-day seminar "Safely Managing the Challenge of Change" with attendance from a broad spectrum of industry, historically ranging from students/apprentices through to CEOs and Owners.

The J F Tunnicliffe and C S Littlewood paper competitions are held annually and are open to younger members of MIMinE.

MIMinE supports the IOM3 "Young Persons Paper Competition", which has an international perspective, and has provided a member to participate on the judging panel of the national final.

## Development of individuals and scholarship funding

Fundamental to the ethos of MIMinE has been the development of young persons and we are fortunate to have at our disposal three charitable trusts which are governed by the trustees. Access to this funding is restricted to members of MIMinE and funds are made available in accordance with the trust deeds.

These funds are intended to provide some additional financial support allowing individual members to gain a broader knowledge and understanding of their field of activity.

### **Amco Bursary Fund**

This fund provides enhancement of education in the science and practice of mining, work-related training for students who may have difficulties in obtaining practical instruction and work place participation.

### **Peake Travelling Scholarship**

The Peake fund is open to members who have attained the age of 21 years and is aimed at assisting in meeting the cost of travelling and subsistence, either in the UK or internationally, where the aim is to enhance the value of a suggested field of study related to their overall education, training and experience in the science and practice of mining engineering.

### **Noel Webster Travelling Scholarship**

The Webster travelling prize is open to members under 35 years of age and is also aimed at assisting in meeting the cost of travelling and subsistence, either UK or internationally, where the aim is to enhance the value of a suggested field of study related to their overall education, training and experience in the science and practice of mining engineering.

MIMinE also assists with financial assistance to become student members of IOM3 with the proviso that they also become student members of MIMinE. MIMinE has a Younger Member/Student Section which benefits from limited direct funding thus inviting young members to become active.

## ***Join the Midland Institute of Mining Engineers***

An individual can become a member of MIMinE in one of two ways:

1. Directly become a member of MIMinE, or
2. A member of IOM3 can identify MIMinE as their preferred Local Society. This route provides for access to both MIMinE benefits and to professional accreditation.

Further details can be obtained by visiting the stand at one of the breaks or by contacting the Honorary Secretary, Stephen Straw or by visiting the web site [www.themime.org.uk](http://www.themime.org.uk)

# Speakers

## **Dr Neil Slatcher**

Research & Development Manager  
3D Laser Mapping



Neil is the Research and Development Manager at 3D Laser Mapping. He specialises in the application of laser scanning to slope stability and geotechnical analysis with an interest in sensor integration.

With a background in both volcanology and product design, Neil has a practical understanding of the technical challenges faced when using laser scanners in the field, an experience he uses to drive the continued development of 3D Laser Mapping's monitoring solutions.

## **Daniel Brunt**

Commercial Director  
Ardent UK



Daniel Brunt is Commercial Director for Ardent Ltd, working with key safety, operations and senior-level personnel to help deliver the safest of work environments and maximise productivity for the company's business through mobile plant fire suppression. Daniel works with companies ranging from multinational mining corporations to local recycling centres, in a variety of sectors such as mining, recycling and waste processing ports and wood processing around the world.

Daniel has over 14 years of experience in the vehicle fire protection industry. After joining Ardent in 2003 as Operations Manager, Daniel quickly progressed to General Manager, where he regularly visits mining sites through Africa, Middle East, East Asia and Europe to help manage the risks of fire and increase safety standards for their business.

Daniel believes in zero compromise when it comes to fire protection, always prioritising the customer's best interests over company profit.

**Martin Oldroyd**

Principal HSE Leader  
Doosan Babcock



Martin started his career in the mining industry with the NCB, holding positions as Project Engineer at Stillingfleet Mine, Undermanager at Kellingley Mine and finally Safety Engineer at Riccall. He left in 2001 to work for Exel Logistics where he was Regional Health and Safety Manager looking after the North of England warehousing and logistics Operations.

He took up the post as Head of Health and Safety for OTTO UK in 2003, looking after the safety arrangements for 68 sites and 12,000 employees. The portfolio included printing, facilities management, call centres, distribution centres, warehouses, shops and offices.

Martin joined Doosan in 2008 and is responsible for all operations within the Central Branch; this includes Doosan operations on three nuclear sites, two nuclear restoration projects, five thermal stations as well as five COMAH top tier petrochemical establishments, and several small industrial projects. He has several degrees; these are in Health and Safety Management, Mining and Mechanical Engineering, Business and Finance, and Environmental Management.

He is a Chartered Engineer, a Chartered Environmentalist and a Chartered Fellow of IOSH. He also lectures on Health and Safety Management in High Hazard Industries.

**Jim Holmes**

Mines Inspector Ireland  
HSA

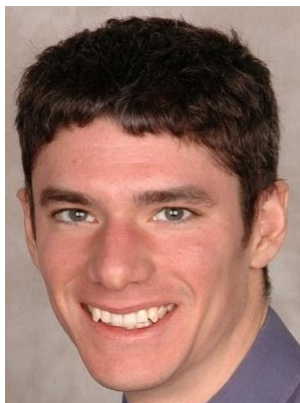


Jim has 40 years' experience in the mining industry including 13 years with British Coal in South Yorkshire, five years with Cementation Mining at North Selby, Hatfield and Cornwall and almost 23 years as a Mines and Quarries Inspector with the Health and Safety Authority (HSA) in the Republic of Ireland.

He is a Chartered Mining Engineer holding a first-class certificate of competency. He has been a Fellow of the Institute of Minerals, Mining and Metallurgy for over 20 years, and a Chartered

Member of the Institute of Occupational Safety and Health holding a Post Grad Diploma in Occupational Safety and Health from University College Dublin. He holds a MSc in the Management of Information Systems from Dublin City University and project managed the development of HSA's Information systems for inspection, investigation and file management, website and intranet. Jim is primarily involved in policy, guidance and legislative development in the Mines and Quarries sector.

**Simon Coldrick**  
Senior Scientist  
HSL



Simon Coldrick works in the Fluid Dynamics Team at HSE's Buxton laboratory. He is a Chartered Mechanical Engineer and holds a PhD in gas turbine engineering.

The Fluid Dynamics team provides scientific support to HSE's regulatory function and Simon has been involved in a range of modelling activities covering dispersion of flammable and toxic materials, evaporating liquid flows and heat transfer. As well as carrying out modelling, Simon has been involved in several European-wide initiatives on quality and fitness-for-purpose in predictive modelling. Recently, he has been applying computational modelling to the underground storage of explosives, in collaboration with HSE's Energy Division.

**Peter Baldwin**  
Chartered Physicist  
HSE



Peter Baldwin is a Chartered Physicist and Chartered Occupational Hygienist. Peter has been employed by HSE Science Division to provide support to companies by performing research on exposure assessment.

He developed aerosol sampling and dermal sampling techniques. He has a background in physics with practical experience in collection of samples of hazardous materials in workplaces, designing and performing exposure surveys, analysis of exposure data and assessment of exposure controls. Peter performed the initial research in the practicability of personal dust monitoring in coal mines.

**James Forder**

Lead Analyst  
HSE



James Forder is the lead analyst at HSE for the measurement of elemental and organic carbon in particulates arising from emissions from diesel engines. He has authored a report for HSE describing the availability and efficacy of several optical techniques for the measurement of elemental carbon in diesel exhaust in a non-laboratory setting, this is available on the HSE website as HSE Research Report RR994 and in the paper “Simply Scan” Annals of Occupational Hygiene, 2014, vol. 58, 889-898.

**Sarah Boad**

Membership Development Manager  
IOM3



Sarah Boad has a degree in Metallurgy from University College of Swansea. She started her working life at Morganite Electrical Carbon Ltd in Morriston, Swansea working on carbon brushes for electrical machines, she then moved to Dunlop Aviation in Coventry where her focus was on carbon-carbon composites for aircraft breaks.

Sarah started working with the Institute in the early 1990s as the Regional Consultant for the Midlands Region, working on membership and supporting local societies. In 2004, she took on the new role of ‘National Co-ordinator – Regions’ liaising with all the local societies across the UK and Ireland.

She ran the Young Persons’ Lecture Competition, and administration of grants and local society lecture programmes and activity. In the autumn of 2010, she became Membership Development Manager, working with Universities, Companies and individuals promoting professional membership of IOM3 and other professional bodies. She was Vice President of the South Wales Materials Association in the 1980s and is currently a member of the Coventry and Warwickshire Materials Society Committee.

**Steve Ainsworth**

Mine Safety & Development Manager  
Lovell Stone



Steve's career commenced at South Crofty Tin Mine, Cornwall, in 1970 as an underground miner. He qualified as machine man shotfirer in 1972 and moved to (Cleveland Potash) Boulby Mine in 1973 as underground leading miner/shotfirer. In 1974 he was appointed Underground Supervisor and from 1976 District Production Supervisor on continuous miners.

He returned back to Cornwall in 1978 briefly at Mount Wellington Mine, and then to Geevor Tin Mine staying for eight years until the 1986 tin crash. At Geevor he started as Machineman, and then Underground Shift Boss and Shaft Captain. He was a member of the mine rescue team for seven years.

When Geevor Tin Mine shut, he moved to Northern Sudan as Mining Supervisor and then Mine Captain in a remote gold mine. He came back to the UK in 1989, and spent 12 years in the quarrying industry eventually becoming Assistant Manager of a large limestone quarry in North Yorkshire. In 2001 he went back into underground mining as Mine Manager at Hartham Park underground quarry.

Subsequently after qualifying, he moved to Lea Park Mine as Health and Safety/Mine Manager for the underground storage and manufacturing facility. In 2005 Steve was invited to go to Southern Armenia and assess mining methods in a post-Soviet polymetallic mine in Kapan. He stayed in Armenia for the next 12 years managing underground mines, quarries and opencasts and then working in Southern Greenland as a Mine Director and in Kazakhstan as a Health and Safety Advisor.

Steve returned to the UK in 2015 having been offered a position again at Hartham Park underground quarry which had a new mine operator. From 2015 to present date, Mine Development and Safety Manager for this new mining project.

**Adrian Barratt**  
Sales Manager  
PBE Europe Ltd



Adrian was educated at Sheffield Hallam University and started his working life for GEC Marconi as a Communications Engineer. He has spent 20 years working in wireless network



communications. He has built cellular networks for radio links, wireless SCADA networks for the utilities and railway industries.

He is now employed by PBE Europe working in wireless communication, productivity systems and safety systems.

**Mark Thompson**  
Senior Project Manager  
TFL



Mark has 25 years' experience in the mining and civil engineering industries, primarily in underground construction and operations with Trafalgar House, Cementation Mining, Kvaerner and Skanska Construction.

He has worked on a wide range of mine developments, operational mines, tunnelling and heavy civil engineering construction projects.

His mining expertise includes deep shaft sinking, hard and soft rock tunnel developments (including coal, salt, potash, gold, platinum, lead/zinc and copper) and production operations. Specialist engineering work has included tunnel boring machines, tunnel refurbishment, sprayed concrete linings, hydroelectric schemes.

Mark has held a series of leadership roles within a range of specialist businesses which have incorporated strategic development, project financing, mergers/acquisitions and divestments. He holds a Bachelor of Engineering in Mining Engineering and a Master of Philosophy in Geomechanics, both from Camborne School of Mines.

He is a member of the UK Institute of Materials, Minerals and Mining and a Chartered Engineer.

**Matthew Evans**  
Business Manager  
Trolex



Over the past 17 years Matthew has been involved in the detection of particulate matter across a vast range of industrial applications, using different detection methods. His career to date has enabled him to get involved in the consultation of UK and EU standards for the detection of particulate monitoring, as well as running local education/training sessions for industry and local authorities around the country.

A move to Trolex at the start of 2017 has enabled him to develop a new core business within Trolex, which provides innovative solutions within particulate monitoring. A very exciting time for the company and industry.

# A new age of particulate monitoring

Matthew Evans  
Business Manager – Particulate Monitoring  
Trolex

## *Introduction to Trolex*

Trolex Ltd is a leading global supplier of gas detection systems, explosion proof connectors, Strata Monitoring and Particulate Monitoring solutions to the mining, tunnelling and hazardous industry sectors.

Our products are deployed in over 60 countries by some of the world's leading corporations to protect their people and assets, maximize efficiency and improve the experience of workers.

Trolex is a company that has innovation at its heart. We innovate to save lives, save money and to make life better for our customers and the people they employ. Here are a few examples of our world-class innovations, and the benefits they bring?

- We have recently introduced the world's first totally wireless underground gas detection system that is revolutionising the deployment and functionality of safety systems in mines and tunnels.
- Our new dust monitors are the first to accurately monitor real-time dust levels in harsh environments without the need for filters and pumps. We believe that 1/2 million deaths a year globally, from work-related dust inhalation is an unacceptable statistic and we are working with several partners in the drive to reduce this number and eventually eradicate it.
- Our eModule technology allows calibration of gas sensors to take place in 1/5th of the time of standard gas detector calibration routines, providing massive savings to our customers and changing the way gas detection service and maintenance are carried out.
- Trolex GasHawk is a 1-6 gas personal gas detector is the first product of its type to incorporate inductive charging technology and to incorporate wireless tracking capability. Workers can now be protected and located in a single portable unit, wirelessly and in real time.

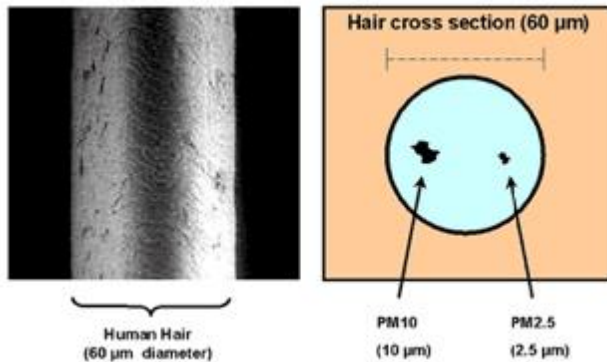
## *Background*

As you will all be aware there is an ever-increasing media coverage of how poorly the world is doing in meeting its particulate matter limits and you will have also picked up that there is an increase in activity around workplace exposure to particulate matter and the long-term health implications of this.

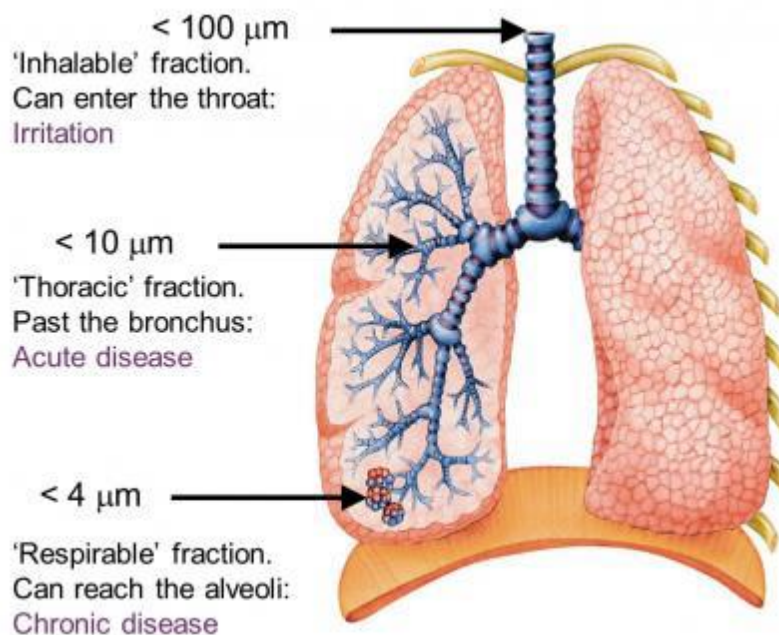
Four years ago, Trolex with the aid of an Innovate UK grant and in collaboration with The University of Hertfordshire, made significant headway in the research of a technique that could measure the respirable concentration of particulates with the air.

This research project led to the development of our first particulate monitoring system which not only has a focus around the respirable content of particulate matter (PM) in the air, but it also counts and collects into “virtual bins”, every PM size between 0.38µm and 17.5µm.

To put into perspective what we are measuring with our unit, a human hair is around 60 µm and we can measure all the way down to 0.38µm.



This measurement range allows the Trolex unit to measure PM in the respirable, thoracic and some in the inhalable ranges, as well as measuring the standard PM for environmental monitoring such as PM 1, 2.5 and 10.



There are some very sobering statistics related to particulate inhalation and its effect on health:

- In the UK alone some 12,000 deaths each year are linked to past workplace exposure
- Dust related cancer causes 90% of annual deaths worldwide.

According to HSE Reports 2015-16, Dust-related Cancer causes about 90% of annual deaths at workplace worldwide. Out of these 90%, 33% is accounted by Chronic Obstructive Pulmonary Disease (COPD) and 35% show signs of asbestos-related cancer.

- 18,000 new cases of breathing/lung problems related to work place exposure are reported each year in the UK
- Silicosis is estimated to cause around 500 deaths a year in the construction industry worldwide
- Asbestosis deaths were around 470 in 2015 worldwide

Health professionals, governments and industry are now, more than ever, asking whether some of these deaths could have been prevented by accurately monitoring the levels of particulates within the working environment.

With the advancement in measurement techniques, for the first time, industry will be able to accurately monitor dust levels and to act in mitigation.

### *Technology Landscape*

Within the world of air quality there has been little innovation to help improve current measurement technique but also there is little in the legislation that talks about BAT (best available technique). BAT need to be considered within any application as not one technology will suit all applications.

There are lots of parameters that can have an influence on BAT such as quality of measurement, legislation/approvals required, the application itself, budget, accuracy, moisture, temperature and dust concentration.

Current techniques on the market are well established, for example:

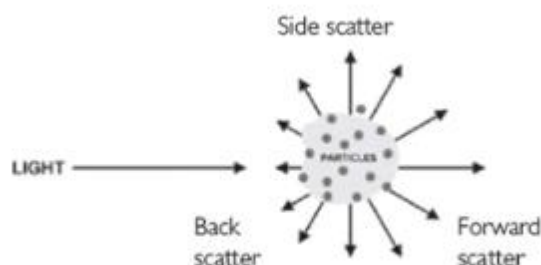
**TEOM** – Tapered Element Oscillating Microbalance: uses a size selective inlet head as a way of filtering Particulate Matter (PM) sizers onto a glass tube with filter paper that acts as a microbalance. As the particulates are collected on the filter paper, the oscillation of the tube changes and thus is referenced back to a mg/m<sup>3</sup> measurement.

TEOM usually uses heated lines which helps prevent the ingress of water droplets. However, they tend to have a limited measurement range and can be affected by temperature and humidity.

**Beta Attenuation:** uses absorption of beta radiation to determine the concentration of particulate matter. It works by having a ribbon which passes through a radiation source and then the ribbon is subjected to air pulled in from the inlet; finally, the ribbon is then subjected to another source of radiation and the radiation is measured.

The difference between the initial radiation source and the secondary source gives an indication of the number of particulates on the ribbon.

**OPC** - Optical Particulate Counters: there are many different OPC on the market but they all use light scatter to determine PM concentration. When a light source is shone at a particulate, the most intense scatter is in the forward direction, but scatter will also occur at the sides and the back.



The basic set up of an OPC is to have a laser beam which passes through a mirror and filter to focus the beam; then within the measurement area, a detector will capture any scattered light.

Particulates, when illuminated with a beam of light create a scattering pattern depending on their size, shape and structure. This scattering pattern is like a thumbprint by which the particulates can be quantified and classified.

Some OPC use a size selective inlet head that only allow a certain size of PM into the measurement volume.

### *The Trolex Technology Approach*

Trolex takes a collaborative approach at the research phase and then seeks to develop and commercialise products itself.

Key partners are the University of Hertfordshire for OPC research and Liverpool University on alternative sensor technologies for particulate monitoring.

As mentioned earlier, no single technology will be suitable for all applications; thus, we are looking at a multiple stream technology approach. One stream is using OPC of three types for the detection of general particulates, crystalline silica or asbestos; while the other stream is focussed around emitter and receiver technology.

The initial research project, mentioned above, in conjunction with the University of Hertfordshire sought to deliver respirable particulate monitor for the use in industrial applications. This resulted in the 2017 launch of the Air XD.

This unit is designed to measure all types of particulates without characterising what exactly the particulates are. A highly advanced OPC technology is used within the unit that allows the AIR XD to increase the accuracy of the measurement. The OPC has a focused measurement point and multiple receivers; this ensures the light being scattered by the particulates are collected from more than one direction. A sophisticated, patented algorithm then sorts and interprets the data.

Air XD can identify and count all PM sizes from 0.38 to 17.5µm, as well as giving a µg or mg/m<sup>3</sup> quantified reading.

The unit does not use any pumps or filters inside and does not have any size selective inlet, it is very easy to maintain and has increased accuracy over other techniques more commonly used within industry.

To date there are three variants of the AIR XD: one has a focus around the respirable content of the air being sampled 4.25µm; the second can be focused around two PM sizes and the third can have a focus around one PM size. In each of these, the same core technology is deployed, and the same level of accuracy obtained but the focus of the algorithm is altered to meet the applicable requirement.

The instrument collects a huge amount of data, at some 8000 lines a day so Trolex has additionally, developed an application software platform that can take all this data and present it in a well-defined format. The software will display any alarm that may have occurred within a time; illustrate short and long-term trends and allows for drilling down into the data to investigate, for example, high readings.

As well as recorded data, the unit can display readings in real time. Where multiple sensing measurement is required, Trolex has designed SCADA based systems for multiple inputs, such as air flow, temperature, humidity and wind direction.

### *Technology Road Map - want to add a jpeg of the slide?*

Trolex has a very ambitious road map for the next couple of years which includes an ATEX version of Air XD by the end of 2018, a real time Respirable Crystalline Silica (RCS) monitor and Asbestos unit by early 2019 and a ceramic fibre and open path unit by late 2019.

Respirable Crystalline Silica Monitor (AIR XS) – a further collaboration with the University of Hertfordshire and again supported by a grant we are looking to have a patented technology around the detection and characterisation of Respirable Crystalline Silica (RCS). This sensing technology would utilise a variant OPC but would also include additional detectors and further

unique algorithms to identify RCS. This instrument would be a world leading measurement technology.

Asbestos (AIR XA) – this instrument is a type of OPC with additional measurements for asbestos characteristics. The particulates enter the first laser beam and generate a scatter pattern, which is captured. Next the algorithm determines whether it is a fibre or not and then passes through a second measurement which determines whether it is asbestos.

### *Application Focus*

Air XD has been mounted near a conveying system in a non-ATEX environment underground mining application. This application within the mine was given an alarm level of 1mg/m<sup>3</sup> over a 15 minute period and on several occasions the alarm level was reached, indicating elevated levels of particulate present for a prolonged period. The instrument measured particulates of 20,000 µg/m<sup>3</sup>.

The mine had never measured particulates before and the instrument has given them an insight into how much PM is being generated by such a straightforward process and they are now looking in to a way of controlling the amount of PM generated.

The second application note is a tunnelling application where the instrument was installed after the tunnel had been bored. This application was more around monitoring the background level of PM when various work was taking place within the tunnel.

What this long-term application note proved was that even though there were a few times when the instrument went above the alarm set on the 8hr average, over 99% of the time the background PM was well below the alarm set point of 1mg/m<sup>3</sup>.

The Air X range of products being launched and developed by Trolex are at the very leading edge of particulate monitoring technology.

Hazardous industries are set to come under mounting pressure to safeguard occupational health and having instruments that can collect accurate data and help take mitigating action will be key contributors to safer working environments for all.

For any further information please contact Matthew Evans – Business Manager – Particulate Monitoring.

E mail: [matthew.evans@trolex.com](mailto:matthew.evans@trolex.com)



# Protecting workers from industrial plant: The role of a proximity alert system

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## The PBE Group Overview

A global manufacturer of safety and productivity solutions

1. PBE have been a leading manufacturer of safety, monitoring and communications equipment for 45 years
2. 170 employees, 9 regional service centers and over 30 distributors
3. With an estimated 850 tunnels and mines, served by Over 70 proprietary products - all designed and manufactured in house to form a total integrated solution
4. As the manufacturer and owner of the technology, PBE has the distinct advantage of being able to work with clients to meet specific requirements



Innovating Safety. Powering Productivity.  PBE



## A Selection of PBE Customers

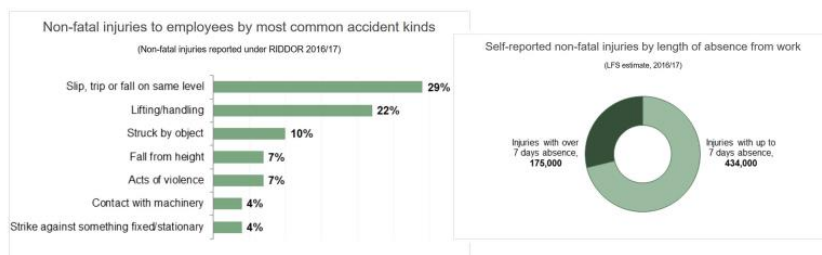
Including a global portfolio of major UK customers and contractors



3

## Some Accident Statistics

Source HSE Headline results 2016/17

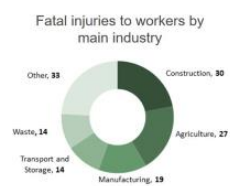


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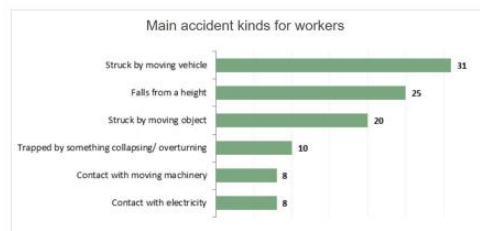
4

## Statistics continued

Source HSE Headline results 2016/17



### 137 Fatal Accidents



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5

## Safety Management Systems PAS is only one element



Important part of any safety management system, highlights the reasons why accidents occur and how to prevent them.

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6

## Accident Investigation



The primary purpose of accident investigations is to improve health and safety performance by:

- Exploring the reasons for the event and identifying both the immediate and underlying causes;
- Identifying remedies to improve the health and safety management system by improving risk control, preventing a recurrence and reducing financial losses.

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7

## So what makes a PAS Solution



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8

## In Vehicle Installation

- Each vehicle had a complete 360° zone configured to 5m
- Alarms activated for the following:
  - The PAS unit in the vehicle alarm, showing the driver the range and direction
  - An external strobe/siren on the vehicle providing localized warning to personnel
  - If a person is within the zone, their tag would alarm with a sounder and vibration
  - The interaction would automatically be highlighted on the computer in the control room, showing the location of the interaction on a map and sending email/SMS notifications if required



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## Report Setup

- General set up of report shown right
- For reporting purposes, data focused on:
  - 4 week period starting 16<sup>th</sup> October with all tags/vehicles
  - 3 zones of 15ft, 30ft and 50ft (approx. 5m, 10m & 17m)
  - Heat Zone range of 40m
  - Speed zones of 5-10-30mph

Report Configuration

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10

## All vehicle/personnel interactions (0-50ft)



All zones all vehicle/personnel interactions (0-50ft)

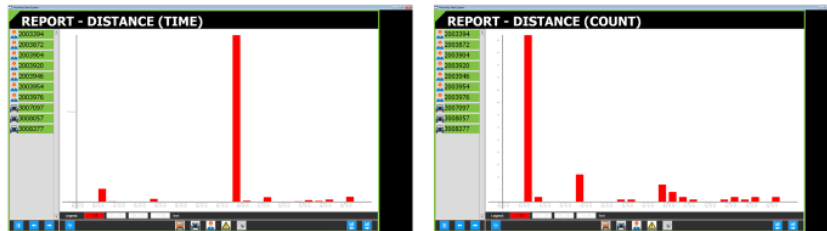
- 3 other vehicles and 7 personnel during the period
- Ranging from 0-330 minutes per day and 0-1800 times a day for an area of 50ft around the vehicle
- Vast majority of these interactions are within the non-alarming zones (>15ft)

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## All Vehicles/Personnel Urgent Zone Only (0-15ft)



All Vehicles and Personnel urgent zone only (0-15ft)

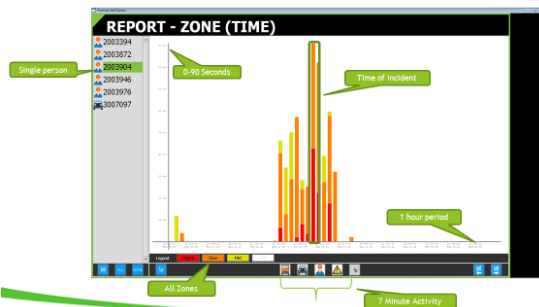
- Average the number of interactions per day was approximately 4, on average 1-2 minutes a day in total
- Spikes caused by identified PBE engineering (suppressed alarms) and approved close works

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12

## Incident Analysis (Total Time) (Vehicle to Person urgent zone intrusion)



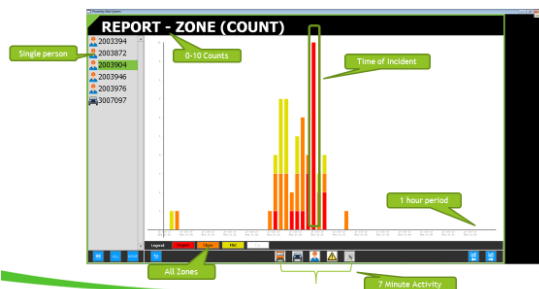
- Each bar of the chart represents 1 minute
- During the actual incident, the employee was in the urgent zone for a total of 42 seconds
- Prior to this, he had entered the fringes of the zone for 1-2 seconds on 4 occasions (shown by the red bars on the chart)
- He had been in the vicinity for 7 minutes prior to the event

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## Incident Analysis (Total Count) (Vehicle to Person urgent zone intrusion)



- Number of times he actually went in and out of the zone and set the alarm off
- Highlighting that for the period he was working on the edge of the zone, entering for very brief periods until the events when the accident occurred
- Common as people tend to judge the size of the zone knowing alarming will occur

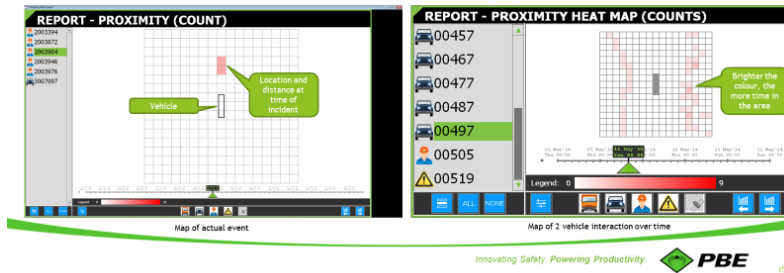
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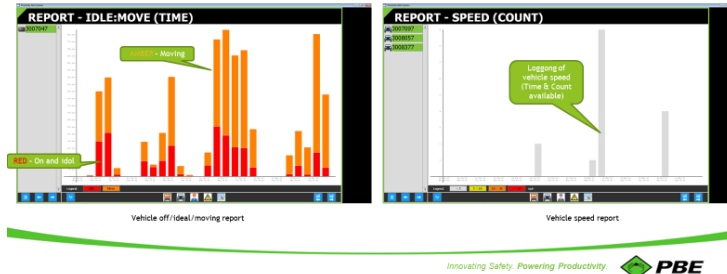
## Heat Maps

- Heat map shows range and direction of incident
- Over time analysis shows danger zones
- This actual distance was 12ft away from the vehicle central location



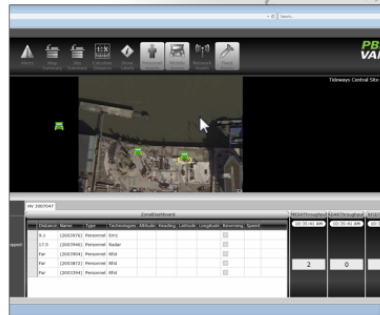
## Vehicle Analysis and Productivity

- Monitors the usage of vehicles and provide productivity information. This includes Speed of vehicles, Usage (Time vehicle running) and Vehicle idle/moving information



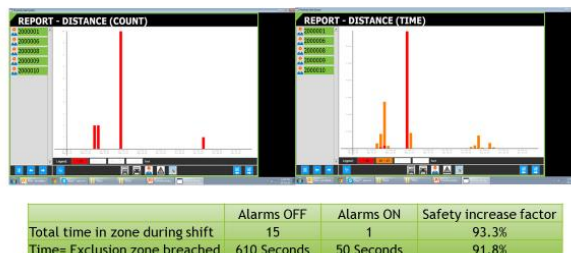
## Real Time Remote Monitoring and Warning

- PAS system has a Control and Monitoring System (Vantage) that allows for remote monitoring and real time mapping of all vehicle activity using the 3G network
- When personnel are near vehicles, they will also be shown on the map.
- The system will provide automated reports when there is an interaction that can be emailed or SMS
- Allows remote configuration of machines allowing changes to be made to the configuration
- Shows the performance of the system and the current ranges being identified by each technology



## Can a PAS system Change Behaviour A real world Example

Behavior analysis - 2 day comparison with alarms on and alarms off



## Conclusions



- The system can provide an accurate record of all events on site to within 1ft (30cm) of accuracy and ranges of upto 50m
- Behavior shows an appreciation of the danger zones - personnel working on the limits with minimal intrusions
- Vehicles are monitored around the whole site showing location, speed and usage
- The system can work for an unlimited number of vehicles and personnel both above and below ground
- Using 4 technologies, the system provides redundancy and reliability
- There are other optional parts of the system that will provide a complete integrated solution including:
  - Integrated Tracking - integrated tracking seamless solution above and below ground using the same tags can be deployed with the addition of tracking beacons. Same software, same solution
  - Entry/Exit - extending the electronic tag board functionality that can be linked to HR/CRM systems to monitor personnel access to the site/tunnel and make sure they are trained and have the licenses required
  - Geo fencing - Functionality that is already included but not being used is the Geo Fencing of areas

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# Ardent fire suppression for mining mobile equipment

Daniel Brunt  
Commercial Director  
Ardent Limited

## 1.Introduction

The outbreak of fire is one of the most common incidents in mines and can lead to downtime, revenue losses, loss of critical assets and in the worst-case scenario, injury or even loss of life. Effective management of fire hazards is key to enabling organisations to maintain production levels and sustain growth. When done correctly, management of fire hazards protects reputation and most importantly, the people.

Fire hazards exist in any situation where a fuel source and an ignition source are combined in the presence of oxygen. When in conjunction, these three elements can sustain a chemical reaction that will keep a fire burning until at least one of the elements is eliminated or isolated to break the chemical reaction.

Fuel, heat (i.e. ignition source) and oxygen are therefore the three requirements for a fire to occur, as shown in the fire triangle below (Figure 1).



Figure 1 – Fire Triangle

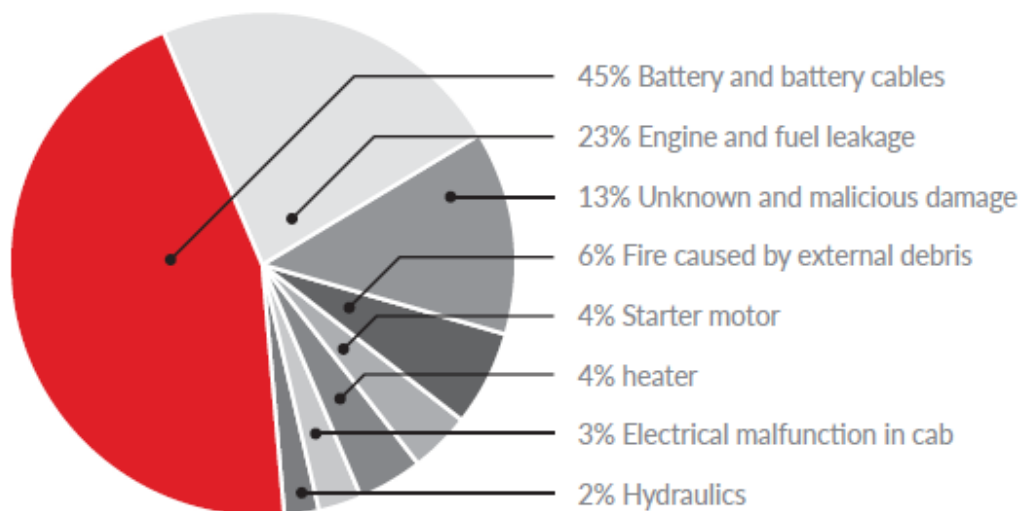
Fuel and ignition sources are present in every mine especially in mobile equipment frequently used in the mining process. The table below (Table 1) details the most common fuel and ignition sources found in mining mobile equipment.

Fuel sources	Ignition Sources
Diesel Hydraulic fluid Debris (combustible, oil, coal dust, etc.) Rubber Plastics Upholstery	Engine blocks Turbochargers Exhaust manifolds Brakes Bearings Electrical equipment

Table 1 – Fuel and ignition sources in mining mobile equipment



The graph below (Graph 1) summarises the most common causes of fire among mobile equipment reported to Ardent Limited. Based on the company's years of experience, electrical faults and fuel or hydraulic fluid leaks account for almost 70% of all machinery fires reported.



*Graph 1 – Most common causes of fire among mobile equipment*

There are several regular procedures and inspections that can be easily carried out to lower the risk of fire in mobile equipment, such as washing down of the vehicle engine bay at the end of each work shift with water or steam to remove debris, regularly tightening oil, hydraulic and fuel line fittings and removing any residue, etc. However, even with these regular safety procedures while fuel, heat and oxygen remain present, the risk of fire cannot be eliminated. Vehicle fires still occur in mines with profound consequences.

The installation of a pre-engineered fire detection and suppression systems in off-road vehicles is now widely accepted through a variety of sectors such as recycling and waste processing, wood processing, ports and bulk handling, and mining, where the risk of fire is significantly high. Over the past decade, significant developments have taken place on mobile plant fire protection systems. The result is that today's equipment is more refined and robust than ever before, providing extensive protection for off-road vehicles in many types of environments.

However, experience shows that in many cases fire suppression systems are often only installed as an after-thought, if indeed they are fitted at all.

The benefits of installing reliable fire detection and suppression systems are self-evident, both from an economic and, more importantly, a safety point of view. The decision on whether to fit these systems rests with either the end-user, OEM dealer or, occasionally, the insurer. However, the specification, design and installation of a fire suppression system is not usually a straight forward task.

A risk-based approach should be followed, where the vehicle specification and layout as well as the operating environment is considered to assess the potential fire scenarios and types of fire. Based on this information and individual customer requirements, the designed parameters can be defined, and the right system can be specified.

To assist decision makers in the choice of system and supplier, this guide provides a general overview of the components of a fire suppression system and the factors that dictate the design, installation and on-going maintenance of an effective system. It also discusses how different hazards, environments and applications demand a different approach.



## *2. The Combustion Process*

In firefighting, fires are classified by the fuel involved, which will determine the most effective extinguishing agent. In Europe, fires are classed in five types, namely A, B, C, D and F, denoting respectively carbonaceous fires, flammable liquid fires, flammable gases, metal fires and cooking fires. These classifications are subject of BS EN 2:1992 entitled 'Classification of Fires'.

### **Class A fires**

Class A fires involve solid materials normally of an organic nature, in which there are glowing embers, such as wood, cloth, rubber, plastic, paper, biomass, coal, etc. In off road vehicles, Class A fires generally involve combustion of the volatile gases resulting from the decomposition of the fuel as well as combustion within the mass of the fuel. The former is called flaming combustion and the latter 'glowing' or deep-seated combustion. While the two modes generally occur concurrently, either can precede the other, depending on the fuel type and configuration. Flaming combustion involves rapid vapour-phase oxidation and heat transfer back to the fuel. Deep-seated combustion is characterised by slow rate of heat loss and slow rate of reaction of oxygen with the fuel, which is controlled by diffusion.

### **Class B and Class C fires**

The combustion of volatile liquids and gases are considered Class B and Class C fires and involve the rapid vapour-phase oxidation of the fuel, subsequent evaporation of more fuel due to radiated heat transfer, and cracking of the fuel in the vapour-phase.

In this type of fire, the combustion process is characterised by a chemical chain reaction involving rapidly reacting species called radicals, which are fragments of the fuel and/or oxidising agent molecules.

It should be noted that although plastics are considered Class A hazards, some plastics can decompose into volatile liquids which then present a Class B hazard.

### **Class D fires**

Class D fires involve combustible metals such as magnesium, titanium, sodium, potassium etc. The combustion of metals depends primarily upon the physical state and the chemical nature of the metal. In general, finely divided metals (dusts) and liquid metals will oxidise rapidly and burn at temperatures more than 1100 °C. The rate of oxidation is extremely rapid (explosive) with some finely divided metals and slower with liquid metals. This reaction is dictated by the presence of moisture and temperature of the metal.

### **Class F fires**

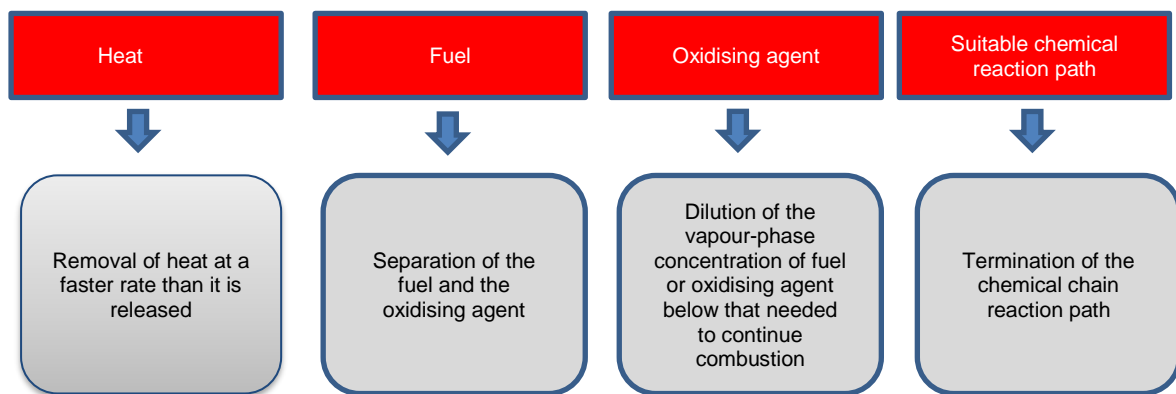
Fires that involve combustible cooking media such as oils, grease, fat, etc. We would not normally expect to see Class F Fires in vehicle fire protection.

### **Electrical fires**

In Europe, electrical fires are not generally considered as a class as they are an ignition (heat) source rather than a fire type. Once the electrical ignition source has been isolated, the fire can be treated as either a Class A or Class B fire (depending on the scenario).

Electrical fires usually start because of short circuiting machinery or overloaded wiring. When electrical equipment short circuits, it is possible that the wire will heat up because of an increase in current. The materials around the equipment or wiring (usually plastic or metals) can combust or melt. This in turn may start a fire and damage other electrical components.

From these classifications, it is clear there are four basic prerequisites for any fire: heat, fuel, oxidising agent (oxygen) and a suitable chemical reaction path. Armed with this knowledge, it follows that any method for inhibiting a fire must involve one or more of the following:



Graph 2 – Methods for inhibiting a fire

### 3. How Vehicle Fire Suppression Works

Pre-engineered vehicle fire suppression systems use extinguishing agents to obstruct and inhibit the chemical reaction that sustains a fire when fuel, heat and oxygen are combined. As oxygen will always be present and cannot be easily excluded, the system will focus on isolating and controlling the fuel and heat sources.

#### 3.1. Key components

A pre-engineered fire suppression system consists of four major components:

1. A detection system to provide automatic fire detection, usually linear heat detection cable, spot detectors, infra-red flame detectors, or a combination of the same.
2. An actuation system operated manually and/or automatically.
3. A tank or several tanks to store the extinguishing agent.
4. An agent distribution network which delivers the agent from the tank through hydraulic hose and fixed nozzles to the hazard area/s.

If an automatic actuation system is not installed, the system can only be activated manually by the operator. Relying purely on a manual system usually leads to a slower reaction to fire. A combination of automatic and manual actuation is recommended to achieve higher levels of reliability.

Pre-engineered fire suppression systems are not designed to extinguish all fires, especially when unusual amounts of combustible material (fuel) are present. It is highly recommended to supplement the system with portable hand-held fire extinguishers located on-board the vehicle to assist with operator's egress.

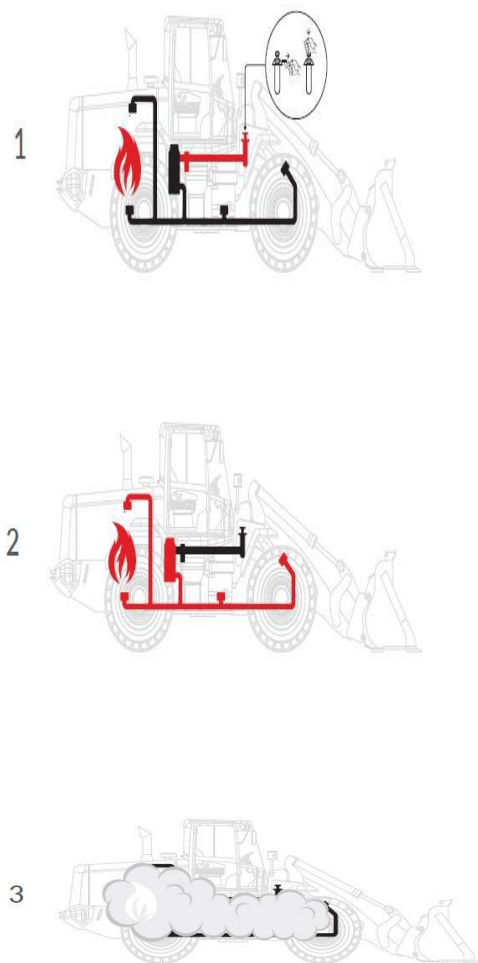
Additionally, means to automatically shut down the vehicle and isolate the battery are highly recommended to significantly reduce the risk of fire re-ignition after the system has discharged. When a fuel or hydraulic line or connection fails, it can spray fluid on to a super-heated component such as a turbo or exhaust manifold, starting a fire.

As long as the engine continues to operate, this fluid will continue to fuel the fire. Additionally, damaged wiring can be a source of electrical fire and as such, it is recommended that the vehicle's battery is isolated.

#### 3.2. System operation

##### Manual operation

1. Discharge of the fire suppression system manually is initialised from a manual actuator or from the manual activation button on the control module, should the system have one. When the operator presses the button on the control module or pulls the ring pin and strikes the plunger on the manual actuator, the system actuates.
2. The expellant gas 'fluidises' the extinguishing agent and propels it through the distribution hose network.
3. The extinguishing agent is then discharged through fixed nozzles into the protected areas, suppressing the fire.



*Figure 3 – Manual operation of a fire suppression system*

#### *Automatic operation*

1. Linear detection cable, spot detectors or infra-red flame detectors instantaneously signal and alter the system control module.
2. The control module actuates the fire suppression system. Depending on the level of the system installation, the control module can also provide a time delay, shut down functions and activation of auxiliary vehicle components.
3. The expellant gas 'fluidises' the extinguishing agent and propels it through the distribution hose network.
4. The extinguishing agent is then discharged through fixed nozzles into the protected areas, suppressing the fire.

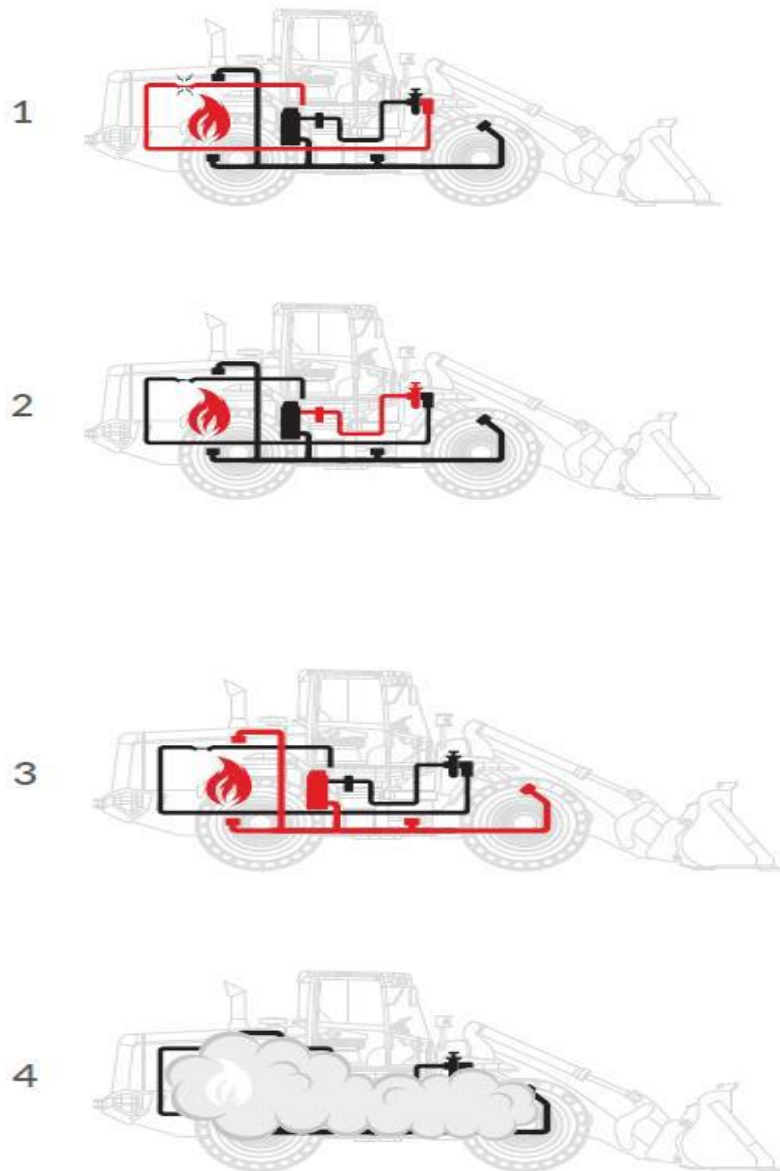
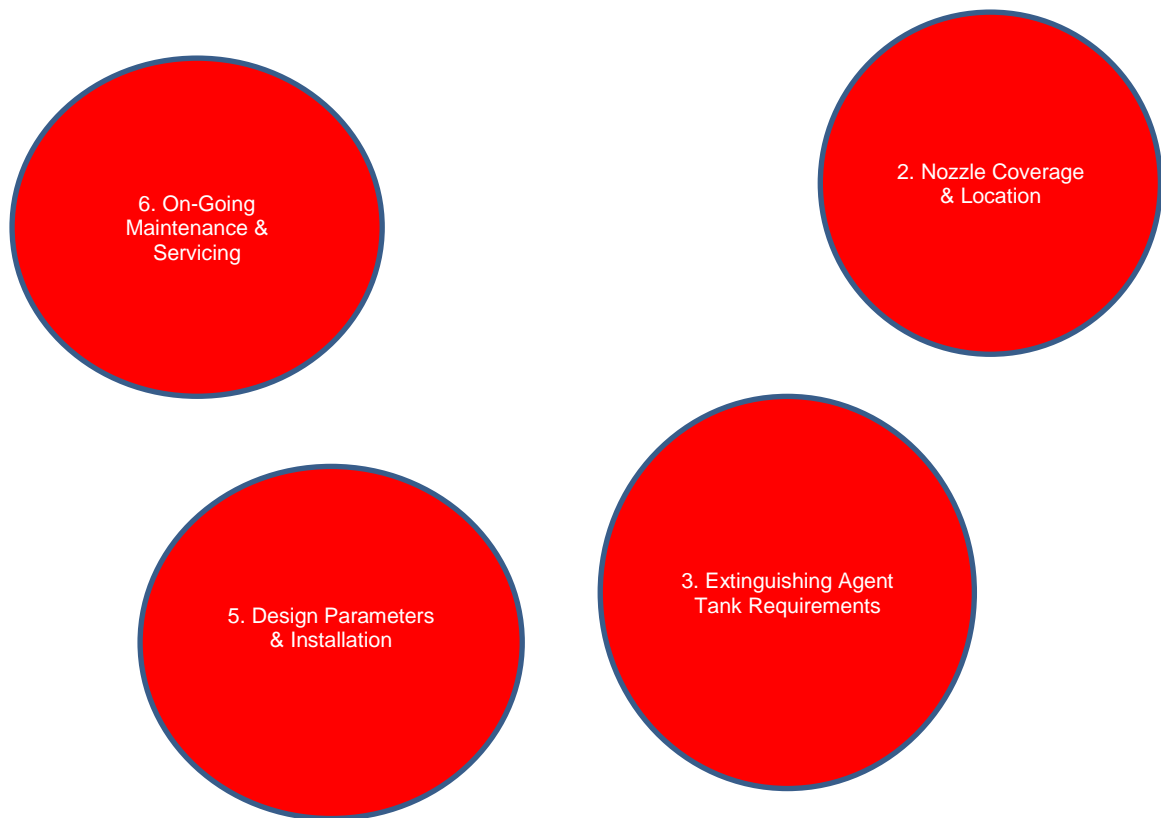


Figure 4 – Automatic operation of a fire suppression system

#### 4. Current Generation of Vehicle Fire Suppression

Graph 3 summarises the process that should be followed to specify, design and maintain an effective fire suppression system. This approach ensures the right system will be in place to protect each specific item of mobile equipment operating in a certain environment. All design decisions are based on an initial hazard analysis, which should be an on-going process as fire risks evolve.



*Graph 3 – Effective fire suppression system process*

#### *4.1 Hazard analysis*

Off-road vehicle fire protection is usually based on local application system design, which involves the identification of each individual hazard area in the machine and a selection of the correct type(s) and number of nozzles to provide the most effective coverage of the area. Total flooding application are applicable only when a hazard is in an enclosure (openings shall not be more than 15% of the enclosure's total surface area). Fire hazards in mobile equipment are usually situated in open spaces, or have a high volume of air flow, therefore a local application system design should be used.

All fire hazards in the vehicle must be identified and assessed to guide the fire suppression system design. Fire can only occur in the presence of heat, fuel and oxygen. Where these three elements are brought together a hazard exists. Oxygen is always present; therefore, it is crucial that all potential sources of fuel and heat are identified.

The figure below (Figure 2) highlights common fire hazards in off-road vehicles; however, hazards will differ from model to model, the machine's work schedule and environment so a hazard analysis should be carried out on each vehicle.

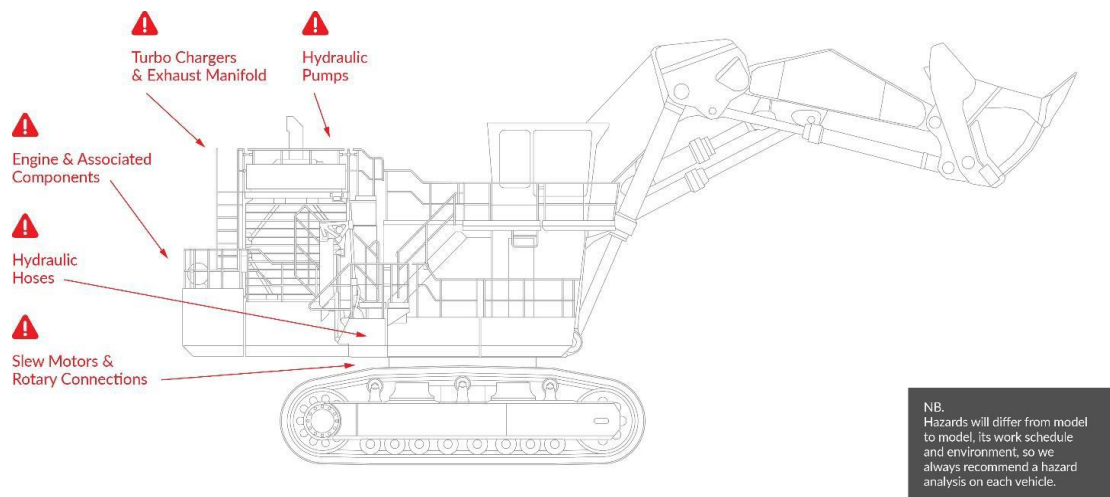


Figure 2 – Common fire hazards in an excavator

#### 4.2 Nozzle coverage and location

Having identified the key hazards and areas which require protection, it is important to determine what nozzles are needed and where they should be placed to protect each individual hazard area.

Gaining full coverage of the hazard surface area is paramount to achieving the most effective fire suppressions. System design and selection of the nozzle type/s should be based on the turbocharger size, manifold length and possible nozzle locations. The size of the hazard must be determined and compared to the nozzle's effective discharge pattern. It is important to remember that different makes and models of nozzle will vary in their discharge patterns. This allows system designers to provide coverage specific to the shape of the hazard area. Different nozzle variations offer a variety of discharge patterns that accommodate to the varying distance from the turbocharger and manifold and a variety of sizes, ensuring the highest level of protection.

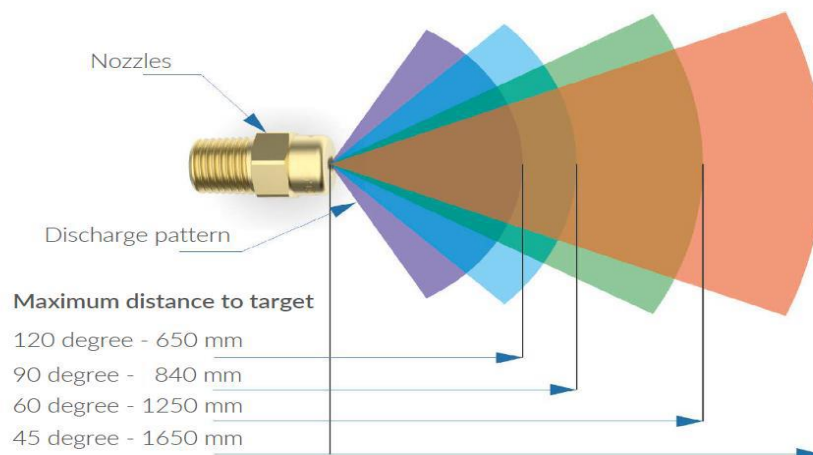


Figure 3 – 4 nozzles variations (45° to 120°) available with Ardent Wet Chemical system

#### 4.3 Extinguishing agent and tank requirements

After completing a hazard analysis and having established nozzle quantity and location, the type and quantity of extinguishing agent tanks can be determined.

Fire suppression extinguishing agents work in several ways, for example, by separating the fuel and air (oxygen), reducing the concentration of oxygen in the atmosphere around the fire

below the amount needed to sustain combustion, or by absorbing the heat from the combustion.

The agents currently favoured for protecting off-road plant are multi-purpose dry chemical (monoammonium phosphate-based powder) and wet chemical (either Aqueous Film forming Foam – AFFF – or other liquid-based agents.) These extinguishing agents have proven to be the most effective on the types of fires commonly experienced in vehicle and mobile plant.

#### *Dry Chemical/Powder*

This agent is currently the most widely used agent in the vehicle suppression market. Dry chemical systems are relatively compact in size, requiring little if any modification to the vehicle during installation. On a weight basis, they are probably the most effective agent in extinguishing fires to provide rapid fire knockdown capabilities. These systems also have a broad operating temperature range of -54°C to 98.9°C without any form of modification.

Dry chemical extinguishing agents are comprised of a finely-divided powdered material that has been specifically treated to be water repellent and capable of being fluidised and free-flowing when under expellant gas pressure. They are available for almost all types of fires and almost instantaneously quench flames by chemical inhibition. However, they offer poor post-fire security and a possibility of the fire re-igniting once the powder has settled. Improperly sealed containers can also be contaminated with moisture, leading to caking of the powder and reduced suppression qualities.

#### *Firefighting Foams*

Firefighting foams are a watery suspension of gas - usually nitrogen or air – in the form of bubbles separated by films of solution. Foam is produced mechanically by mixing a liquid concentrate with water and forcing the gas in to this solution, producing bubbles.

The most common foam used in vehicle fire protection systems is Aqueous Film Forming Foam (AFFF). AFFF is water based and therefore it can cool the area down, reducing the chance of the fire reigniting. An incidental benefit of AFFF is that the 'run off' agent may also suppress secondary fires which can occur where fuel, debris etc has collected such as the vehicle's belly pan.

AFFF works by creating a thin film on the fuel surface stopping fuel from evaporating and reducing its oxygen supply. Because the premix solution is usually 94% water (can be 99%), the solution has a high freezing point of 0°. This can be reduced to as low as -30°C and as high as 99°C by introducing additives, but this degrades the performance and life of the AFFF. The AFFF containers are also relatively large, which can sometimes pose difficulties for installation.

#### *Wet Chemical*

The wet chemical agent is a blend of organic and inorganic salts coupled with surface active agents. It has comparable properties to the AFFF, but it provides a strong measure of freeze protection (as low as -50°C.)

Like AFFF, wet chemical systems are relatively large compared to dry chemical systems. This may make installation of the systems difficult.

#### *Twin Agent Fire Suppression Systems*

Twin agent systems use a combination of dry chemical and AFFF/wet chemical agents to provide rapid fire suppression and surface cooling in the hazard area. The multi-purpose dry chemical discharges to rapidly knockdown the fire. At the same time, the AFFF/wet chemical agent will discharge to give effective cooling, preventing the fire from reigniting. Arguable twin agent systems are the best and most efficient solution on the market.



#### *4.4 Electronically monitored system*

Electronically monitored fire suppression systems significantly reduce the chance of false discharges in comparison to pneumatic systems, as they can differentiate the electric signal resulting from an increase in temperature from the one resulting from a failure or damage to the system. They can also communicate any damage to the system's control module, providing increased reliability for complete peace of mind.

Full electronically monitored systems with their own independent power supply enable automatic protection 24/7 with fault detection across the detection and actuation lines. Electronically monitored systems often offer an isolate mode option, which allows the operator to prevent the system from actuating while carrying out maintenance on the machine, minimising the chance of accidental discharge.

#### *4.5 Fire detection*

Even the most effective extinguishing agents depend upon a rapid and reliable detection system. There are three types of detectors commonly used to sense the presence of fire: smoke, flame and heat detectors.

##### *Smoke detectors*

Smoke detectors sense the presence of visible or invisible particles released in combustion. In a hostile/off-road environment, the debris generated by exhausts or the dust and debris in the atmosphere would generate frequent false alarms and this makes them unsuitable for this environment. They are best used in industrial or commercial premises where the atmosphere is relatively clean.

##### *Flame detectors*

Modern flame detectors use infra-red, visible and ultra violet radiation to detect fires. These are used widely in the vehicle and mobile plant industry due to their high performance and reliability. Some models also have the capability to detect a wide range of electro-magnetic radiation (emitted from combustion or other sources,) meaning that the detectors can eliminate false alarms from sources such as sunlight, welding torches and other heat sources.

##### *Heat detectors*

Heat detectors are the most widely used mean of fire detection in vehicle fire suppression. Several groups of detectors fall in to this category: linear pressure heat detectors (loss of pressure,) point or spot heat detectors and linear heat detectors.

##### *Linear pressure heat detectors/Loss of pressure (LOP)*

Pneumatic and pressure detectors have been used for many years and operate by using simple mechanical /pneumatic principles. A pressurised detection tube runs throughout the protected area, and when ruptured by heat or flame, the pressure is released, activating the system.

These systems can be used without electronics and are appropriate for hazardous areas where the expense of using intrinsically safe or flameproof electrical systems may be prohibitive. However, they offer relatively low detection temperature - 120°C – which can lead to false alarms. This form of detection also relies on reservoir of gas to keep the tubing pressurised and any damage to the tubing can result in false discharges.

##### *Point or spot heat detectors*



These are set temperature detectors or rate of rise sensitive detectors. Spot detectors are used in heavy mobile equipment because of their rugged design and simple actuation. They come in different formats and with varying actuation temperatures to suit different applications.

Spot detectors are relatively low cost and provide effective means of detecting fire; however, by their very nature, these detectors only monitor a local area for temperature. Unlike flame detectors, they have fewer checks to determine if a fire or heat source is a false alarm.

#### *Linear heat detectors*

The most common type of linear detection cable that uses two spring steel conductors, separated by a heat sensitive insulator. At a predetermined temperature, the insulation melts. This allows the conductors to come into contact, resulting in a change in signal relayed back to the control module. To overcome the problems of different temperature sensing requirements, spot heat detectors or thermal switches can be placed in areas requiring specific point detection. These can be interlinked with linear detection cable.

Electronically monitored systems that use linear detection cable significantly reduce the chance of false discharge in comparison with pneumatic loss of pressure systems, because they are able to distinguish between an electric signal resulting from an increase in temperature from the one caused by damage to the cable. They also communicate any damage to the operator, providing increased reliability, and can isolate the detection circuit for machine maintenance.

Linear detection is a 'one shot' operation. Therefore, following any fire or overheat the cable needs to be replaced.

### *5. Key Considerations when Choosing Vehicle Fire Suppression*

When choosing a fire suppression system for mobile equipment, decision makers want to be certain that it will work even in the most challenging circumstances. However, it is important to remember that not all systems of the market are the same and not all suppliers offer the same level quality, service and support.

The following points highlight key areas to be considered when selecting a system and supplier for vehicle fire protection.

#### *5.1 Independently tested systems*

Due to the complexity and critical nature of fire suppression systems, it is recommended to choose a system which has been independently tested or carries an internationally recognised standard of approval.

Systems that hold independent testing certificates have been through rigorous test which ensure that a system will work for the application. Third party certification schemes for fire protection products are an effective means of providing the fullest possible assurances, quality, reliability and safety compared to non-certificated products.

#### *5.2 Thorough hazard analysis*

As covered in section 4.1, an effective system design is based on an exhaustive hazard analysis. Some fire suppression suppliers offer 'off-the-shelf' systems that do not take into account engine size, vehicle layout, operating environment and working conditions. By ensuring the system supplier carried out a thorough hazard analysis and assessment of the fire risks in the asset, decision makers can be reassured all fire hazards have been protected.

#### *5.3 Installation standards*

The quality of the installation work has a direct impact on the system's reliability as well as providing a professional finish. It also affects the amount of repair work and downtime required in the long-term. The list below includes some examples of how to achieve high installation standards in vehicle fire suppression:

Use of P-clips (instead of plastic ties) to mount distribution hoses and detection cable, meaning the system is more secure

Use of spiral wraps to protect hoses from sharp edges

Use of rubber grommets to protect hoses from sharp edges

#### *5.4 System supplier*

##### *ISO certified*

Followed by companies all over the world, ISO International Standards provide world-class specifications to ensure products and services work the way they are expected to, ensuring their quality, safety and efficiency.

Suppliers that focus on delivering a consistent level of quality to their customers usually hold the ISO 9001 certification. In addition, some suppliers also hold the ISO 14001 and 18001 certifications, showing their commitment to managing their environmental responsibilities and following occupational health and safety management best practice.

##### *Level of support*

An effective fire suppression system relies on regular maintenance and inspection. System servicing reduces the likelihood of breakdown or failure, and it ensures the best possible protection against expensive repair cost, downtime and delays to production.

Operator training on basic fire prevention, system functioning and inspection, and what to do in the event of a fire is critical to minimise the risk of fire in the vehicle and consequences should it occur.

##### *System servicing, maintenance and emergency response*

Given the significance a loss of a machine can have, it is important to consider what level of support a fire suppression supplier will be able to provide in terms of scheduled servicing and call outs in the event of a system discharge. The number of engineers available to cover a region is a good indication of the supplier's capability to provide system support. It is recommended to look for suppliers that can measure their emergency response time in hours, not days, so machines are back into production with minimal downtime.

Suppliers should investigate every fire to establish the cause and provide a post fire report making recommendations to prevent reoccurrence.

##### *Operator training*

The training process should start with the system handover delivered by the supplier, ensuring that at least one person on site is trained to operate the system. Suppliers should also provide extensive training materials in the form of manuals, videos, etc. some suppliers also offer tailored training to individuals and groups, including how to maintain, service and recharge the system.

##### *Failure to perform cover*

What happens if the fire suppression system fails to perform? Will the supplier take responsibility?

In addition to product liability insurance, some suppliers offer further protection in the form of inefficacy cover, which may also be referred to as failure to perform. This cover provides customers with the peace of mind that if a suppression system that has been installed by the insured supplier fails to perform its intended function resulting in a loss, then, subject to their terms and conditions, it will be covered by their insurance policy, up to the limits of indemnity.

## 6. Conclusions

Instances of fires on mobile equipment used in mining (surface and underground) have increased in recent years.

Equipment rely upon high pressure hydraulics, high torque engines or high amperage motors and when combined with continuous operation, constant vibration and rugged environments, the risk of fire can be high. A single malfunction in any one of these areas could cause a sudden ignition, engulfing the engine and cab area in flames.

It is therefore in a company's best interests to install reliable fire protection systems; a fact confirmed by numerous economic studies. This is especially true on elevated risk, heavy plant machinery like excavators, off-road trucks, dozers, loaders, shovels, draglines and drill rigs.

The cost of fitting effective fire suppression systems roughly equates to .5-8% of the purchase (or replacement) cost of the equipment in question, and in some instances even lower. While regular service costs must be added to the initial investment cost, these costs can be minimised by training on-site engineering staff to perform maintenance. Alternatively, this procedure can be undertaken by a qualified fire equipment supplier.

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Crowther, N. K. and Brunt, D.M. (2016). *Vehicle fire suppression systems design and selection*. York: Ardent Limited

Department of Mines and Petroleum (2013) *Prevention of fires in underground mines – guideline*: Resources Safety. Western Australia: Department of Mines and Petroleum

# Exposure measurement of diesel engine exhaust emissions (DEEE) in mines

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Higher Scientist  
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## Assessment and control of DEEE in Mines

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James Forder MChem MRSC

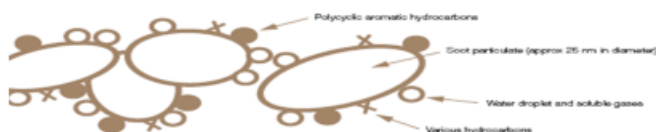
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## What are DEEEs?



- Consists of many components
  - Gases –  $\text{SO}_2$ ,  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{NO}$ ,  $\text{NO}_2$
  - Particulates organic carbon (OC), elemental carbon (EC)
- Use 'markers' to measure DEEEs



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## What do they do?



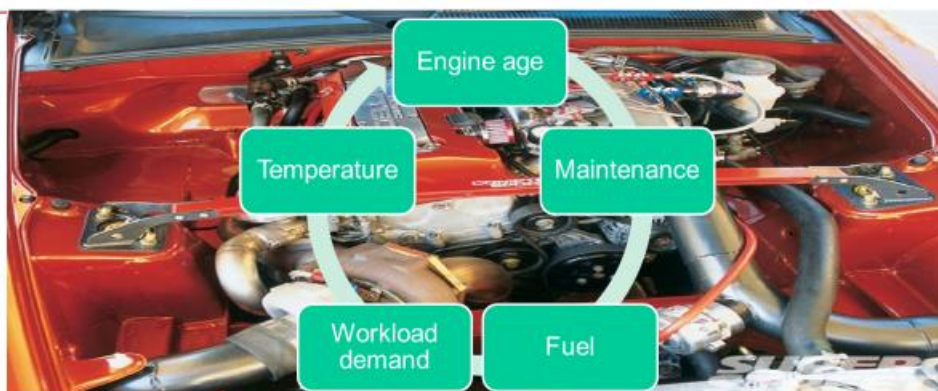
- Acute – respiratory/eye irritation
- Persistent - lung cancer, rhinitis and cardiac illness.
- Classified as carcinogen by IARC



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## Factors affecting composition



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## Some proposed DEEEs markers limits



Standard	CO ppm	NO <sub>2</sub> ppm	NO ppm	SO <sub>2</sub> ppm	EC µg/m <sup>3</sup>
WEL	30				
IOLEV proposed (from 2023)		0.5	2		
IOLEV proposed	20			0.5	
SCOEL suggested					100
Mines and Quarries Act 1954, general air body	30	2	5		150
HSE guidance HSG 187	CO <sub>2</sub> and observation				

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## Overview of talk



- Presents two HSE projects on DEEE
  - Real time monitoring of EC
  - Assessment of DEEEs in mines

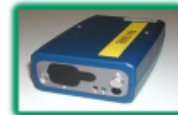
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## EC in real time



- Incorporate pump, sampler and measurement in one device. Several options.
  - General particle counters
    - Readily available
    - Non-specific, result is number of particles not mass of EC
  - FLIR Systems Airtec
    - Developed to replicate NIOSH 5040
    - Light absorption measurement technique
    - Result given is EC based on a calibration study
  - AethLabs AE51 microaeth
    - Developed for ambient air measurement
    - Miniaturised version of OT21 measurement technique
    - Result is Black carbon



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## Real-time monitoring of Elemental Carbon



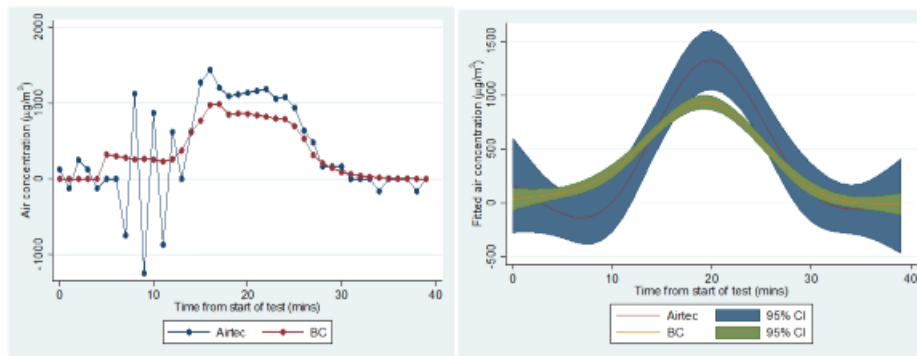
- HSL has studied the performance of the  $\mu$ Aeth and Airtec in parallel sampling tests with filters analysed by EN14530.
- A controlled atmosphere of diesel exhaust has been prepared and measured in the laboratory.
- In addition the instruments have been tested in field trials in a variety of workplaces.
  - RO-RO ferries
  - Vehicle test station
  - Underground non-metal mines



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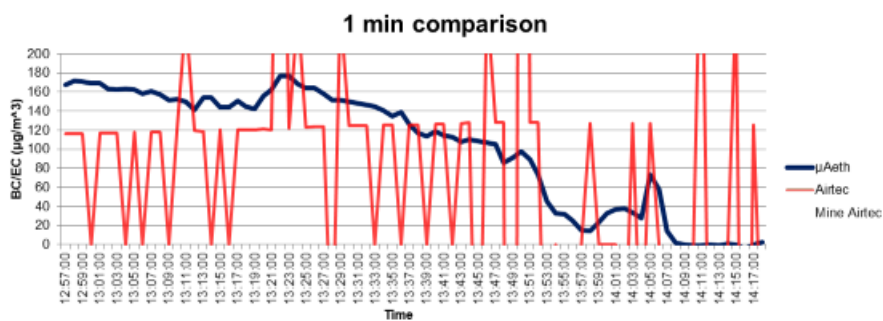
## Laboratory measurements



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## On site measurements



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## EC Real-time monitoring – Conclusions



### Airtec

- Advantages
  - Can sample for a full shift at high concentrations
  - On board display
- Limitations
  - Slow response time – not truly real time
  - High limit of detection, especially for short term sampling

### AE51 microAeth

- Advantages
  - Low detection limits
  - Quick response
- Limitations
  - Short monitoring period at high concentrations
  - Does BC = EC?
  - Separate device required to view results in real-time

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## DEEE exposure in mines



Visit mines to measure DEEE

Exposure controls assessed

Sampling for DEEE markers

Gases - SO<sub>2</sub>, CO<sub>2</sub>, NO, NO<sub>2</sub>

Particulates Dust, EC and OC



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## DEEE marker measurement methods

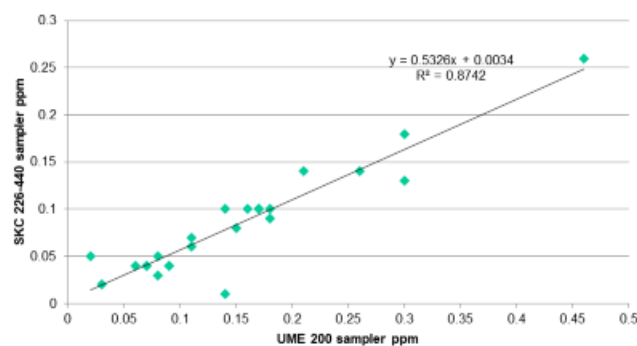


Analyte	Pumped	Diffusive	Real time
Resp. dust	Quartz filter		Dataram
OC	Quartz filter		
EC	Quartz filter		Airtec
NO	SKC 226-40		Multirae
NO <sub>2</sub>	SKC 226-40	UME 200	Multirae
SO <sub>2</sub>		UME 200	
CO		SKC 810-1D	Multirae
CO <sub>2</sub>		Dräger 500/A-D	Multirae

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## NO<sub>2</sub> measurement

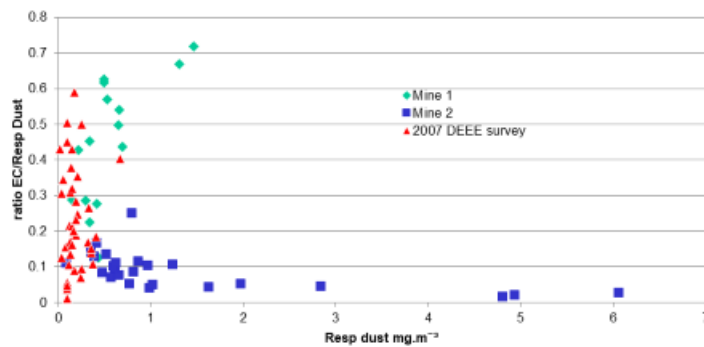


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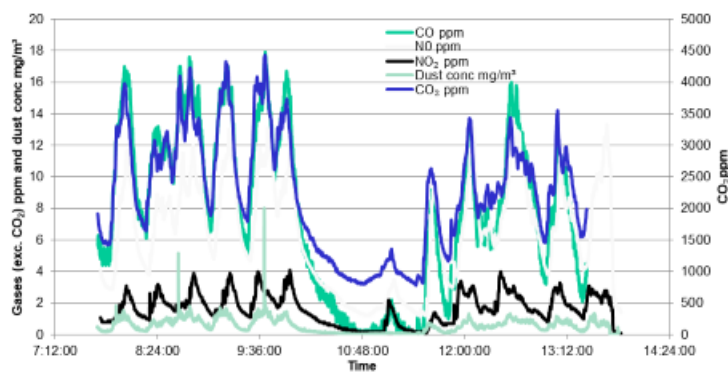
## EC and respirable dust



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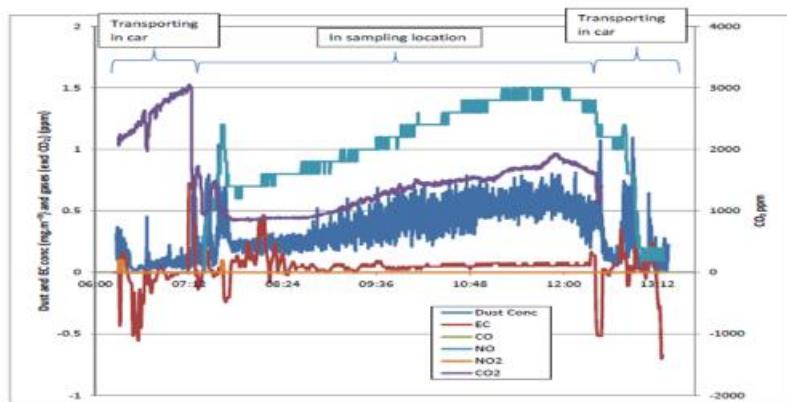
## Real time measurements (1)



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## Real time measurements (2)



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## Preliminary findings



### Gases

- Two NO<sub>2</sub> methods gave different results
- Proposed IOELV for NO exceeded at one mine
- More data needed to assess NO<sub>2</sub>
- SO<sub>2</sub> < LOD
- CO<sub>2</sub> exceeded 1000 ppm

### Particulates

- Real time can be helpful
- Exposure to EC
  - All areas of mine
  - exceed 0.1 mg.m<sup>-3</sup>,
  - highest exposure >1 mg.m<sup>-3</sup>

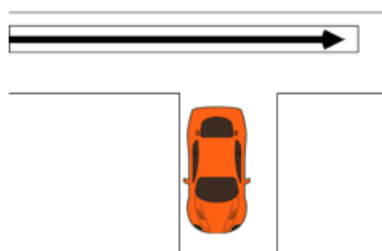
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## Control issues identified



- DEEE measured at fixed locations
- Engine emission tests
- Contaminated clean air
- No LEV in engine test areas
- Auxiliary ventilation



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## Conclusions



### HSE project to date

- Initial data presented
  - EC can be very high
  - IOLEV can be exceeded
  - Controls can be improved
- Real time can be useful

### Next steps

- Project to be completed
- Report will be produced
- NO<sub>2</sub> measurement examined

### Future work

- HSE to investigate DEEEs control

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# Benefits of Professional Membership of the Institute of Materials, Minerals and Mining

Sarah Boad  
Membership Development Manager  
IOM3

The Institute of Materials, Minerals and Mining (IOM3) - Membership and what it can do for you.

We are once again pleased to support the activities of the Midland Institute of Mining Engineers and to be invited to join in this year's Safety Seminar.

Professional recognition and registration is even more important currently of legislation and litigation. It is independent proof of technical "competence" with colleagues, customers, suppliers or regulatory bodies. Professional recognition belongs to you, and only you (not your employer even if they pay your fees,) and it is the international benchmark of professional competence which cannot be disputed or devalued. In these continuing difficult and uncertain times of redundancies and factory closures the benefits of membership are even more important – keeping up to date technically and with who is doing what, and networking may all assist if you have been or may be affected. It can only help...but like most things you get out what you put in.

IOM3 has a current membership of over 16,000 individuals, across the world, with licenses from the Engineering Council (EngTech, IEng and CEng), Science Council (CSci, RSci and RSciTech) and the Society for The Environment (CEnv). CEnv allows members to demonstrate their environmental credentials at a time of increased pressure on green or sustainability related matters.

The main benefits of Institute membership are:

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- Access to local society meetings and events, such as MIMinE
- Discounted rates for conferences, workshops and seminars and proceedings
- Access to members' discussion boards and social network sites
- Fellows Lounge / microsite and discussion boards

## *Publications*

- Choice of a free monthly member's magazine – Materials World or Clay Technology
- Free online access to technical journal content
- Free access to the 'Materials World App'

## *Information services*

- Access to bespoke technical information and impartial advice from experts through the Materials Information Service
- Access to the library Grantham, [IMMAGE](#) an abstracting and indexing database for the mining and minerals sector
- Free email notifications of news and content updates relevant to your interests

Optional subscription to TMS (The Minerals, Metals and Materials Society of America) at additional cost.

#### *Careers*

- Industry-recognised professional qualifications including CEng, IEng, EngTech, CSci, RSci, RSciTech and CEnv
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- Job alerts from the IOM3 website
- Online recording of continuous professional development (CPD)
- Assistance in times of hardship from the Member's Benevolent Trust

#### *Younger members*

- Events and meetings hosted by the Younger Members' Committee
- Discounted student membership
- Young Persons' Lecture Competition

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# Mining dimensional stone and controlling major hazards at Hartham Park underground quarry

Steve Ainsworth  
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Lovell Stone Group

## *1.Introduction*

Currently, underground mining in the United Kingdom (UK) has shrunk to a mere shadow of its former glory. But perhaps we are now at the watershed as new projects herald a major expansion.

When preparing this paper, I examined how the realisation of major hazards caused catastrophic mining disasters in the late 19<sup>th</sup> and 20<sup>th</sup> century. One thing that became obvious was that although modern technology, mechanisation and safety should have developed hand in hand, they inevitably didn't. Safety was often compromised by ignorance of the risks involved in using the very technology that was supposed to improve mining.

It should be remembered that the major hazards of the past will still be the major hazards of the future. A fire is still a fire, and an inrush (as we recently saw in Wales) is still an inrush. Nor do we have the luxury of a large national mines rescue organisation upon which we could previously rely.

I will ask you to consider the following quote by Chief Inspector R.A.S.Redmayne (Sir Richard Augustine Studdert Redmayne KCB MICE MIMM FGS) at the enquiry into the second disaster at Senghenydd Colliery on Tuesday 14<sup>th</sup> October 1913. Redmayne was deliberating over the potential of the underground signalling system to ignite methane. Redmayne commented❶:

"In this connection I can only regret that a safer plan of excluding sparks altogether was not adopted. It is more astonishing that the management should have faced the risk that the sparks produced might have ignited gas in view of the Bedwas Colliery explosion, which occurred on March 27<sup>th</sup>, 1912."

This must be seen in the context of the comment made by Helen and Baron Duckham in their book "Great Pit Disasters" sixty years later:

"Obviously the [signalling] apparatus was used in good faith; the real failing – if we may depart slightly from Redmayne's view – was not in consciously taking an overt risk, but in not being sufficiently aware that a risk existed."❷

It only became clear during tests after the disaster that it wasn't just the voltage of the signalling apparatus that was critical, it was also the amperage.

The understanding of electrical mining technology has greatly improved over the last 100 years, but with the increase in mechanisation the complexities of that specific discipline have exponentially increased. We realised at Hartham Park Underground Quarry that we needed a competent electrician with a very specific skill set to safely undertake our mining operations. We are addressing this issue by training our own mine electrician who is presently being mentored by two retired mine electrical engineers with an average age of 77!

## *2. Our mine*

### **2.1. History**

**Slide 1.** Hartham Park Underground Quarry produces Dimensional Oolitic Limestone. The mine has been intermittently in production for over a hundred years but has been a consistent producer of the Hartham bed of dimensional stone for the last 20 years.

**Slide 2.** Lovell Stone Group took over the operation of the mine on the 1<sup>st</sup> February 2016 and we have been steadily producing and developing the mine infrastructure.

**Slide 3.** As well as the phase 1 North West Development we are mining a new incline to surface to give us better access to the mine.

### **2.2. Workforce**

**Slide 4.** We have a small, but very experienced work-force the core of whom have worked together for over 30 years.

### **2.3. Ground Conditions**

The ground conditions at Hartham Park mine are generally good. Localised poor roof conditions occur only rarely due to 'bad ground' because of adversely orientated discontinuities or bedding plane deflection due to separation along the bed in the immediate roof beam. Any separation is dressed down by hydraulic hammer or saw until the beam is 0.5 metres thick and the undercut brows supported by rock bolts, wire mesh and strapping. All headings are systematically bolted using resin encapsulated steel rock bolts.

### **2.4. Mining extraction parameters**

Depending on roof conditions and the quality of the dimensional stone, our maximum extraction ratio is 75%. Attention is paid to correct and appropriate ground support as it constitutes one of our major hazards. Bolting is done using a mobile rock bolter and hand-held bolting is avoided at all costs, thus removing the miner from the hazard as far as is reasonably practicable.

### **2.5 The operational extraction cycle**

**Slide 5 – 9.** This consists of sawing, extracting the sawn stone, scaling the advancing heading and supporting the freshly exposed roof (and sides if necessary).

### **2.6. Mining the new incline**

**Slide 10.** We are currently driving a new incline to surface using our own electric tunnelling excavator (ETE). The ETE will mine 155 metres of inclined roadway to connect to the surface decline. The ETE will achieve this using a hydraulically driven cutting head.

### **2.7. Mining equipment**

**Slide 11 – 12.** The equipment is predominantly diesel driven, except for the electric excavator and arc wall saw. There is an increasing emphasis on replacing diesel driven equipment with electrically driven equipment, both to reduce Diesel Engine Exhaust Emissions and to reduce the higher potential fire risk from diesel equipment.

## *3. Prescriptive to preventative, the evolution of hazard risk control in UK mining*

**3.1.** The coming of the Industrial Revolution and the development of steam power resulted in a huge expansion in the UK mining industry in the second half of the 19<sup>th</sup> century. Advances in steam powered pumping machinery enabled the development of deep mining, not only of coal, but of other minerals.

The Industrial Revolution, and Britain's rapacious demand for minerals led to vast increases in output and a corresponding growth in manpower in both established and new mines. Unfortunately, it also brought in its wake many calamitous disasters which were not exclusive to coal.

**Slide 13.** This led to a raft of mining legislation and royal commissions which did little to reduce the level of fatalities. This situation perpetuated until the middle of the twentieth century. But thereafter a greater understanding of major hazard risks, improved preventative and mitigating controls, and to some extent advances in mechanisation led to a gradual decline in injury and fatality rates. But the Aberfan disaster in 1966 (116 children and 28 adults buried alive) illustrated that management of the risks arising from certain major hazards within the nationalised coal mining industry was still woefully inadequate.

Aberfan (and other non-mining disasters) marked a turning point away from prescriptive to proactive management of Health and Safety in the UK. Lord Robins (chairman of the National Coal Board in the 1960's) reluctantly headed up a committee to examine which direction future legislation should take. Essentially, he stated that those persons who create the risks and must work in them should be the people who manage those risks.

This statement represented a major change in regulatory control, by firmly setting the responsibility for the management of Health and Safety on the persons who were creating risk. The new ideology was enshrined in the Health and Safety at Work act 1974, the principles of which have been almost universally adopted throughout the world. The remaining years of the 20<sup>th</sup> century saw a raft of new regulations in the UK specifying risk assessment-based control of work activities and environments. Risk control-based regulations were also developed for the mining sector, culminating in the Mines Regulations 2014.

**Slide 14.** The guidance issued by the Hazardous Industries Division (HID) succinctly sums up the rationale behind modern UK mining regulatory control.

**Slide 15.** Page 6 of the guidance explains the future rationale of the Mines Regulations 2014 emphasising the need to ensure that adequate risk control is in place, responsibilities are established, and persons are competent to undertake them.

Regarding the statement on page 7. In my opinion, the statement on page 7 is not quite right. I am sure that your Mines Inspector is still proactively inspecting traditional Health and Safety as well as focussing on Major Hazards.

**3.2.** Finally, in this section I will use the Senghenydd Colliery Disaster as a model to illustrate how even the most trivial preventative barriers can make the difference between life and death. So, what were the root causes of the disaster, and would a modern Safety Management System with good preventative control systems prevented it, or failing prevention would robust mitigating controls have saved hundreds of miners' lives?

HMI Redmayne stated that the Colliery Manager was competent, and the colliery workforce were well disciplined so obviously we need to look deeper. I will look at the three fundamental problems that are elicited in Redmayne's report to the Secretary of State for the Home Office. Then I will look at how the system failures that hampered the rescue could have formed the basis for good preventative and mitigating controls.  
Regarding the fundamental problems I believe:

**3.2.1.** Firstly, the colliery engineering staff of Edward Shaw, the Colliery Manager, (hampered by the lack of known technical knowledge in 1913 regarding current and pressure required to ignite methane by electrical sparking) were using an intrinsically unsafe underground electrical signalling system. The explosion at Bedwas Colliery the year before though might have given them the hint.

**3.2.2.** Secondly, Shaw failed to comply with the 1911 mining regulations on some fundamental requirements e.g. fan reversal. Also, Shaw ultimately bore responsibility for the committing of

many minor breaches and poor practices which probably led to a subsequent 'domino effect' after methane released into the mine's general air body reached a critical level and was somehow ignited. This caused a truly devastating explosion which resulted in impassable roof falls, raging uncontrollable fires and the death and entombment of 428 men. As Redmayne commented:

*"Some of these breaches, compared with those to which I have already given special prominence may appear trivial, but taken in the aggregate they point to a disquieting laxity in the management of the mine" ❶*

The modern legal requirement ensures that a system of Safety Performance Indicators (SPI's) are established. SPI's monitor the functionality of the mine's preventative and mitigating controls and are an effective tool to stop 'laxity' setting in. One look at your SPI results is usually enough to stop you getting complacent!

**3.2.3.** Thirdly, the Colliery Operators and Management didn't heed the lessons resulting from the first disaster at Senghenydd in 1901 (81 killed) and a major gas blower in 1910. If they had, they would have realised that they needed more preventative and mitigating controls to prevent or ameliorate the effects of gas and coal dust explosions and to effectively kill underground fires.

**Slide 16.** Had actions been taken to eliminate the breaches and infringements that were prevalent at Senghenydd Colliery before the explosion, those actions could have formed the basis for a set of controls that might have prevented that explosion or at least mitigated its outcomes.

Finally, in this section it is interesting to observe the statement of Sir Evan Williams (Chairman of the South Wales and Monmouthshire Coalowners' Association). Williams considered that the explosion was not caused by any lack of precaution, and that except for the fan reversal the remaining breaches of regulations were actually failures *"to comply with formalities of no importance in themselves"*. ❷

Hopefully Mine Operators nowadays understand that compliance 'with formalities' saves lives.

#### *The management of major hazard risk at Lovell Stone*

### **Preparation, controls and monitoring of the Safety Management (SMS) and Competence Management Systems (CMS).**

#### **4.1. Preparing Major Hazard Assessments.**

**Slide 17.** The preparation of Major Hazard Assessments is a complex activity consisting of:

Identification of the major hazard risks

Identifying adequate preventative and mitigating controls to reduce the risk to an acceptable level (the barriers)

Identifying who is responsible for undertaking the activities required to ensure the preventative and mitigating controls remain effective

Establishing what training and education is required, and to what standard to ensure the competency of all Mine Operators, Command Supervisors, Craftsmen and Managers.

Preparing a system of Safety Performance Indicators (SPI's) to periodically audit the systems and activities that support the preventative and mitigating controls.

I will briefly provide a glimpse of our journey through the process of establishing just one section of our Major Hazard assessments (tiring journey it was indeed). We are looking here at Mobile plant fire. **Slides 18 – 32.**

#### **4.2. Why so much emphasis on fire?**



During my career, I have observed first-hand on several occasions that the mitigating controls to reduce the effects of an underground fire can quite often be compromised as the fire seldom cooperates with your best laid plans.

Ultimately, as the Mines Inspectorate always stress, it is better to stop a fire starting than to deal with it when it has. 105 years after the Senghenydd disaster we still consider an underground fire to be our preeminent hazard at Hartham Park Mine. We recognise that our preventative controls for combatting the hazard of underground fire are the best defence we must prevent that nightmare ever happening and that they are not “formalities of no importance in themselves”.

**Slide 33.** These are some of our most effective preventative controls. Incidentally, I would like you all to look at the amount of heat and products of combustion in the truck fire and imagine that in a mine.

## **5. Conclusions. Will it work?**

In a word, yes. Major Hazard Assessment is a dynamic and predominantly preventative control system that goes a long way in preventing complacency from creeping into the way you perceive safety performance. But there are some caveats attached to that as it is quite a complex system to establish and maintain.

The only real concern I have, is with the issue of maintaining competence. The demise of the mining NVQ system is placing significant strains on small mines where mining staff are now having to train their own people. This is because the awarding body cannot find enough ‘takers’ to make mining NVQ’s a viable business proposition. There is nothing wrong with training your own staff and it fits in well with succession management when you are endeavouring to pass on years of experience and skills to a young work force to ensure their future safety and prosperity.

But it only works if you have competent and experienced miners who have the necessary skills to become trainers and assessors. Conversely if you have, it is better I believe to train internally as your people realistically have a better understanding of the work activities, operational techniques, and hazards in their own mining environment.

Perhaps in conclusion, the efficacy of the Major Hazard Assessment Scheme is best judged by Chief Inspector R.A.S. Redmayne’s comment 76 years ago:

“There are mines which are so well laid out and managed as to be in advance of statutory requirements. For it is impossible for legislative enactment to keep pace with improvement; there must be a time lag. The object, therefore of a Mines Act should be, and in respect of the Act of 1911 – still in force – was to bring the backward mine up to the level of the best-managed mine.” ⑤

I believe the HSE Hazardous Industries Division and Mines Inspectorate concur with Redmayne’s opinion. Hence the decision to introduce the requirement to manage Major Hazards in the 2014 Mines Regulations.

It’s not the size of your mine that matters, what matters is whether you manage your risk effectively and how proactive you are in achieving that. Effective administration of your Safety Management System may be complex and time consuming, but it is an absolute duty which is why R.A.S. Redmayne established the principle in the 1911 Mining Act.

Redmayne muses in his autobiography how he travelled underground as an Apprentice Manager:

*“...sometimes a distance of two and a half miles along the main travelling road, inches deep in coal-dust (for strange as it may now seem, coal-dust was not then regarded as a potential danger)”.* ⑥

We have not the luxury of ignorance that a Mine Manager had in the 1880's. The hazards of the underground environment in which we work are well known now; thus, it is incumbent on us to not make the same mistakes that led to the mining disasters of the 19<sup>th</sup> and 20<sup>th</sup> Century.

When establishing our preventative controls, we must ensure we don't have any failures "to comply with formalities of no importance in themselves", because those unimportant formalities are usually the ones that overtly combine to sow the seeds of future calamity in a mine. That's why every mine in the UK needs to invest in good Major Hazard Control.

# Critical task analysis – “Managing change in high-risk environments”

Eur Ing Martin Oldroyd, MSc, BEng (Hons), CEng, CEnv, CFIOSH  
Principal HSE Leader  
Doosan Babcock



## Company Profile

**Doosan Babcock unites leading companies to deliver expertise in technology products and services to our Customers globally.**

As part of the Doosan Group, Doosan Babcock, along with its sister companies has become one of the most internationally recognized construction companies in the UK and Europe. Our company mission is to ‘deliver the sustainable energy solutions of tomorrow by embracing the energy of our world and our people today. We rely on our innovation; commitment; and collaborative spirit to realise smarter energy solutions’.

<b>Doosan Group</b>	<b>Doosan Heavy Industries &amp; Construction</b>	<b>Doosan Babcock</b>	
<i>A Forbes Global 2000 Company</i>	<i>A global leader in power and water</i>	<i>A pioneering technology, projects and service provider</i>	<i>Oil, Gas ,Petrochem and Pharma Service, Projects and Optimisation</i>
Revenues (2015)	Revenues (2015)	Revenues (2015)	Thermal Sector Retrofit and Optimisation
<b>\$ 17.4 billion</b>	<b>\$ 11 billion</b>	<b>\$ 900 million</b>	Nuclear Sector New Build, Service & Decom
Employees	Employees	Employees	Green Power Solutions EPC Integration & Service
<b>43,000</b>	<b>19,000</b>	<b>6,000</b>	
Global reach			
<b>38 countries</b>			

As can be seen from the chart above, Doosan Babcock has a sectorised business model, which means that our services approach to MRO activities has been developed across all sectors of the UK generation markets as well as the Petro-chemical and Pharmaceutical markets. This ensures that we have SQEP resources that can be deployed from within a pool of expertise. The sector model has been established to deliver a more efficient service to our clients who operate in similar environments. The sector is structured in such a way as to deliver a “single point of contact” service. The above means we are positioned to offer a wider range of services including;

- Maintenance and Outages
- Construction Projects
- Engineering and Technology Services
- EPC Projects
- Manufacturing and Fabrication

In our delivery model Doosan Babcock focuses on several key strengths and values, these include

**Commitment** to the successful delivery of construction projects of all scales, where the health & safety of our clients, sub-contractors and our own personnel is paramount;

**Quality of Service** – Doosan Babcock personnel have consistently exceeded national targets for Small Bore (<100mm ø) and Large Bore (>100mm ø) welds;

**Resourcefulness** – Doosan Babcock is an international Engineering Services company with a local feel, having a depth of resource available throughout the UK. We are also one of a small number of MRO companies in the UK who have the internal resource to take a major project from scoping through to delivery and commissioning but who are equally prepared to service the requirements of smaller contracts

Doosan Babcock values Reliability, Commitment, and Collaboration - hence, we strive to:

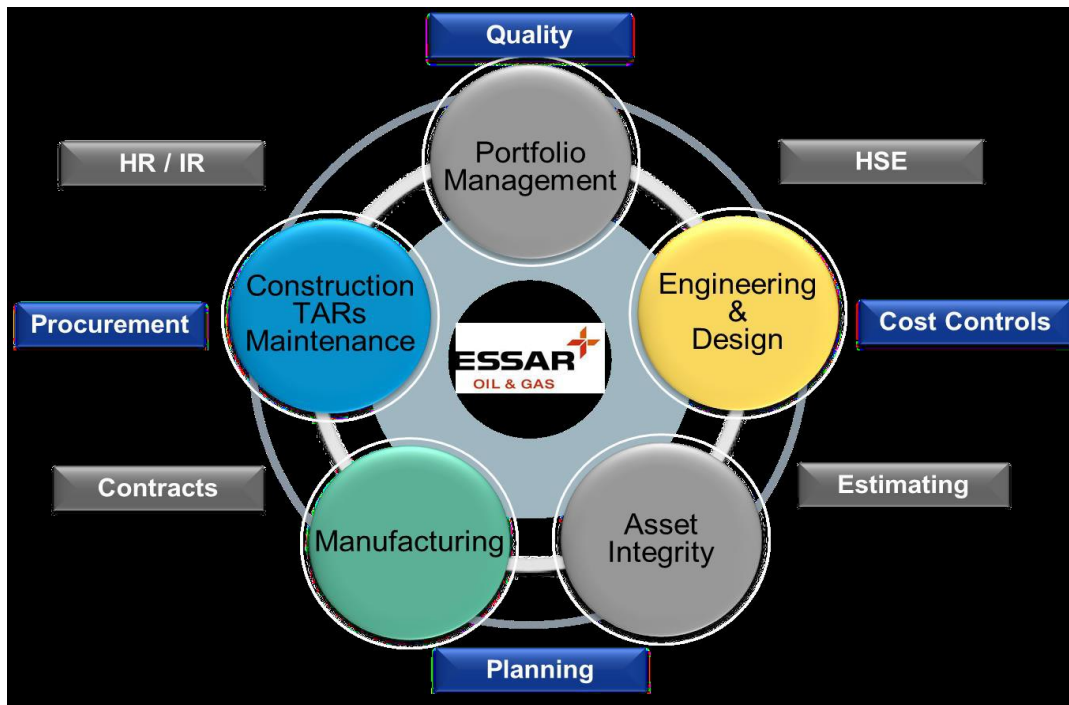
Deliver on our promises without compromise;

Build lasting ties with our customers, based on mutual understanding and trust;

Work together with our partners; employees; and customers in delivering excellence.

### *Doosan Babcock's Integrated Approach*

The focus point of the Doosan Babcock business model is to provide a client focused integrated engineering solution. Hence, we are structured to deliver EPC projects that are formulated with a thorough understanding of the asset management issues that are faced by operators of legacy plant.



### *Doosan Babcock Service Organisation*

Generating increased value for our clients through service excellence, technology solutions and MRO / EPC in the energy and process sectors

#### **Service products include:**

- Major outages and turnarounds;
- Routine and term maintenance;
- Retrofits and Upgrades;
- Technology solutions;
- EPC projects;
- Construction project management;
- Construction expertise – high integrity systems;
- Decommissioning and de-planting;
- Fabrication and spares.



Our integrated Design & Installation teams deliver the optimum construction approach, which realises the following benefits for our clients:

- Safe, productive and predictable performance – “Assured Delivery”;
- Leveraging the extensive knowledge acquired by Doosan Babcock of the specific requirements of framework partners;
- Elimination of project interface inefficiencies;
- Dynamic resource deployment to deliver planned and responsive works;
- Shape, develop and maintain a core site team tailored to the specific needs of customers;
- Minimising customer construction support resource;
- A partner with a passion for innovation;
- Industry leading productivity and value for money; and
- Direct access to process and engineering to improve efficiencies.

### *Change Management – A Journey*

In 2006 Doosan Babcock embarked on a journey that was called ‘focus to zero’. This journey was all about empowering and engaging with employees and particularly supervisors to manage change out in the organisation. The reason for this is that change was identified as a continual causal factor in safety and quality events that had occurred within the organisation over the previous six years.

In that time (since 2000) Doosan Babcock had used technical, systematic, and psychological systems and behavioural management to drive incidents to near zero. It was felt at the time that 'Human Performance' which is primarily an engagement tool would act as an organisational change tool to enable management of change through self-propelled behaviours and application of positive intervention, peer checking, coaching and mentoring.

Several 'error traps' were identified from lessons learned over the previous six years these were:

- Change
- Lack of planning – and the introduction of scope for change
- Turning a blind eye – not challenging change
- Inexpensive to recognise change
- Lack of awareness of change.
- Several other error traps that disguise or mask change such as, time pressures, communications, lack of challenge, poor design and favours without thought

The management of the error traps and the incumbent change would be obviated through, what we called "error prevention tools". Again, as noted these "tools" would be a mixture of encouraged, empowered, taught behaviours and existing systemic risk management tools. These 'error prevention' tools were:

- Leadership
- Induction – orientation
- Planning and preparation
- Procedural use and adherence
- Risk assessment
- Pre and post job briefs, lessons learned developed into best practice
- Ownership and accountability, intervention and a questioning attitude that should head to coaching mentoring and observation and feedback.

This was definitively a macro change management system that focused on fully on organisational behaviours. Doosan Babcock spent four years until 2010 developing refining, training and integrating these tools and behaviours into the organisation. The result was that the level of accidents and incident reduced, and we went several years with no more than minor first aid incidents.

Then in 2010 Doosan Babcock suffered a significant loss event at an oil refinery. At that juncture it became apparent that simply managing change within your organisation if you are a service provider is not enough. In a high-risk environment, you really need to be cognisant of significant external change especially within the client host environment.

Given Doosan Babcock work mainly on top tier COMAH sites or nuclear establishments management of the process would not be our domain and therefore we are somewhat exempt from the process safety management system. We as an incumbent service provider are reliant on the client giving us "safety from the system". Therefore in 2010 we commence work on a micro change management system specifically designed to manage and assess change during high-risk operations on sites where we do not have full operational control. This is around 95% of sites and operations. This task was known as "Critical Task Analysis".



The system comprises of a 5-part process, firstly the risk assessment that is site specific, and must be peer reviewed prior to commencement of the task. There is also functionality to change the risk assessment at the time of undertaking the task where change is identified.

Second there is a 'standing instruction' that must be signed by the supervisor to ensure all requirements of the framework management system have been actioned, risk assessment, method statement, training, medical checks, rescue and other functional requisite controls.

Thirdly there is a 'take five' that asks the operatives a string of salient control questions around how they have been put to work. If any of these do not fit the requisite YES or NO requirement then the task must stop. It also asks a series of practical questions based on environmental conditions of the client plant and process, where again if they do not fit the requisite YES or No, then work, again, must stop. For example, in the breaking containment take 5 it asks can you feel heat on any of the pipes, can you hear the product in the pipes, are there any indications that the system is not isolated. These are designed to manage client error and unmanaged change.

The fourth part of the process is the Human Performance Audit". This is undertaken by the supervision and brings together both macro and micro change management tools by making the Human Performance assessment of error traps part of the critical task analysis process.

The final part of the Critical task process is the training. The training is given as a Computer-Generated module. There is one module to cover the process and another module to cover each of the specific eight hazards. These training modules are then examinable and certificated before the supervisor or operative can be authorised to work on the tasks

An overview of both Human Performance and critical task analysis is given in the following pages: -

### *Human Performance*

The Babcock Human Performance programme focuses on raising awareness of how organisational and individual behaviours contribute to our Performance, it's objective is to raise awareness of human performance and maximise the potential of our people by providing a working environment where they are encouraged to make a direct and positive impact on our business to ensure predictable delivery of our products and services. Our Human Performance Programme, designed in consultation with leading industrial psychologists, builds on the well-established principals of Human Performance and provides our people with the tools they require to help support error free operations.

Our Human Performance Policy, endorsed by our CEO, recognises that leadership commitment and sustained action helps to maintain the trust of the workforce and involve workers in sustaining a positive culture within the organisation. We also believe that there is more to an effective HS&E Management System than documents alone, success is ultimately dependent on the behaviours and interaction of our people, processes and other resources aligned towards our common goal. Personal responsibility by all and the leadership role of management cannot be underestimated.

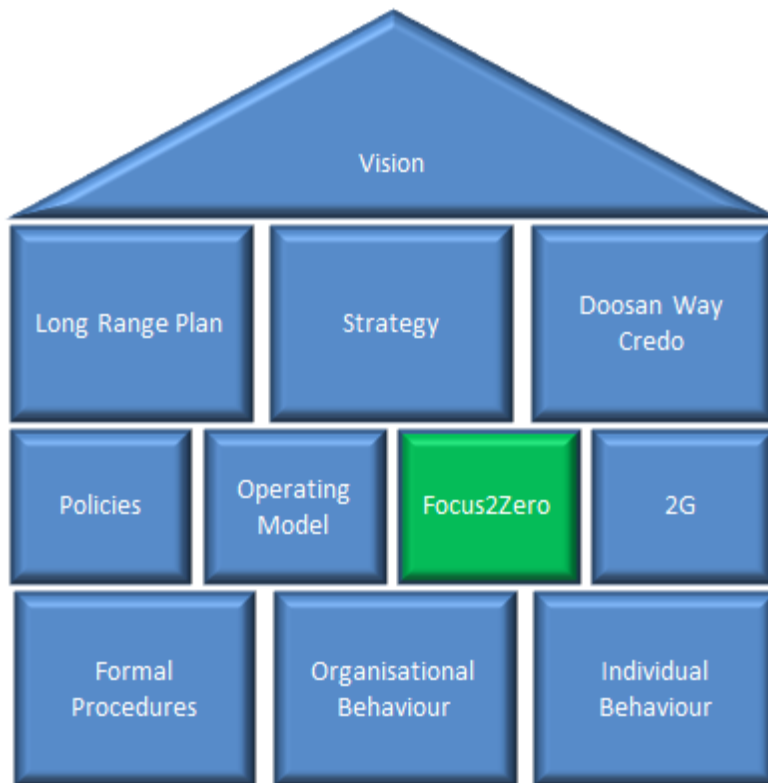
We are totally committed to delivering safe high-quality products and services that satisfy our customer requirements, our applicable legal and other commitments those of other stakeholders and strategic partners.

In our continued pursuit of world class business delivery, a cross company steering group was established to further enhance our performance by embarking on a Human Performance programme. This strategic approach is linked to many of our strategic initiatives together they enable us to achieve our mission: Branded **focus2ZERO** 'An Error-Prevention Journey' we are embedding a Human Performance Culture in all aspects of our business and that of our wider supply chain as we aim for;

- Zero Harm to People



- Zero Product Failures
- Zero Harm to the Environment
- Zero Regulatory Breaches
- Zero Reputation Damage to Clients
- Zero Reputation Damage to Ourselves



A positive Culture is continually fostered and maintained within the organisation, characterised by communications, founded upon mutual trust and by shared values. All activities will be planned, specified and implemented in a manner that maximises error prevention. This is implemented through a policy of commitment that has clear individual and corporate leadership responsibilities and accountabilities for delivery of our programme.

We actively instil into staff and supply chain personnel the right attitudes and behaviours to promote a strong Safety Culture.

Integrating these principles into an organisation's processes and values, as well as management and leadership practices, helps to drive the improvement programme and provide the platform upon which improvements are identified and implemented.

This type of change management improvement programme is aimed at raising awareness of human performance, standards and expectations, with the focus on error prevention and working towards excellence in all aspects of our business delivery. All our personnel are required to attend IOSH Licensed Human Performance '**focus2ZERO**' workshop training; in their personal working environment:

Managers and Supervisors – Leadership Workshop (2 Days)  
Office and Site based Operatives – Foundation Workshop (1/2 Day)

Human Performance training focuses on five key principles;

### ***1. People are fallible and even the best people make mistakes***

Human fallibility is a permanent feature of human nature and we have a natural tendency to make mistakes. Human Performance should not be solely relied upon to control and manage activities critical to plant or equipment safety.

### ***2. Error-likely situations are predictable, manageable, and preventable***

Experience has shown that errors associated with tasks are preventable. Recognising error traps and actively communicating these hazards to others permits us to manage situations proactively and prevent errors and unwanted events.

### ***3. Individual behaviour is influenced by organisational processes and values.***

The Doosan Babcock organisation is characterised by goal-directed behaviour in which management processes will direct the behaviour of the individuals in the organisation to achieve these goals. We recognise that a poor or weak management structure and control systems are often the root cause of poor human performance by:

Applying time pressures

Having poorly written control processes

Providing a poor working environment

All individuals will be trained in application of our human Performance tools and techniques.

### ***4. People achieve high-levels of performance largely because of the encouragement and reinforcement received from leaders***

The seven-day IOSH Certified Human Performance course focuses on enabling supervision to manage both upwards and downwards in line with the principles of Focus to Zero. This is where behaviours, expectations and attitudes can be taught in. The main area of focus and development are:

- Principles of management
- Characteristics of effective teams
- Communications skills
- Delegation and personal development
- Preventing human misery
- Behavioural safety
- Planning and performance
- Working with teams
- Presentation master class
- Managing conflict
- Challenging unsafe behaviours
- Challenging upwards
- Individual coaching and mentoring

### ***5. Events can be avoided through an understanding of the reasons mistakes occur and application of the lessons learned from past events (or errors)***

All minor, adverse and significant loss events are investigated and analysed against the error traps and promulgated across the organisation. This is also true of all projects and contracts, however these lessons learned bridge the whole project spectrum, planning, fiduciary, safety, quality, HR and IR and so on.



## ROOT CASUAL FACTORS

The scaffold gate to access the ladder access egress was constructed of heavy steel instead of either a purpose-built gate or a light metal (aluminium) construct with a plastic protective cover.

The scaffold gate to access the ladder access egress was constructed in such a way that the bar when dropped did not swing away from the person accessing or egressing the ladder.

The bracket holding the access

gate/scaffold bar was not facilitated at 45 degrees and swung directly open.

Human error did have a part to play.



## RECOMMENDATIONS

Review of the use of steel bar as gate – MO to engage with Senior Management at CAPE.

Remove ALL steel poles/bar on site that are used as gates at ladder access and any other points also making all branch operatives aware of the dangers of gates and communicate Corporate and Branch by Lessons Learned – Site Team to action at a local level – MO to facilitate Local/Branch and Corporate Lessons Learned.

Ensure a review is carried out at all Central

Branch sites with feedback to CAPE if this type of gate is being utilised with steel bar. Site Team to action at a local level and MO to facilitate Branch/Site Review.

On completion of the specific training all personnel are issued with the focus2ZERO booklet and individual prompt cards (as shown above) for use in their personal working environments.

## HUMAN PERFORMANCE Error Traps



- Change
- Lack of Planning & Preparation
- Turning a Blind Eye
- Acceptance of Poor Standards & Conditions
- Inexperience
- Taking Short Cuts: Bending the Rules
- Poor Design
- Lack of Pride & Ownership: Complacency
- Time Pressures
- Poor Communication
- Lack of Assertiveness & Challenge
- Favours Without Thought
- Lack of Awareness & Understanding



Doosan Power Systems

## HUMAN PERFORMANCE Error Prevention Tools



- Leadership
- Induction & Orientation
- Planning & Preparation
- Procedures (Use & Adherence)
- Pre & Post Job Briefing
- Risk Assessment
- Ownership & Accountability
- Questioning Attitude
- Intervention
- Lessons Learned & Best Practice
- Coaching & Mentoring
- Observation & Feedback



Doosan Power Systems

To bring our Human Performance Programme (focus2ZERO) to life and embed it in all our activities our Managing Director sponsored a Steering Group, made up of senior Directors and Managers who are Responsible for defining Human Performance Standards and Expectations Accountable to the CEO Doosan Babcock (Sponsor) for Reporting Progress against focus2ZERO Delivery within Doosan Babcock and agree any Executive Support required, including budgets and resources.



### *Critical Task Analysis*

#### **Introduction**

After the significant loss event in 2010 Doosan Babcock commenced a review to both identify and manage change inherent to critical tasks on major hazard industry sites and projects. The first part of the review concentrated on the minimization and mitigation of risk by utilising the Critical Task Analysis process to ensure that any identified high-risk task is managed by due process. Another area of the review looked at how we also concentrate on risk generated from that task by facilitating the correct person for the task.

Once the systemic management process was developed, which will be further explained within the content of the paper we then focused on for each critical task and an “indicative” table of requirements for individuals to be able to control and manage change for each task [critical]. It was at this point we decided to integrate the Human Performance initiative into the overall competency requirement for the individual.

#### **Critical Task Process and People Management**

The critical task process is an activity that Doosan undertake, where, if a failure were to occur, the outcome severity could very easily result in significant injury. The process is used to increase personal awareness of risk whilst undertaking such activities and increase governance for supervision from a personal accountability perspective. This in turn, we have found increases procedural adherence and significantly reduces the risk of an incident, injury or error.

The critical task ensures the following in terms of task hazard management:

Clear standards and expectations for each critical task.  
 Clear lines of responsibility and accountability.  
 Independent verification from both supervisors and operatives.  
 Enhances procedural compliance.


The process takes the form of the following layers of process:

Risk assessment that identifies any task as “Critical”.  
 The second phase is that assurances are made with respect to correct competence and training for that task.

The third phase is the utilisation of a “Critical Task Standing Instruction” to enhance the risk framework around the task and have a “gated” procedure.  
The fourth phase is the completion of a “take 5 point of work assessment” by the operatives involved in the task to ensure that all risk associated with the task is mitigated and controlled.  
The last phase is a “human performance audit” on the task undertaken by the supervisor.

## Risk Assessment

The “Critical Task Process” is designed to support and strengthen the risk reduction process. The supervisor identifies on the front sheet of the risk assessment that a task is deemed as critical. This initiates a visit to the work site so that the supervisor can get a feel for the task and inspect all areas of risk and develop coherent risk reduction strategies within the confines of the assessment. In the plan and preparation phase generic assessments can be utilised – however they must be made site specific post site visit. As a secondary control all critical task risk assessment are subject to a peer review. Where there is a change of supervisor on any critical task then the change supervisor will review the risk assessment and sign it as well.



**RISK ASSESSMENT RECORD**

**Section A – Document Headings**

Project/Site/Location	Area/Plant/Unit		
Task Assessed			Doc Ref
			Rev
Assessment Date		Review Date	
Assessor		Assessor Signature	
Critical Task Peer Review		Peer Review Signature	

**Section B - Assessment Tool Hazard List**  
Please consider hazards below with regard to the task being assessed, this list is not exhaustive, detail other hazards in the appropriate section)

Hazard/Error Traps	Y/N	Hazard/Error Traps	Y/N	Hazard/Error Traps	Y/N	Critical Task List	Y/N
<b>Work at Height</b>		Dust		Hydraulic/Pneumatic		1 Hot Thermal Environments	
Potential fall of Objects		Electricity		<b>Lifting Operations</b>		2 Work at Height	
Potential Fall of Persons		* Ionising Radiation/Contam		Over Live Plant		3 Confined Space	
<b>Hot work</b>		<b>Environmental</b>		Overhead/Mobile Crane		4 Breaking containment	
Fire/Explosion		Lack of ventilation/oxygen		Poor Ground Conditions		5 Rider Operated Mobile Work Equip	
Sparks/Molten Slag		Hot or cold thermal temp		<b>Insulation/Jointing</b>		6 Lifting Operations	
Radiant Heat		Excessive Noise/Vibration		Asbestos Materials		7 Work On, Near or Over Water	
<b>Plant and Equipment</b>		Extreme weather conditions		Non asbestos Materials		8 Pressure Testing	
Mobile or Fixed Plant		Excessive Waste		<b>General</b>		9 Live Working	
Moving Vehicles/Traffic		Lack of light/Glare		Slips, Trips and Falls		<b>Ref OP-90-00-017 Control of Critical Tasks</b>	
Adjacent Live Plant/Equip		Biological e.g. legionella		Multi-Level Working		<b>Other Hazards Identified</b>	
<b>Contact with Process</b>		<b>Access Egress</b>		Other Work Parties			
Oil (high/low Press)		Restricted access		Excavations			
Steam/Vapour (high/low Press)		Stairways and walkways		Deep/Fast Flowing Water			
Water (high/low Press)		Temporary Access/Scaffold		Animals/Rodents/Birds			
Gas/Fume (high/low Press)		Ladders (Fixed/Temp)		Lone working			
Hydrocarbons (high/low Press)		Passenger lifts (Fixed/Temp)		Manual Handling			
Solvents		<b>Tools</b>		Repetitive Task			
Acids/Alkali		Hand held		<b>Confined Space</b> Specific			
Stored Energy		Portable electric		Assess ref BOP OP-10-01-097			

\* seek advice from Radiation Safety Co-ordinator

**Section C- Those Affected By This Assessment (Please Tick)**

Employees	Adjacent Workers	Other Contractors	
Members of the Public	Children/Young Persons	Visitors	Others (Specify)

The risk assessment is the primary control document for any critical task. Once this is completed then the supervisors then utilise the Standing Instruction once the training records for any individual involved in the task have been checked. A section was also added in to the risk assessment process to control change at source

G – MANAGEMENT OF CHANGE/UPDATED CONTROL MEASURES (use separate sheet where required and carry out re-brief with all those affected by the change)													
Activity		Hazard	Potential Outcome	Existing Control Measures	EXISTING RISK RATING L X S = R			Additional Control Measures to Reduce Risk			RESIDUAL RISK RATING L X S = R		
DATE	JOB STEP	ASSOCIATED WITH THE ACTIVITY		e.g. design, guarding, procedures, training, PPE, signs, permit to work etc.	H	M	L	e.g. risk elimination, alternative methods, and ADDITIONAL - guards, barriers, design changes, procedures, training, supervision to monitor controls, PPE, IRR-PRA, ALARP etc.			H	M	L



### *Standing Instruction*

The standing instruction is a mandatory tool for supervisors that will ensure full consideration is given to the planning and preparation for setting persons to work on critical tasks. The SIN form has an instructions section which is a risk prevention framework for the task that requires the supervisor to ensure each line item is done before he can proceed to the next. The SIN must be completed by the supervisor and held in the work pack for the duration of the task. This addresses the full knowledge of responsibilities box in the person specification boxes.

The content of the instructions is controlled by the technical authority and deviations are only permissible in writing from the technical authority. The SIN is a tool to assist the supervisor to ensure that the safe system of work is both in place and understood by the operatives. Below is the SIN documentation for lifting operations.

### *Take 5 - Operative Risk Prevention and Change Management Gate*

Once the supervisor has completed all the boxes in the SIN he can then deploy the work party members, at this stage he will check to ensure they are aware of the process, if they are uncertain about any aspect it is at this point the supervisor should coach team members on the use of the take 5.

Both the supervisor and the operatives have sections of the Take 5 to fill in, but the main reason is to second check that the safe system of work is in situ prior to deployment. [Permits, Method Statements, Risk Assessment, Manual Handling and COSHH Assessment].

The take 5 is a mandatory tool for use by the critical task work party and must be completed prior to the task commencing. It is a pre-defined checklist to be completed at the work face. It allows the work party to consolidate the requirements of the risk assessment and other instructions given at the pre-job brief. It is also a vehicle for the identification of hazards that have presented since the risk assessment was undertaken or any local issues.

### *Critical Task Human Performance Audit*

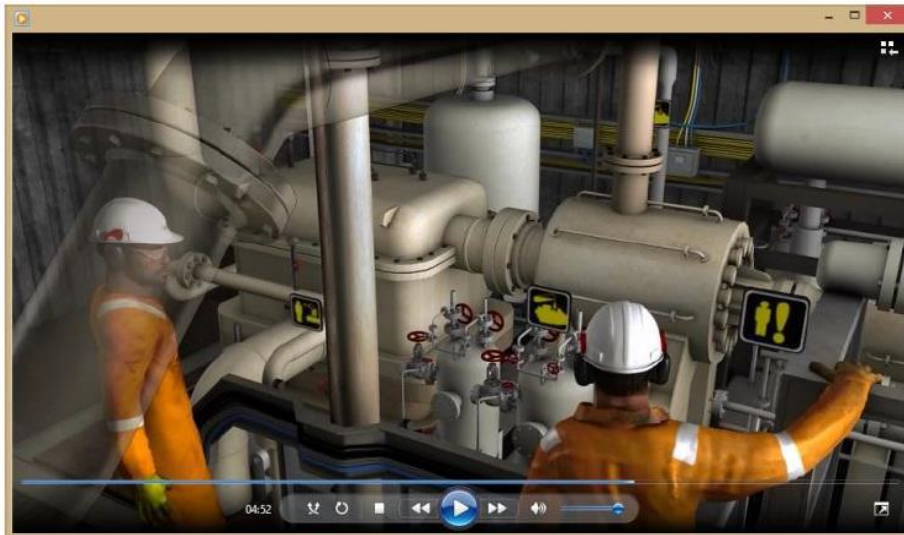
This is undertaken when the task is ongoing. It is a pro-active tool that helps assure the safe completion of the task. The auditing is arranged by the supervision and undertaken by any member of the management team. It uses again pre-determined checks specific to each critical task for example we have the HU audit for lifting shown below.

It helps identify positive compliance as well as noncompliance and focuses as well on the human performance aspect of the task, specifically to help reduce error and manage change.

### *Critical Task Training Modules*

The training for all eight Critical Tasks was developed using specific loss events encountered by the organisation. For example, the Breaking Containment training reflected the Linsay Oil Refinery loss event and all the others followed suit. The Critical task process training is a separate presentation.

The training is all delivered using Computer Generated Images to ensure that we get similar quality of delivery across the organisation. The supervisors and operatives are then examined on the presentation using a questionnaire with an 80% requisite pass mark.



The training is also complimented by cross use of images from the Human Performance training presentations to strengthen the safety “brand”.





## *Conclusion*

It is very difficult for an organisation to manage change and it is also difficult to manage change when that change does not come from within the organisation itself. This is particularly pertinent when managing in a high-risk environment.

In 2006 we developed a change management needed that was focused on behaviours. It had a compelling and clear articulated, shared vision of involvement. It was a partnership approach that engaged all parts of the workforce empowering them to question and engendering a culture of engagement to deliver a high quality safe service to clients.

The loss event in 2010 gave the organisation a fundamental understanding that management of change was required at a micro level (task) as well as a macro level (organisation) with a critical focus on core high-risk activities. This gave rise to the critical task analysis which is a system is model that now sits well and has synergies with the human performance initiative which is very much a behavioural model.

From a staff perspective change management now involves organisational structures and behaviours, teams, roles, work practices, cultures and systems procedures.

# Managing the challenge of change in Irish mines

Jim Holmes  
Mines and Quarries Policy Inspector  
HSA

## *Safely Managing the Challenge of Change at New Boliden Tara Mines*

### **Autonomy in Mining**

Autonomy enables an item of equipment to have the freedom to govern itself or control its own affairs; it is beyond automation as it gives the equipment the power to make decisions at a much quicker speed than a person can make that decision. It is beyond the normal level of automation or of remote control. We are effectively giving the equipment the ability to think for itself.

Autonomous mining allows many mining processes that have traditionally been carried out using equipment operated by a miner to be carried out without a miner with the equipment deciding what to do next and when to do it. Because modern processors and sensors can operate so quickly they also allow the processes to be speeded up whilst logic circuits and sensors can ensure that this is carried out safely.

What is currently being trialled at New Boliden Tara Mines may not be truly considered autonomous mining; however, it goes far beyond automation.

The theme of the seminar is 'Safely Managing the Challenge of Change' so I aim to show why autonomous mining enhances safety and will allow mining operations to continue to operate in conditions where miners could or should not be exposed to for extended periods and the potential cost savings that could make previously uneconomic deposits viable.

### **Overview of Mining Technology Advances**

Mining has always been extremely progressive and has had to change to survive as depleted reserves, competition, prices and costs can soon put a mine into financial meltdown.

I worked in the UK coal mining industry from 1977 until 1995 and the industry was at that time always at the forefront of technology, in fact the first remotely operated longwall face (R.O.L.F) was trialled at Bramley Vale Colliery in 1964 and companies in Australia and the USA are still working to achieve the dream of a fully automatic longwall coal face more than 50 years later. I still recall the introduction of new technologies such as the MINOS (Mine Operating System) which was a computer system for centralised monitoring and control of Colliery systems), MIDAS, a machine information display and automation system introduced in the 1980's along with IMPACT (Inbuilt and machine performance and condition testing) and FIDO (Face Information Digested on-line – which operated like a tachograph monitoring operational and downtime). The technology used in the coal mining industry in the UK was amazing when you consider that the state of the art home computer at that time was the Sinclair ZX Spectrum with its 16Kb of RAM and mobile phone technology was almost non-existent.



**Sinclair ZX Spectrum**



**NCB Control Room**

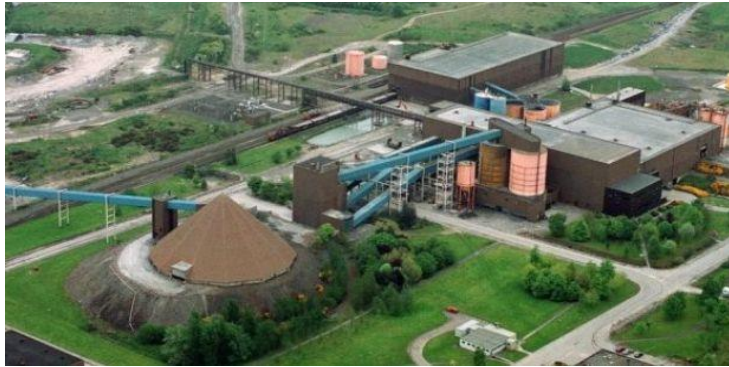
### *New Boliden Tara Mines*

New Boliden Tara Mines is Europe's largest zinc mine and has been in production for over 40 years, and up to 2016 more than 85 million tonnes of ore have been extracted.

In 2016 the mine produced 2.6 million tonnes of ore with a zinc grade around 7% and lead grading at over 2% and had an operating profit of €48 million. The mine employs approximately 600 people and the ore are won wholly by drilling and blasting mainly through stopping methods. The depth of the deposit is currently between 150-1000 metres below ground. Recent discoveries from exploration drilling are much deeper than this (1500 metres) and 5 kilometres from the current shaft and portals which will increase the operational difficulties placed on the mine.

Only a few years ago Ireland had three modern lead/zinc mines and was one of the world's largest producers of Zinc, but two have since closed following exhaustion of reserves. Exploration drilling has identified an area in Limerick where 42Mt of ore has been proven and this is the likely location of a future mine.

### *Overhead view of new Boliden Tara Mines*



When I joined the Health and Safety Authority in the Republic of Ireland in 1995 I was shocked to see a Scoop Tram loading shovel mucking a stope operated remotely using a belt mounted remote control. Seeing such a large vehicle operating in a dangerous area whilst the driver controlled it from a place of safety was technology beyond what I had known.



Having worked for British Coal and Cementation Mining I was familiar with rock bolting and cable bolting using hand held machines but at New Boliden Tara Mines I observed these operations being carried out from purpose-built rock bolting vehicles with the operator inside an enclosed cab. The cassette on the rig automatically connected and disconnected the drill rods and loaded the rock bolt.



Hand Held Rock bolter  
Rock Bolting Rig



Similarly, longhole drilling of stope fan holes was carried out from a position of safety with the Miner either in an enclosed cab or controlling the drilling remotely located some metres from the area being drilled using a floor mounted console.



But in all these cases it was not a fully autonomous process; it still required a miner underground to operate the equipment although the process generally moved the miner to a position of safety. These processes still relied on human factors and were dependent upon the miner following procedures.

A fatality occurred at the Lisheen Lead/Zinc mine in Tipperary in 2013 where the Operator did not park the Scoop tram and get out of the vehicle to operate it remotely and instead drove the scoop tram directly into a stope and was killed in a subsequent collapse whilst mucking out. It took several days to reclaim the body of the dead miner following a fall of over 1000 tonnes of ore. This highlights that where the miner is the key decision maker dangerous short cuts can be taken.

So, whilst we had seen considerable improvements in automation in the mining sector we still had two issues remaining, a dependence upon human factors and miners working in areas where they could be harmed.

New Boliden Tara Mines has now introduced semi-autonomous systems in certain areas of the mine where the miner has been removed from the working area completely, either to the surface or to a safe position within the mine.

Semi-Autonomous mucking of stopes is carried out between shifts in designed areas of the mine remotely from the surface when the mine is evacuated, and high levels of blasting fumes are present. This allows mucking to be continued for 4 hours during which time there are no miners in the vicinity. An operator on the surface operates two scoop trams during loading and unloading operations; the tramming from the stope to the tip point is carried out autonomously as the sensors on the vehicle allow it to manoeuvre through the tunnel much faster than if it were operated manually.





Currently the mined ore from the stope is either transported to a storage area (remuck) or to a draw point (ore pass as the automation has not yet been extended to the operation of the 60 tonne trucks.

When miners are in the mine, systems are now available so that the miner does not have to keep getting in and out of the vehicle when drawing from the stope to use the remote control in the stope area and the miner can now operate the scoop from a purpose-built vehicle mounted remote unit.



### *Autonomous Stope Longhole Drilling*

Drilling a stope longhole ring can now be carried out autonomously at Tara Mines from a surface location and is not dependent upon miners being in the mine or not. The drilling rig is driven in to the hanging or foot wall tunnel and positioned. The operator can leave the vehicle after selecting automatic mode and the vehicle can then be operated from the surface (this could also be vehicle mounted.) The drilling machine can centre the rig and the computer system drills the fan pattern based upon a predetermined program loaded on to the system. The operator can monitor the drilling speed, pressure; machine metrics etc. although normally everything is carried out without operator intervention and provides a fully-automated execution of the drill round. The system is particularly suitable for remote drilling in unsafe areas such as frozen or broken ground.



Miners are prevented from entering areas where autonomous mining is taking place by the provision of a laser light curtain, identified by warning signs. The vehicle will stop and the engine, electrical and hydraulic systems shutdown if the beam is broken and this requires a manual intervention to override the shutdown. It is a fail to safety design



### *Drivers for Change to Autonomous Mining*

There are obvious drivers to change to autonomous mining and the most obvious of these are reduced operating costs and increased equipment uptime. Autonomous mining is designed to operate the equipment to maximise the efficiency of the machine, because it works autonomously it can operate quicker and more accurately than if manually operated and as decisions are made in microseconds it does not cause unnecessary wear and tear on the machinery and increases the life of its consumables such as tyres, drill bits etc. and there is an improvement in fuel efficiency and reduced downtime as the vehicles are not restricted by shift changeovers or environmental considerations.

Because the vehicle is unaffected by blasting fumes or other contaminants in the mine ventilation circuit it can operate when it would be unsafe for a miner to be present.

In addition to this there is a reduced manpower cost as a miner is only required at certain times such as refuelling, and servicing and the cost of employing someone to operate a vehicle from the surface would be significantly less than employing an underground miner.

The safety of the miner is improved because the miners are removed from the point of danger, either to the surface, an underground office, or a mobile unit in the rear of a vehicle. If there is a vehicle fire within the mine, then the miner is at less risk as the miner is not in the development or stoping tunnels which probably only have a single exit route and is therefore in a better place to escape from the mine or travel to a safe-haven.

We must also take note of the improvements to the health of the miner, because the miner is removed from the working area their exposure to respirable dust, silica dust, oxides of nitrogen, diesel fumes and carbon monoxide are significantly reduced. Underground control points can be air conditioned and the air scrubbed of contaminants.

### *Reductions in Acceptable Exposure Limits in Mines*

The limits to each contaminant permissible in a mine that a miner is exposed to continue to fall as more and more evidence indicates the serious health affects they have on the persons



working at the mine. We must remember that Mines are places of work and we cannot expect continuous derogation from the levels required at other places of work.

Crystalline silica has been classified as a human lung carcinogen. Additionally, breathing crystalline silica dust can cause silicosis, which in severe cases can be disabling, or even fatal.

Diesel emissions are now incontrovertibly linked to lung and bladder cancer and concerns with exposure to oxides of nitrogen, sulphur dioxide and carbon monoxide have seen exposure levels fall significantly in the last 40 years.

Employers are required to prevent exposure to carcinogens or to control exposure adequately to remove risk of cancer where prevention is not possible.

When we consider carcinogens, we must decide how low an exposure is permissible, and we must remember that what it is presently considered acceptable may not be in 10 or 20 years' time. Exposure levels historically decrease, they do not go up.

The acceptable Exposure levels have been reduced/introduced for the following contaminants:

Contaminant	8Hour - TWA	15 Minute -STEL
Carbon Monoxide	20 ppm (23 mg/m <sup>3</sup> )	100 ppm (117 mg/m <sup>3</sup> )
Nitrogen Monoxide	2.5 mg/m <sup>3</sup> (2 ppm)	
Nitrogen Dioxide	0.995 mg/m <sup>3</sup> (0.5 ppm)	1.91 mg/m <sup>3</sup> (1 ppm)
Silica Dust	TWA: 0.1 mg/m	
*Diesel Fumes SCOEL Identified as Carcinogenic – OEL under consideration		

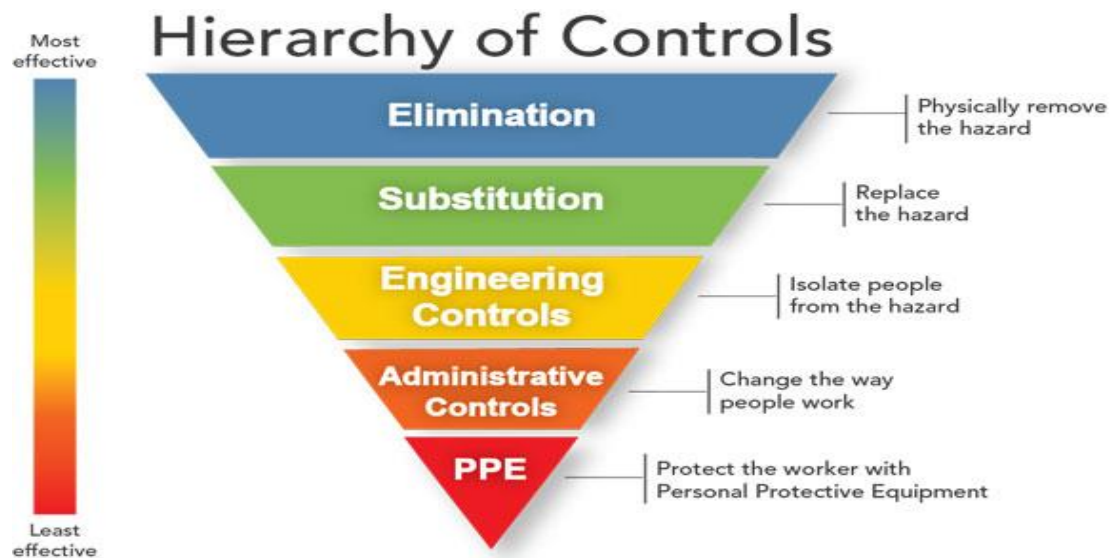
There is 5-year derogation for the mining industry during which time they must show what they have implemented to achieve these levels. It is not expected that the derogation will be extended.

There are no diesel engines or diesel fuels currently available or under development that will meet the emission levels necessary to achieve these new exposure levels in most mines.

There is a limit to the ventilation that can be forced through the mine without causing discomfort to the miners and the levels needed to dilute the contaminants to an acceptable level are a multiple of what we currently have so we need to look at what else can be done.

Most mines are aware of the hierarchy of controls that can be used to address hazards. What is possible at one mine may not be suitable at another but irrespective of individual circumstances it will fall upon mine operators to implement measures that will control the hazard to an acceptable level.

At New Boliden Tara Mines it would not be possible to move away from drilling and blasting and there are limitations to the ventilation that can flow through the mine particularly as the workings get deeper and further away from the surface portals. There has already been a move to the use of emulsion explosives which produce lower volumes of contaminants.



As previously discussed Tara Mines are introducing autonomous mining which will remove the miner from the area where the contaminants are going to be produced. These remote stations if not on the surface can be in air-conditioned vehicles or underground offices.

Tara Mines are commencing a move to an all-electric fleet of vehicles by 2023. The first fully electric Sandvik Jumbo Drill Rig arrived at the mine in October 2017 and a second arrived shortly after that.

The rig, designed for underground development drilling and tunnelling uses electrical power to drill, relying on the mine's power supply network. Battery energy is used for tramming and to provide active network compensation for higher performance during drilling. It does not need a separate charging unit as the rig charges up the battery automatically during the drilling cycle.



Travel through the mine from the surface portal involves the miners being transported to their workplace by crew bus or jeep. There are seventy such vehicles in use at any time in the mine. The first electric jeep arrived at the Mine in November 2017 and it is intended to replace the remainder by 2023.



There are also plans to introduce electric scoop trams and mechanical scalers in 2018.

### *The Limitations to Autonomous Mining*

I would draw your attention to limitations to the use of autonomous mining. These are quite simple considerations to make.

You cannot expect an autonomous vehicle to operate continuously in mining conditions that are unsafe for a manned vehicle to operate. As good as the electronic management system is on these vehicles an unexpected breakdown will occur at some time, such as a failed hydraulic hose which may require on site repair and if it is unsafe for the fitter to travel to the vehicle then how do we repair it?

Miners and autonomous vehicles must be segregated until there is absolute confidence in the vehicle being able to detect that person and taking the appropriate action if their paths cross

Mining systems that use some autonomous vehicles integrated with manually operated vehicles should be avoided. Autonomous vehicles operate and make decisions much more quickly than a human operator and a human operator does not always do the expected.

### *Summary*

In this paper I have offered some history to the use of autonomous techniques in mining, how autonomous vehicles are being introduced at New Boliden Tara Mines, the drivers for the changes and the other measures New Boliden Tara Mines are taking to reduce the exposure of their miners to carcinogens and other contaminants. I have also highlighted the potential dangers from the introduction of this modern technology. The miner of the future may be the teenager sat in his bedroom playing on his Xbox or Playstation 4; they may already have the skills a miner will need in the future to operate mobile plant.

# Modelling for the underground storage of explosives

Simon Coldrick  
Senior Scientist  
Health & Safety Executive



## Underground storage of explosives

MIME seminar, 20<sup>th</sup> April 2018

S Coldrick, Fluid Dynamics Team, HSL

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## Background



- The Explosives Regulations 2014 require anyone who stores explosives for more than 24 hours at a specific location to have a licence to do so
- Explosives can be stored on the surface or underground and the particular conditions of each type of storage need to be considered when granting licences
- For any storage location, separation distances need to be set for over-pressure from an accidental explosion
- A risk assessment is required to prove that underground storage is no less safe than on the surface and one way of demonstrating that the risk is acceptable is by use of a model

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## Background



- There is established guidance for overground storage, but for underground storage, the hazard depends on the geometry as well as the quantity and type of explosives
- This presentation reports a feasibility study for the use of ANSYS Autodyn for modelling underground storage of explosives
- The presentation covers validation of the model against test data, followed by an example application

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## Modelling

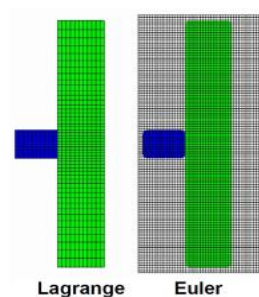


- ANSYS Autodyn is an analysis program for modelling high-speed flows and structural response
- Autodyn models fluid-structure interaction, blast waves, detonation of explosives, fragmentation etc.
- Autodyn solves the equations for conservation of mass, momentum and energy, linked by an equation of state

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## Modelling



- Lagrange formulation typically used for solid mechanics
- Eulerian formulation typically used for fluid dynamics
- In Autodyn, solids can be modelled using the Euler formulation

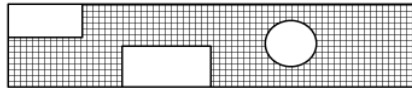
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## Modelling



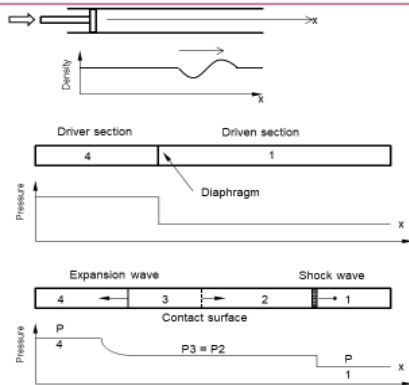
- Fluid flow modelling using the Euler formulation does not account for viscous effects/turbulence
- Suited to high-speed flows and transmission of shock waves
- Limited to Cartesian hexahedral mesh



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## Test case – shock tube



$$a = \sqrt{\gamma RT}$$

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## Test case – shock tube



- 1 m tube
- Two meshes: 1000 and 100 cells
- Initial conditions:

	Driver section (4)	Driven section (1)
Length (mm)	500	500
Pressure (kPa)	500	20
Temperature (K)	303	303
Density (kg/m <sup>3</sup> )	5.747	0.2299
Internal energy (J/kg)	217467.4	217467.4

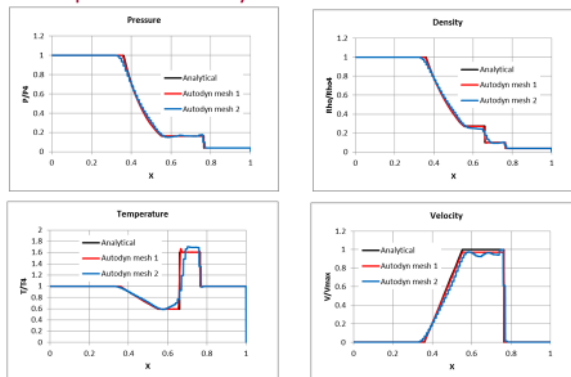
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## Test case – shock tube



- Compared with analytical solution



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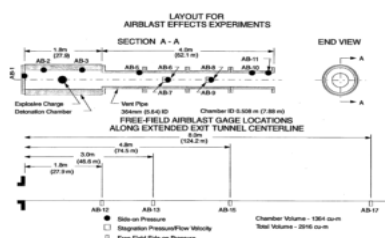
## Test case – shock tube



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## Test case – blast in tube



Technical Report SL 68-5  
August 1968

US Army Corps  
of Engineers  
Waterways Experiment  
Station

**Airblast Effects Research:  
Small-Scale Experiments and Calculations**

by Charles E. Jachim, Gordon W. McMahon, Charles V. Lundeman,  
Sharon B. Gerner

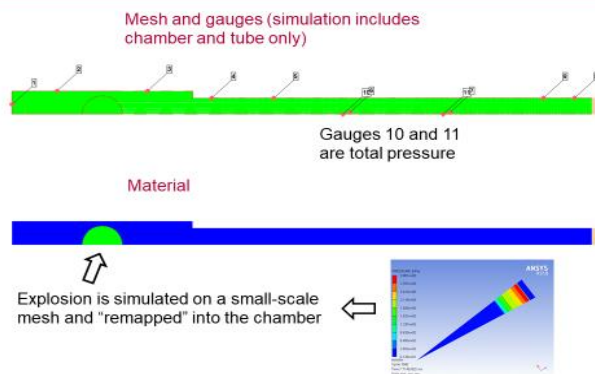
Test No.	C-4 Explosive Mass (kg)	Chamber Loading Density (kg/m <sup>3</sup> )	Total Loading Density (kg/m <sup>3</sup> )
1	0.110000	0.404	0.184
2	0.110000	0.404	0.184
3	0.110000	0.404	0.184
4	0.280000	1.028	0.468
5	1.360000	4.893	2.272
6	0.048000	0.165	0.075
7 <sup>a</sup>	1049.000000	1.028	0.468

<sup>a</sup> CTH computational model for prototype underground magazine.

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## Test case – blast in tube



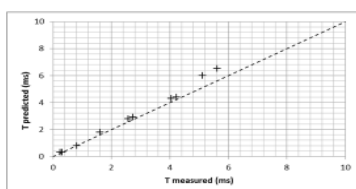
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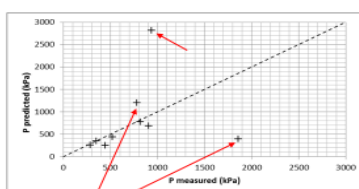
## Test case – blast in tube



### • Results: arrival time and pressure



Good agreement on arrival times



Chamber pressures poorly predicted

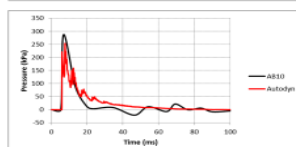
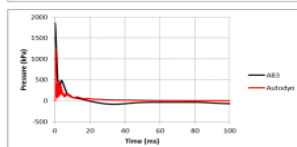
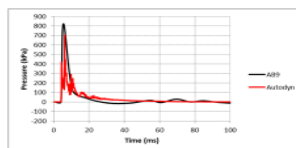
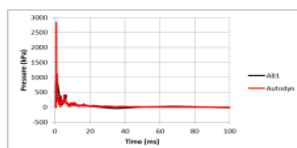
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## Test case – blast in tube



### • Results: pressure



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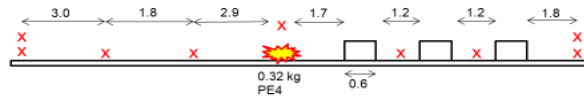
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## Test case – unconfined explosion



- HSL tests to examine the effects of blast sheltering (report CM/01/02) test 1



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## Test case – unconfined explosion

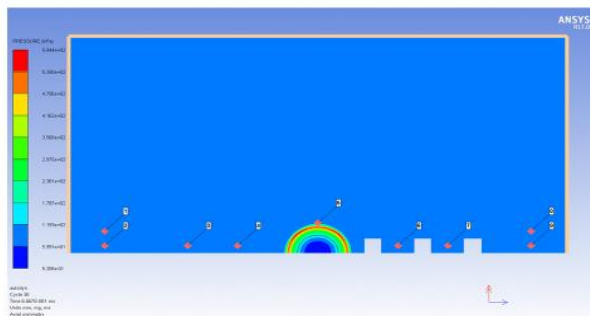


- Modelled in 2D axisymmetric in Autodyn
- Different methods used to model the explosion:
  - A remapped explosion
  - Modelled directly in the mesh
  - Approximated as a compressed “balloon”

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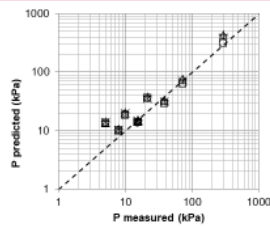
## Test case – unconfined explosion



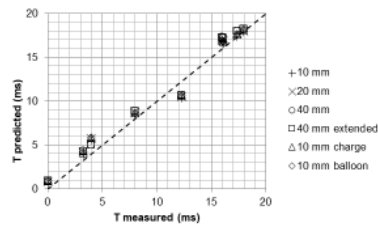
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## Test case – unconfined explosion



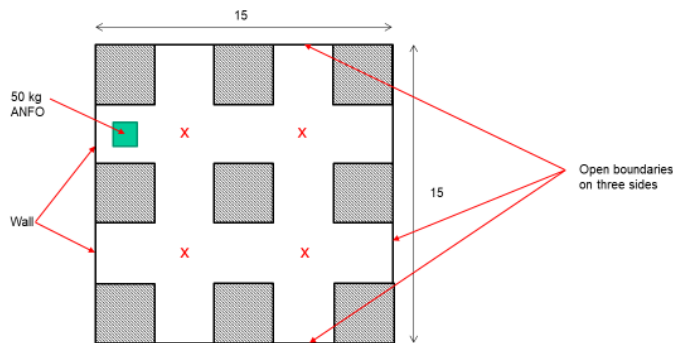
- Results for different mesh sizing and methods of representing the charge



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## Test case – complex geometry



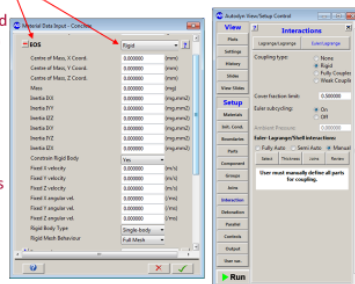
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## Test case – complex geometry



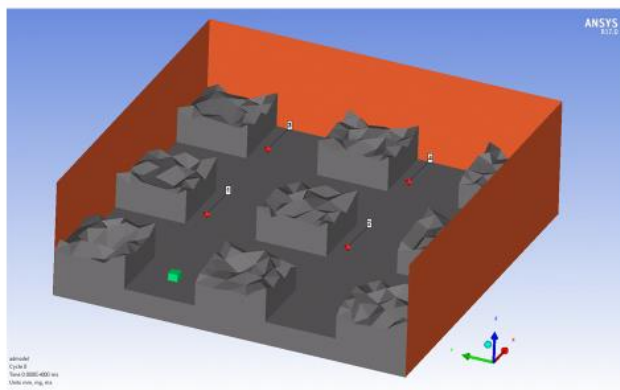
- The solid walls are modelled as a rigid body
- Coupling between the fluid and the solid are set to rigid i.e. no strength equations are solved in this part
- Only the Euler part is solved which reduces computing overhead
- Assumes completely rigid walls



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## Test case – complex geometry



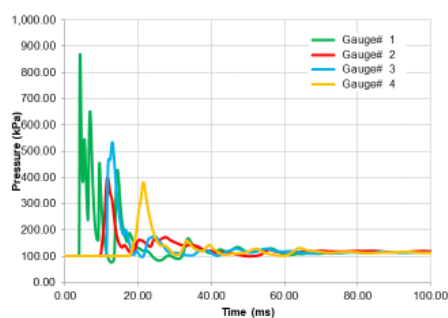
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## Test case – complex geometry



- Sample plots of pressures at gauges



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## Mitigation by water barriers



- Water barriers have been proposed as a mitigation measure against explosions, where appropriate stand-off distances cannot be achieved
- Historically, water has been used in coal mines to suppress the effects of gas and dust explosions. These methods are aimed at quenching the flame front, rather than suppressing the blast wave from a solid explosive
- Water barriers have also been used to mitigate the effects of blasts from solid explosives, both in the open and in enclosed spaces
- There is some uncertainty over the mechanism of operation and the effectiveness in different scenarios. Nevertheless, commercial products are available

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## Mitigation by water barriers

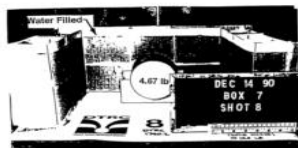


- There are numerous examples of water barriers as an effective explosion mitigation measure
  - at different scales
  - within different geometries
- In some cases, such as single entry tunnels, the use of water barriers created a jetting effect when the water vapour/mist is added to the HE gases
- The mechanism of operation may depend on the barrier arrangement and geometry:
  - Some of the energy is absorbed by heating and vaporising the water
  - Some is absorbed by mechanical acceleration and break-up
- Studies to date have assumed either mechanism is responsible in isolation

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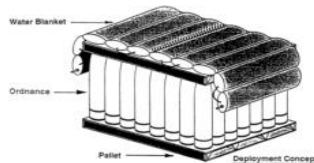
## Mitigation by water barriers



### MITIGATION OF CONFINED EXPLOSION EFFECTS BY PLACING WATER IN PROXIMITY OF EXPLOSIVES

By

W.A. Keenan and P.C. Wager  
Structures Division, Code L51  
Naval Civil Engineering Laboratory  
Port Hueneme, CA 93043-4328



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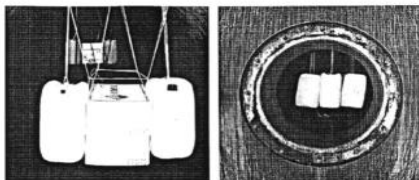
## Mitigation by water barriers



- Work is in progress to extend the feasibility study to the modelling of water barriers
- Some data are available, e.g:

### BLAST MITIGATION IN CONFINED SPACES BY ENERGY ABSORBING MATERIALS

Sivert Eriksson & Bengt Vrethblad  
Confortia, Box 332, S-631 05 Eskilstuna, Sweden



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## Conclusions

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- This presentation has covered the application of a commercial software package to modelling of underground explosions
- Model validation against simple test cases to increase confidence in predictions
- Application to realistic geometries
- Extension to water barrier modelling in progress

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**Thanks for listening!**

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