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Natural Resources and Mines

QUEENSLAND MINING COUNCIL

Contents

SAFE PRODUCTION SYSTEMS IN MONKLAND MINE

Rowan Johnston General Manager Site Senior Executive
Clive Hausmann Human Resources Co-ordinator

My commitment
(Rowan Johnston, general manager [Site senior Executive])

This is a statement of my commitment to health and safety in the Gympie Eldorado Gold mines' Monkland mine project. In making this statement I am representing the corporation to the project employees. It is a duty of the site senior executive to demonstrate corporate commitment to health and safety. My commitment is best reflected in the organisation safety and health policy statement. I am committed to:

1 achieving safe production by ensuring worlds best practice in our mining operations and management systems

2 complying with Queensland mining legislation and other relevant legislation, standards and codes of practice

3 ensuring adequate resources including competent operators, plant, and equipment is available to achieve safe production

4 through consultation with employees, contractors, suppliers, and other stake holders ensuring ongoing innovation and continual improvement

5 maintaining a risk management system that will identify all hazards and establish controls before the risks can be realised.

To demonstrate my commitment:

- I sit as chairperson of the site 12 person health and safety committee which meets once per month
- I review and authorise all standard work practice documents on and for the site
- I chair the weekly heads of departments meeting, a forum where heads of departments are held responsible and accountable for the safe production of their departments
- I am a member of the corporate physical risk committee (meetings every two months approx).

Our involvement
(Clive Hausmann, Human Resources Co-ordinator)

Summary

Since the paper 'CHANGE MANAGEMENT' (Johnston & Hausmann 2000) was presented in this forum in August 2000 the Gympie Eldorado Gold mines' safety and health management programs and systems have continued to improve.

The system is developing into a mature safety management tool as demonstrated by the organisations much improved health and safety outcomes. In the year 1999/2000 the mine production was 130,000 tonnes of ore for 33,000ozs of gold at a health and safety cost of lost time injury frequency rate (note1) 63, duration rate (note2) 38 and an incident rate (note3) of 13.

The year 2001/2002 saw figures of 180,000 tones of ore for 55,000ozs of gold, lost time injury frequency rate 13.9, duration rate 11 and incident rate of 3.5.

The management structure of the operation has been revitalised with the introduction of two new senior management positions and the reorganisation of the human resources area. This revitalisation has been achieved while maintaining a flat management structure.

Training programs in place ensure all employees have access to relevant training both on-the-job and off-the-job. This standard applies equally to the non-mining section and the mining section of the work force. The training programs are based in a system of task and training needs analysis.

There has been a major and ongoing upgrade of plant and equipment. This upgrade is a move away from hand-held mining methods to a more mechanised operation. As well as improving the safety and production outcomes these changes have meant a major revision of project work procedures and standards has been necessary.

The level of work place environment monitoring has increased significantly. Both internal and external monitoring has increased. Air quality, water quality and noise levels are measured on a regular basis. Environment monitoring is conducted both by site employees and consultants and in the case of water quality the testing of site gathered samples by an independent laboratory.

Introduction

We in the Monkland mine do not think of safety as an independent system to be managed separately to other systems, we now think in terms of safe production. This is not a new concept but it is a concept that requires managers to think outside the box, outside the scope of most new managers professional expertise.

To achieve safe production the four controlling influences must be targeted (Fig.1):

- controlled work environment
- fit for purpose equipment

- work procedures
- competent people.

This paper will review the GEGM management of these influences in the Monkland mine operations.

Monkland mine, a vertical shaft access gold mine, is located under the city of Gympie in south-east Queensland, on the Bruce Highway approximately 180 kilometres north of Brisbane. The mine employs 130 company operators and 30 contractors in Monkland mine and processing plant.

During the past three years the operation has undergone major re-organisation, the management structure has evolved, the hand-held mining methods have, in the main, given way to more modern mechanised methods. An award-winning training program (note 4) has been adopted and work procedures based in risk/hazard management developed

The organisation as well as mining and processing operates a regional exploration group. A second mine, the Lewis mine, is being developed by Roche Mining as a decline access operation. This paper will reflect the changes that have occurred in the two years since the Monkland mine operations were last reviewed in this forum (Johnston and Hausmann 2000).

We have still not achieved the industry (Queensland Underground Metalliferous) average for that sad old safety benchmark – the LTIFR. The LTIFR for the group during the 2001-2002 reporting year was 15.5, this being made up of the mining and processing figure of 13.9 and the exploration's 25.4. The overall figure is down from 229 in the 1997-1998 year and a peak of 292 early in the 1998-1999 reporting period. This same improvement is reflected in disabling injury frequency rate, lost time injury duration rate and severity rate.

Operational Control

Without corporate direction a mining organisation is a lot like a headless dragon – hazardous by nature and dangerous by habit.

Gympie Eldorado Gold mines corporate input to risk management increased with the establishment in 2001 of the corporate physical risk committee. The first action of the physical risk committee was to commission a review of the catastrophic risks at Gympie Eldorado Gold mine's Monkland operation and the conduct of a major hazard risk assessment.

This process involved Professor Jim Joy of the Mining Industry safety and Health Centre at the University of Queensland and Safe Production Solutions (Peter Standish) reviewing GEGM's risk management procedures and facilitating the identification of catastrophic risks by a brain-storming session involving mine management and operators. *' One hundred and five (105) catastrophic loss scenarios were identified by the team'* (Standish 2002).

The second action of the physical risk committee has been the drawing up of the corporate risk management policy document. This policy establishes safe production as the goal of the risk management system, confirms corporate commitment to the risk management process and details reporting standards.

The mine management structure has been revised to comply with the Queensland mining legislation. This was achieved by appointing the general manager as site senior executive, 10 safety and health representatives and a person to control winding operations.

All other statutory appointments were already in place–eg mine manager, electrical supervisor, shot firers etc. The six departments within the mine, underground operations, surface operations, human resources, geology, administration/finance and environment/tenements are headed managers/coordinators appointed by and reporting to the Site Senior Executive.

Two new senior management positions within the organisation are:

1 Underground operations manager who has responsibility for long term strategic planing for both the Monkland and Lewis mines, Budgeting and resourcing of both underground operations, co-ordinating short and medium term outputs to achieve corporate business plans, administration of the Lewis mine contractor and to manage mine maintenance.
2 Surface operations manager has responsibilities as project management of the treatment plant up grade and management of processing operations generally. This position will also take responsibility for special projects.

Responsibility for health and safety management systems hazardous substance control, injury rehabilitation, training and emergency response have been grouped together and placed within the responsibilities of the human resource co-ordinator.

To aid the mine manager, foreman and mine supervisors to better plan their work schedules targets, have been set to reflect the planning time frames. Under this system the mine manager has targets for the full year, the mine foreman's targets are for the next three months and the supervisors' targets are for the next seven days. The targets are based on safe production and include improving safety outcome and a fixed production target.

To ensure access to the best available people all recruiting for positions, other than senior managers and professional people, is conducted on behave of

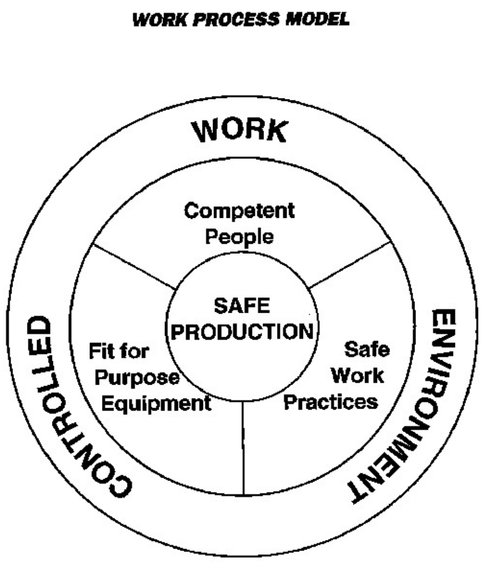


Fig. 1

the organisation by an employment agency. This process is designed to meet equity and affirmative action standards while being fair and just.

Work Environment

The introduction of diesel plant has meant a major increase in the underground work place environmental monitoring program. An analysis of all diesel exhausts is conducted each month, after each exhaust system overhaul/replacement, after each motor overhaul and after each motor change out.

There is in place a work place environment monitoring program supported by annual surveys by both SIMTARS and Allhealth and safety Solutions. The surface work place environment is subject to site monitoring and monitoring by SIMTARS and Allhealth and safety Solutions. Particular attention is given to the surface workshops and the gold room. mine discharge water is tested by an independent NATA testing laboratory (ALS).

A continuing program of noise monitoring is in place and noise assessment is included in plant and process risk assessments. Noise surveys are conducted annually by SIMTARS and Allhealth and safety Solutions.

The ventilation of Monkland mine has been an ongoing area of concern with the mine in the past recording high wet bulb temperatures-rarely exceeding 32deg C.

A flow-on effect of the long hole stoping is the limited number of production units available and therefore a limited number of areas that can be worked simultaneously (Scargill & Kahler 2002). The mine now spreads 60m3/s across four working levels compared to 40m3/s across eight working in 1999. The need to wet our old timber shafts contributes the high humidity in the mine.

Work Procedures

All work procedures are included in the Gympie Eldorado Gold mines occupational health, safety and environmental management Plan 1999 (GEGMSafe). This plan is available to all employees on the site net and on CD for computers not connected to the site net as well as for home computers. An updated CD is issued each month and loaded into those site computers not connected to the site net. This is seen as a much more effective means of ensuring up-to-date information is available to the workforce.

All organisational work standards are developed as a product of a system of risk assessment. Risk assessment within the GEGM organisation takes three forms.

These are firstly the catastrophic risk management system that, as the name implies, addresses those risks that, were they realised, would have the most adverse effect, to the extent of destroying the organisation. This process is driven by the corporate physical risk committee.

The second risk assessment system is applied to all plant, equipment, planning, substances, environment and processes. These risk assessments are conducted by a project team. A typical GEGM risk assessment team would be:

- facilitator
- area manager
- area supervisor
- maintenance person
- operator
- safety and health representative
- consultants and other experts as required by the team.

To ensure quality and consistency in our risk assessment procedures risk assessment facilitators will have completed the minerals Industry Risk management plan of the University of Queensland Graduate Certificate in mineral Resources program. We have two persons currently enrolled in this program.

The third site risk management procedure is a system of job safety analysis (JSA). The site JSA system addresses the operators' 'apply local risk control processes' competencies. This process requires supervisors and operators to be involvement in a formal process of hazard identification and risk assessments including identification and application of controls.

A safety and health committee has been formed and meets on the fifth working day of each month. The committee is made up of the 10 site safety and health representatives and the general manager as chairperson with the human resources co-ordinator as minutes secretary. Having the site senior executive and the human resources co-ordinator at the safety and health committee meetings permits fast tracking of complex items brought before the committee.

Fit for Purpose Equipment

Monkland mine has been undergoing a metamorphosis during the past two years. The mine spent the years from 1987 until 2000 as an ugly handheld operation dependant upon rock drills, jacklegs, pneumatic rail boggers and a battery electric rail haulage system. The mine is emerging from its metamorphosis as a pretty little diesel operation.

Toro diesel LHD units have replaced many of the Atlas Copco LM56/57 rail shovels, a diesel electric jumbo now does 75 percent of the development work while long hole drills have replaced the rock drills in production work.

Diesel Locos are replacing the battery locos. The use of 8 kilogram spawlling hammers has given way to hydraulic rock breakers. It should be noted at this point that all of this plant and equipment must fit through a 1.1 metre X 1.1 metre opening, as these are the cross section dimensions of the compartments of the Scottish Gympie Number 2 shaft and the only current access to the underground workings for this plant and equipment.

The Toro 151s (already very small), the jumbo, the rock breakers, locos, drill rigs needed to be reduced to bite size pieces on the surface and reassembled underground. While it is possible to cut the Toro buckets in half it was necessary to alter the shape of the tyres, as ovals they fit but in their normal donut shape they do not fit. This disassembly and reassembly adds considerably to the cost of the plant.

New plant introduced in the past two years includes:

- 5 Toro 150/151 LHD units
- 1 Baldwin Diesel Loco (two more planned for this fiscal year)

- 1 Quasar electric/hydraulic long hole drill rig
- Hydraulic rock breakers
- 2 Valpadana 9565 underground service vehicles (tractors)
- 1 Quasar H104 Jumbo

Two of the Toro LHD units are fitted with line of sight remote operation controls.

While these changes may appear as small potatoes to some they represent major change to the Monkland mine and Monkland mine workers.

Consultation

The management-operator consultation process is aided by a system of meetings and risk assessment processes:

- safety and health committee
- Supervisors production meeting
- Weekly team meetings
- Pre-shift meetings
- Risk assessment
- Job safety analysis.

We have, with the aid of a consultant and with workplace consultation, developed and introduced a system of supervisor/operator review of performance. This program, known as the *'Individual Development & Performance Plan 2002'*, is a system designed to identify shortages in performance and to determine both training and non-training solutions for those shortages. Having identified the shortages and determined the solutions an action plan is developed, implemented and review at the next 6 monthly meeting.

Competent People

Gympie Eldorado Gold mines has established a training system that addresses both vocational and workplace training as well as professional development.

All mine training and assessment is conducted on site. A partnership has been established with TQ Mining Services (Central Queensland Institute of TAFE) under which GEGM resources the training and TQ Mining Services provide administrative services and quality control.

The training agreement with TQ Mining Services covers certificate II to Certificate IV in Underground Metalliferous Mining, Certificate II to IV in Metalliferous Processing and Exploration.

All new employees who are also new to the industry are enrolled in trainee ships that are administrated by Queensland Apprenticeship Services. All new employees must complete the Queensland generic induction program (suface or surface and underground) before commencing employment with Gympie Eldorado Gold mines.

To address the requirements of the *Mining and Quarrying safety and Health Act 1999* section 86 as well as supervisor risk assessment, investigation and communications competencies QLD39065 Certificate III in site safety and health representative has been included in the agreement with TQ Mining Services for delivery on site.

To date all safety and health representatives plus 25 company managers and supervisors and six contractor managers and supervisors have completed this training.

A front line management training program conducted by a private provider ensures all supervisors have adequate management skills. This program is at the AQF4 level and is designed to address five of the FMI units of competency at this level. An extension of this program, with the same provider, provides middle managers with the Diploma of Front Line management competency.

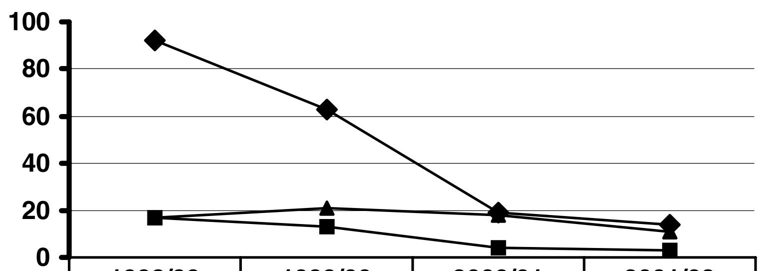
All GEGM employees are currently competent in unit MNMCCCOO005A 'Apply local risk control processes' of the National Underground Metalliferous Training Package. It is planed to run a training program to lift this competency level to QMS1 for all employees.

Auditing, of both safety and environmental systems, is conducted internally by employees with the appropriate competencies as well as by outside experts. Our nomination in the 2001 MINEX Awards provided very useful feedback on the status of our management systems.

Conclusion

These past two years have seen Monkland mine achieve a 38 percent increase in ore production for a 66 percent increase in gold while reducing the lost time injury frequency rate(LTIFR) by 78 percent, the duration rate (DR) 48 percent and the incident rate (IR) by 68 percent. (fig. 2).

For a much more detailed overview of the Monkland mine production operations and details of changes to the mining methods I recommend you refer to a paper presented at the Underground



	1998/99	1999/00	2000/01	2001/02
LTIFR	92	63	19	14
IR	17	13	4	3
DR	17	21	18	11

Fig. 2

Operators Conference 'Gympie Gold – The Revival of the Monkland mine'. This paper is the work of Gympie Eldorado Gold mines' underground operations manager Rob Scargill and Monkland mines' planing engineer Daniel Kahler.

We believe that programs and systems planted three years ago are now bearing fruit. We believe that the options we chose have been proven the correct options and although the rate of improvement has slowed improvement is continuing.

It is not possible to separate work procedure, training, safety and health. These issues must be addressed as one if they are to be addressed in an effective manner.

This is by no means a comprehensive review of Gympie Eldorado Gold mines safe production programs and systems. However, it does give some indication of our involvement in addressing the complex issues of modern mine operations. While it is evident that Gympie Eldorado Gold mines has made significant improvement in safety and production in the past two years there is still a long way to go. We believe that with the continual improvement systems we have in place our safe production targets will be met.

References

1 Johnston, R. J. & Hausmann, C. 2000 Change management *From Prescriptive to Participative management at GEGM,* QMIH&SC 2000.

2 Scargill, R. & Kahler, D. 2002 *Gympie Gold – The Revival of the Monkland mine*, Underground Operators Conference 2002.

3 Standish, P. 2002. Review of the Catastrophic Risks at Gympie Eldorado Gold mines and the Conduct of a Major Hazard Risk Assessment, Safe Production Solutions, Dubbo East NSW.

Notes

1 Lost time injury frequency rate (LTIFR): Number if injuries/million hours worked

2 Duration rate (DR): Number of days lost/Lost time injury

3 Incident rate (IR): Number of injuries/100 employees

4 (i) QMITAB excellence in Metalliferous Training 2001
(ii) Wide Bay Sunshine Coast Large Employer of the Year 2002 (Queensland Training Awards presented by the Training and Employment Board and the Department of Employment and Training).

Improving the

SAFETY AND HEALTH PERFORMANCE OF COPPABELLA MINE

Shane Stephan B.Bus MBA (AGSM) Australian Premium Coals Pty. Ltd

Summary

During the previous financial year the safety performance of the Coppabella coal mine deteriorated significantly despite significant efforts directed at the mine's safety management system.

Following a high potential incident that occurred during December 2001, operations at the mine were stopped for 24 hours and all site employees met with senior management to discuss mine safety performance.

A set of initiatives targeting the safety and health behaviour of employees was introduced. Coppabella's safety performance during the current year has greatly improved from LTIFR of 18 last financial year to less than two currently. The organisational culture at Coppabella continues to be positively impacted by the human factors initiatives introduced.

The paper shall discuss in chronological sequence the reasons for the poor safety performance at the Coppabella mine during 2001, elucidate the many safety initiatives introduced at the start of 2002 and discuss the relative success of these initiatives.

The information presented should prove useful to other mines considering the implementation of human factors initiatives as a method of improving safety and health performance.

Introduction

Australian Premium Coals Pty Ltd is the operator of the Coppabella Coal Mine located approximately 130km west of Mackay in Central Queensland. Mining operations were established extremely quickly with the mining lease being granted on 1 June 1998 with the first shipment of coal occurring on 6 November 1998.

The mine currently operates a conventional open cut truck and excavator strip mining operation. Market acceptance of the low volatile PCI coal produced has been rapid and therefore production volumes have grown rapidly from a production rate of 2Mtpa to 4Mtpa product coal during the past 18 months.

The operational management structure at the Coppabella Mine is unusual in that all mining and coal processing operations on site are undertaken by contractors and unlike most other contract mining operations in the Bowen Basin a number of mining contractors are engaged in the removal of overburden and coal mining.

During the 2001 financial year in order to meet production targets three mining contractors were engaged, Peter Champion, Roche and Leighton with Sedgman responsible for the operation of the coal processing plant and train loading operations.

Australian Premium Coals (APC) manages operations through a site senior executive who is responsible under the Coal Mining Safety and Health Act for site safety management as well as the production performance of the mine.

Due to the number of separate organisations operating on site a great amount of effort was invested during 2000/2001 to ensure that the site safety management system adequately addressed site hazards and introduced communication systems that led to appropriate controls being in place to manage the interface between the various site contractors.

Both internal and external audits undertaken upon the safety management system indicated that although there was room for further refinement the system operated well and covered all identified principle hazards appropriately.

Historical Safety Performance

The Coppabella mine was constructed without the occurrence of a lost time injury and began operations with a good safety record. However, a seriously deteriorating trend developed during the financial year 1999/2000. During 1999/2000 the serious incidents included a steel splinter penetrating an eye caused by the use of a steel hammer when replacing a scraper cutting edge and a fracture to an ankle caused through improper practice when replacing a haul truck tire.

During 2000/2001 nine lost time injuries were sustained, the most serious of which included:

- an operator sustained a serious eye injury and fractured cheek bone when a hydraulic oil cap blew off unexpectedly
- an operator sustained a fracture to the lower leg when a co-disposal pipe he was separating dropped unexpectedly
- a boilermaker sustained burns to his right hand when he opened a bottle of acetylene whilst holding a striker in the same hand
- two injuries were sustained resulting from splinters of steel penetrating the legs of maintenance personnel when striking steel hammers against hardened steel surfaces.

A significant number of high potential incidents also occurred during the 2000/2001 year.

Triggers for Action

The significant deterioration of Coppabella's safety performance during the 2000/2001 year resulted in concentrated efforts to improve the mine's safety management system.

Activities during 2000/2001 included the undertaking of two site wide Principal Hazard Risk Reviews, two external safety management system audits as well as a number of internal audits undertaken by the principal site contractors.

The Mines Inspectorate also undertook audits of Coppabella's safety management system with generally favourable results.

At 4am on the 21 December 2001 a truck driver was hit by a CAT 785 haul truck during a 'hot seat 'change out. The driver passed underneath the truck between the tires. The operator only sustained a minor fracture to the right foot and minor abrasions.

How close the mine had come to the occurrence of a fatal accident was a shock to all of us associated with the operation. The near fatal consequences of the accident triggered an immediate senior management review of our safety management approach.

It was decided that a set of initiatives targeting the human factors impacting upon safety performance would be introduced at Coppabella. Management believed that the Safety Management System adequately covered issues such as safe conditions and equipment and a multitude of safe work procedures but that recent initiatives had not targeted safe work behaviours adequately (see figure 2).

Initiatives Targeting Safe Work Behaviours

APC undertook a review of human factors safety initiatives both within and external to the coal mining industry in Australia and the United States in particular targeting health and fitness initiatives.

Generally, the responses received from contacts[1] within the United States indicated that employer assisted exercise or fitness initiatives were common in particular amongst manufacturing firms.

Quite often organisations have gyms on site or will financially assist employees to join a fitness club or gym. Some organisations are introducing yoga and aerobic classes at work generally with the active assistance of their employees.

In Queensland, Powerlink Queensland has a large gym facility established at their central office and workshop facility in Virginia.

The company funded the provision of the gym equipment whilst ongoing maintenance is funded by employees through social club fees. An active recreation club committee manages the facility which is actively utilised during lunch periods and

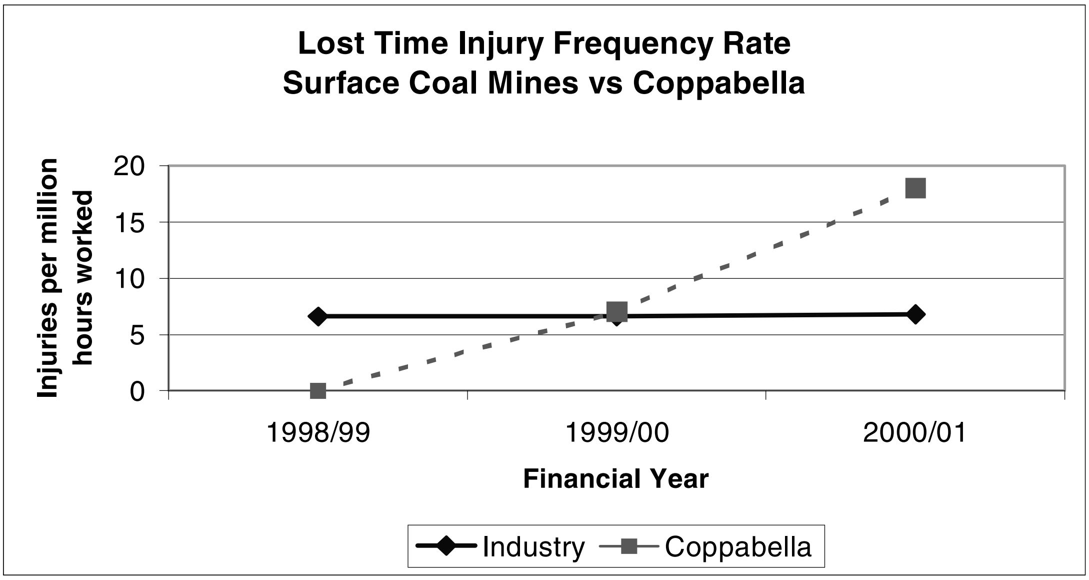


Figure 1. Historical Coppabella and Industry Average LTIFR

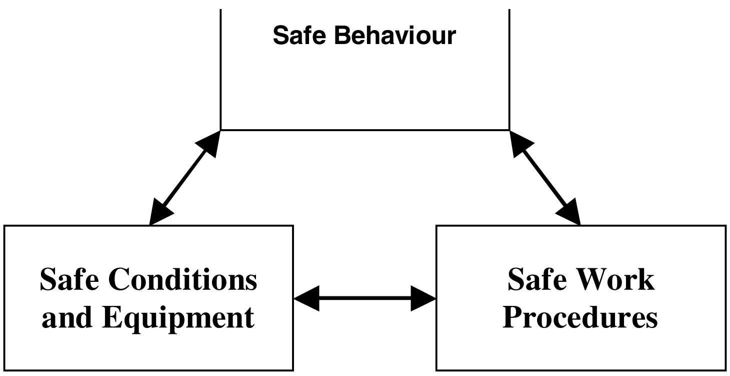


Figure 2: Safety Management Model

prior to and after work hours. Approximately 40 percent of recreation club members utilise the gym facilities on a regular basis.

The recreation club employs a part time qualified gym instructor. The facility is seen as an important symbol of commitment by the employer to the health and wellbeing of their employees. Powerlink has an exceptional safety record working within a potentially hazardous work environment.

Discussions with organisations such as SIMTARS, QMC, CFMEU and Mines Inspectorate and several Queensland mining managers were held to gain an appreciation of the human factors initiatives occurring within the coal mining industry.[2]

Many of the initiatives active in the industry reflect the particular fitness for duty policies of each mine, particularly in relation to drug, alcohol and fatigue issues.

From discussions with industry stakeholders it was apparent that Thiess had significant experience with human factors safety initiatives in particular, health and fitness, driver training and employee assistance programs.

There does appear to be an increasing interest in the application of exercise and other health initiatives to improve safety performance in Australia.

Key lessons from interviews with many people undertaking human factor safety initiatives are the importance of visible CEO commitment and involvement of the workforce in the implementation of any initiatives.

In many instances what some Australian mining companies are implementing is at the forefront of general industry safety practice.

Coppabella Human Factors Safety Initiatives
Mine Safety Day:
On the 8 January 2002 mine operations were halted for 24 hours so that an opportunity was provided for all employees to attend a safety seminar. More than 160 employees, supervisors and management attended the seminar. The Chairman, General Manager and Senior Site Executive of Australian Premium Coals made presentations upon safety performance and safety objectives for the mine. The results of the investigation into the near miss fatal accident were also presented.

Senior executives of all of the contractors and sub-contractors to APC were in attendance to ensure that a consistent message of commitment was sent to the entire workforce.

Following the presentations a workshop was held with supervisors, open cut examiners and management to share views upon ways to improve the safety culture and safety performance at Coppabella.

Shift durations and fatigue:
Although not an identified direct contributing factor to the accident of the 21 December, fatigue is considered as a potential hazard. All contractors were asked to undertake a review of their shift roster arrangements in particular to investigate the hazards associated with the duration of the first night shift back from a break.

1 A list of contacted organisations is available from the author upon request.
2 A list of consulted organisations is available upon request.

Yoga influenced exercise program:
APC would arrange for yoga influenced exercise classes to be held at suitable locations to allow employees and their families to attend over a three month trial period. The objective of the classes was to improve employee fitness and alertness. Over time the exercise initiatives have shifted to focus aerobic exercise.

Operator cabin housekeeping initative:
An inspection of the cabins of mine vehicles demonstrated that in some vehicles the cabins were being kept in an untidy manner. Vehicle cabin housekeeping standards are a reflection of the employee's view of their workplace and therefore a program of housekeeping improvement and inspection was initiated.

Entry to Minex safety assessment process:
In order to benchmark Coppabella's safety

APC SAFETY AND HEALTH BELIEFS

- **All fatalities, injuries and diseases are preventable.**
- **No task is so important that it cannot be done safely.**
- **All hazards can be identified and their risks managed.**
- **Everyone has a personal responsibility for the safety and health of themselves and others.**
- **Safety and health performance can improve.**

Safety awareness is the state of mind where we are constantly aware of the possibility of injury and act accordingly at all times.

Figure 3. APC Safety and Health Beliefs

management systems and standards APC committed to entering the Minex Safety Awards process during 2002. The Minex awards process is run annually by the Minerals Council of Australia as part of its safety and health leadership program which aims to eliminate industry fatalities, injuries and diseases.

Numerous other smaller initiatives were undertaken on site and further are planed in the future including the introduction of a Contractor Heath and Safety Charter.

Measurement of performance

All improvement programs have an audit or measurement process to monitor improvement progress. The graph below indicates the number of attendances at fitness classes has declined over time. Contractor project managers are responsible for undertaking weekly audits of the condition of their mine vehicle's operator cabins and reporting results to APCs site senior executive. Every month the table of outcome statistics illustrated in Figure 5 is reported to Joint Venture participants.

Safety and health beliefs statement:

Coppabella currently has a safety and health policy for the guidance of the safety management system however the policy does not provide motivating objectives that would influence safety behaviour. A Safety and Health Beliefs statement has been developed as indicated in Figure 3.

Results

During the past financial year the LTIFR at the Coppabella mine has decreased from 18 to less than two, the mine only experienced one lost time injury during the past financial year. The DIFR has also been halved from what it was twelve months ago to just over eight. Despite such progress significant room for improvement remains in both DIFR and reducing the frequency of high potential incidents.

The pace of change at Coppabella has been rapid and these changes present further opportunities to improve the site's safety performance. During the course of the next year the number of principal contractors will reduce from four to two. Such a reduction will greatly reduce the complexity of the safety and health management system and thereby decrease the probability of non-compliance.

Lessons Learned

The three hurdles which need to be overcome to improve human factors safety performance are:

1 **Complexity**: Safety management systems can become too complex to enable high levels of compliance to be achieved with limited resources. A common response to an accident is to impose another layer of control instead of improving the effectiveness of the existing controls. The change in safety and health legislation and enforcement has tended to lead to increasing complexity of safety management systems at times to the detriment of safety performance outcomes.
2 **Cynicism:** Everyone needs to believe that APC management is committed to improving safety and health performance at the mine site. Consistently 'walking the talk' is the only way to decrease cynicism.
3 **Complacency**: Long-term familiarity with equipment, systems and processes can lead to an 'it will never happen to me' attitude. An organization can also become complacent following a period of relatively good safety performance. Constantly striving for excellence and introducing changing safety initiatives are appropriate weapons against complacency.

The three features that safety improvement initiatives need to impact to eliminate complexity, cynicism, and complacency are:

1 Commitment: Top down management action for improving safety performance needs to be demonstrated. Management need to publicly demonstrate their belief that the Coppabella safety vision can be achieved and that resources are available to achieve the vision.
2 Consistency: People seek consistency between values and behavior. APC must be able to establish safe work behaviour as a true and fundamental value in the workplace. Management actions and works in support of the safety vision must be consistent and constant, if we are to be taken seriously by our employees and peers.
3 Co-operation:A team based approach has been

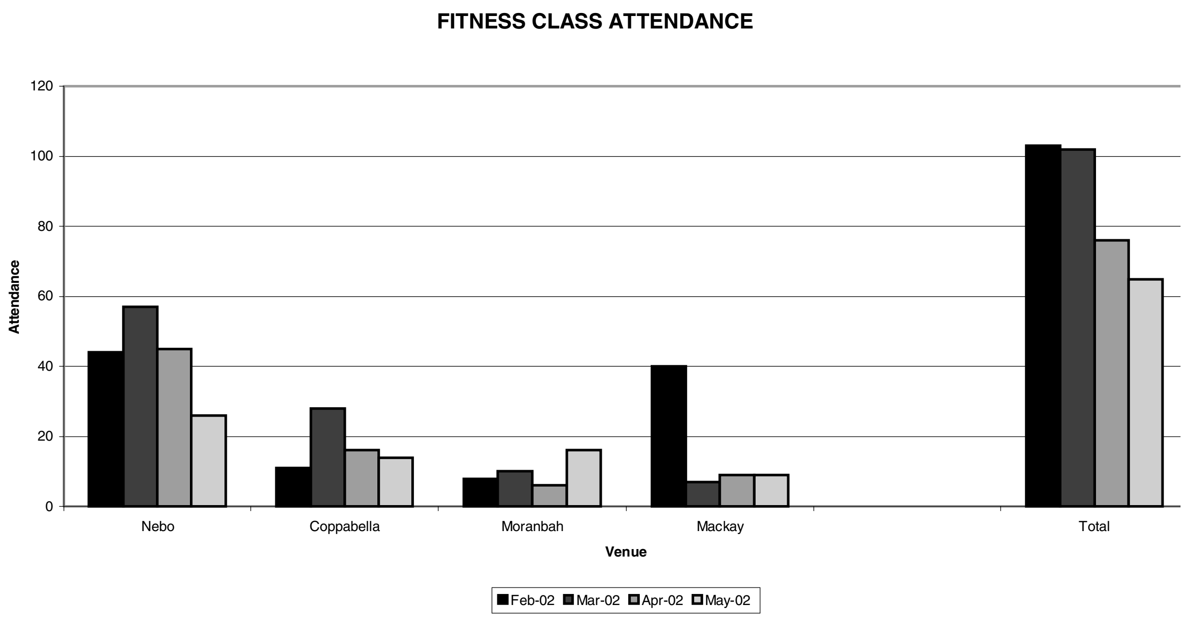


Figure 4: Exercise Class Participation

found to be more successful in achieving positive safety perceptions and therefore behaviour. Senior and site management need to agree upon strategies for safety improvement and also operator level initiatives need to be encouraged and supported.

One management initiative that was utilised at Coppabella perhaps more than during other mine safety improvement initiatives was the use of the media. Historically, the media has not been utilised to demonstrate corporate commitment to safety improvement in the mining industry.

The high level of media interest in the safety initiatives at Coppabella indicates the increasing level of general public interest in safety. The public increasingly will not accept fatalities occurring in a workplace and will exercise their power through the media and political representatives to drive change.

The decisive and public response by APC to the serious accident in December 2001 converted a potentially negative media event into a positive news story for the mine and the industry. The Coppabella exercise program was one of the few front-page positive news stories during the past year for the coal mining industry.

Media coverage gained through the introduction of the exercise classes at Coppabella also put fitness and safety on the crib room table agenda. People began to talk about safety and fitness at the workplace.

Not everyone had a positive opinion of the initiative but everyone had an opinion and having those opinions shared at the operator level around the crib room ensures that safety issues are being discussed.

Figure 5: 2001/2002 Year To Date Safety Statistics

	APC	Contractor 1	Contractor 2	Contractor 3	Contractor 4	SITE WIDE TOTALS
TOTAL MANHOURS	10,587	126,154	222,030	198,492	50,119	**607,382**
DISABLING INJURIES	0	0	3	1	1	**5**
LOST TIME INJURIES	0	0	0	1	0	**1**
D.I.F.R	0	0	13.51	5.04	19.95	**8.23**
L.T.I.F.R	0	0	0	5.04	0	**1.65**
MEDICAL TREATMENT INJURIES	1	2	2	4	2	**11**
FIRST AID TREATMENTS	0	0	3	4	4	**10**
DAYS LOST TO INJURY	0	0	0	30	46	**76**
HIGH POTENTIAL	0	1	4	4	2	**11**
NEAR MISS	0	1	2	3	1	**7**
FIRE	0	0	1	5	0	**6**
DAMAGE INCIDENT	0	3	12	8	2	**25**

Please Note: As from AFY02 onwards, annual safety statistics will be reported as a 'rolling safety statistics report'. This means that at the start of each financial year the statistics will not 'zero', rather a month will be dropped off as another month is recorded, this will keep an accurate report of the last twelve months regardless of which month we are currently in.

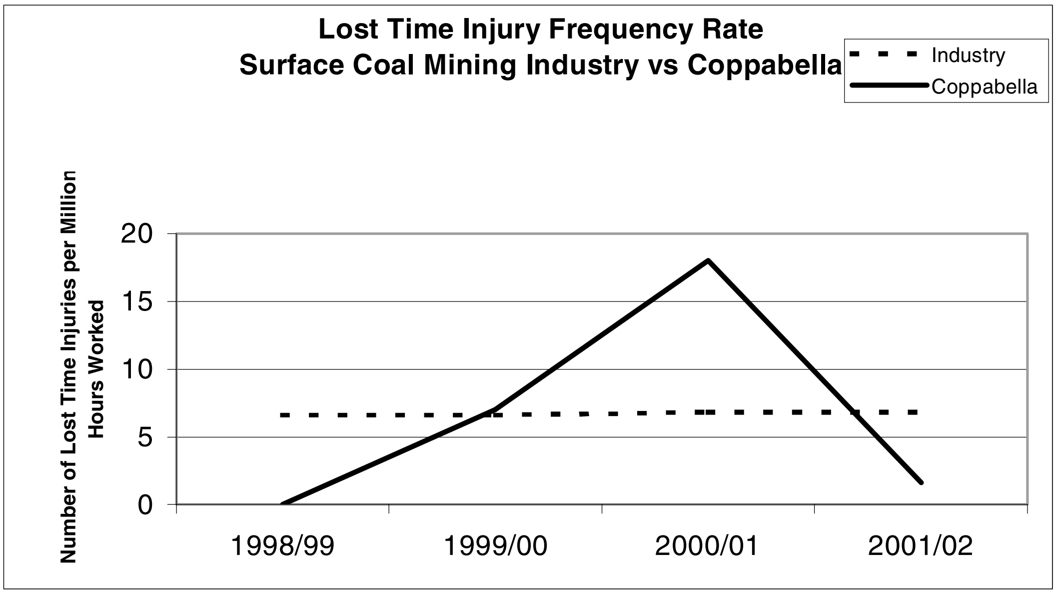


Figure 6: Coppabella LTIFR

The use of both internal and external media has a powerful impact upon behavioural safety programs and a media strategy should be considered whenever a behavioural change program is being implemented.

Future Initiatives

One comment consistently heard from safety and health professionals and line managers with experience in human factors safety initiatives is that no matter how good your safety and health program, it needs to be changed every three to five years as it grows stale. APC shall therefore review human factors safety initiatives on an annual basis with a view of implementing a program of continual change in human factors safety initiatives.

Such change ensures that site safety management does not become complacent especially should current initiatives demonstrate a high level of effectiveness.

Conclusion

The increasing complexity caused by the rapidly increasing scale of mining operations at Coppabella was one of the causes of the poor safety performance achieved during the 2001 financial year.

The fast pace of change led to a less than adequate compliance performance with the safety management system, however through concerted management action safety performance has rapidly improved.

The historical safety performance of the mining industry demonstrates that high standard safety management procedures and standards alone are not the answer to improved safety performance.

Similarly, human factors safety initiatives implemented in isolation will not be successful in reducing incident rates.

The integration of efforts that improve the standard of safety management processes with efforts that positively influence the safety and health culture and thereby behaviour of mine workers is critical to ensure success in improving safety performance.

'Anything in history or nature that can be described as changing steadily can be seen as heading toward catastrophe.' SusanSontag

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[2] A list of consulted organisations is available upon request.

An estimation of the exposure of Queensland

UNDERGROUND COAL LONGWALL WORKERS TO RESPIRABLE DUST

Dr David Cliff and Dr Guldidar V Kizil - The Minerals Industry Safety And Health Centre Frank White Annexe The University of Queensland Brisbane Australia

Abstract

This paper presents analysis of the personal respirable coal dust measurements recorded by each mine and the Department of Natural Resources and Mines up to mid 2001 for the 11 longwall mines in Queensland. A total of 813 results were analysed both for each mine and for the seven occupations characterised by Kizil and Donoghue previously. The mean respirable dust concentration for all occupations was 2.06 mg/m^3 (SD 2.04 mg/m^3). Measurements exceeded the eight hour equivalent exposure standard in 15.6 percent of cases. This compares to a mean of 1.51 mg/m3 and 6.9 percent exceedances in NSW. Using the formula of Kizil and Donoghue this would translate to a mean loss of FEV_1 of 100.5ml. The increased risk of coal workers' pneumoconiosis was also estimated.

Introduction

In 201, Kizil and Donoghue (Kizil and Donoghue 2001) reported the analysis of 11,829 respirable coal dust samples collected over 15 years from 33 longwall mines in NSW. This is equivalent to 24 samples per mine per year.

Following the results obtained it was decided to carry out a similar investigation of the Queensland underground coal mining industry.

The Queensland Coal Mining Safety and Health Regulations 2001 state:

Section 89 - the worker does not breathe an atmosphere at the mine containing respirable dust exceeding an average concentration calculated under AS 2985, equivalent to the following for an eight hour period

i For coal dust – 3 mg/m^3 air

ii For free silica – 0.1 mg/m^3 air

If the worker works a shift more than eight hours at the mine, the system must provide ways of ensuring the person's dosage of respirable dust is not more than the equivalent dosage for a person working an eight hour shift.

In this paper we present an analysis of data collected from the mines and also samples collected by the Department of Natural Resources and Mines. Most data lies within the period mid 1999 to mid 2001 though some data was collected prior to this.

Method

As there is no equivalent of the Coal Services in Queensland the responsibility for undertaking respirable dust monitoring lies with each mine. Therefore each mine was contacted with a request to provide data.

The quantity of the data provided depended on what was readily available. In most cases the mine referred the researchers on to the agency that actually undertook the survey on their behalf. As these organisations could not be reimbursed for their time in collecting and providing the information, and they had other commercial pressures on their time, it was not possible to amass as comprehensive a dataset as was available for the NSW study.

The data were then converted to eight hour equivalent exposures based on the formulae of Tiernan and van Zanten (Tiernan and Van Zanten, 1998). This allows comparison with the regulatory exposure standard of 3 mg/m^3 for an eight hour day and 40 hour week.

Given the finite size of the dataset, the analysis of the data was limited to the average for each mine over the time period for the data supplied and then the whole dataset was segregated into the operator classifications derived by Kizil and Donoghue.

As they demonstrated that there was no discernible change in the average respirable dust concentration in NSW over the past 10 years it was assumed that this would also be true in Queensland and no attempt was made to differentiate data by year.

In order to overcome the different sized datasets for each mine, the average value for each mine was compiled first and then the mean value from each mine was averaged to gain the industry-wide value.

The mean loss in lung function FEV_1 was then estimated using the formula cited in Kizil and Donoghue (2001).

A recent publication by the Health and Safety Laboratory (2000) has released formulae that relate the mean respirable dust exposure to increased incidence of coal worker(s) pneumoconiosis These formulae make allowance for coal type, the hours worked per year and the number of years worked.

It is important to recognise that typically in Queensland respirable dust monitoring is undertaken from the time the worker leaves the surface until he returns to the surface.

This is different to the Coal Services approach, which monitors from the time the worker leaves the underground crib room at the start of a shift until he returns there at completion of shift. This will cause there to be a difference between the two datasets with an expectation that the NSW data will be approximately 10 percent higher than the Queensland equivalent.

RESULTS

Table 1 below lists the results obtained from the survey by mine and they are depicted graphically in figure 1. The percentage of each mines dataset that exceeds the standard 3mg/m^3 is also listed.

The mean value of the NSW data is lower than the Queensland data however they are not statistically significantly different at the 95 percent confidence level. The significance is only at a 75 percent confidence level.

The data are not normally distributed. For example in figure 2 below the data from one mine are plotted in a cumulative distribution. The mean of this distribution is 2.98 mg/m^3, the median is 2.52 mg/m^3 and the distribution is skewed with a long tail to the high dust concentrations. For example removing the top 10 percent respirable dust measurements reduces the mean value to 2.45 mg/m^3.

The seven operator categories analysed in the NSW study were:

1 deputy
2 shearer operator – combines maingate and tailgate operators
3 chock operator– includes shield operator, chock operator and support operator
4 maingate operator
5 face operator – this is a catch all for persons working a range of tasks on the face including job rotation
6 boot end operator – most mines did not have a specified boot end operator.
7 tradesman – includes fitters, electricians etc.

Analysis of the data by operator category is listed

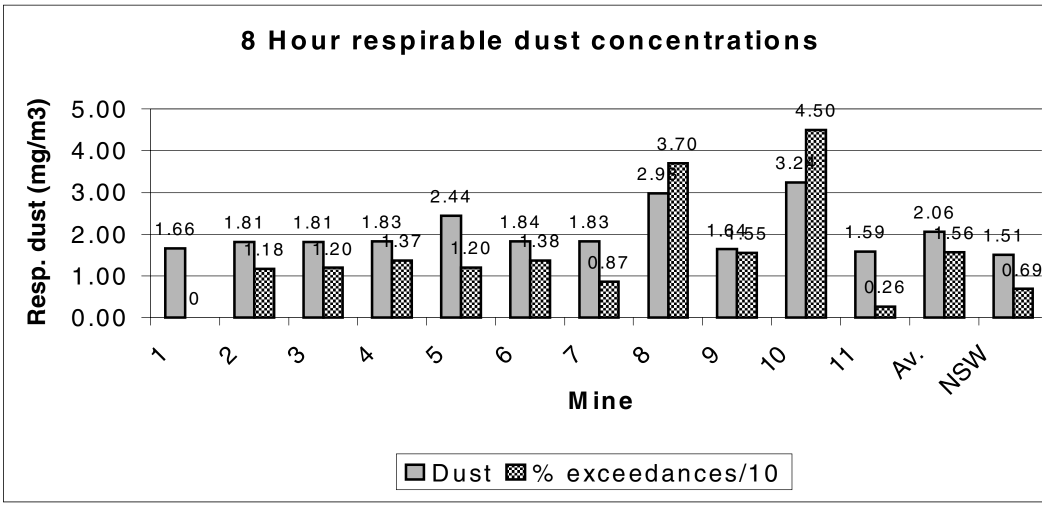

Figure 1

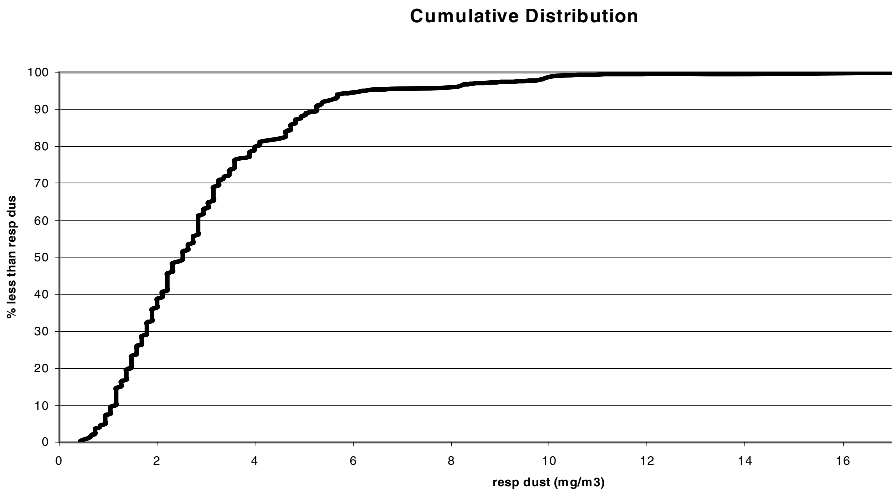

Figure 2 Cumulative respirable dust concentration for mine 8.

Mine	1	2	3	4	5	6	7	8	9	10	11	Av.	NSW**
Av 8 hr eq resp dust	1.66	1.81	1.81	1.83	2.44	1.84	1.83	2.98	1.64	3.24	1.59	2.06	1.51
SD	0.61	1.31	1.21	2.42	4.20	1.17	1.60	2.17	2.10	2.05	0.69	1.08	1.08
no. of samples	25	51	92	73	50	58	69	219	58	80	38	813	11829
% exceed	0.00	11.76	11.96	13.70	12.00	13.79	8.70	36.99	15.52	45.00	2.63	15.64	6.90

Table 1 Average eight hour equivalent respirable coal dust exposures for the Queensland longwall mines

**Note that for comparison, it would be more appropriate to reduce the NSW values by approximately 10 percent to reflect the differences in sampling methodology.

in table 2 and figure 3.

Again these results are not statistically significantly different from their NSW corresponding values at the 95 percent confidence level due to the high standard deviation of the measurements.

In general face workers – shearer operators, chock operators and general face workers tend to have higher dust exposures than personnel who spend less time at the face.

Discussion

The last published comparison of respirable dust measurements for Queensland underground coal mines was undertaken in 1995. Bofinger et al (1995) reported the results from respirable dust monitoring for the four operating mines over the period 1992 to 1994. The results are outlined below in tables 3, 4 and 5 with the comparable figures from the current project.

They reflect a total of 166 measurements.

These data show a wide variation between the mines and between the individual years. The increase in exceedances at mine B from 1992 to 1994 was attributed to the coal seam thinning and the shearer cutting into the roof more.

Mine	1	2	3	4	5	6	7	8	9	10	11	Av.	NSW
Operator													
Chock operator	1.69	1.82	1.86	2.26	2.84	1.70	1.68	3.66	2.08	3.92	2.01	2.32	1.58
Shearer operator	1.74	1.80	2.44	1.72	2.65	1.75	1.87	3.03	1.79	3.20	1.46	2.13	1.72
Maingate operator	1.13		1.35	0.95	0.82	2.47	2.05	1.84	0.47	2.77	1.00	1.48	1.36
Deputy		1.37	1.41	0.42	2.82	1.90	1.53	2.76	0.80	2.71	1.70	1.74	1.29
Tradesman		2.14	1.43		1.78		1.46	2.65		2.87	0.65	1.85	1.15
Face operator	1.87	3.32	2.82	2.00	1.56	2.01	2.95	1.00	0.96	2.96	0.30	1.98	1.67
Bootend operator		1.05	0.80				0.93		0.90			0.92	0.93

Table 2 Analysis by operator category – eight hour equivalent mean respirable dust exposure

Mine	**% dust exposures exceeding the regulation limit**			
	Current survey	**1992**	**1993**	**1994**
A	**13.8**	**30**		**33**
B	**15.5**	**0**		**55**
C	**11.8**	**12**	**0**	**0**
D	**2.6**		**13**	**20**

Table 3 Percentage of workers with respirable dust exposures exceeding the regulatory limit in Queensland 1992 – 1994

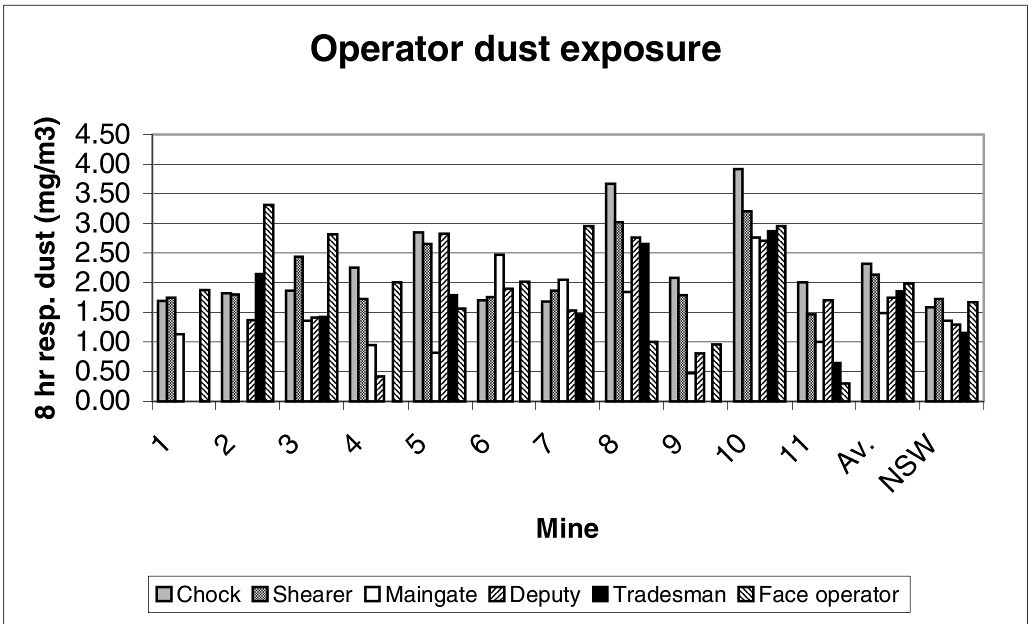

Figure 3 Operator category eight-hour equivalent mean respirable dust exposure

Mine	Current survey	1992	1993	1994
A	1.64	2.6		2.4
B	1.84	1.1		3.5
C	1.81	1.8	1.5	1.3
D	1.59		1.6	2.2
Average	2.06	1.83	1.55	2.35

Table 4 Average personal dust exposures – respirable dust 1992 - 1994

Mine	Shearer operator	Chock operator
A	2.85	2.3
B	2.15	1.6
C	2.0	1.8
D	1.8	2.0
Average	2.2	1.93
Current survey	2.13	2.32

Table 5 Average personal dust exposures – by operator category 1992 -1994

Given the variability and wide scatter of the data it is not statistically valid to interpret these results in any detail. In general there appears to be a reduction in the number of exceedances from the 1992-1994 data to the current data set.

The increased risk posed by these dust concentrations in the absence of effective personal protective equipment was estimated by using the Health and Safety Laboratory model of Hurley and Maclaren (HSL, 2000).

This model allows for the rank of the coal to which the worker is exposed, by building in the carbon content of the coal as a factor. The model is based upon regression of the pneumoconiosis database maintained by the HSL since the 1950s. The equations for category 1 and 2 pneumoconiosis are:

$$p_{\mathrm{CAT1}} = -\frac{104}{R} + \frac{0.0517 * C_{AV} * R * Y * H}{1631 * 40}$$

$$p_{CAT2} = -\frac{53}{R} + \frac{0.01667 * C_{AV} * R * Y * H}{1631 * 40}$$

Where C_{av} is the average dust concentration in mg/m^3, R is the dry ash free carbon content, Y is the number of years worked and H is the number of hours worked per year. Using the eight hour equivalence basis, a 40 hour working week is used, 1840 hours are assumed to be worked per year and 40 years worked in the industry.

The values predicted for Queensland coals are:

P_{cat1} = 8.85% after 40 years For NSW the value is 6.26%

P_{cat2} = 2.63% after 40 years For NSW the value is 0.98%

These values are lower than the predictions made by the HSL for UK coals as the rank of UK coal tends to be significantly higher. These increased risks assume that the personal protective equipment is not worn effectively.

The expected loss in lung function (FEV_1) can be predicted from the formula:

1.22 x mean dust exposure x 40 years = 100.5 ml

This compares to 73.7ml calculated for the NSW study. Neither of these values would indicate a significant loss in lung function.

Conclusions

The main conclusion of this study is that the respirable dust concentrations currently measured in Queensland underground coal mines at the longwall face regularly exceed the statutory limit. Of concern are the relatively few very high measurements (> 5 mg/m3). As such unless personal protective equipment is worn and is effective, the workers are exposed to an increased risk of respiratory disease.

Within the bounds of the accuracy of the analysis and the variability of the measurements the respirable dust levels in NSW underground coal mines appear to be lower than their Queensland counterparts, both overall and by operator function.There have been no new reported cases of pneumoconiosis in Queensland or NSW in the past five years.

Acknowledgements

The authors would like to acknowledge the support of all the mines and the DNRM in providing information, and also to SIMTARS (Mackay), CCI (Moranbah) and Safety and Health Services (Gladstone) for providing the bulk of the data.

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The development of an industry wide framework for the

COLLECTION AND MANAGEMENT OF CONTRACTOR HOURS AND COMPETENCY

Clifton Cunningham Managing Director MineIT Pty Ltd

Abstract

This paper discusses the development of an open communications framework that will allow the collection of contractor hours, competency and general OH&S information from any site (including contractors themselves) regardless of the means by which the information is collected. This framework is built around existing MineIT technology in the form of our mesh internet services.

The information collected could be used to solve current problems such as contractors working for unsafe periods of time, even across multiple sites, and would add value to the generic induction process for both contractors and mine sites as it would allow industry to track the currency of a generic induction based on its work history. The *open-ness* of such a framework is essential if it is to be adopted industry wide as it must be capable of bringing together information from, and delivering information to, a wide variety of sources.

This paper will examine the technology behind the development of such a framework, examine why the industry needs it and take a look at the issues that could inhibit its development and how to overcome these issues. Examples will be taken from existing MineIT clients in the coal mining industry.

The author

Clifton Cunningham is the founder and Managing Director of MineIT Pty Ltd. He is a graduate of the University of Queensland with a Bachelor of Engineering (Electrical & Computer Systems) with First Class Honours. He has worked in the underground coal mining industry in Queensland and New South Wales and is now based in Mackay.

The company

MineIT was founded in early 1999. The first products included the Competency & Training System, Mine Reporting System and Statutory Event Scheduling System. The core focus of the company always remained firmly on the Competency & Training System and as such this remains the 'flagship' product. MineIT pride's itself on being at the cutting edge of technology and as such providing fast, cost effective and flexible solutions.

Why does industry need a centralised framework?

There are a number of reasons why any industry with high usage of contractors in high risk environments needs a centralised method of determining and managing information such as competency, work hours or accident/incident reports. Many of these reasons can be traced back to concerns about safety and fatigue, while others are purely driven from an administrative time and cost perspective. Regardless of what reason you see as the most important, mine sites, contractors, workers and regulatory agencies would all derive benefit from a centralised and standardised framework managing this information.

Management of contractor competency

It is now a requirement that there be a training framework at each mine site that manages how a person is identified as competent to perform a duty or operate equipment and how that competency is maintained. As many sites (and contractors) are building this framework around the National ITAB CULP's they are inevitably heading in the same direction. A centralised framework developed at the same time most mine sites are developing their procedures could save a considerable amount of hassle in the future arguing over definitions and terminology.

Key Point: An electronic framework must have a way of defining each individual competency linked to a recognised standard. It must go 'inside' the competency units to the level of actual equipment being operated. This is how things are done on an operational level and it is these people that the framework is designed to help.

One of the most important aspects of competency-based training is in determining the currency of a particular competency. An example of this that is particularly applicable to contractors is the currency of the generic induction. Under the current system, even if a contractor works continuously in the industry over a two-year period (attending several site specific inductions in the process) they have to waste time and money redoing the course. By linking existing on-site management procedures to the framework (such as swipe in/out units) work hours across multiple sites can be centrally monitored.

Key Point: An electronic framework can be used to track the amount of time spent working in the industry which can then provide a gauge of generic induction currency.

Transportability of contractor competency

If everyone is trained by accredited trainers to a nationally recognised standard then why shouldn't they then be allowed to use that competency at another site with only a small site-specific induction? This is particularly important to contractors who now waste a considerable amount of time and money getting their workforce authorised to operate the same piece of equipment at different sites.

Key point: An electronic framework provides a means of allowing each contractor and site to train people to a recognised standard through an auditable process and then communicate this information in a common format.

Managing safety and fatigue

By linking existing site systems for management of contractor hours to the electronic framework a simple method of managing contractor work hours and fatigue across multiple sites emerges. The system does not need to (though potentially could) be configured to warn in 'real time' of excess work hours. It could simply monitor individual work hours over predetermined periods and generate exception reports when required.

Key point: An electronic framework could monitor contractor work hours across multiple sites and provide early warnings of unsafe work hours.

Unlimited potential

One key aspect to this framework is its ability to manage any type of information. It simply requires the central definition of a data type and then the transmission of that definition to all clients using it.

This framework can be extended to manage information such as safety bulletins, contractor work hours (collated from local swipe in/out systems), industry news or shift reports (between remote site and head office or contractor and mine site).

Potentially any information that needs to be collected from a wide range of locations in a common format can be managed using this framework.

mesh

The MineIT mesh framework was originally developed as an internet service designed to add value to our existing range of products. It soon became apparent that with a bit of thought it could easily be designed to do a lot more than that and was an 'innovative solution' in its own right.

It is a range of services available to anyone over the internet who is granted access by us or one of our clients. In a nutshell it is best described as a flexible method of collecting, storing and retrieving data securely across the internet. As soon as we began full scale testing it was apparent that a solution for the management of contractors industry wide had emerged.

The internet

The internet has now been in mainstream business use for almost a decade. Despite the hype claiming that the internet would revolutionise the way we work I personally don't think that anything too 'revolutionary' has really happened.

The main problem with the internet is that people often don't see the bigger picture and are trapped by attempting to think of it like they would any other software tool in their office.

It is a tool, and a useful one, but if you try to use it to solve problems the same way you have in the past then you will end up with the same solution.

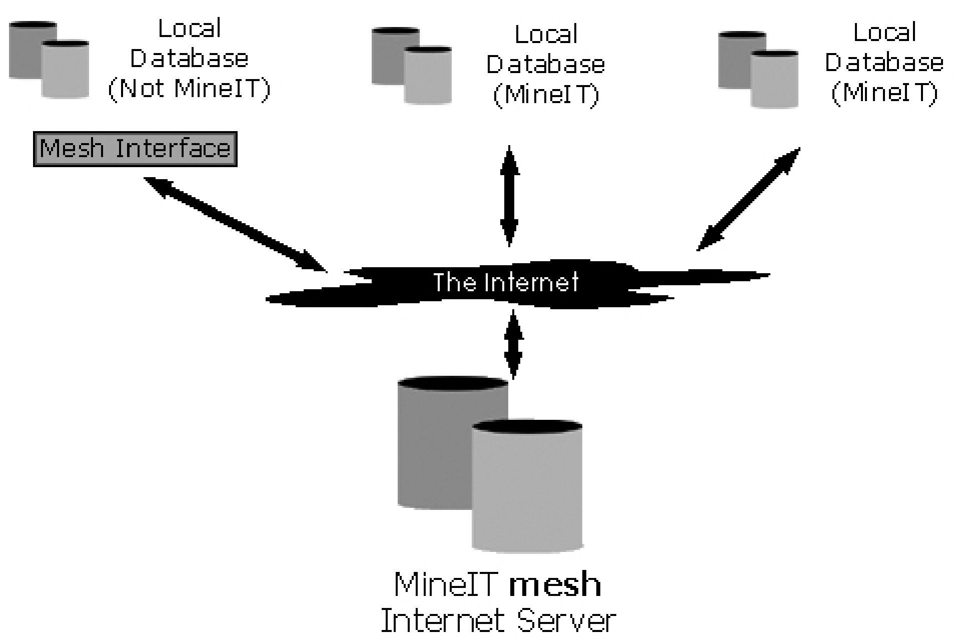
The only 'real world' analogy I will apply to the internet is that regardless of how you transmit information across the internet, via email, web pages or instant messaging; you are ultimately just sending a small packet of information from point A to point B.

When you then take into account there are an infinite number of ways to send the information, an infinite number of things that point B can do with the information before sending it back, storing it or sending it on and then an infinite number of point A and B's things get a little more interesting.

Now, if we take point B as our server (www.mineit.com.au) and point A as our mine site or contracting client a simple picture begins to develop.

The server is going to be the one in charge; it will define the structure of the data that the clients can fill with information (or retrieve from it). Clients are only allowed to 'play ball' if they comply with all of the requirements that the server puts in place – keeping in mind that the server can place

Figure 1 **mesh** *overview*



limitations not only on the structure of the data but the actual data itself. In no time at all you have a clear picture of a centrally managed electronic framework. You may understand exactly 'how' it works but you can see where each player fits in.

Flexible data

Anyone who has been involved in the development of a database to manage any kind of information will understand that the first step is in defining the information and its internal relationships. This can often be a long and complicated task – but absolutely vital to the end result and one that can prove very difficult to change down the track.

A framework of this type stops dead in the water if you attempt to define the information in the traditional way. You have to take a step back and decide that rather than directly managing the information; you will manage information 'structures'. This means that your database ends up being a database of structures (both simple and complex) and the relationship between them. You can redefine a particular structure without redesigning the database. You can add new structures without redesigning the database. You can remove unwanted structures without redesigning the database. This is crucial.

With mesh in mind, we have chosen to name our information structure definition a metafrag and an information structure containing data a frag (this is short for fragment – as many of these are included in a single package sent between client and server).

Our server now contains metafrag definitions for contractors, training records, skills, locations, sites, classifications, swipes, swipe units and more.

These definitions are used by the client to create data from a local database or parse data from the server into a local database.

The *metafrag* definitions for our contractor management framework are defined by us, though our clients also have the ability to define their own custom *metafrag* definitions for their own use.

There are also a range of 'transforms' that can be used to turn data contained in a *frag* into a printer friendly PDF document.

XML

The actual format of our information is XML (eXtended Markup Language). This is now a very common method of transferring information across the internet – mainly due to the fact that it is 'clear' text and not specific to any particular operating system.

Tools to 'parse' XML (go through an XML document to retrieve data for use in a local database or use a local database to create an XML file) are now an integral part of every operating system and freely available.

This means that you do not need to be using MineIT software to make use of the framework.

You just need to understand how to create and read the XML data and create an interface between them and your existing systems.

You can connect to our server and retrieve data from within an Excel spreadsheet for example.

An 'open' framework

By ensuring that all of our data structures are clearly defined and easily available, it is very easy for other developers to create interfaces between existing systems and our framework.

It doesn't matter what you have behind the scenes, provided it can be transformed into a frag compliant with our metafrag definitions you will be able to send information to our server and retrieve information from it.

In this sense it is an 'open' framework as we are not requiring that you use MineIT software to connect to it. We will be making the knowledge of how to connect to the framework available to other developers.

Has this been done before?

The framework we have developed is completely original, and all of the technology used to develop it has not been used together in an application of this kind before.

Keep in mind that although the application is new, the technology is not - we have simply developed a new way of bringing it together.

A lot of the concepts are based on other emerging standards (such as SOAP) but have been modified by us to make it more useful to this particular application.

A 'real world' example

Coalroc Contractors is an underground coal mining contractor with offices in Mackay, QLD and Wyong, NSW. They have had long running contracts at Newlands Southern Underground (who is also a MineIT client) in central Queensland.

Coalroc has spent a substantial amount of time and money developing their internal competency based training system built around the ITAB CULPs.

This system is backed up by the latest version of the MineIT Competency & Training System that is used to manage the information.

Coalroc, like most contractors, wanted to be capable of managing and storing all of the documentation concerning training at their head office while doing the actual training on-site.

As contracting isn't typically a business with a large IT budget they had very little existing structure to work with, and needed to end up with a flexible solution with minimal ongoing cost.

Their key requirements were as follows:

- Allow for the electronic transfer of competency and employee information from head office to each project site. The medium selected to do this was the internet using mesh.
- Offer the potential to develop an electronic 'relationship' with each mine site worked at. All

information stored in the head office database would be made available to each mine site to audit at any time.

- Provide a means of communicating important information both to and from the employees themselves. This includes current training information, simple messages, important documentation (ie risk assessments and safe work procedures), work hours and also record activities were performed during each shift.

Coalroc was the first of our clients to become fully compliant with the electronic framework defined in mesh.

This means that all of the skills, classifications, sites and locations used in their local database were compliant with those listed in our central database located on our server.

This gave them the ability to transfer employee and competency information from their local database into their secure area on our server. This then made the information available to each of their projects who could access this information after logging into the Coalroc homepage.

Compliance also provided Coalroc with the ability to package a group of employees into a single file that could be sent to the training department at Newlands and opened using their copy of the MineIT Competency & Training system.

While the interface between Newlands and Coalroc's database is still under discussion there is now a means by which Coalroc can provide Newlands with information on training it has carried out on an employee, and Newlands can then electronically provide Coalroc with information on site specific training it has carried out on the same employee.

Coalroc then took the further step of asking us to build a touch-screen kiosk that would provide its employees with a means of accessing training information, messages from head office and important documents.

This kiosk interfaces directly with the MineIT internet server through a dial up connection to maintain up to date records from head office and also sends information on employee hours and activities.

Coalroc are now looking at using the information collected on employee activities to determine the currency of particular employee competencies.

All of this was only made possible once Coalroc had developed a standards based training system to back up the electronic one and then agreed to comply with MineIT standards for defining competencies and employees.

Clearly, in order for two different sites to share information they must be talking the same language, or calling a spade a spade if you like.

Our other underground contracting clients, Mastermyne and Ground Consolidation are following a similar path and are fully compliant with the MineIT standards.

How would a framework like this be implemented?

The MineIT mesh framework has been developed and is fully functional. This paper is not proposing the development of such a framework, rather explaining how this existing framework can be utilised to solve a problem. With this in mind many of the issues inhibiting the implementation of such a framework industry wide are primarily administrative, political and financial – not technical.

Administrative problems exist in the respect that each individual site and contractor must decide if they wish to comply with the central list of competencies defined by us and our existing clients.

This list is flexible and any site (MineIT client or not) has the ability to request new competencies be added.

The list is by no means complete and is a work in progress. This applies to our list of classifications, locations, sites and contracting companies.

If a site does decide that they do wish to comply they then need to move any existing information over to the new codes and definitions and choose a method of connecting to the framework.

Political and financial problems exist due to the administrative problems defined above. Many companies and contractors have a considerable amount of money invested in existing systems and these are often very inflexible.

The cost of having their developers add in the ability to export or import *frags* compliant with our definitions would be prohibitive in most cases. The key to overcoming this issue is to ensure that the advantages gained by connecting to the framework outweigh these costs or alternatively provide low cost solutions to replace existing systems.

The other key concept is that a site does not necessarily have to have their local database compliant to implement a solution to track contractor work hours and competency.

MineIT has a range of products that can be placed on site that can be used to manage contractors' separate from existing internal systems.

Where to from here?

MineIT will continue to offer secure mesh web services to our existing clients regardless of whether it is adopted as a possible solution industry wide.

We will continue to work with our clients to develop a centralised list of competencies that will then enable them to communicate information amongst themselves.

By centrally managing these commonly used lists we can save our clients a considerable amount of general 'administrative' time and also allow new clients as quickly as possible.

Shae McCartney
SolicitorEmployee Relations - Freehills

Why undertake an internal investigation?

- To isolate cause
- To review systems
- To improve systems
- To prepare for external investigation

Freehills

Case Example

Freehills

Who can investigate?

- Internal
- External

Freehills

Internal Investigation

- Operator
- DDE
- Other officeholders

Freehills

External Investigators

- Union
- Chief Inspector
- Board of Enquiry
- Coroner
- WorkCover
- Police

Freehills

Legal ramifications of an accident

- Coroners Court
- Board of Enquiry
- DNR prosecution
- Chief Inspector directives
- WorkCover claim and worker rehabilitation
- Common law claim
- Criminal Code

Freehills

So there has been an incident...

- Safety
- Notification
- Investigation
- Damage Minimisation (including Rehabilitation)
- Future Risk Minimisation

Freehills

Safety

- Employees, Contractors and other people on site
- Investigators
- The Community
- Other related persons

Freehills

Notification

- Who should I call first?
- What do I have to tell who?
- What are the Company's rights and obligations?
- What are my rights and obligations?

Freehills

Internal Investigation

- Practical steps
- Reasonable Direction
- Scope of investigation
- Confidentiality
- Privilege
- What do we do with the report?

Freehills

Police Investigation

- Obligation to give a statement
- Legal representation
- Police powers and responsibilities

Freehills

Investigation by statutory position holders

- Obligation to provide information
- Rights and obligations generally
- Legal representation

Freehills

Investigation by Workcover

- Obligation to provide information
  - Self incrimination
- Rights and obligations generally
- Legal representation

Freehills

Protection of information

- What if investigation shows changes are required?
- What are the Company's obligations if it finds fault?
- Does subsequent change prove prior liability?

Freehills

Rehabilitation

- Obligations
- Company's Rights
- Ongoing Issues
- Stress Claims

Freehills

Risk Assessment

- Systems Review
- Training
- Ongoing management of risk areas

Freehills

Freehills

A quantitative method for assessing

THE IMPACT OF ACCLIMATISATION

in the workplace

Rick Brake
Principal Consultant, Mine Ventilation Australia

Abstract

One of the important ways that humans cope with repeated exposure to heat stress is by physiological adaptation, a process known as *heat acclimatisation*. This paper identifies the issues of acclimatisation and de-acclimatisation that impact on fly-in, fly-out (FIFO) and local-domicile (LD) operations and proposes a model to obtain some quantitative indication of the impact of different types of rosters on FIFO and LD operations, as well as the impact of workers changing job type or returning from vacation or other work absences into hot conditions. Using the methodology, important differences can be seen in the acclimatisation status of workers domiciled locally, compared to those on a fly-in, fly-out roster, depending on the type of roster, their fly-out location and other factors.

Introduction

Excessive heat stress in the workplace can result in heat illness, poor safety, low productivity, poor morale and increased costs. It is therefore important to provide a ‘ holistic’ approach to the management of heat stress in the workplace (Brake et al, 1998).

Symptoms of heat illness range from headache and nausea through vomiting and syncope to more severe central nervous system disturbances. The most severe form of heat illness is heat stroke, which if untreated or sufficiently severe, can lead to death and frequently leads to permanent organ damage. Heat exhaustion has been shown to have a clear clinical profile (Donoghue and Bates, 1999) and may well have been under-reported in many industries during periods of high ambient temperature.

One of the important ways that humans cope with repeated exposure to heat stress is by physiological adaptation, a process known as *heat acclimatisation*.

This adaptation is expressed in at least the following ways: an increase in circulating blood volume, an increase in sweat rate, a reduction in the time delay prior to the onset of sweating, a reduction in the sodium and other solute (salt) content of sweat, a reduction in both deep body core temperature and heart rate during the exposure, an increase in total body water and an increased resistance to sweat gland fatigue and hidromeiosis.

When exposed to heat, the thirst sensation of unacclimatised persons is also much weaker than that of acclimatised persons, predisposing unacclimatised persons to a much greater probability of dehydration, which is one of the most common causes of heat illness.

As an indication of the impact of acclimatisation on productivity alone, one study (Leithead and Lind, 1964) found that acclimatised workers are most *efficient* at about 27^0 ET, whereas unacclimatised workers are most efficient at about 18 to 21^0 ET. Other studies have found a 2^0 to 4^0 ET (or WBGT or WB, depending on the study) difference in the practical *maximum* working limit of acclimatised and unacclimatised workers (ACGIH, 1998; Ramsey and Beshir, 1997; Schutte et al, 1991).

If the heat adaptation process reaches completion, acclimatisation therefore produces quite profound reductions in the heat strain of humans exposed to identical levels of heat stress.

The physiological process of *heat* adaptation can be compared to that of *exercise* adaptation, as illustrated in Table 1.

These similarities should not be pressed beyond the fact that when the human body is exposed to certain types of stress, it can adapt, that the adaptation can lead to substantial benefits in terms of future exposures to that stressor and that there are similarities between the requirements needed to adapt to heat and exercise, and the results of the adaptation to each of these.

In an occupational context, a loss of heat

Stressor ->	Heat	Exercise
Name of adaptation process	Heat acclimatisation	Aerobic exercise
End point	‘ Heat acclimatised’	‘Fit’
Time to reach end point	4 weeks plus	4 weeks plus
Frequency of each exposure	Daily (minimum about 4 times per week)	Daily (minimum about 4 times per week)
Intensity of each exposure	Sweating, preferably at least 50% skin wetness	Heart rate more than 40% of cardiac reserve
Duration of each exposure	30 to 120 minutes	Minimum 30 minutes

Table 1 Similarities between heat adaptation and exercise adaptation

acclimatisation (or inability to gain full acclimatisation) results in lower productivity, poor morale, and a much-increased risk of fatigue and more serious forms of heat illness.

Until recent times, industrial workers have usually been domiciled within a short distance of their place of employment, and have worked a repeating pattern consisting of typically five or six days at work, followed by a (short) rest of one or two days.

If their workplace subjected them to heat stress, they therefore reached a fully acclimatised state and retained this during their period of employment. In recognition of the importance of acclimatisation, some mines have introduced formal acclimatisation protocols.[1]

In more recent years, changes to this historical practice of housing workers on site can have a significant impact on the ability of workers to develop and then retain this important mechanism for coping with heat stress. Two of these changes include:

- Extended rosters, eg nine work days followed by five non-work days. However, some rosters are as long as four or six weeks of work followed by one or two weeks of non-work
- Fly-in, fly-out (FIFO) commuting.This refers to the practice of domiciling workers in one or more major regional towns (typically a large town with established facilities and sometimes a more temperature climate) and flying workers up to 1000km or more to a work site, frequently located in a much more severe climate.

It is clear from the above discussion that these new work arrangements may not allow workers to develop and retain the same degree of heat acclimatisation that they might have been able to in the past.

There is therefore a need for health and safety professionals who manage work sites with a significant heat stress exposure to be able to assess the impact on workers of the following sorts of situations:

- A new employee from a temperate climate commences at a workplace with a serious heat exposure and it is desired to know how long it will take for him to become as acclimatised as his colleagues
- An organisation is reviewing its roster arrangements and wants to examine the impact on safety and health of different combinations of days on and off, in terms of the likely changes in the acclimatisation levels of its workers
- An organisation is establishing a new facility in a remote area, which will be run as a FIFO operation, and needs to examine the impact of two or more different domicile locations on workers' acclimatisation
- An organisation wishes to examine the difference between the gain and loss of acclimatisation in summer versus winter, for various roster arrangements
- An organisation is considering transferring a worker into a job that has a significantly increased level of heat stress (either due to a hotter environment, more severe clothing requirement, or higher work rate) and wants to assess issues of acclimatisation
- An organisation is planning a major plant shutdown and refurbishment during the Christmas/New Year period and wants to examine the impact of contractors bringing in workers from temperate climates into work which involves significant heat stress
- An organisation wishes to assess the impact of loss of acclimatisation on a worker leaving the job in mid summer for a holiday in a cold climate.

There is currently no agreed 'index' for acclimatisation, nor any method of assessing any of the issues of acclimatisation such as those listed above.

This paper proposes a method of assessing, both quantitatively and qualitatively, acclimatisation in industrial workers.

Methodology

Substantial studies have been conducted into the effects of human heat acclimatisation, particularly on soldiers during and after WW2 (Adolf, 1947; McArdle et al, 1947), elite athletes and workers in some industries including mining.

A useful discussion on many features of human heat stress and acclimatisation is given in the International Labor Organisation *Encyclopaedia of Occupational Health and Safety* (ILO, 1998).

Whilst there are significant differences in individual responses to heat, the following is generally agreed about the overall human response (Leithead & Lind, 1964; ASHRAE, 2001; Gisolfi, 1987; Sawka et al, 1996):

- Humans cannot adapt to an unlimited level of heat stress; the end-point of heat adaptation is limited and at this point the human is ' fully acclimatised'
- The process involved in gaining acclimatisation takes four to six weeks, perhaps more, but most of the gain (typically about 70 percent occurs in the first seven days of continuous exposure. The most significant improvements,in fact occur in the first three days of exposure
- The key requirement to achieve acclimatisation is to be sweating. Exercise in itself will not result in any significant heat acclimatisation, although fit persons acclimatise faster than unfit persons.
- There are some differences between acclimatising to a hot, humid environment or a hot,dry environment, and between the acclimatisation of men and women, along with ethnic differences; however, for persons of working-age, these differences are minor compared to other risk factors relating to heat illness.
- Salt concentration in the sweat of unacclimatised persons is about 4g/litre, reducing to about 1g/l in acclimatised persons (the typical diet contains 10g/day salt). However, unacclimatised persons produce much less sweat (one to 1.5 times the evaporative heat loss[1]) than acclimatised persons (two to 2.5 times the evaporative heat loss). Unacclimatised persons may therefore need some salt supplementation during heat exposures (eg extra salt on meals) but additional salt intake should not be required for acclimatised persons.
- Humans need to be exposed to somewhere between 30 and 120 minutes of heat stress per day to commence and then continue the acclimatisation process through to its end-point.

- Humans adapt to the level of heat stress to which they are habitually exposed. Hence, a person can be ' 100% acclimatised' (ie fully acclimatised) to the heat stress in his normal workplace, but much less than fully acclimatised to an environment of higher heat stress.
- The wide range of individual responses to heat stress reduces as persons acclimatise. The variation in heat tolerance of a well-acclimatised group is therefore much less than that of an unacclimatised group.
- The process involved in losing acclimatisation is more poorly understood (as it is generally of less consequence for athletes or soldiers than the process of gaining acclimatisation). The consensus is that it is roughly similar in duration to the gaining of acclimatisation, but most authorities agree that the loss in the first few days to a week of non-exposure is modest. However, for persons needing to be highly acclimatised, even two or three days of non-exposure could result in a significant loss of acclimatisation.

The challenges in understanding the impact of acclimatisation on work rosters are therefore:

- To develop an index of acclimatisation, preferably both an absolute and relative scale
- To determine the level of acclimatisation ('end-point' or full acclimatisation state) that could be reached by moderately fit and healthy humans in a particular environment
- To determine the residual level of acclimatisation retained when humans move into a less heat-stressful environment.

In terms of developing an index for acclimatisation, two important physiological parameters could potentially be used.

The first of these is deep body core temperature as this is the key determinant of hyperthermia, which in turn is strongly related to the development of heat illness. The second is sweat rate.

These two are also causally related; an increase in deep body core temperature promoting a range of important physiological responses (including vasodilation and an increase in heart rate), but the most externally-obvious of these possible indicators is sweating.

Sweat rate has some advantages over core temperature as a possible index. Whilst core temperature does *increase* when a human is exposed to heat stress, it subsequently *reduces* as an individual becomes acclimatised to that same environment.

Sweat rate increases on exposure to heat stress, and increases further as a human becomes acclimatised to that environment.

Furthermore, in some circumstances exercise may produce an increase in core temperature unaccompanied by either heat stress or any sweating (eg in an elite swimmer).

Finally, deep body core temperature is difficult to measure in a workplace, whereas sweat rate can be measured or estimated by using a mass balance and some simple field controls over the intake and release of fluids and solids.

Consider therefore a particular environment requiring a sweat rate of (say) 1.2 litres per hour from a highly-acclimatised group. If the maximum sustainable sweat rate from this same highly-acclimatised group was (say) 1.5 litres per hour, then this environment could be described as requiring an *absolute* acclimatisation level of 1.2/1.5 = 80%.

This assumes a nil sweat rate for the fully unacclimatised state, however, the choice of the ' zero point' for an acclimatisation scale is not particularly important – it would simply mean that even an unacclimatised person has a positive residual acclimatisation value (ie ability to sweat) using such a scale.

Furthermore, with such a scheme it would then be possible to assess a group's *relative* degree of acclimatisation. For example, assume the same highly-acclimatised group in a particular environment has a sweat rate response of 1.2 l/hr, and the unknown group exhibits a mean response of 0.8 l/hr, then the unknown group could be said to be 0.8/1.2 = 66% acclimatised (on a *relative* basis) to that environment.

For the purpose of this proposed model, an upper sweat rate of 1.5 litres per hour has been selected as the '100 percent absolute acclimatised' value. This is based on the work of McArdle et al (1947) in many experiments (leading to the development of the Predicted Four-Hour Sweat Rate, or P_4SR scale), the work of Wyndham (1967) and also of others. Note that the only use of this assumed upper limit of 1.5 l/hr is to develop a ' percent absolute acclimatised' scale and it is of little practical consequence otherwise. However, if a more conservative lower value was selected (e.g. 1 litre per hour), then some environments would result in highly acclimatised workers being '120 percent acclimatised' (eg if they had a sustainable sweat rate of 1.2 litres per hour), which could be confusing.

Once such a scale has been selected, it is then possible to describe the *rate* of gain or loss of acclimatisation in terms of that scale.

Figures 1a and 1b indicate the likely rates of gain and loss of acclimatisation, based on a general consensus within the literature; these curves are therefore subject to modification as further studies becomes available.

However, they are unlikely to change dramatically from the shapes shown and in any event, the purpose of this model is to identify basic trends and issues.

Broadly speaking, both the acclimatisation and de-acclimatisation processes are complete at about the 28-day mark, but the gaining of acclimatisation is faster, being about 70 percent complete after seven days of exposure, with the losing of acclimatisation being slower, showing a residual level of about 60 percent after seven days of non-exposure.

The following equations can be fitted using least-squares means to these curves (with $r^2 > 0.99$ in each case):

Where acclimatisation is being gained:

$$Ac(g) = \tanh(0.124 * D) \qquad \text{Equation 1}$$

Where: D is the day of exposure (first day being day 1)

Where acclimatisation is being lost:

Ac(l) = 0.9663 - (Tanh (0.06054 (D - 0.55626))) Equation 2

It is therefore assumed that any group of moderately fit and healthy workers will, if exposed to heat stress, acclimatise approximately along the curves shown with the end-point being the level that would be reached by a notional highly-acclimatised group.

To translate this into an effective model, it is necessary to know what the ' end-point' and 'starting point' of the acclimatisation process would be, in terms of the agreed acclimatisation index.

In terms of the heat-acclimatised end-point, we need to know the sweat rate response of a highly acclimatised group to any particular environment. A model of human thermoregulation has been recently described, which is based on the thermal work limit (TWL) index (Brake and Bates, 2002).

This model was based on detailed laboratory testing of highly acclimatised workers and, for any given work rate and set of environmental conditions (temperature, humidity, wind speed, radiant heat loads and clothing ensembles) will provide, amongst other parameters, the sweat rate and deep body core temperature response of such a group. The TWL model has therefore been used to predict the acclimatised end point.

The unacclimatised end-point is more poorly defined. It is likely that a person who retreated to an entirely air-conditioned environment in a tropical city for his off-duty break would retain no more acclimatisation than a similar person who retreated to a temperate city for his break. However, this is not normally the case. It is reasonable to assume that a worker returning to a tropical city in mid-summer will continue to experience the outdoor heat and a higher level of heat stress (and therefore of residual acclimatisation) than a similar person returning to a much more temperature city.

For the purposes of this model the ' residual acclimatisation state' has been assessed as follows: The residual state of acclimatisation is defined as the acclimatisation level (sweat rate) developed by a person at a work rate of 110 W/m^2 (ie a light work rate, typical of light gardening or a leisurely stroll, - the type of activity that most persons would experience even on their 'days off'). Whilst this is a somewhat arbitrary approach, it will be seen later that the actual level of this 'off-duty' acclimatisation state does not have a profound impact on the model and therefore errors in this value are unlikely to be of vital consequence for most workers.

In addition, there is little difference in the sweat response of acclimatised and unacclimatised persons to *low* levels of heat stress. However, there remains considerable work required to properly describe the unacclimatised state and therefore more adequately validate this proposed model.

Results and discussion

The methodology is best illustrated with some case studies. Table 2 describes the various work and off-work situations in the case studies:

Different domicile locations for FIFO operations:

Consider a person working in condition A, but who can be domiciled in either conditions E or H. If he is on a seven days on seven days off roster (' seven on seven off'), his acclimatisation state is shown graphically in Figure 2.

This chart indicates that the absolute acclimatisation level required at work is 66 percent but that he ranges from 43 percent to 59 percent due to his off-duty acclimatisation state being only 16 percent. In effect, on a relative basis, he cycles between being about 65 percent and 90 percent acclimatised compared to the ideal acclimatisation level for his work environment.

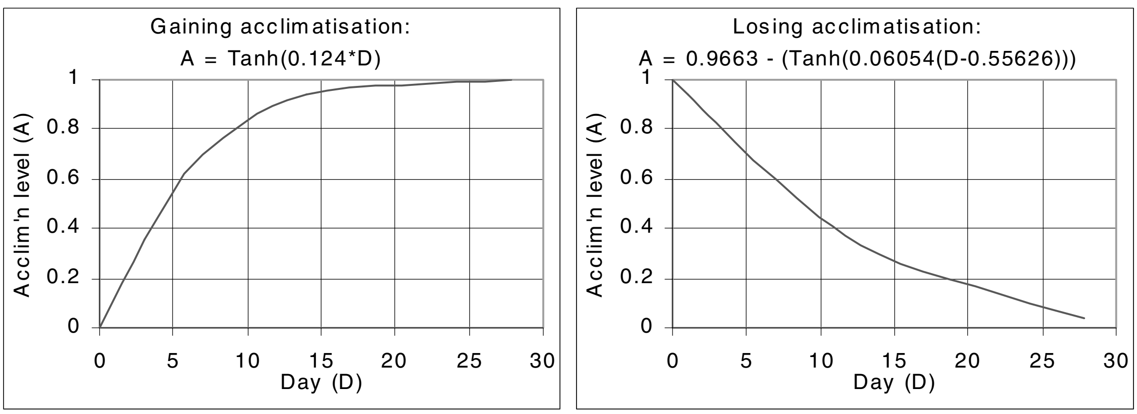
Note also that it takes at least two roster cycles for him to develop his long-term acclimatisation cycling pattern.

Clearly, the more time spent by a worker near the fully acclimatised state (for this environment), the less stressful the environment will become. In addition, the long-term health effects of workers continually 'acclimatising' and then 'de-acclimatising' (hereafter described as *acclimatisation cycling*) are not known, but it may be reasonable to assume, by analogy with exercise adaptation, that it is desirable to keep the 'range' (or 'spread') of this acclimatisation cycling to a smaller rather than a greater value.

Impact of holiday periods

Consider now a worker in environment A in the Southern hemisphere, who takes a four-week summer vacation into the Northern hemisphere winter in environment G. If he is on a four on four

Figure 1a and b. Process of gaining and losing acclimatisation



off roster, his acclimatisation state is shown in Figure 3.

It can be seen that, on returning to work, it takes him three roster cycles to achieve a ‘steady state’ acclimatisation pattern.

Impact of changing seasons on acclimatisation state

Consider a person working in winter conditions D, but domiciled in condition G. If he is on a seven on seven off roster, his acclimatisation state is shown in Figure 4. These conditions of 22^0 WB, 28^0 DB, a small radiant heat component and only low wind speed would be typical of many ‘summer’ conditions in temperate climates, and therefore also shows the low levels of acclimatisation required (and obtained) for workers in such conditions.

Impact of different ‘panels’ on roster design

Consider a worker in conditions A and F, but working either a four on four off roster, or a four week on one week off roster. His acclimatisation state is shown in Figure 5 and Figure 6.

Now assume the same worker was working a roster in which there were four separate panels, these being four on four off, seven on seven off, nine on five off, and five on two off. His state is shown in Figure 7. This illustrates the potential complexity of acclimatisation cycling in more complex rosters.

Impact of a worker changing work rate, temperature/humidity/wind speed or clothing

Consider a worker in environments A and F, working seven on seven off roster, who accepts a transfer into a job requiring a higher work rate (situation B). His acclimatisation state will be as shown in Figure 8.

If, however, his work rate remained as per his previous job but the environmental conditions in the new job were much poorer (situation C), then his acclimatisation state would be as shown in Figure 9. In this particular case, there is not a big difference between the results.

How long it takes for a new ‘starter’ to become as acclimatised as his colleagues

It can be seen from the above charts (eg Figure 5a) that it can take several roster cycles to obtain the long-term acclimatisation state possible under that roster.

It is important to note that an acclimatisation scale, whether based on core temperature or sweat rate, will not be linear.

It is obvious that an increase in deep body core temperature from 37.0 to 37.5^0 C will not result in the same strain on a human as an increase from 38.5^0 to 39.0^0 C – the first 0.5^0 C increase is well within the safe core temperature response of humans, the second is much closer to the point at which moderately fit and healthy industrial workers can be expected to suffer from collapse.

However, this non-linearity is true of most physiological parameters – the further the parameter moves from the central point, the more severe the strain.

Summary and conclusions

Acclimatisation is an important means by which

Table 2 Key parameters for workers in the case examples. In all cases, the vapour permeation of clothing was assumed to be 0.45 (dimensionless). The off-work clothing insulation of 0.33 is based on typical off-work shorts and shirt (clothing expected to be worn when off-work under low levels of heat stress); the at-work clothing insulation of 0.35 is based on typical dry values of 0.55 (short shirt, long trousers, boots, hard hat) reduced by 40% to account for the (sweat) saturation of clothing under these conditions

	A	B	C	D	E	F	G	H
	Underground miner at work, summer	As for A, but higher work rate	As for A, but hotter work	As for A, but winter	Home environ – tropical coastal location, summer	Home environ – temperate coastal loc, summer	Off-work environ – cold loc, winter	Home environ – cold loc, summer
WB, °C	28	28	28	22	26.7	20.4	6.0	17.8
DB, °C	36	36	36	26	31.0	32.9	12.0	25.0
GT, °C	38	38	38	28	33.0	34.9	14.0	27.0
WS, m/s	0.5	0.5	0.5	.5	2.0	2.0	2.0	2.0
BP, kPa	111	111	111	111	101	101	101	101
Clothing insulation, clo	0.35 (wet)	0.35 (wet)	0.35 (wet)	0.35 (wet)	0.33 (dry)	0.33 (dry)	0.33 (dry)	0.33 (dry)
Work rate (metabolic)	150	200	150	150	110	110	110	110
Sweat rate, litre/hr	0.99	1.45	1.32	0.28	0.24	0.21	0.02	0.10
Skin wetness, fraction	1.00	1.00	1.00	0.98	0.91	0.50	0.05	0.28
Core temp, °C	37.90	38.73	38.31	37.5	37.29	37.24	37.00	37.07
TWL (std), W/m^2	174	174	144	275	339	339	457	373

Note: WB = wet bulb temperature, DB = dry bulb temperature, GT = globe temperature, WS = wind speed, BP = barometric pressure.

workers in hot conditions reduce the heat strain on their bodies. A method has been proposed to provide a preliminary quantitative assessment of the impact of various rosters and work and domicile climates on the acclimatisation state of workers. It shows that, as is often described anecdotally by workers themselves, there are significant issues involved in acclimatising, de-acclimatising and re-acclimatising to the work environment, depending on the combination of heat stress and required metabolic rate at work, the roster, and the climate in the 'off-work' domiciled situation.

Further research needs to be undertaken to fully understand and to be able to quantitatively assess the impacts of acclimatisation (and loss of acclimatisation) in hot working environments in Australia.

Figure 2 Case study for worker A domiciled in conditions E or H

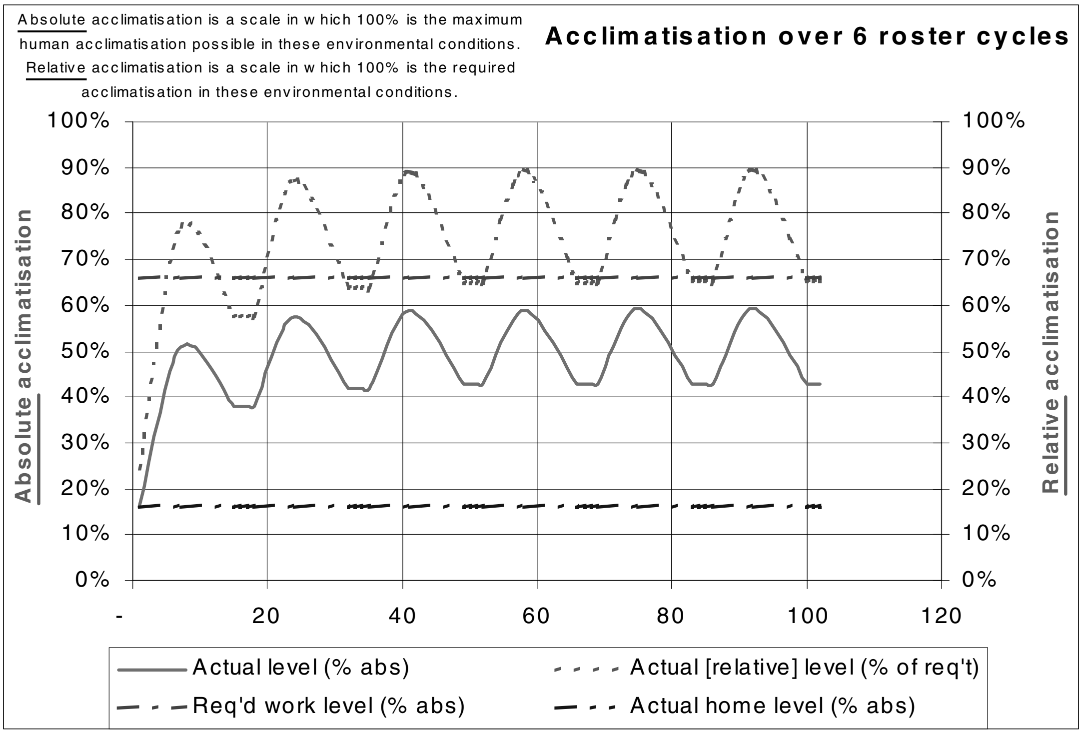
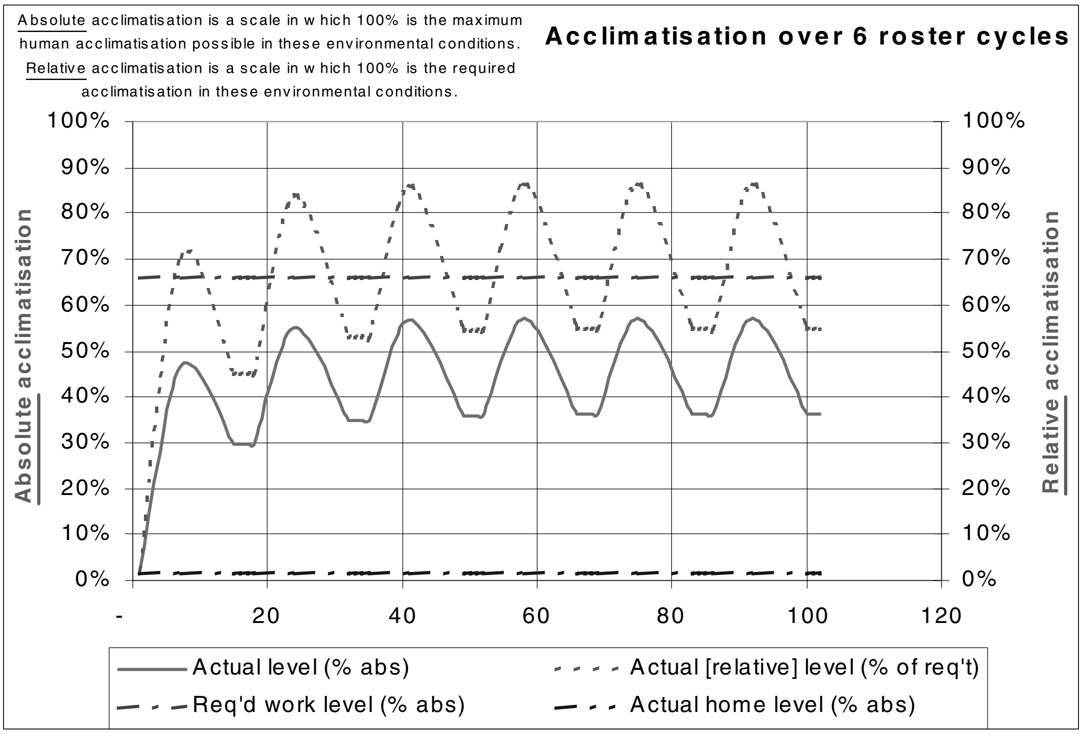


Figure 3 Case study for worker A taking 4 week holiday in conditions G



It can also be seen that the ' residual level of acclimatisation', under this scale, for most climates in summer is not dramatically different (typically ranging between 0.2 l/hr and 0.3 l/hr, a difference of only 0.1 l/hr, refer to situations D to F) and that this therefore does not impact dramatically on the ' acclimatisation cycling' for those workers under significant levels of heat stress (where sweat rates are invariably more than 0.7 l/hr). Where work is not being carried out under such high levels of heat stress (e.g. required sweat rates of only 0.3 to 0.4 l/hr), then an error of 0.1 l/hr in the 'non-working' acclimatisation state will have a much higher relative impact. However, the problems of losing and gaining acclimatisation are also of less significance for such workers. This is particularly true since even unacclimatised workers can safely sweat at rates of up to at least 0.6 l/hr.

Figure 4 Case study for worker D domiciled in conditions G

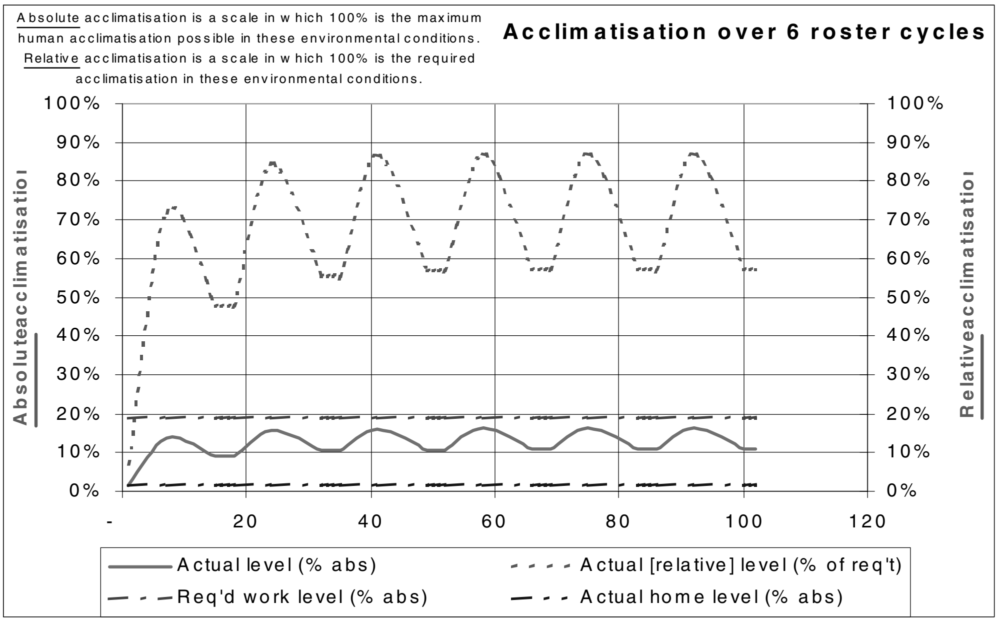


Figure 5 Case study for worker A on 4 day on – 4 day off roster

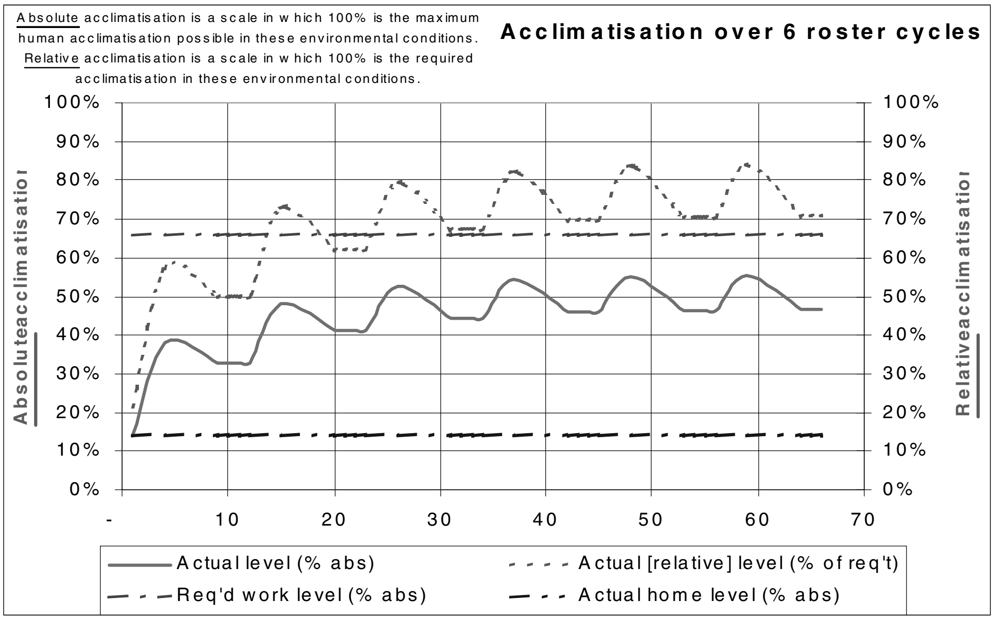


Figure 6 Case study for worker A on 4 week on – 4 week off roster

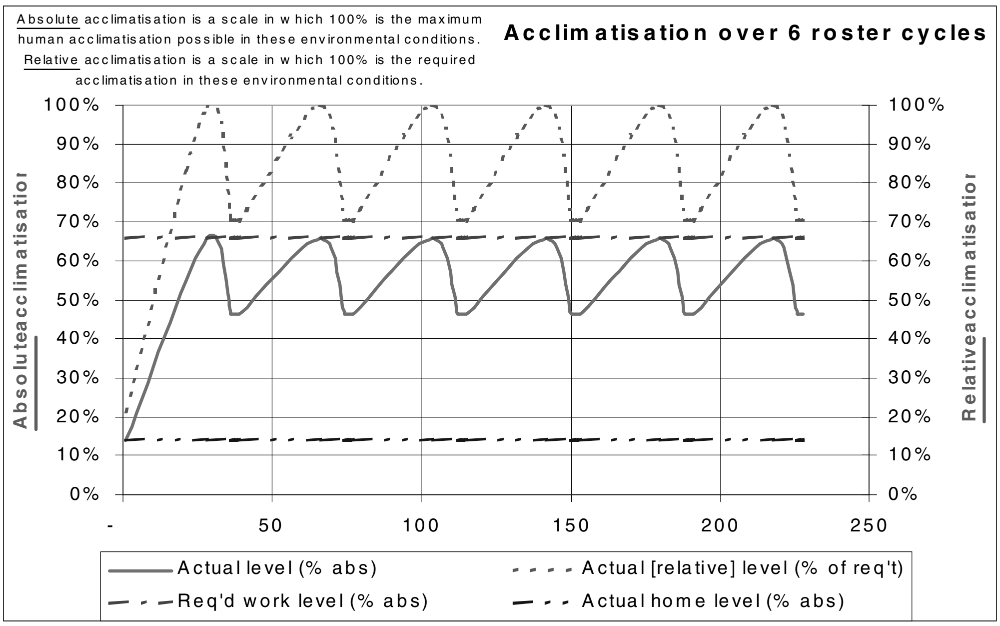


Figure 7 Case study for worker A and F, working 7 day on – 7 day off roster, transferring into situation B

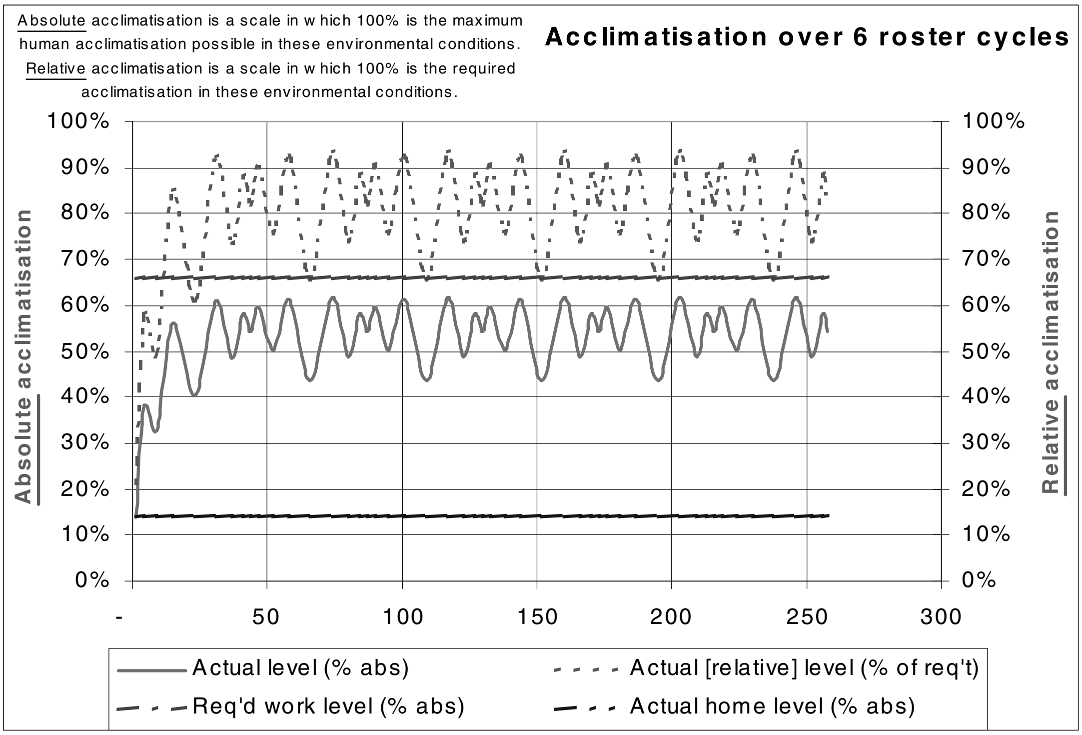
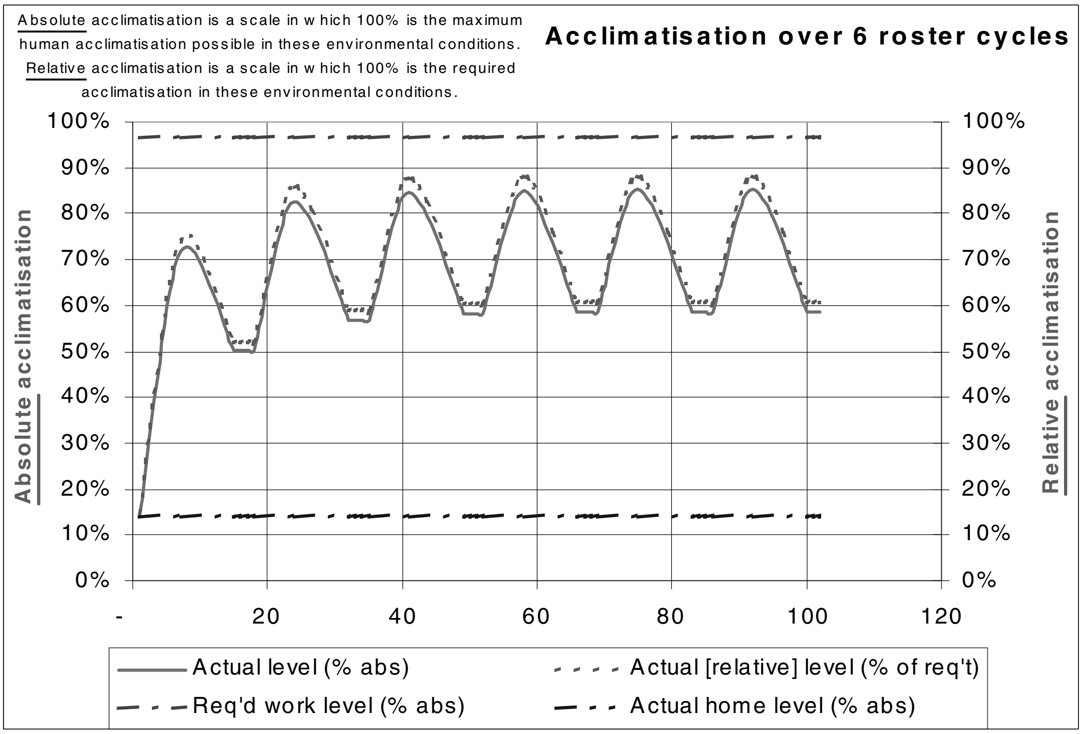


Figure 8 Case study for worker A and F, working 7 day on – 7 day off roster, transferring into situation B

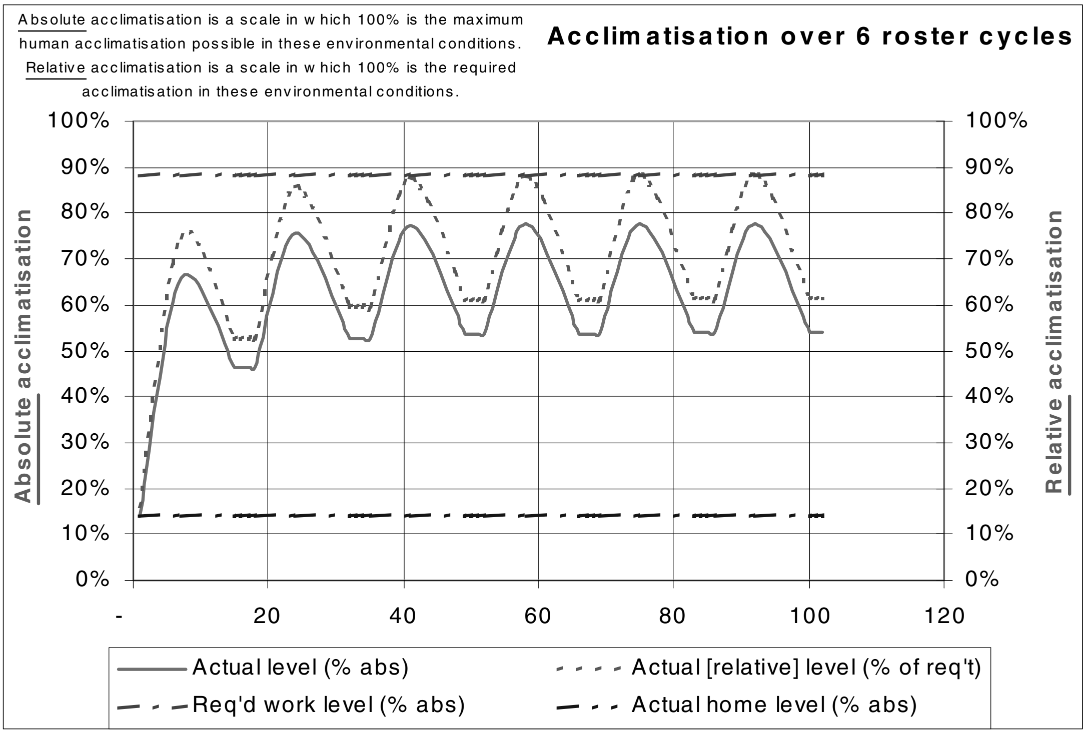


Notes

1 An acclimatisation protocol was introduced into South African mines in 1925, after the first deaths from heat stroke in 1923. A two-stage acclimatisation process was introduced in 1953, with surface acclimatisation starting in 1960. In 1974 the acclimatisation process was reduced from a maximum of eight days to 5 days, with a Heat Tolerance test introduced in 1977 and microclimate acclimatisation introduced in 1982. In recent years, the South Africans have gone almost ‘full circle’ with most acclimatisation now being ‘on the job’ supplemented by a 30 minute ‘heat tolerance test’ on surface prior to initial exposure. However, levels of heat exposure and work rates are much higher in South African mines than are generally found in Australia (Kielblock and Schutte, 1991)

2 When a human becomes thermally stressed, he starts to sweat. The evaporation of sweat from the skin produces most of the cooling needed to avoid the body over-heating. However, the body produces ‘surplus’ sweat for a variety of reasons (which drips off or remains on the skin). Humans who are poorly acclimatised produce much *less* sweat than those who are well-acclimatised.

Figure 9 Case study for worker A on 4 week on – 4 week off roster



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A STRUCTURED APPROACH TO INSPECTION OF MINES

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Abstract

The regional business plan of the Mines Inspectorate (MI) in Mount Isa Queensland incorporates the values and mission objectives of the Department of Natural Resources and Mines (NR&M).

OUR VISION

'Our Industries Free of Safety and Health Incidents'

OUR MISSION

'Continually Improve the Safety and Health Standards and

Practices in the Explosives, Gas, Petroleum and Mining industries'

This plan is achieved primarily through mine and quarry site inspections within Queensland. The fundamental aim of these inspections is to assist our customers, at the mine and quarry operations, achieve a standard of safety and health within the mining industry that is incident and accident free.

Executive summary

This is a non-technical paper that describes the re-engineering of part of the business process of conducting mine and quarry inspections by the MI. Until recently, mine/quarry inspections were for the large part unstructured in nature and not formally scheduled. The MI management team in Mount Isa, led by the District Inspector, recognised that the inspection resources of the MI could be managed more effectively if it developed and implemented a suitable system of control. A system was required that would demonstrate that all the pertinent areas of mine/quarry operations, were being appropriately inspected and monitored.

Reviews of the MI have also been conducted through the Australian Business Excellence Framework. One common issue recognised through this forum is that relations and interactions with the mine and quarry operations during inspections, and the people, who operate them and work there, must continually improve.

A system of structured audits and inspections have been developed in response to addressing the issues of customer relations and management of the mine inspection process. The issues discussed in this paper include short descriptions of the previous inspection process, attributes of the new system of inspecting mines and the benefits for the MI and their customers.

Previous inspection process

Prior to the introduction of the Mining Quarrying Safety and Health Act (MQSHA) in early 2001 the Mines Regulation Act 1964 (MRA) and the Metalliferous Mining Regulations 1985 were in force.

This legislation was prescriptive in nature and in many circumstances required an inspector to provide 'approval' for a particular activity or piece of plant to be used and operated on a mine/quarry site.

This led to many of the inspections undertaken by inspectors being focused on ensuring that compliance with the legislation or particular conditions relevant to an approval were maintained.

Many inspectors developed notable expertise within their field or discipline and focused mainly on these areas during their inspections.

This ensured a high level of compliance in those particular areas but other areas of the operation were not as thoroughly audited.

There was also potential for inconsistency to develop when an inspector provided approval for an issue, activity and/or conducted an inspection outside their area of expertise.

It was recognised that the variance that sometimes resulted between inspections was an opportunity to capture and combine the expertise of all inspectors in a manner and format that would eliminate, as far as possible, the inconsistencies.

Mine record entries

At completion of a mine/quarry inspection, an inspector will make a written report within the mine record. The report is a summary of the inspection that may include statement/s directing the mine/quarry to undertake corrective action of one kind or another to address non-conformance identified by the inspector.

If a review of the mine record was conducted at a later date it was often difficult to determine exactly what activities, what sections of the operations and to what depth the inspection had encompassed.

The greater the length of time between when the inspection had taken place and when the review occurred, the greater the difficulty in determining exactly what had occurred.

This meant that it was also difficult to determine whether all areas of a mine that required inspection were being appropriately monitored.

A process was required that would permit an inspector to review previous inspections and understand completely the nature and depth of activities conducted by him/her thus overcoming the obscurity inherent in the mine record entries.

At the same time this was considered it was believed that the quality of inspections could improve if they were better able to detect non-conformance.

It was decided that this could be achieved by refocussing inspections on narrower fields and activities as opposed to attempting to inspect too much in one inspection.

Safeguard and introduction of structured inspections

A change in focus of the activities undertaken by MI also occurred following the introduction of the MQSHA in 1999.

The current legislation is less prescriptive and is performance based. Mines/quarries with more than ten persons are now required to develop and implement safety management systems to control risk of injury to personnel.

Inspectors were no longer required to issue approvals and the MI now has to refocus to a large degree on how effectively mines/quarries are controlling risk and re-configure its inspection procedures accordingly.

An excellent auditing process known as 'Safeguard,' implemented in the mid 1990s, is used to review safety and health management systems and risk management performance on mine/quarry sites in Queensland. While Safeguard effectively audits higher-level systems and policies it cannot be used to review every facet and level of an organisation's activities.

This would be impracticable, as it would take a team of inspectors weeks and possibly months to complete such a review.

However a system of lower level inspections that combines the expertise of all inspectors, conducted infrequently throughout the course of 12months, in a structured format and manner can be used to comprehensively inspect all pertinent areas of a mine/quarry operation.

Review of activities

The Safety and Health Division of the then Department of Mines and Energy adopted the Australian Business Excellence Framework in 1997 and reviews of the MI have been conducted annually.

This process has highlighted a number of areas where improvement can be made, one particularly area is customer focus.

The management team of the MI within the Mount Isa District began to review its activities in early 2001.

Reviews were focused on how the effectiveness, value and consistency of the inspections being undertaken could be improved. In particular how these

Table: 1 Table from Emergency Procedures Proforma

ITEM						
EMERGENCY PROCEDURES ALL MINES	**Yes**	**No**	**P**	**F**	**G**	**OBSERVATION**
1. Is there a documented emergency response plan? **Part 5-35.1R**						
2. Was the overall emergency response procedure and system subjected to a formal risk assessment during development for all foreseeable emergencies per requirements of section 32? **Part 5–32.1R**						
3. Does the risk assessment consider the following: 1. Coordinating control of emergencies? 2. Giving notice, information and warning about emergencies? 3. The immediate availability of trained rescue persons or emergency services? 4. Locating and accounting for persons? 5. Controlling or re-establishing control of the hazard causing the emergency? 6. Isolation of the area including cutting of supply of energy to the area of the incident? 7. Emergency egress and evacuation, including refuges? 8. First aide and persons trained in first aid? 9. Liaising with and using local or state emergency services? 10. Back up services and facilities for the emergency**?** **Part 5-32.2R**						
4. Has the mine ensured that it has all of the resources, facilities and procedures identified in the risk assessment available and in place? **Part 5—33R**						
5. What inspections are carried out on the emergency response facilities? **Part 5-40.1R**						
6. Is there a formal review of actual emergency performance? How often does the mine test and review its emergency response plan? (should be annually 40.2.a) **Part 5-40.2R**						

could be better aligned with the MI's vision and mission and address the legacies present in the inspection procedure at the time.

It was unnecessary for inspections to be structured or pointed while the prescriptive MRA was in force, however mines/quarries now wanted assistance in understanding their obligations under the new MQSHA and improving their safety and health management systems.

One of the key developments to address all these issues was the introduction of the structured inspection process.

A process that addresses all the concerns of obscurity in mine record entries, varied expertise of inspectors and a way in which all facets of an operation can be inspected.

Structured inspections

The first change implemented by the MI was to introduce the structured inspection process and support it with documentation.

These auditing tools are benchmarked against the Queensland mining legislation, Australian Standards and good industry practice to provide a system of inspections that ensures consistency amongst inspections and inspectors.

In Table: 1, a section of the emergency response proforma has been reproduced to display the format that these structured inspections undertake.

In column one of Table: 1, reference to the relevant section of the MQSHA legislation is denoted at the end of each question. The table also includes columns for making a value judgement about the degree of compliance, ie poor, fair and good (PFG).

A notification may be issued to the mine/quarry informing it that corrective action should be taken to rectify a substandard condition or practice.

If compliance is non-existent a directive will be issued to the mine/quarry being audited.

In summarising, the purpose and intent of the structured inspection philosophy it is to provide a way to review a pre-selected section of the safety and health management system, examine documentation and then verify that the mine/quarry is in compliance with legislation and its own procedures through conducting physical inspections of activities and the operations.

All regions within the state of Queensland have developed these tools in the past however they were tailored to suit the mines in the district they were created in.

Furthermore it was thought expedient that a suite of proformas be developed for all the critical processes and hazards as opposed to having only a few strategic ones. A total of 36 proformas (elements), outlined in Table: 2, have been identified to date and developed under the five broad categories of mining, mechanical, chemical, electrical and general.

The frequency of when an element should be inspected at a mine has also been considered using the utilitarian principle.

For example higher level audits pertaining to ground control and winding operations are tentatively flagged at four yearly intervals. Lower level inspections, such as heat stress measurements and development mining, are to be conducted more than

Table: 2 Elements of Structured Inspections

	CATERGORY				
	MINING	MECHANICAL	ELECTRICAL	GENERAL	CHEMICAL
ELEMENT	Development mining	Cranes Fixed and Mobile	Plant Equipment	Emergency Procedures	SXEW Plants
	Ground Control	Fuel and Oil Storage	Sub Stations and Switch Rooms	Project Management & Contractors	Smelting
	Production	Forklifts	Motor Control Centres	Exploration	Concentrating
	Transport and Haulage	Crushing and Conveying	Bore fields	Warehousing	Sulphuric Acid
	Remote Control Equipment	Workshops and Maintenance Services	Power Generation and Distribution		Reagents and Chemical Batching
	Explosives Storage and Transport	Vehicle Management Systems	Accommodation Facilities		Leaching
	Ventilation and Working in Heat	Structural Inspection	Welders		
	Hoisting and Shaft Inspection		Pump Stations Workshop Installations		
	Backfill		Trailing Cables and DCB's		
			Mobile Electrical		

twice a year.

The frequency of when the element should be re-inspected is determined by considering the degree of risk, the sustainability of the systems of control and how well a particular mine is managing the risk associated with that element.

It is believed by the MI that the majority of activities, issues and hazards have been adequately covered by all of the elements described in Table: 2, however they are under constant review and will be added to and modified as required.

Immediate customer benefits

The tangible benefits for our customers through the use of structured inspections have been the capacity to assist mines/quarries in identifying non-conformances and hence reduce and manage risk associated with the elements being audited.

Feedback from the industry, to date, has been mostly positive and there have been requests for the MI to hand out the information detailed in the proformas.

However the MI believes that releasing these documents to the industry would encourage some of our clients to only manage safety and health at the level the proforma is defined at rather than allowing them the opportunity to improve the safety and health standards through their own systems.

Record of inspections

In order to ensure that all elements were being inspected at appropriate intervals it was necessary to begin to record them. It should be noted here that Lotus Notes remains the network database platform used for management of statutory information and mine records for the MI, however, it is not presently configured to capture and display information in a format that permits identification of the previously mentioned limitations with mine record entries.

There are approximately 580 inspections to conduct in the Mount Isa District if each element pertinent to a mine/quarry is inspected.

To manage such a large number, recognising that the frequency of when an element should be inspected varies from mine to mine and throughout the duration of one year, a database was developed in Microsoft Excel named the ‘Inspection Performance Database’ (IPD).

A section of the database is duplicated below in Table: 3. The database includes provision for input of information pertaining to the date and type of inspection performed by the inspector.

Note that, the table also includes hyperlinks to the relevant proforma documents making the database a one-stop shop. It includes a risk matrix rating that will be discussed later.

The next stage of the process in managing the large number of structured inspections to be conducted, amongst seven inspectors, involved scheduling activities. Our customers again were considered in this process. It was decided by the MI in Mount Isa to observe a protocol, where possible, of ensuring during scheduling that each major entity, quarry or mine is inspected at least once a month.

Microsoft Excel has been used quite effectively to address this issue by providing a database that can produce schedules which ensure timely intervals between inspections and that appropriate elements are inspected.

Table: 3 Inspection Performance Database (RIPS) Scheduling

ELEMENT	Ground Control	Explosive Storage/ Transport
Frequency Of Inspection per annum	0.25	1
Structured Inspection Proformas	Ground Control	Explosives Storage 1.doc

MINE

Mine 1					13	3	18			18
Risk Matrix Index		Inspection progress			Date	Person	SA/SI	Date	Person	SA/SI
Ranking	Score	No of SI's Completed	No of Investigations Completed	No of SA's Completed						
23	7	11	1	2						
Structured Inspections Per Annum for the Individual Mine					0.25			1.00		

Quarry 2										
Risk Matrix Index		Inspection progress			Date	Person	SA/SI	Date	Person	SA/SI
Ranking	Score	No of SI's Completed	No of Investigations Completed	No of SA's Completed						
22	11	6								
Structured Inspections Per Annum for the Individual Mine					0.25			1.00		

Prior to the use of formal inspection schedules mines/ quarries could be inadvertently inspected two or three times a week by different inspectors. Mine management could find this to be disruptive especially in light of the fact that a lot of inspections are not announced to the mine.

The MI will notify a mine/quarry in most cases of its intention to conduct an inspection however there are times when a surprise inspection will be carried out. Mines/quarries need notification of higher level audits so that documentation and people can be prepared and provided accordingly.

However while mines/quarries may often be notified of the intention to inspect, the element or the content of the inspection might not be revealed.

Inspectors enter data into the IPD relating to the date and element inspected.

Formulas and macros within Microsoft Excel are used to transform, what was once a full day's activity of scheduling one month worth of inspections for seven inspectors, into a 15-second process.

Risk matrix index

Prior to the development of the IPD the Technical Services Branch (TS) of the then Department of Mines and Energy had developed a risk matrix index (RMI) for all mines and quarries within the state.

The TS determined that a risk management process would be used to evaluate the safety performance at mine sites for the purpose of enabling the MI to schedule and deploy its inspection/auditing resources more effectively.

Mines and quarries are rated in the RMI on a scale in terms of risk associated with the operations.

The overall site surveillance rating for any particular mine or quarry is obtained from objective and subjective analysis of safety and health management performance and inherent mine hazards on that site.

For example an underground mine is presumed to have a higher amount of residual risk because of the nature of its operation as opposed to an open cut operation.

However an underground operation may conduct very effective accident/incident analyses and score better overall than an open cut operation that does not do as good as investigations despite its inherent nature.

Note that, this is one of the many performance indicators that are considered during evaluation of a mine or quarry's safety and health performance in the RMI.

The RMI is reviewed at timely intervals and therefore the rating of an operation's safety performance will change over time as improvements are made.

One of the most powerful indicators that the RMI can demonstrate is the overall performance of the mining industry's safety performance. The RMI combines traditional indicators such as lost time injury and fatality rates with positive performance indicators to provide an overall rating score.

The RMI and the IPD are legacies brought about by the initiatives of the MI and TS in the endeavour by both parties to enhance its inspection performance and achieve the mission and vision goals of the MI.

They remained two distinct systems for a period of time and were not greatly utilised. Both of these systems were integrated in early 2002 in order that the benefits of both might be realised.

The combined database is known as the Risk Based Inspection Performance and Scheduling Database (RIPS).

The result is a database that schedules activities (structured inspections) based on the risk score evaluated in the RMI, the degree of risk associated with the element being inspected and how well an operation is managing the risk associated with the element.

Summary of benefits for mi and customers

The RIPS is a database that is used for decision support, management of information and automation of scheduling activities.

Through RIPS and the business process described a system has been developed that:

- Permits demonstrable performance of inspection progress
- Enables manageable scheduling of activities
- Identifies objectively the resource requirements required for the MI to achieve its objectives under the MQSHA
- Comprehensively audits safety and health performance on mine and quarry sites hence, ensuring risk is being appropriately managed
- Protects the MI to a degree from loss of corporate memory
- Assists the MI to achieve its mission statement and hence many other attributes associated with good sound business management practice

For customers it has enabled the following:

- It has created a mostly non-disruptive inspection routine
- Assists clients in identification of non-conformance
- Allows contribution towards improvement of a mines Safety and Health Management System
- As a whole of government initiative it contributes towards a safer and healthier industry for people to work in

Future direction

Although the RIPS system and its associated documentation is only relatively new it is based on a quality process and as such is subject to continual review and improvement.

The potential use of Arcview, a Geographical Information System (GIS), to further enhance the user interface with the RIPS will be explored in the future.

It is envisaged that Arcview can be used for visual representation of database information that has been collected for RIPS.

As mines sites move towards full compliance with the legislation there will be an opportunity to introduce other elements into the structured inspections. As already discussed the concept of continuous improvement is inherent in the mission statement of the MI within the NR&M.

Secondly the inclusion of continuous improvement elements in the structured inspection document will enable the MI to identify areas in mine site safety and health management systems where improvements can be made and encourage the mines to refine the application and approach of their systems towards best practice.

Part of this process will include expansion of the number and scope of the structured inspections.

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HEARTS, HEALTH AND COAL MINING

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Abstract

An increased risk of death from heart attack has been identified in coal miners in the United States. The prevalence of coronary heart disease and the effect on the mortality rate of Australian coal miners has not been previously investigated.

This project examined the question as to whether there is an increased risk of coronary heart disease in the coal mining industry by determining the mortality rate for Australian miners associated with heart disease, and level of risk associated with the work and lifestyle risk factors associated with heart disease in the coal mining industry.

A number of factors are present in the coal mining industry that are known risk factors for cardiovascular disease and coronary heart disease and these are present at a higher level than the general population.

The increased risk has not resulted in an increased mortality rate. The current mortality data is based on historical data and the future may present a different scenario. Monitoring of the risk factors needs to continue to enable continued benchmarking with the general population.

Introduction

Based on death certificate data from NIOSH's National Occupational Mortality Database, coal miners in the United States appear to have an elevated risk of death from coronary heart disease, specifically heart attacks (NIOSH, 2001). There was not an overall increase in risk from cardiovascular disease generally.

The prevalence of coronary heart disease and the effect on the mortality rate of Australian coal miners has not been previously investigated. This project was funded by the Joint Coal Board (JCB) Health and Safety Trust.

Methodology

The aim of this project was to determine the mortality rate for Australian coal miners associated with coronary heart disease (CHD), the current prevalence of CHD disease, and examine the work and lifestyle risk factors associated with CHD.

CHD is a generic term describing disease that results from insufficient blood flow to the heart caused by the narrowing of the coronary arteries due to atherosclerosis. Acute myocardial infarction (AMI) is the most severe form of CHD and occurs when the heart muscle is damaged as a result of a sustained blockage in a coronary artery.

There were four stages in the project:

1 establishing the mortality rate from heart disease data for coal miners
2 establishing the current incidence of heart disease
3 identifying the risk of heart disease associated with lifestyle factors
4 identifying the risk of heart disease associated with work related factors.

1 Mortality and heart disease

A retrospective study was undertaken to identify the mortality of coal miners from heart disease through analysis of the Australian Institute of Health and Welfare (AIHW) data. This was compared to the general population mortality data.

2 Incidence of heart disease

The data currently held in the Queensland Coal Mine Employees Health Database and the JCB was examined to provide comparison of the physiological indicators of heart disease with the general population. These indicators included:

- blood pressure
- BMI (BMI)

3 Lifestyle factors

Information on lifestyle factors affecting the risk of heart disease available from projects and published information was analysed (Parker et al, 1996; Harris et al, 2000; Bofinger and Mahon, 2001) eg:

- exercise
- stress
- diet
- smoking
- alcohol abuse.

4 Work related factors

Work-related factors influencing the risk of heart disease were analysed. These included:

- exposure to atmospheric contaminants eg dust
- shiftwork
- noise.

Heart disease – general population

Through the 1970s and 1980s, heart disease data was collated by the National Heart Foundation (1990) in their efforts to make the Australian public more aware of the widespread occurrence of heart disease. More recently, the AIHW (2001) has taken the lead in compiling and publishing data on heart disease and health issues generally.

Coronary heart disease was the major cardiovascular cause of death and was the largest single cause of death in Australia (AIHW 2001). It consists mainly of acute myocardial infarction (heart attack) and angina.

Overall, males were almost twice as likely to die from coronary heart disease as females in 1998, with males aged 25-64 having death rates three to five times those of females. Non-fatal heart attacks were three times more common among men than women in the 35-69 age group (AIHW, 2001).

When comparing Australian data with the data available from other countries, Australian death rates from coronary heart disease rank towards the middle of the countries compared (Figure 1).

Factors affecting heart disease

Risk factors are defined by the AIHW as determinants, characteristics or exposures that are associated with a greater risk of ill health. For all types of cardiovascular disease they include genetic, behavioural and physiological factors.

The behavioural risk factors can influence physiological risk factors eg poor diet and physical inactivity can lead to being overweight or obese, having high blood pressures and high blood cholesterol.

Increasing age and being male increase the risk of coronary heart disease.

The preventable risk factors for coronary heart disease are:

- tobacco smoking
- high blood pressure
- high blood cholesterol
- overweight and obesity
- insufficient physical activity.

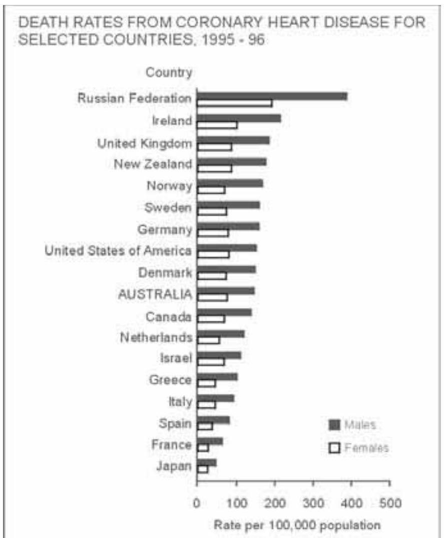
Dietary factors and diabetes have also been associated with a higher risk of coronary heart disease.

There is also evidence that social, economic and environmental factors can contribute to disease.

Social and economic factors

Marmot (2000) showed that a dominant feature of the occurrence of cardiovascular disease in most industrialised societies is the higher rate of heart disease in people of a lower socio-economic position.

Figure 1



Note: Death rates have been standardised to the 2000 WHO standard population.

Sources: WHO 2000; AIHW National Mortality Database.

Factors may include material depravation, standing in society, power relationships and education relating to health and nutrition. Wlazelek (1999) reported that in Pennsylvania, heart disease rate was 145.7 deaths per 100,000 after age correction compared with 134.5 per 100,000 in the general US population.

Factors that were suggested as affecting this rate included mining associated health issues, smoking, eating fatty food, insufficient exercise, high blood pressure, high cholesterol and poorly treated diabetes.

Environmental factors

Particulate matter (PM) in ambient air is a complex mixture containing particles of different sizes and chemical composition. Epidemiologic studies have described an association between increases in cardiovascular morbidity and mortality and short-term increases in ambient PM – particularly fine particulates with aerodynamic diameters of <2.5 Fm, $PM_{2.5}$ (US Environmental Protection Agency, 1996). Cardiac morbidity and mortality have been associated with daily variation in the concentrations of particles lower than 30-50 Fg/m^3.

Work related factors

In a review of the literature linking workplace factors to cardiovascular disease, Steenland (2000) noted that risk factors included:

- stress
- shiftwork
- heat, particularly above 27°C
- noise
- numerous chemicals that have some direct effect on the heart function.

As previously discussed, particulate matter also has an impact on the risk of coronary disease.

Analysis and results

Limitations of analysis

There are limitations to the analysis of the mortality data that need consideration. These include:

- The difficulties encountered in the initial matching of the coal miners data with the AIHW data. This resulted in 3049 New South Wales records and 276 Queensland records being disregarded.
- The analysis completed includes the deaths from 1996 to 2000. These years were chosen as reliable death data and miner data was available for both Queensland and New South Wales. This does result in a relatively small number of deaths per year per age group. The coal mining death rates over that period are compared to the 1998 death data from the AIHW.
- The AIHW information is based on the surviving population. It was not possible to establish a surviving population for the coal mining industry. The coal population analysis is based on state records. The birth cohort for each age group was the basis of the rate of death analysis. This will result in a lower death rate per 100,000 when compared to the AIHW data. The difference will become more noticeable in the older age groups.
- Workers tend to be healthier than the general population – the 'healthy worker' effect. This will also affect the mortality rate compared to the general population.

All causes of death

Data of cause of death is shown in Table 1. Deaths from diseases of the circulatory system in the NEW SOUTH WALES population are comparable to the national average.

In Queensland, deaths from diseases of the circulatory system were 26 percent compared to the national population at 40 percent.

Cardiovascular and coronary heart diseases

Coronary heart disease and stroke are the most common fatal cardiovascular diseases. Queensland and New South Wales data for coal miners matches closely that provided by the AIHW as shown in

Figure 2 and does not indicate an increased risk of coronary heart disease. The test of proportion did not show any statical difference between the coal mining and general populations.

Analysis of health database medical factors

Data from the state databases on blood pressure and BMI were analysed to estimate the incidence of cardiovascular and coronary heart disease risk factors.

High blood pressure

There is considerable difference in the incidence of high blood pressure between the mining community and the general community as shown in Figure 3.

The World Health Organisation definition of high blood pressure was used ie:

- Systolic blood pressure $140 mmHg; and/or
- Diastolic blood pressure $90 mmHg.

Overall, both Queensland and New South Wales miners show significantly higher percentages of the population with high blood pressure. Using the test of proportions, the difference is statistically significant in all cases, except for Queensland routine and entry, 55-64 age group.

Of particular concern are the high percentages of high blood pressure for the initial medicals in New South Wales. The reason for this high rate is not obvious and is currently being investigated.

BMI – overweight and obesity

BMI is used as an indicator to assess if a person is overweight or obese. Figure 4 shows that in all age groups, a higher percentage of coal miners are overweight than the same age groups in the general population.

The difference between the mining population and the general population is statistically significant using the test of proportions. There is generally no statistically significant difference between entrants, miners or contractors.

Lifestyle factors

Physical activity

The level of physical inactivity was compared to the general population. Physical inactivity was defined as not participating in some form of exercise for at least 20 minutes more than twice a week. Results are shown in Table 2.

Levels of inactivity in the mining industry do not include any physical activity undertaken for work purposes. The coal industry results are comparable with the general population.

Table 1
Coal Miners – All Causes of Deaths – 1996 to 2000

ICD Code Number	Cause of Death Category	NEW SOUTH WALES Number of deaths	QLD Number of deaths	NEW SOUTH WALES % of deaths	QLD % of deaths	Australian Population* % of deaths
II	Neoplasms	987	113	34	39	27
IX	Diseases of the circulatory system	1111	75	38	26	40
X	Diseases of the respiratory system	280	12	10	4	10
XI	Diseases of the digestive system	80	8	3	3	3
XIV	Diseases of the genitourinary system	36	2	1	1	2
XVI	Peri-natal Conditions	0	0	0	0	0
XIX	Injury etc – external causes	117	37	3	13	6
XX	External causes of morbidity and mortality	66	29	3	10	(combine XIX and XX)
	All Others (to compare AIHW)	213	16	7	6	10
Total	All classes	2890	292			

AIHW, 1999

Alcohol use

Hazardous alcohol use is based on five or more drinks for five or more days per week. The level of hazardous alcohol use in the general population is 8 percent (AIHW, 2001). The results for the coal mining industry are shown in Table 3.

The overall level of hazardous alcohol use in the mining industry is consistent with the general population level of 8 percent. Of concern is the high level of hazardous use of alcohol in the 18-24 age group.

Tobacco smoking

Smoking levels in the mining industry and the general population are shown in Table 4. Smokers are defined as current or occasional smokers. The Queensland medicals have self-reporting questions on smoking. The data from these medicals was included and is consistent with the data from the lifestyle questions from the other projects.

Diet and nutrition

The NHMRC Dietary Guidelines (1998) recommend the following:

- Vegetables 4 serves daily
- Fruit 3 serves daily
- Grains and cereals 5+ serves daily
- Fats and sugars # 2 serves daily

Based on these recommendations, the coal miners maintain a reasonable diet. Increase in the amount of fruit and vegetables, and grains and cereals, would improve the diet. The results of the questionnaires did not provide information on the total intake for a day.

Occupational factors

Noise exposures

Noise exposures in coal mining are controlled by regulation in Queensland and New South Wales.

In Queensland and New South Wales, legislation refers to the National Standard for Occupational Noise (NOHSC:1007). This specifies a daily noise dose equivalent to 85dB(A) and a peak at not more than 140dB(lin).

From surveys undertaken by Simtars (unpublished data), the following average results can be shown

Figure 2

Distribution of Deaths from Cardiovascular Disease

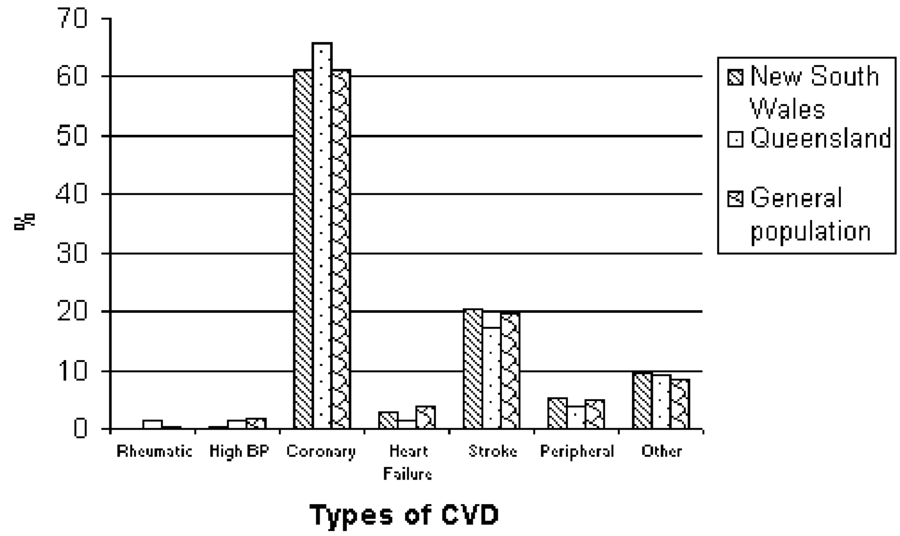
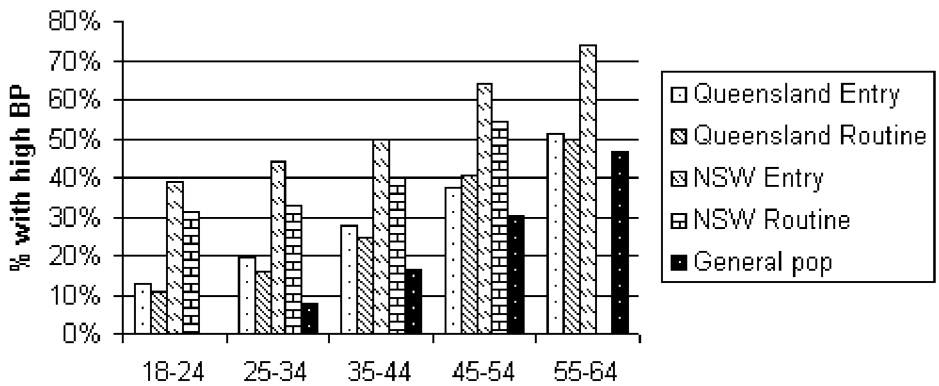


Figure 3

Incidence of high blood pressure



(Table 5).

These levels indicate that noise levels could contribute to the incidence of CHD in the mining industry.

Dust exposures

The average percentage of particles of PM<2Fm generated during coal mining has been estimated at between 1-3 percent of respirable dust when no diesel particulates are present (Burkhart, McCawley and Wheeler, 1987: Unsted, 1996). Data to estimate the PM<2.5 is not available.

Using 2 percent as a working figure, the average exposures of miners to particulate matter of < 2Fm are shown in Table 6.

The limitations of such 'averaged' data are acknowledged. It does, however, indicate that the levels of particulate matter to which underground workers are exposed could increase the risk of coronary heart disease.

The use of diesel equipment underground could increase the level of particulate matter <2Fm.

Shiftwork

The coal mining industry has a high level of shiftwork with > 80 percent of workers working some form of shift arrangements (Department of Natural Resources and Mines, 2001). Results from investigations into shiftwork in the coal industry (Bofinger and Mahon, 2001) have shown that 10-20 percent of shiftworkers have problems balancing work, family and social life. This is shown in Figure 5.

Heat

Surface and underground mines are required to manage exposure to heat. The *Queensland Coal Mining Safety and Health Regulations* (2001), Chapter 4, Part 12 Division 2 – Heat Stress Management, calls for heat to be managed in underground coal mines if the wet bulb temperature exceeds 27°C and work to cease if the wet bulb temperature exceeds 29°C. Surface mines are required to have heat management procedures in place.

As limited data is available to determine the exposure of coal miners to heat, it is not possible to estimate the contribution of heat exposure to the incidence of coronary heart disease.

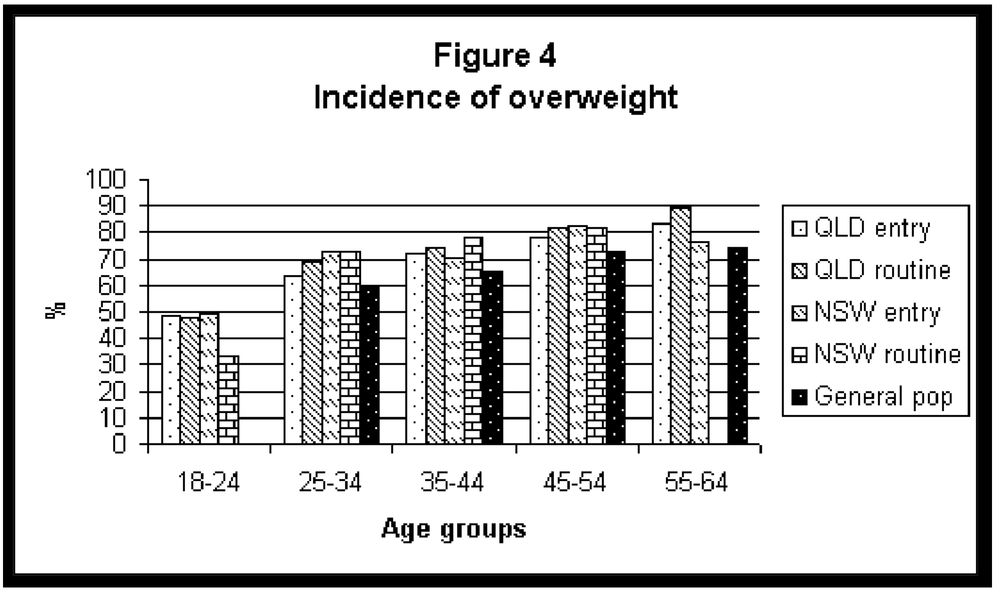


Figure 4
Incidence of overweight

Table 2
Levels of Physical Inactivity

<table>
<tr><th>Population group</th><th colspan="2">18-29</th><th colspan="2">30-44</th><th colspan="2">45-59</th><th>60-75</th><th>18-75</th></tr>
<tr><td>General population (AIHW, 2001)</td><td colspan="2">31.3%</td><td colspan="2">46.5%</td><td colspan="2">50.0%</td><td>46.0%</td><td>43.3%</td></tr>
<tr><td></td><td>18-24</td><td colspan="2">25-34</td><td>35-44</td><td>45-54</td><td colspan="2">55-64</td><td>Overall</td></tr>
<tr><td>Coal Mining - all groups</td><td>28%</td><td colspan="2">40%</td><td>45%</td><td>43%</td><td colspan="2">49%</td><td>42%</td></tr>
</table>

Table 3
Levels of Hazardous Alcohol Use

Population group	**18-24**	**25-34**	**35-44**	**45-54**	**55-64**	**Overall**
Coal Mining – all groups	28%	6%	5%	4%	3%	7%

Cardiotoxic compounds

Levels of carbon monoxide and other atmospheric contaminants are regulated by legislation in both Queensland and New South Wales.

The level of atmospheric contaminants regulated for and experienced in coal mines is unlikely to affect the incidence of heart disease.

Conclusions

The results of the analysis show there is no statistically significant difference between the death rate from coronary heart disease for the coal mining industry in New South Wales and Queensland and the general population.

The distribution of the types of cardiovascular disease is consistent with the distribution in the general population.

The Australian coal mining population does not appear to have an increased risk of death from coronary heart disease. The situation in Australia does not appear to reflect the problem identified in the United States of America

There are however, a number of factors that indicate that an increased risk could be expected in the future. These risk factors include the results from the comparison of blood pressure and BMI that are in turn influenced by lifestyle factors.

The long-term nature of lifestyle changes that are needed to modify health risk factors indicates that health promotion needs to be considered as a long-term project.

There are work related factors associated with coal mining that have been shown to increase the risk of heart disease. Dust and noise exposures have been present in the coal industry for considerable time and are more controlled than in past times. There has been an increase in shiftwork in the mining industry.

In addition, there are other factors known to influence the risk of heart disease that were not considered. These include genetics, socio-economic factors and the direct influence of stress.

The inter-relationships of the factors affecting heart disease demonstrates the complexity of the issue.

It is of concern that there are a number of

Table 4
Smoking Status

Population group	18-24	25-34	35-44	45-54	55-64	Overall
General population	39.3	38.3	27.5	28.9	29.3	30.2 (25+)
Coal Mining – all groups	21	28	30	26	16*	27
Data from QLD medicals	30	32	28	22	15	27

Table 5
Noise Exposures exceeding 8 hour dose equivalent to 85 dB(A)

Sector	Measurements exceeding Regulatory limits
Underground Coal	>40%
Surface Coal	>20%

Table 6
Dust Exposures of Miners

Sector	Average respirable dust levels mg/m^3	Average levels of < 2Φm Φg/m^3	Data Source
NEW SOUTH WALES underground	1.5	30	Kizil and Donoghue, 2001)
NEW SOUTH WALES surface	0.6	12	Joint Coal Board, 2000
QLD underground	1.9	38	Bofinger, Cliff and Tiernan, 1995
QLD surface	<0.4	<8	Unpublished data, Simtars

factors in the coal mining industry that are known risk factors for CVD and CHD and these are present at a higher level than the general population. The current mortality data is based on historical data and the future may present a different scenario. Monitoring of the risk factors needs to continue.

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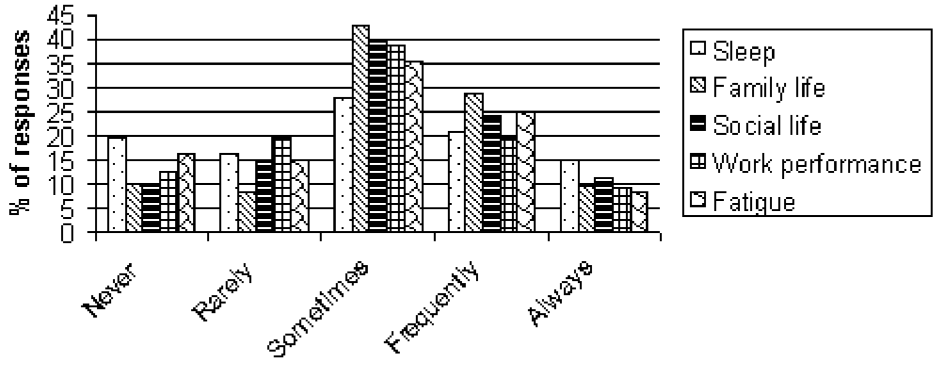
Figure 5
Problems with Shiftwork



The management of

HEALTH AND HYGIENE AT QUEENSLAND FERTILIZER OPERATIONS

M D WickingOccupational HygienistWMC Fertilizers

Executive summary

Queensland Fertilizer Operation (QFO) is a world class high analysis fertiliser manufacturing plant in North-West Queensland operated by WMC Resources.

The complex processing plant poses occupational hazards as diverse as gaseous fluorides, sulphur dioxide, sulphuric acid mist, inspirable dust, respirable quartz and noise.

To accurately determine the risk posed by these hazards QFO has collaborated with James Cook University (JCU) to develop a long term three phase program.

JCU began by undertaking an exercise that combined employee health assessments, an environmental contaminant sampling survey and employee focus groups.

This provided a baseline understanding of employee health and an indication of atmospheric conditions. Phase II and III will involve biological monitoring and will establish methods to reduce identified risks.

In addition QFO completed a baseline health survey according to the WMC Health Impact Standard.

This survey involved employee interviews and task observations to identify chemical, physical, biological and ergonomic workplace hazards.

This combined approach enabled QFO to confidently design a routine sampling program for all atmospheric contaminants.

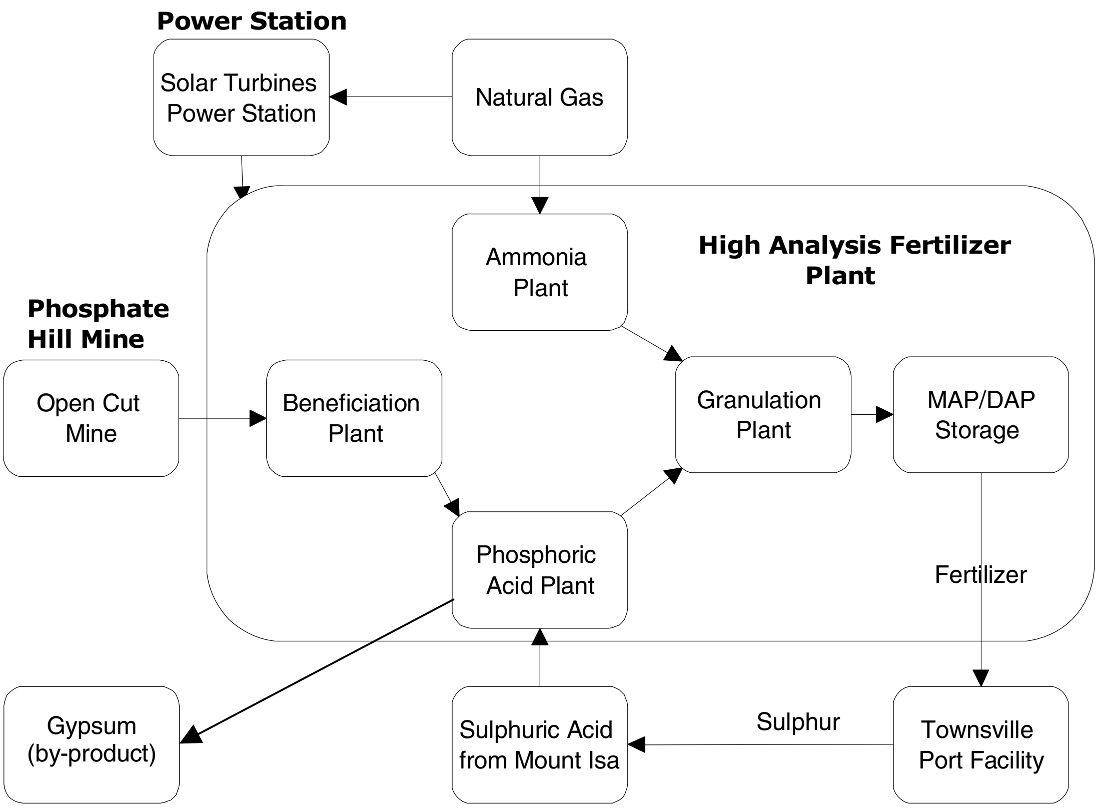
The results of this monitoring are compared to exposure standards documented by the National Occupational Safety and Health Commission (NOHSC) to determine risk for each identified work group.

Statistical tools are applied to the results to determine the potential for resultant health effects and the effectiveness of the program.

Introduction

Queensland Fertilizer Operations is a fully integrated operation owned and operated by WMC Resources encompassing three sites in North Queensland. WMC Resources also owns world class operations in Nickel

Figure 1 – Schematic of Queensland Fertilizer Operations



and Copper-Uranium. QFO is consists of Phosphate Hill, an open cut mine and fertiliser manufacturing facility, an Acid Plant in Mt Isa and a materials storage and handling facility in Townsville. The Operation is detailed in the schematic in Figure 1.

The very nature of these operations has the potential to cause harm to health. The most significant health issue at Phosphate Hill is the emission of gaseous fluorides. The primary sources of these emissions are the Phosphoric Acid Plant (PAP) and the Gypsum stack. Fluoride is released from the phosphate rock ore after the addition of sulphuric acid in the PAP. The fluoride is scrubbed during this process using a wet scrubbing system. A by-product of this is gypsum which is stacked on site in lined dams. Traces of fluoride remain in the impure gypsum.

The management of the more 'typical mining' health risks of respirable quartz and noise is also required at Phosphate Hill. Sulphur dioxide emissions in Mt Isa pose a potential health risk to employees at the Sulphuric acid Plant. These risks were being well managed by QFO but it was decided to go one step further to ensure the long term health and wellness of all employees. This holistic approach to health and hygiene will improve employees lifestyle as well as their occupational health.

Health and Hygiene at WMC

Recently WMC undertook a company-wide review of its health risk management processes.

Following the review, a structured risk management system specifically designed to guide the management of health risks at sites was developed.

The management system now incorporates the standard risk management principles of Australian Standard AS 4801 ' Occupational health and safety management systems - Specification with guidance for use' .

The management system utilises risk management processes which constitute industry best practice. This ensures the application of due diligence in the day to day management of health risks, while at the same time providing the basis for sound corporate governance in relation to the management of health in WMC.

Fundamental to the effective management of risks is the identification and evaluation of those risks. This requires not only the identification of hazards but also:

- the definition and application of risk assessment strategies
- the development of acceptable risk criteria
- the application of decision logic based around those acceptable risk criteria
- the application of control measures to eliminate or mitigate risks
- the evaluation of the effectiveness of those control measures.

WMC recently implemented the initial phase of such a risk management process across all of its Australian operations with the application of a structured and comprehensive hazard identification and risk assessment process.

Health hazards at sites were identified through a team based health hazard identification and documentation process. This was facilitated by external and independent occupational hygiene consultants, in conjunction with key site personnel, including operators, and specialist health and hygiene personnel.

The consultants identified health hazards through task observation, then applied the WMC prescribed risk assessment process in order to prioritise risks for the application of control measures as appropriate.

The risk assessment process also identified those risks which had yet to be satisfactorily characterised, ultimately leading to the development of a health hazard monitoring strategy for sites which was aimed at providing valid data upon which to base subsequent risk management decisions.

Health and Hygiene Management at QFO

QFO recognised from the outset the requirements for a statistically valid routine monitoring program encompassing all potential health hazards.

The sampling program prior to the baseline survey was not considered statistically valid and was primarily based on employee concerns at the time. One reason for this was the unsteady state of the operation prior to mid 2001.

Now that QFO is approaching nameplate production levels it is an ideal time to undertake an assessment of baseline health that could be used to predict future sampling strategies.

The baseline health survey was carried out across all three QFO sites between April and May 2002. The work was completed by Southwest Occupational Health

The Phosphoric Acid Plant at Phosphate Hill

Services, with assistance from the site Occupational Hygienist.

The main objectives of the health hazard survey were to:

- Identify health hazards associated with jobs and tasks on site
- Review previous hygiene monitoring results
- Make recommendations in regards to controlling the identified health hazards
- Make recommendations on further monitoring requirements

The health hazard survey process involved:

- Collection of health hazard information for each job group and task by interviewing members of each occupational group
- Verification and validation of the information collected, by job and task observation
- Statistical review of historical exposure monitoring data
- Development of a monitoring schedule for Phosphate Hill Operations based on the statistical review of previous monitoring data and the information collected during the health hazard survey (Linto, 2002)

The sampling program will assess all the chemical hazards identified and will be statistically interpreted to develop future monitoring and management regimes.

The quota required is 850 samples over the next twelve months. The main samples are dust (inspirable and respirable including quartz), gaseous fluoride (as HF), acid gases, which includes HF, sulphuric acid and phosphoric acid mist, sulphur dioxide and ammonia.

In addition there are also samples for welding fume in the workshop. The samples will be collected by the site Occupational Hygienist with assistance from the Environmental/Health Technician.

The samples are collected in accordance with National Institute of Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA) techniques and analysed in an off-site NATA accredited laboratory.

James Cook University Workplace and Environment Study

QFO first discussed the collaboration with JCU in 2000. Following the original meetings it was decided to approach the work in three phases.

Phase I was designed to establish a baseline of employee health and workplace conditions. Phase II was to introduce biological monitoring and investigate influencing factors while Phase III is expected to run parallel to Phase II and look at ways to work more healthily.

Phase I of this study was conducted between November 2001 and July 2002 and constitutes the baseline survey.

Phase I involved the following components:

Environmental Exposure Mapping

- Comprehensive Medical Check-up
- Health Questionnaires
- Focus Groups on the Perception of Occupational Risks

Environmental Exposure Mapping

The Environmental Exposure Mapping involved ambient air sampling of the following contaminants:

- Hydrogen fluoride
- Sulphuric acid mist
- Phosphoric acid mist
- Ammonia
- Carbon monoxide
- Sulphur dioxide (Mt Isa only)

The sampling was conducted by staff and students of the Department of Chemistry from James Cook University in December 2001. Measurements were taken to look at what's ' out there' .

The samples taken were positional only, no personal samples were taken during this activity. The data collection was undertaken to locate sources and identify general distributions of atmospheric contaminants as opposed to measure/monitor actual exposure.

The main findings of the exercise were that:

- there were significant variations in exposure to potential toxicants observed between groups of employees working in different plants
- hydrogen fluoride, sulphur dioxide and sulphuric acid mist need to be considered in assessing human health risk
- in general, concentrations of chemicals are well below current exposure standards
- The highest concentrations of HF were recorded on the gypsum stack and in the Phosphoric Acid Plant.

The Gypsum stack (as photographed from the Granulation Plant)

These are summarised in the tables .

Medical Check-up and Questionnaire

The Health assessment consisted of the following tests:

- Full blood count
- Liver function test
- Electrolytes and Albumin-Creatinine Ratio (ACR) urine test
- Basic physical examination
- Visual acuity
- Joint mobility
- Blood pressure
- Height and weight

At the same time as the physical assessment participants were asked to complete a comprehensive Health questionnaire which included questions on:

- Demographics
- Medical history
- Risk conditions/behaviours
- Current medications
- Smoking, alcohol and drug consumption
- Diet
- Other symptoms

A response rate of approximately 60% was achieved with 218 staff and contractors participating (Carter 2002). Initial indications are that employee health is more governed by lifestyle factors than occupational exposures at QFO.

This was considered a representative sample considering the availability of the workforce during the assessment period. Absences owing to Annual Leave, R & R, and variations in shift rosters meant that not all employees were on site to participate in the assessment.

The major findings of the survey were that, on average, the results from the workforce were higher than would be expected in the normal population in the following areas:

- Body mass
- Waist to hip ratio
- Blood pressure
- Dehydration

The key now is to improve employee wellness while at work without significantly interfering with their private lives. Dehydration will be investigated further in Phase II of the project with JCU to better understand what employee groups are most affected and how this issue can be better managed.

Employee perceptions

A qualitative research project comprising seven focus groups and one interview was conducted in December 2001 by two researchers from JCU.

The aims of the project were to:

1 Investigate employees perceptions of the types and sources of occupational health and safety hazards at Phosphate Hill;
2 Investigate employees perceptions of the current handling of identified occupational health and safety hazards in general and of the current response to employee concerns at Phosphate Hill;
3 Identify suggestions of employees on how WMC could respond to occupational health and safety hazards at Phosphate Hill and improve conditions/ procedures (Devine 2002).

Common themes identified by the survey were:

- Chemical related issues
- Fatigue & general Fitness for Work
- Drug and alcohol issues
- Management and procedural issues

These issues are currently being addressed by QFO. The focus groups will be repeated regularly to determine how effectively these concerns are being handled. Many of the perceived issues can be addressed by communication and at low cost to the organisation.

Discussion

QFO has already addressed some of the issues

Table 1 – Results from the Gypsum Stack (Ridd, 2002)

	[HF] mg/m^3	[H_2SO_4] mg/m^3	[H_3PO_4] mg/m^3
Maximum value	2.60	0.12	0.06
Median	1.01	0.10	0.00
NOHSC Exposure Standard	2.6	1.0	1.0
Number of Samples	5	5	5
Detection Limit	0.03	0.10	0.03
Number < detection limit	0	3	4

Table 2 - Results from the Phosphoric Acid Plant (Ridd, 2002)

	[HF] mg/m^3	[H_2SO_4] mg/m^3	[H_3PO_4] mg/m^3
Maximum value	2.36	0.73	0.03
Median	0.20	0.07	0.00
NOHSC Exposure Standard	2.6	1.0	1.0
Number of Samples	30	30	30
Detection Limit	0.03	0.10	0.03
Number < detection limit	6	26	29

raised by the baseline health surveys. Trenchsportz, a fitness and lifestyle contractor has been appointed to improve the general health of employees at Phosphate Hill.

Two co-ordinators are responsible for developing fitness regimes for individuals and organising team activities. This combined with WMC's Fitness for Work Policy, (requiring 0.00 % Blood Alcohol Concentration) has improved employee lifestyles while on site.

A thorough sampling program has been designed and will be underway in August 2002. The program requires approximately six samples a day to be taken from a cross section of the workforce.

Over 12 months an accurate exposure profile across all operations and climatic conditions will be obtained.

Personal hydrogen fluoride monitors for Phosphate Hill and sulphur dioxide monitors for Mount Isa have been purchased and are currently being trialled at each site.

If successful more units will be purchased to assist with monitoring requirements. The units are data-logging and alarm when exposed to concentrations above the set limits.

Planning is currently underway for Phase II of the collaboration with JCU. The program will aim to address some of the concerns from Phase I as well as build on the knowledge already gained. Anticipated projects for Phase II include:

- Further Environmental Exposure Mapping
- Further Substance Specific Exposure Matrices
- Repeating the Personal Activity Questionnaire
- Repeating the Comprehensive Medical Check-up
- Focus Groups on the Perception of Occupational Risks
- Biological Monitoring
- Hydration Strategy development
- Fatigue Management Review
- Injury Data Analysis

Conclusion

The challenge of adopting two approaches to the management of health and hygiene at QFO was to not repeat or double the work involved. To date QFO has managed to do that successfully. Our challenge now is to maintain the focus and achieve the targets set by the program.

The successful implementation of the WMC baseline survey combined with the ongoing involvement of JCU will ensure the occupational health of all employees at QFO is maintained at a world class standard.

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A HEALTH PROMOTION PROGRAM FOR YOUR WORKPLACE?

IS IT IMPORTANT AND HOW WILL YOU KNOW WHICH ONE TO CHOOSE?

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Abstract

When considering specific health issues, it is alarming to find that men have the poorest health outcomes when compared to women. Of all occupational groups, male blue-collar workers have the most rapidly increasing incidence of many of these health problems. Statistics also reveal that men have the lowest rates of health service utilisation, generally only addressing acute medical issues.

In response to the latest findings, current occupational health and safety legislation has placed increasing emphasis on work-sites to take a more pro-active approach in regards to employee safety as well as health. In a business climate where emphasis is placed on the bottom line, health promotion programs have often been viewed as expensive and ineffective with limited or no measurable return. Benefits, unless quantifiable in the short term, have been largely overlooked.

Yet, effective health promotion programs have been shown to decrease not only workplace injuries, but also have a flow on effect in reducing employee absenteeism, improving morale and decreasing many major health risks.

Results from longitudinal studies on work-place health promotion programs are beginning to show that the workplace benefits on a number of levels, with not only a safer environment but also healthier employees. This can then impact positively on both productivity and profitability.

There are a number of key factors recurrent in successful health promotion programs. Offering the program to the employee at their workplace and creating it as part of the weekly schedule, increases acceptability and participation.

Success is further enhanced when a program creates an environment conducive to change by encouraging participants to determine their own health goals and using trained health professionals who are specialists in their field to guide them.

Ongoing support and monitoring after the completion of the health program are also key factors in long-term success.

The real choice is not whether to run a health program, but how to determine which of the health programs on offer fulfils proven criteria for long term effectiveness. That program will then be of benefit in meeting both the specific needs of the individual, and the health and safety concerns of the employer.

Health promotion is a social movement of major proportions that has evolved around three related postulates: 1) prevention is preferable to cure; 2) teaching people to stay healthy is generally less expensive than treating them when they are ill; and 3) healthful lifestyles offer improved health, a better quality of life and possible increased longevity (1). Health promotion in the workplace refers to those educational, organisational or economic activities that are based in the workplace and are designed to improve the health of workers, their families and the community at large (2).

Even though a productive organisation may not necessarily be health oriented, it has been established that no organisation can remain productive without maintaining the health, job satisfaction and morale of its employees (1). Accidents, disability, and sick days always involve some readjustments to work schedules that affect entire work organisations. When considering the costs of poor health to business, and the rate at which this is growing, it becomes evident that initiatives need to be taken to stem the growing tide of accidents and injuries and subsequent workers'compensation claims (3).

In a business climate where emphasis is placed on the bottom line, health promotion programs have often been viewed as expensive and ineffective with limited or no measurable return. Yet, a growing body of evidence suggests that successful health programs play a pivotal role in reducing employee absenteeism, enhancing production and morale, and improving the retention of highly skilled staff (2,3,4, 5,6,7). Because of this evidence, there is growing enthusiasm for health promotion in the workplace (8). Business and industry leaders are now viewing employee health as an asset to be maintained and enhanced (1) and as a result, increased attention has been directed at health promotion and disease prevention initiatives.

Workplace health promotion has evolved over the past two decades and is now viewed as fundamental to improving the health and longevity of workers worldwide (9). While health promotion in the workplace is not new in Australia, there has been little documentation of programs, particularly those targeting blue-collar workers. On the other hand, the United States have been running and documenting cost savings of health promotion with blue collar workers for many years. Evidence continues to mount around the positive relationship between the running of a workplace health promotion program and improvements in the health behaviours and health status of participating employees (3,5,7).

A recent study of a comprehensive health program run by a large American industrial company employing a workforce of predominately blue collar workers showed measurable reductions in accidents and disability costs (10). After beginning a comprehensive health program in 1996, the organisation managed to reduce their workers compensation claims by 7.9 percent in 1997 with a further reduction of 5.5 percent in 1998, followed by a further decline of 0.4percent in 1999. Long-term disability cases also reduced by 29 percent over the same four years (10).

One of the major areas of workplace concern in Australia is workers' compensation costs. In Queensland in 2000/2001, more than $285,000,000 was paid out in 85,340 claims (11). Costs per claim rose by 24percent in the same period. The mining industry's average cost per claim was $11,710, more than double the state average cost per claim of $4900 (11).

Of total claims, 47percent were as a result of sprains and strains (including back injuries) at a cost of over $127.5 million, with back injuries accounting for 19.7 percent of the total claims. While the mining industry represented just 2.5 percent of total claims, they accounted for 4.4percent of total payout costs (11). Similarly, the construction industry represented just 7.8 percent of claims, however accounted for 11percent of total payouts (11).

With the mining industry in Australia employing 0.8 percent of the population, and contributing 4.4 percent of the Gross Domestic Product (12), it vital that this workforce, in particular, is offered every opportunity to enhance their health. The maximisation of productivity as a result of health and safety initiatives further enhances these figures not only for the individual or the organisation but the country as well.

Worksite health promotion programs are generally designed to help employees reduce specific health risks such as high blood pressure, high cholesterol, overweight and cigarette smoking and to improve overall health through physical exercise, nutrition and stress management (3).

These programs are prevention oriented with measurable differences seen in the short and long term. Primary strategies can be initiated by health promotion professionals that complement the existing, more traditional efforts of the organisation. This provides a cohesive foundation from which all other programs can build (6).

These programs are in a strong position to influence change within the organisation because they focus exclusively on employee health and well-being. Failure to adopt primary strategies that address the underlying issues of poor health can lead to an ineffective program resulting in little or no long-term change (6). By intervening early with appropriate health promotion programs, employers can improve the health and productivity of their workers (13).

Health promotion programs can be successful in reducing employee risks, but changing human lifestyles is a difficult task (14). It is important that any organisation planning to undertake health promotion, clearly defines the outcomes they wish to achieve. If management is concerned primarily with corporate image, then highly visible exercise facilities might be given priority (15). These often fail to produce benefits within themselves unless used as an adjunct to programs with proven results.

The exact economic benefits of health promotion programs are only now being researched and documented. Peterson et al found that as a consequence of health promotion interventions, employee absenteeism due to poor physical health, as well as workers' compensation claims had reduced (7). A number of recent studies have shown an encouraging association between worksite health promotion programs and reduction in health care costs, accidents and absenteeism as well as improved fitness (5, 6).

A comprehensive health and productivity bench marking study researched 43 large public and private employers in the United States, who had undertaken health promotion initiatives. The study documented median annual health and productivity costs per employee of $9992 of which 47percent were group health costs, 37percent productivity related costs, 8 percent due to absenteeism and 3 percent workers compensation (10).

The study noted that employers median cost savings directly on health and productivity was approximately $2600 per employee (10).This will have a cumulative effect over time, particularly in reducing later demand for expensive medical services, after health has deteriorated (6). As evidence mounts validating the direct economic return of health promotion programs, they will be viewed as a necessity rather than an option.

Health promotion programs are generally based on the premise that poor lifestyle habits are responsible for the majority of chronic disease and therefore can be prevented (13). The latest programs available to workplaces acknowledge the importance of the promotion of health and wellness (9).

In the short term, participation in a well-structured health promotion program can result in a decline in employee absenteeism, (6), as well as a reduction in workplace injuries (14). Group participation in programs also leads to team building, improved morale and a flow on effect in productivity (16).

Studies have also found that lesser educated, lower socioeconomic groups and ethnic minorities were just as likely to want to participate in health promotion, when given the opportunity. Employers benefit, therefore, when they foster employee health, as healthy employees help create and maintain healthy organisations (1).

Current attitudes within Australia are changing, with the promotion of wellness being actively encouraged by federal as well as state governments and health care organisations (16). The ACTU also believes that the workplace is a valuable vehicle in which to implement programs designed to assist workers in making informed decisions regarding their health and well being (3).

Emphasis on a preventative approach is part of National Health Policy (17) with healthy diet and exercise choices being the preferred option in prevention and treatment of many lifestyle related diseases. Reducing obesity, through diet and exercise is also a strong recommendation of the National Heart Foundation (18).

Healthy eating enhances both health and quality of life. Thus it can contribute to improved employee morale, decreased absenteeism, higher productivity and lower health care costs (19).

Obesity, in addition to its role in risk factors for heart disease, diabetes and some cancers, increases the chances that employees will suffer from back pain and other preventable injuries (19). A decrease in weight, with a concomitant reduction in abdominal obesity and blood pressure as well as improvement in other areas such as cholesterol levels and blood glucose management, reduces risk in relation to heart disease, diabetes, stroke and other debilitating diseases, including back pain (19).

These preventative measures enable the retention of highly skilled staff who can contribute to an effective and productive organisation for a longer period of time. Research also indicates that employees who participate in effective health programs are more likely to take an interest in other aspects of their health and safety (20).

Men, in particular have focused more on earning a living than concerning themselves with their health (17). As in most other industrialised countries, Australian men fare worse on most health indexes when compared to women (21). Levels of obesity and overweight in Australian working men are reaching 'crisis' proportions (22).

Obesity, is one of the main contributors in the development of heart disease, diabetes and stroke (19). Abdominal obesity, in particular has its own inherent risks with particular reference to lower back pain (19).

A leading figure in Australian men's health, Egger states, 'It is imperative that health promotion initiatives be developed and implemented in order to counteract the potential long term effects on the health of Australian men' (22).

Blue-collar workers, in particularly, experience poorer health and die at an earlier age when compared to their white-collar counterparts.(23).

The 'aging workforce paradox' (24) acknowledges the deterioration of health as skilled workers get older. The increasing costs of maintaining a skilled yet aging employee can eventually become a counter productive measure, as health deteriorates and productivity ratios decrease.

This is further exacerbated by the unwillingness of a male to have regular medical check ups, except for acute conditions (15). Responsible health promotion programs will require a medical review before commencement. This becomes an effective screening tool for addressing health concerns of individuals.

Primary health intervention with its emphasis on prevention, can have a positive flow in reducing the frequency of illness over time (6). This can stem the costs associated with diminishing health of valued employees as well as the added burden of recruiting and training new staff. Implementing appropriate worksite health promotion programs can reduce health care costs, accidents and absenteeism.

One study, reviewing nine health promotion programs involving 68,812 employees over 24 worksites, validated the hypothesis that employees who participate in worksite health promotion programs have lower subsequent levels of absenteeism when compared to employees who did not participate in a program (14).

Long range planning is an essential part of corporate success (3). Therefore it is vital that companies put in place strategies that will ensure the maintenance of good health by low risk employees as well as those at greatest risk (4).

Properly planned and implemented programs can improve the health of employees, improve employee/employer relations and morale and also improve physical, mental and social health of the workforce (3). The ACTU has also welcomed the initiatives designed to educate workers on making better choices regarding their own health and that of their families (3).

Another area where health promotion has made a significant difference is in work culture. When corporate culture places emphasis on production to the exclusion of employees' humanistic considerations, the potential for resentment and ill health is increased (7).

This counter culture can be appeased through health promotion programs. An attitude is conveyed to staff, that management is willing to provide programs and facilitate changes to help workers (7). Strong management support is vital to a successful program. When the culture of the workplace has a core value of improving the health and well-being of its workers, then enhanced productivity and employee morale are evident.

Organisations within Australia, that have been pro-active in running health promotion programs acknowledge their importance as part of a productive organisation. They have found that participants are more effective in their roles and have noted improved morale and communication across the broad spectrum of employees (3).

One Australian company states 'It is difficult to estimate productivity, except that people involved in the program enjoy their involvement, appear to be more punctual and there is an air of renewed vitality throughout the organisation. Absenteeism for reasons other than sickness has declined and turnover of staff has decreased markedly' (3).

With such benefits available, it is important to determine desired outcomes and then develop or select a program which will best meet the needs of the employees as well as the organisation.

Programs targeting nutrition, cholesterol and stress generally attract the greatest number of participants (5) and are far more likely to attract greater numbers of workers in the high health risk groups. These also provide the foundation on which other programs can build.

The choice of which program to offer rests upon a number of key factors. If these criteria are met, then the program will have the greatest chance of success.

Key Criteria

1 Is the program aimed specifically at employees in your industry?

Although many health programs are on offer, it is important that they are designed specifically for the needs of their target audience. Once health priorities have been determined, it is important to find a program that addresses the specific needs of the target group.

Blue-collar workers face more barriers than other employment groups, especially if shift workers. A program aimed at health issues of blue-collar workers must identify the health and lifestyle issues of these workers and focus on addressing them (25).

The program needs to be acceptable in terms of length and number of sessions and duration of the course. Materials and content also need to be appropriate for the literacy and ethnic background of the participants.

Workplace health promotion programs targeted at blue collar workers, became a priority agenda item in the 1990s in the USA (26) after it was recognised this group of people were at high risk for many degenerative diseases and least likely to participate in health promotion.

Blue-collar workers have identified certain barriers that will stop them attaining optimal health (26) and it is essential that these perceived barriers are addressed.

Lifestyle including shift work, overtime, and availability of food and exercise facilities, all influence the acceptability of a new program and the adoption of suggested strategies. If an organisation claims their program can meet the needs of many different groups, unless it has separate proven results for each particular group, there is a need for caution.

Be very clear about the target group for your health promotion, and ensure the program you choose has a proven record working with this target group and addresses the challenges peculiar to that group. Ask about other organisations that have participated in the program and the composition of their workforce (27).

Some worksites target a specific health issue and the program will be offered to all employees regardless of their position within the organisation. This can work well when management and workers share the same health concerns and a positive and enjoyable learning environment is created by the facilitator. Determining the particular needs of the target group and verifying these will be met by the program is vital to its success.

2 Is there a recruitment strategy?

Inertia is often a problem with those who may have health concerns. Men in their 30s believe that they will address health issues when they have more time and life is less demanding. Conversely, men in their 40s wish they had addressed their health earlier (21). Many health and safety committees assume those people who are unhealthy are not interested in their health (4).

On most occasions it is a lack of knowledge that inhibits people from improving their health. Lesser educated, lower socioeconomic groups, and those people with poor health are just as likely to want to participate in health promotion if given the opportunity (2). Participation in a worksite health program (WHP) must be voluntary (3). This increases ownership of the program and enhances committed participation.

For men in particular, once a decision is made to do something about a health issue, and providing the program fits into the particular scheduling requirements of their work, the success rates can be high.

In order to increase signing up of the target group, the program should be promoted as valuable and interesting (2). The health provider needs to be able to offer successful strategies to enhance recruitment.

Regardless of where those who sign up rank in terms of risk, they will all have one important ingredient for success – desire to make a change. It is important that the recruitment strategy reaches all those who are contemplating change in the targeted area and encourages enrolment in the program.

3 The program should be run onsite at a time convenient to you and your workforce, and should meet the specific needs of your workforce.

Research has shown that there is a higher degree of voluntary employee participation in health services offered at the worksite than anywhere else (1). Health services at the worksite are convenient, and employees assume of a high quality, thus they are more likely to participate (1). In order for this to be optimised, the program needs to be acceptable in terms of duration as well as length and number of sessions.

Although initially, participation levels may be high, the level of retention is a matter to be considered when selecting a health promotion program. To ensure a program's viability, the ease with which it can be co-ordinated into the workplace is a key factor.

The program provider needs to have the flexibility required to be able to meet with and track the participants on a regular basis, even when shift work is involved. Attrition rates can be illustrative of how well a program has met the scheduling requirements of a particular workforce. Even the best program will have no purpose if abandoned before completion.

Peer support is also a key component in reducing attrition (25), and should not be underestimated.

The workplace offers this kind of support, at a level which cannot be generated off site. Research from general studies of health, well-being and stress management, consistently support the proposition that social support can improve health and lessen the impact of work stress on general well-being (1). WHPs being offered on-site offer a greater chance for success because of friendly competition between participants (9).

This extra opportunity for social support can also be gained from positive managerial attitudes (1).

4 The program should be based on the latest research

To ensure the best results, the program should be based on the latest available validated research. Poorly researched or designed programs will not produce the targeted outcomes (14).

Research has shown that men want information and evidence before they will take action (21), thus out of date information will deter further participation in the program. The program provider needs to show evidence that the program material is regularly reviewed and updated in accordance with the latest scientific information and meets the needs of the target group(23).

The facilitator also needs to have on hand, accurate and up to date information. Most importantly, even when the program has been completed, there should be some form of information service in place to ensure participants are kept up to date with the latest information.

5 The program must be designed by specialists in their field. The program should be taught by qualified and accredited staff.

Whatever the particular health parameter, ensure that the program has been designed by a specialist in that area (19).

Research shows that the efficacy of a WHP is increased if contracted to an outside consultant (21). Preference should be given to those who have a proven program with particular experience in a similar industry (27).

Often occupational health and safety staff within the company may advise workers to reduce their weight or cholesterol or alert a patient who has a health risk(18). However, due to familiarity and limited ability to run a comprehensive program there is generally little or no significant change in the behaviour of the individual (21).

When a professional health provider is outsourced, there is greater likelihood that beneficial changes in health behaviour will occur (27). A provider should be well educated in the field, have a tertiary qualification and be an accredited member of their professional organisation.

Experience in health promotion is also essential. They should be able to fine-tune the program to the needs of the participants and be able to answer questions in a comprehensive manner with a sensitivity to the understanding and abilities of the participants. If this is achieved the participants will acquire an understanding of the health concern and then be guided in developing new lifestyle behaviours to elicit change.

While specialists in their field are important for the design and development of the program, other health professionals can be trained to a suitable level to present the program and generate excellent results (19).

The main criteria are that the staff are qualified and dedicated to improving the health of your workforce. The program presenter also needs to have rapport with the group. Strong inter-personal skills, excellent verbal communication, sensitivity to the needs of the group and the individual are also important for the program's success (19).

Most good consulting firms will select trained health professionals and then further train them to a standard acceptable to the consulting organisation. Check that those people employed by the consulting firm have actually had experience with your target market, and will be able to relate to your workforce (23).

The other option is to employ a consultant with experience in your industry to train your own staff to an acceptable level, to be able to present the program, and gain sufficient knowledge to answer any questions that may arise.

6 Behaviour modification strategies should be a key element of the program.

In order to elicit lifestyle changes, there needs to be a movement beyond just supplying information. The latest research shows the most effective worksite health promotion programs are those that use multiple strategies in order to enhance awareness, convey information and develop skills (16).

A program that aims for maximum effect, needs to address the complexity of human behaviour in order to elicit change. One of the most widely accepted methods of ensuring a new behaviour is maintained is using behaviour modification techniques. Individual behaviour changes require modelling, practice, time for learning, recovery and reward. Programs must follow this continuum of change (19).

The American Medical Association Council on Scientific Affairs concluded that behaviour modification of exercise and diet in obesity treatment is essential for long term weight control and a program that incorporated these elements is more likely to succeed (28).

When discussing worksite nutrition programs, the American Dietetic Association also concurred that behaviour modification was an essential ingredient in successful program. By encouraging achievable, incremental changes and then having rewards in place on a consistent basis, the participants can move through their own goals at their own pace and be suitably rewarded as they progress (25).

Desirable behaviours become self reinforcing with correct program implementation (12). Any good health promotion program no matter what the overall aim, should have a large focus on individual goal setting as well as an established track record in motivating participants to achieve their goals with a built in reward structure.

7 The program needs to be motivating and enjoyable.

A large amount of evidence validates the need for the program to be engaging as well as informative (21). If interest and enthusiasm are developed in the individual as well as the group, attrition will be minimised and participants will be motivated towards success(2).

Testimonials of past participants are often a good indicator of the enjoyment level of the class. The program needs to be enjoyable, otherwise retention will be difficult. This is particularly the case for men (19). Another factor which can contribute to retention, is the offering of a high intensity program to smaller groups of 10 to 15. This aids group dynamics and participation and enhances cohesion of the group.

8 Does the program provider offer suggestions for organizing the work environment to support the changes?

When a program is offered in the workplace, strategies need to be suggested to support the changes participants are making. When there is policy change coupled with environmental change, the efficacy of the program is enhanced. This can be as simple as an appraisal by the program provider, of the workplace in relation to the proposed outcomes of the program. In the case of weight reduction, this may take the form of suggestions to enhance the availability and choice of foods via the canteen, mobile tuck shop or vending machines.

Studies have show that change is achieved at up to twice the rate when compared to sites that do not implement structural and environmental change (6). These enabling strategies support the long-term maintenance of positive behaviour changes. These policy changes can be worked on, in consultation with the health program provider and the participants of the program (29).

9 The program should be proven to produce short and long term results.

The health promotion program must include measurable outcomes that can be managed and monitored (30). When selecting a worksite health promotion program, it is important to choose those with validated results achieved and maintained over time (14).

While there are a myriad of programs on offer which can show they have produced plausible results in the short term, it is the maintenance of these results in the long term which will have positive impacts on absenteeism and productivity and produce cost savings for the business (14).

Changing lifestyle is a long-range goal. Results should indicate changes in the targeted areas, over the duration of the program, and then three months, six months and twelve months after completion.

Relapse is a major concern, particularly in the long term. The program needs to have results that are indicative of adherence to new behaviour patterns over time. The more sustained the gradient, the more indicative the results are that the program has been a success.

It is also important to verify how many worksites and participants are represented by the results and how recently the statistics have been updated.

Another valuable source of information is whether the results have continued to improve from the inception of the program. This would indicate the health provider is involved in process and outcome evaluations and improving the program over time. Validating the results by referring to others in the same industry who have participated in the program, is also an excellent reference.

10 The program should have a strong follow up component

Follow up counselling is fundamental to any program designed to enhance adherence to behaviour changes (26). The best programs are those that use a model of health screening, intervention, evaluation and follow up (27).

Monitoring of measurable parameters is a key factor in the follow up program. Ongoing monitoring may be needed to reinforce the adoption of new behaviours (12). When participants know they will be monitored on a continuing basis, they are much more likely to continue with the behaviours adopted in the WHP (19).

An open line of communication continues to be important, once the program has finished. It will allow participants to receive feedback on their progress, but more importantly advice when they find it difficult to maintain their new behaviours.

The use of a follow up program will assist participants in devising coping strategies, allowing them a greater chance of overcoming any potential barriers that may arise in the future (26). Ensure any program selected has ongoing monitoring as well as review sessions with the presenter.

Results of a worksite health promotion program

Following are the results of a healthy eating and lifestyle program, designed specifically for blue-collar workers. The program was developed by two qualified dieticians, using the latest research in healthy eating and lifestyle strategies.

A preliminary overview of the program and results was given to key personnel by the program facilitator. Enrolment strategies were discussed and promotional materials were provided to enhance program enrolments.

Of the 550 workers from three separate organisations, 110 voluntarily enrolled in the program. Of these, 92 were classified as 'blue-collar' workers, the remaining 18 participants were managerial or office staff.

Participants were divided into groups, with the program then scheduled to accommodate the variation of start times of each shift. Six sessions were run weekly with each of the groups, with a 10 week and 16 week review.

A medical screening took place after the initial session. This facilitated a blood cholesterol analysis as well as a medical clearance for a moderate exercise and weight training program. Key health measures were taken weekly to allow participants to monitor their individual progress.

This acted as an inherent reward system as individually set goals were accomplished. Behavioural goals were also monitored and adjusted to reflect the changes over time.

Friendly competition was evident between participants. This competition increased as structural changes were implemented in the workplace. Attrition averaged 2 percent for each of the programs. Those who failed to complete the program were unable to do so because of paternity leave and unanticipated off site demands.

Of the 106 participants who completed the program, the following results were achieved. The trends evidenced at the end of the 16-week follow up were still apparent 12 months after initiation of the program.

Summary

Effective workplace programs can provide a foundation from which further health initiatives can be built. An integrated course not only improves employee health and morale, but also enhances productivity and workplace relations. Being proactive in establishing a healthy workplace also aids in the retention of skilled personnel. Absenteeism, injury rates and workers' compensation costs diminish when well presented and validated health promotion programs are offered.

These changes are more likely to occur if a number of key elements are evident in a worksite health promotion program. A well defined outcome for the target group and selection of an appropriate program provider, with specialist knowledge of the key issues for that group are essential.

The program needs to have validated results in both the short and long term, with at least a 12 month follow up to ensure monitoring and adherence to the goals set. Positive behaviour patterns are more likely to become part of the participant's lifestyle if positive reinforcement is built into the program and behaviours become self reinforcing.

Positive outcomes are further enhanced when management support the program with structural and environmental initiatives. This supportive environment sends a number of positive messages to the employee that further enhances workplace relations.

As employers acknowledge the health and well being of the individual as an asset to their organisation, they can respond to the needs and interests of their employees. By implementing an appropriate health promotion program with expertise in the needs of the workforce, both the organisation as well as the individual will benefit.

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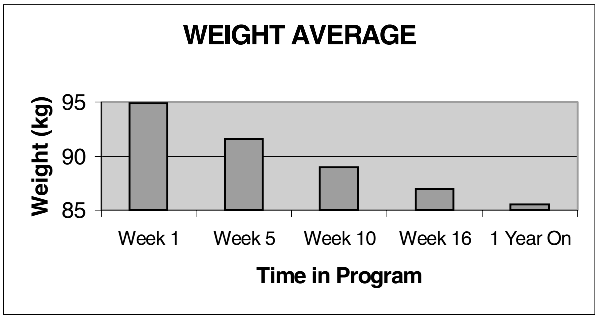
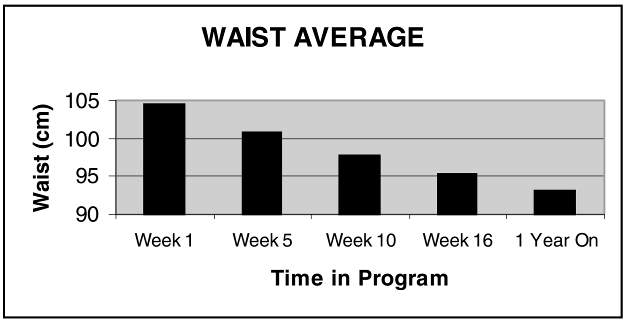
	Week 1	Week 5	Week 10	Week 16	1 year on
Weight (kg)	94.9	91.6	89	87	85.5
Waist (cm)	104.5	100.8	97.8	95.3	93
Body Fat (percent)	28.5	26.8	25.7	24.9	23
Blood Pressure (mmHg)	139/91	127/82	123/78	122/76	121/78
Exercise (hrs/week)	1.3l	3.6	3.7	4.1	3.9
Fat Questions	28	15	NA	14	NA

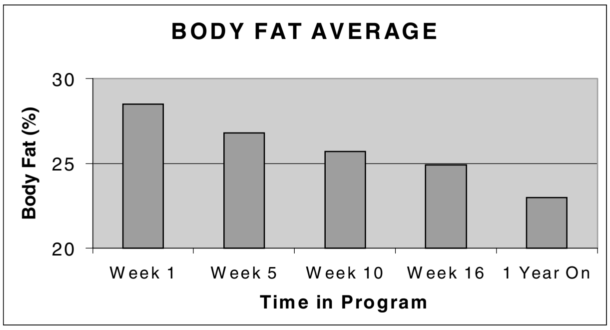
Table 1. Average change in major health parameters of participants in the Working Bodies Program. Source JKL Corporate Bodies (24)



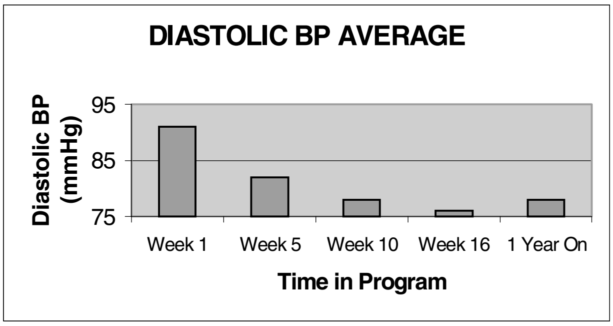
Graph 1. Average change in weight of program participants. Source JKL Corporate Bodies (24).



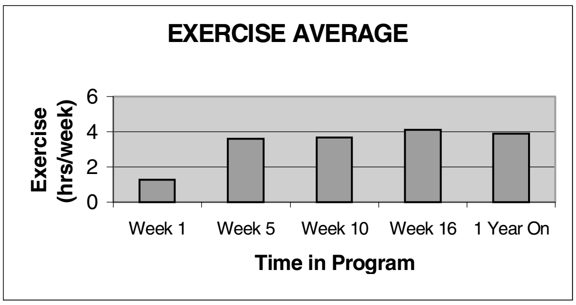
Graph 2. Average change in waist measure of program participants. Source JKL Corporate Bodies (24).



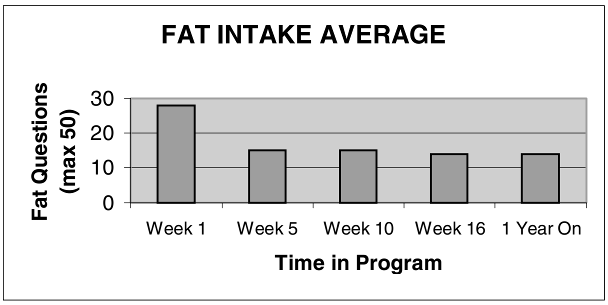
Graph 3. Average change in body fat of program participants. Source JKL Corporate Bodies (24).



Graph 4. Average change in diastolic BP of program participants Source JKL Corporate Bodies (24).



Graph 5. Average change in exercise level of program participants. Source JKL Corporate Bodies (24).



Graph 6. Average change in fat intake of program participants. Source JKL Corporate Bodies (24).

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CONTRACTOR ON-SITE SAFETY….GOOD LUCK OR GOOD MANAGEMENT?

The Mount Isa Mines, contractor safety management system

Glenn Bibby - George Fisher Mine

Introduction

The catalyst for the design of this system was the investigation of a 'high potential' incident involving a contractor.

At the time George Fisher Mine had intense contractor activity, associated with infrastructure works. Actual safety statistics for contracted works were quite acceptable and certainly did not reflect that there was a problem. However, closer investigation led to the realisation that the favourable statistics were more the result of good luck, than good management.

The subsequent investigation of the 'high potential' and a review of other incidents across the lease revealed many common factors.

These common factors were driven by two major symptoms:

1 A lack of, or ineffectual communication
2 No defined acknowledgment of responsibility.

It became apparent for the need to implement a system that would ensure appropriate, effective communication between all parties, and identify individual responsibilities.

A system was developed: Mount Isa Mines Daily On-Site Contractor Safety Management System. (a hell of a lot easier to use than it is to say)

The system

The Daily 'On – Site Contractor Safety Management System' has been developed as a tool to ensure compliance to the new Mining and Quarrying Safety and Health Regulation 2001 and Act 1999 legislation and regulations, related MIM procedures and policies by both Contractors and the MIM representatives responsible for their activities on a daily basis and improve contractor control while on our site.

The system is split into two stages.

The first stage is the sork authorisation and information form. This form creates a forum in which formal conversation is held between the on–site contractor representative and the MIM site representative responsible for the works. Based on the information recorded on this form, work can only proceed with the agreement of both parties.

The second stage is the daily work log sheet. This form provides acknowledgment from Contractor employees that they are aware of, understand and agree with SWIs/JSAs and procedures in relation to the works they are to undertake. The formatting of the form requires that this acknowledgment be repeated at the beginning of each task. The form also requires acknowledgment of completion of each task.

An additional information sheet has been developed for the recording of additional information in relation to either the authorisation of daily log forms and or any other relevant information and record.

The format of the forms has been designed with the intent of the same forms being able to be used across the MIM lease both on the surface and underground.

It is intended with the agreement of managers to introduce this system gradually across the lease both on the surface and underground.

Process

- identification of appropriate on-site MIM representatives responsible for the contractor and the works being carried out
- to ensure appropriate and recorded communication between the MIM and contractor representatives responsible for the works being carried out
- to provide formal appropriate authorisation of daily contractor activities
- to ensure appropriate communication between supervisors and employees
- to provide an appropriate tool for employees to ensure they carry out tasks as per relevant procedures and policies
- to provide an appropriate tool to initiate worker awareness of the work area and surrounds, and proposed method prior to and during each task
- documented proof of compliance
- auditable system.
- a system and process free of commercial implication.

Method of achievement

- work authorisation and information form.
- daily work log sheet.
- daily work log additional information sheet.

MIM

WORK AUTHORISATION & INFORMATION

0011

DATE:..

MIM – GFM REPRESENTATIVE RESPONSIBLE FOR WORKS	ORDER # / CONTRACT #:
NAME:	POSITION:

RESPONSIBLE SUPERINTENDENT	NAME:

CONTRACTOR / DEPARTMENT:

OFF-SITE REPRESENTATIVE:	POSITION:
ON-SITE REPRESENTATIVE:	POSITION:

JOB DESCRIPTION & LOCATION:

DAILY TASK & INSTRUCTION:

J.S.A ☐ S.W.I ☐ DAILY OBSERVATION BOOKS ☐ HOT WORK PERMIT ☐

FUEL PERMIT ☐ OTHER:____

PERSONNEL NAMES	POSITION	SITE EXPERIENCE STATUS

PLANT VEHICLES (RELEVANT APPROVALS MUST BE SHOWN)

SPECIAL COMMENTS:

MIM – GFM REPRESENTATIVE SIGNATURE:____

CONTRACTOR REPRESENTATIVE SIGNATURE:____

Mount Isa Mines

OUR VISION OUR PEOPLE OUR FUTURE

MIM

DAILY WORK LOG SHEET

0011

DATE:	WORK AUTHORISATION SHEET NO:
COMPANY:	SUPERVISOR:

CONTRACT / PURCHSE ORDER NO: TASKS, SWI'S, PROCEDURES AND JSA'S	P.P.E.	Closet working telephone	Ventilation's	Ground conditions	Housekeeping	Procedures, SWI'S & JSA'S	Site risk assessment	Permits / Isolations	ERB's / FAR's Escape routes
Task (1) (start time)									
Task (2) (start time)									
Task (3) (start time)									
Task (4) (start time)									
Task (5) (start time)									

ALL EMPLOYEES TO PRINT NAME & SIGN OFF (START OF SHIFT)

DAILY WORK LOG ADDITIONAL INFORMATION SHEET NUMBERS: END OF TASK / SHIFT REQUIREMENTS	Housekeeping	Energy Sources Isolated / Reactivated	Barricades & Signs	Supervisor Information
Task (1) (time completed)				
Comments				
Task (2) (time completed)				
Comments				
Task (3) (time completed)				
Comments				
Task (4) (time completed)				
Comments				
Task (5) (time completed)				
Comments				

ALL EMPLOYEES TO PRINT NAME & SIGN OFF (END OF SHIFT)

Work authorisation and information form

Intent
- identification of MIM and contractor representatives
- recorded communication between MIM and contractor representatives
- to provide an instant, auditable representation of the scope of work, locations and all appropriate personnel and their representatives.

Provides
- MIM and contractor on–site/off–site representatives
- job description and location
- actual tasks and associated instructions
- acknowledgment of appropriate JSAs, SWIs and procedure or the lack of
- acknowledgment of appropriate permits, both activity and area related
- list of employees working on a daily basis
- identifies employees experience / competence in relation to task
- lists plant, vehicles and relevant approvals
- special comments, eg acknowledgment of new starters and their on–site duties, employees on medication
- signed agreement of daily works and conditions.

Conditions
- no works to be carried out by the contractor that is not listed on the work authorisation and Information form with signed agreement of the two original signatories
- employees who are not listed on work authorisation and Information form are not to proceed underground without the authorisation of both original signatories
- equipment not listed on work authorisation and Information form is not to be used without the authorisation of both original signatories
- contractor supervisor must ensure that all on – site personnel are made aware and are informed on the content of the work authorisation and Information form before the commence work
- the work authorisation and Information form number must be noted on the daily work log form. If additional notes are made on the additional information form the authorisation number must be quoted and the additional information number quoted on the authorisation form
- any additional information associated with the work authorisation and Information form must be recorded on a daily additional information form
- contractor on–site representative must have documented proof of all information relating to employee experience and competencies
- machinery approvals and maintenance schedules
- contractor on–site representative must have copies of all relevant JSAs, SWIs and procedures
- employees listed on the Information and authority forms must confirm to the contractor on–site representative that they are fit for work before they are directed to the work area.

Daily work log sheet

Intent
- to provide an appropriate tool for employees to ensure they carry out all tasks as per relevant procedures and policies
- to provide an appropriate tool for employees to ensure they carry out a risk assessment prior to commencement of each task in each location
- to promote a safety awareness during the shift, by the use of a live document

Provides
- ready checklist of requirements at the beginning of a task
- recognition of individual tasks and the need to reassess each task
- a record of task commencement and finish
- ready checklist of requirements at the end of a task
- A record of employees involved in individual tasks
- encourages use of daily work log additional information sheet
- a ready form of assessment of compliance

Requirements
- actual phone numbers must be listed on form
- all non-working phones must be reported to mine control
- all ground conditions beyond barring down to be reported to mine control
- actual locations of EBRs/FARs and escape routes must be listed on the form
- all relevant additional information must be recorded in the daily work log additional information book
- all site assessments must be signed off by the entire on site crew.

Intent
- to provide opportunity to report all relevant information in relation to tasks being carried out
- to promote individual involvement without limitations of quantity or style.

Requirements
- all reports to mine control must be documented
- visitors to job site including MIM supervisors and shift bosses must acknowledge visit on form and sign
- any directive given on site by supervisors etc must be written down and signed by all on-site employees.

Summary

The system is quick, simple and easy to use, relative to the tasks being undertaken. It formalises what was being done in most areas informally. The system is trackable and auditable.

The system has proved extremely effective and is now being introduced across the entire Mount Isa operation.

Both the contractor work force and operations alike have accepted the system and it is acknowledged as an effective way to ensure communication between all levels and departments of the workforce on a daily basis.

The system has introduced a pro-active rather than reactive approach to daily safety management, aiming to minimise the necessity to react to incidents by communicating them out of the work place.

The system has been trialed successfully at George Fisher Mine for approximately the last six months.

THE AGING WORKFORCE: PERSPECTIVES AND IMPLICATIONS

Professor AW Parker QUT School of Human Movement Studies Kelvin Grove Campus, Brisbane

Abstract

In many industries, there has been an increasing trend for the workforce to become older due to better health and longevity, and because younger people are not being attracted to industries.

Aging brings new challenges with respect to the context and requirements of work and has been the subject of several reviews on the status and promotion of work ability, employability and employment of workers over 45 years of age.

The Australian mining industry is no exception to this trend. As such there is a need to consider the implications of the change and to identify strategies with emphasis on the potential benefits in maintaining the skills and experience characteristic of the older worker, while minimising any negative consequences such as injury risk.

There is little information of specific issues associated with aging workers in the mining industry, therefore this paper will review related information from overseas, including mining and other related industries.

The physical and psychological changes which occur with aging, will be presented as a basis for discussion of the implication of these changes with respect to areas such as health, education and expertise, and work conditions and demands.

The potential for job redesign, fitness for duty measures in the broader context, work ability, and injury prevention and rehabilitation will also be considered.

The discussion will also focus on changing work patterns, shiftwork, and irregular hours, and the implications of these changes for older workers.

Issues including tolerance to shiftwork and identification of organisational changes which may improve or weaken work ability and functional capacity will be addressed.

Older persons have been shown to have considerable capacity to maintain and enhance their functional capacity, but there remains a need to identify the more effective worksite programs which may be used to evaluate, monitor, and improve functional fitness.

At this time, knowledge of issues associated with aging in mining is limited and mainly derived from overseas sources. Consequently, there is a need for research which provides comparative data on the epidemiology, and health profile of the older worker in the Australian mining industry.

Investigation of health indicators, accident profiles, physical work environment, physical and mental demands and work hours in relation to age is also a priority. Information derived from these investigation would be useful in designing and evaluating of worksite interventions

1. Introduction

Aging workers will characterise the Australian labour force until 2016. Australian data indicates that nearly 30percent of the population will be 55 years and over by 2016 [Australian Bureau of Statistics (ABS), 1999].

The Australian population is aging due to the baby boom following World War II (WWII), an increase in lifespan, and a slowing of the birth rate from the 70s onwards.

Those aged 55 and over accounted for 10 percent of the Australian labour force in 1998.

However, this age group is expected to account for half of all the growth in the labour force in the near future. In 1998, the 60-64 years age group accounted for less than 3percent of the labour force, yet this group is expected to account for 15percent of the total labour force growth between 1998 and 2016 (ABS, 1999).

The steady increase in the average age of the Australian work force will have wider social and economic consequences, as well as impact on the workplace setting (ABS, 1999).

The aging of the Australian population is in line with international trends. A United Nations (1996) review of worldwide trends shows by the year 2030, 20 percent of the population will be 65 years and older.

Employers, especially large corporations, have historically reacted to depressed economic times by offering early retirement to older workers in an attempt to cut costs.

Quite often attitudes to older workers may be driven by employers perceptions that older adults are less physically and mentally competent, that their productivity levels are lower, and their accident potential is higher than younger workers.

Thus, the early departure of older highly experienced workers leaves a large gap in the resource levels of organisations.

Organisations tend to overlook the positive benefits in relation to older workers, such as, the substantial work and life experiences which enhance overall capabilities and provide significant advantages in many jobs (Spiruduso, 1995).

Therefore, the purpose of this paper is to identify those physical and psychological factors which characterise the older worker, and to discuss the implication of those to industry.

These factors will be considered in relation to workload demand and the risk of injury. Additionally, intervention and management strategies including health and fitness issues associated with an aging workforce will be discussed. Where possible, implications with respect to the Australian mining workforce will be addressed.

2.0 Changes with aging

2.1 Physiological

An increase in age coincides with physiological body changes, which can cause decrements in physical and mental functional capacity.

Physical changes that accompany aging include a decline in aerobic power and endurance capacity. This capacity can decline by 25percent in men and women after the age of 25 years and these changes are strongly associated with aerobic exercise, or lack of it.

Changes in musculoskeletal capacity can also be pronounced after the age of 45-50 years, and muscle strength can decrease 40-50percent over a ten year period (Ilmarinen, 2001). Declines in muscular strength and endurance occur first in the legs, followed by the trunk, shoulders, arms, and then hands (Kawakami & Inoue, 1999).

Decrements in functional capacity can lesson the aging workers' ability to cope with job demands and could place undue stress on workers, especially in occupations that require a high level of physical exertion such as mining.

It has been suggested that an over-taxing of the heart and the skeletal muscles may lead to a decrease in productivity. This decrease is due to an increase in worker fatigue, that in turn may result in absenteeism, accidents, industrial disputes, increased injury, heart attacks, and strokes (Shephard, 1999).

Another facet of aging is a diminished resistance to physical stress. Older workers are more susceptible to severe injuries resulting from body trauma, and recovery from severe injuries will tend to be slower with an increase in age (LaFlamme et al, 1996).

2.2 Psychological

Changes in mental functioning are associated with a decrease in precision and the speed of perception, involving the whole body.

Changes occur in the ability to process information and reflect alterations in the following systems: the sensori-perceptive system that is responsible for receiving information through the senses (eg sight and hearing); the cognitive system that processes the data from the senses and memory system; and the motor system that is responsible for the realisation of the decided functions (LaFlamme et al, 1996; Spirduso, 1995; Kawakami & Inoue, 1999).

2.3 Variability in the Aging Process

Aging is highly individual, deterioration of physical and mental capacities can start earlier in some people, and the rate of deterioration varies from person to person (Garb, 1991).

Thus, the functional capacity of what is considered to be the aging worker cohort (>45 years) can vary remarkably. For example, it could include a 50 year old worker that has the functional capacity equivalent to the average 25 year old, or a 45 year old worker who may have the functional capacity equal to the average 80 year old.

Therefore, there are some older workers that will have greater physical and mental functioning than some younger workers.

Because of the large variability in capabilities and rate of physical decline with aging it is important that strategies to manage the older worker are targeted at an individual level.

For strategies to be properly implemented it must be possible to estimate functional capacity based on three factors: physical capacity, mental capacity, and social function. In addition techniques for estimating psychological factors such as work satisfaction and attitude, will allow for the fullest estimation of functional capacity and predisposition to injury (Kumashiro, 2000).

In terms of the variability of the aging process the implications for the mining industry are complicated by inter-individual differences in the energy cost of specific tasks and the work structure of a typical day, including shiftwork. Importantly, a potential consequence could be an increase in age related accidents (Shephard, 1999).

3.0 Injury and aging

While many organisations perceive that older workers experience a greater injury potential than their younger workmates the literature is inconclusive on this issue.

3.1 Higher or Lower Injury Risk

A study of age-related risk of occupational accidents in iron-ore miners (LaFlamme et al, 1996) revealed that the accident rate of older miners was not greater but rather lower than their younger co-workers. This finding is consistent with previous injury results in older miners (LaFlamme & Menckel, 1995).

Likely explanations for these findings have been proposed. Firstly, older workers are possibly not exposed to as many accident risks, taking on what could be considered as less physically demanding jobs than their younger co-workers (LaFlamme et al, 1996).

Secondly, older miners may make use of compensatory skills when performing their occupational tasks. That is, the tasks undertaken might be 'age-counteracted' rather than 'age-impaired' (Warr, 1993).

Finally, older workers who find that they are no longer mentally and physically capable of meeting job demands, leave demanding and hazardous jobs. This departure could result in a group of older workers with a relatively high work capacity (LaFlamme, 1996).

Warr (1993) has suggested that performance is the combination of three different factors: physical ability, adaptiveness, and general work effectiveness. While physical ability and adaptability tend to both decline with age, general work effectiveness might remain stable or even increase with age.

In contrast, a retrospective longitudinal study (LaFlamme et al, 1996) indicated a substantial increase in accidents that can be presumed to be more frequent in older workers. In older workers, the lower back appears to be at greater risk of injury from falls and missed steps, as well as from overexertion causing sprains and strains.

This result is in line with previous research showing simular causes of lower back injuries in older miners (Hull et al, 1996). Maximum ability in trunk flexion and extension has been known to decrease 40-50 percent within 10 years in those aged more than 40 years working in physically demanding jobs (Ilmarinen, 2001). This would explain the predisposition to lower back injuries in older workers.

3.2 Mining, Aging, and Injury

The relationship between the nature of injury, injury mechanisms, recovery, and aging in the mining industry has been explored by several research groups. Hull et al (1996) examined lost time incidents (that were non-fatal), involving one or more lost working days, occurring in underground mines. Injuries involving travel to and from work were not included.

Results indicated that older miners did not show a significantly greater frequency in injury rates. However, injuries in older workers were more severe than in younger miners.

The relationship between age and severity may be due to loss of durability, making older workers more susceptible to energy impacts encountered in underground mines. This suggests that in older workers a given amount of energy may result in more severe injuries.

Recovery from injury may be age related, and studies have indicated that older workers may take longer to recover than younger workers for the same given injury (Hull et al, 1996; La Flamme et al, 1996).

Severe accidents (those that required 20 or more days recovery) constituted only 16 percent of all injurious accidents in underground mines. However, this type of injury resulted in 75 percent of the total days lost for the whole of the NSW underground coal mining industry.

Although older miners are not more likely to injure themselves, when they suffer an injury they are likely to be severely injured and require considerable time to recover (Hull et al, 1996).

Results of injury research (Fotta & Bockosh, 2000) showed with few exceptions, older injured workers have the highest median number of days lost per injury within the American Mining Industry.

Hull et al (1996) found that transport related activities, rather than equipment maintenance and metal/mechanical trades, accounted for the majority of severe coal mining injuries (predominantly involving the aging workforce).

The severity of injuries from transport related activities (driving vehicles) may be due to the large role of transport in the extensive mechanisation of underground coal mining operations.

This finding highlights the importance of modifying job and safety training programs in conjunction with changes in mechanisation.

Safety procedures in the mining industry today require a high level of awareness for fellow workers, and considerable skills. It is possible that the learning of these skills as a result of aging is not matched with the pace of mechanisation in the mining industry. The higher incidence of injury severity in older workers may in part, be due to inadequate knowledge of safety procedures and a lower technical ability related to technological change (Hull et al, 1996).

Hull's (1996) work also indicated injury severity was strongly associated with over exertion, fall of a person, and falling object/substance. These findings are comparative to a simular study that found overexertion, coal/rock slide/fall, and tripping resulted in much greater injury severity (VIOSH, 1994).

These mechanisms of injury are prime targets for preventative strategies and further research. What needs to be determined is the context in which these injuries are occurring, and if these injuries are the result of human error, equipment, or physical functioning (Garg, 1991).

Thus, as workers age there is a decrease in functional capacity, or ability to perform duties, that may predispose them to an increased likelihood of injury.

For industries such as mining an increase in the number of aging workers could impact on the already high injury incidence rates.

Nationally, the mining industry has the highest injury incidence rate (89 per 1000 workers) compared to the national average of (49.3 per 1000 workers) (ABS, 2002), and a greater number of workers' compensation claims than any other industry (Worksafe, 1999). It is possible that injury incidence rate, the number of days lost due to injury, and loss in productivity could be reduced if greater effort is targeted towards maximising employee health.

4.0 Shiftwork and aging

Almost all mining settings are 24 hour operations. While the duration and timing of shifts may vary from mine to mine, the impact of working around the clock on the mining workforce has the potential to increase fatigue and accident risk.

The effects of shiftwork are numerous but among the acute effects are increased fatigue and sleepiness, impaired job performance, and reduced and poor sleep; all of which increase with age (Heslegrave, 1998).

Partly as a result of circadian disruption, shift-workers are at risk of sleep deprivation, and both the quantity and quality of sleep may be affected.

Sleep disturbances and deprivation have been associated with poor health (Scott and Ladou, 1990).

The negative effects of shiftwork have been shown to increase in workers aged in their forties and fifties (Heslegrave, 1998; Reid and Dawson, 2001; Scott and Ladou, 1990).

Study results indicate that aging workers become intolerant of their work schedule, even though many have done shift work successfully for many years

(Heslegrave, 1998). Heslegrave (1998) surveyed shift workers to determine whether shiftwork had become slightly or much more difficult as they had grown older.

Survey results indicated that about mid 30 years of age, shiftwork became slightly more difficult. By 35-39 years of age, over 80 percent of shift workers reported some form of difficulty coping.

By 40-44 years of age, 80 percent of shift workers reported an increased difficulty in coping, with 40 percent reporting the increase in difficulty was more severe.

Reid and Dawson (2001) studied performance on a simulated shift rotation in young and older workers.

Their results showed that although the performance of the older workers increased during a 12 hour day shift, it was lower than the younger workers.

In addition, the performance of older workers significantly decreased across the night shifts, in contrast, to the younger workers who were able to maintain performance across both day and night shifts.

Heslegrave (1998) studied shift workers working their typical shift and found a decrease in arousal, increase in fatigue and sleepiness, and a 10-15 percent reduction in performance in aging workers when working an 8-hour night shift.

Thus, a further issue in relation to an aging workforce is the effects of shiftwork. Older miners not only undertake physically demanding tasks but also encounter added effects of shiftwork in mining.

5.0 Intervention and modification in industry

In general, the decline in physiological functioning of the aging worker has often been considered by companies to be a handicap.

Kumashiro (2000) explained that too much emphasis is placed on the decline in physical function of workers and very little or negligible attention directed towards the synergistic capacity of workers.

That is, the general capacity to perform tasks supported by a wealth of experience and knowledge.

The author suggested that this synergistic capacity should be utilised as much as possible to provide support for the declining physiological functioning.

5.1 Compensatory Strategies

Although functional capacity declines with age, and predisposes older people to more severe injuries, older employees have unique qualities that support their continued employability.

Older workers learn to replace uneconomical with economical responses and incorporate different strategies to compensate for physical skill decline.

Those who continue to work tend to maintain the level of physical skill necessary to complete tasks. In industry, older adults generally are more productive, have less absenteeism, have fewer accidents, and change their jobs less often than younger workers.

The greater an employee's skill, competence, and experience, the smaller the decline in productivity with advancing age (Spirduso, 1995).

5.2 Workplace Redesign

Aging workers can face problems at work that can lead to overload and stress (Haslegrave & Haigh, 1995). The main factors causing these are:

- working under pressure of time
- frequent changes in technological process
- high speed working
- the need to process large amounts of information rapidly
- continuous high level of vigilance
- heavy physical work
- poor environmental conditions
- night-time shift work.

The creation of working environments and settings that enable the aging worker to work in conditions of good health and safety is imperative.

A working environment that allows the aging worker to work within their capability serves to boost corporate productivity and efficiency.

A possible solution to the problem could be to move aging workers to less demanding jobs, such as supervisory roles, however, this option is not applicable to most situations, particularly in smaller organisations.

Job redesign to suit the individual worker is also possible but again may be impractical in smaller operations (Haslegrave & Haigh, 1995).

Netherless, it appears that the older worker would be disadvantaged in those workplaces where tasks are designed for the capabilities of the younger worker.

In some cases it may not be feasible to retrain the older worker as a solution to the problem. Training alone may not adequately compensate for the diminished work capacities of older individuals and some form of workplace modifications may be needed to compensate for, or better utilise, the diminished physical and mental capabilities of older workers (Garb, 1991).

Currently, limited research has been undertaken in the area of job redesign for older workers.

Therefore, it is difficult to make recommendations as to how the work environment should be modified to ensure maximum productivity and also protect the health of the older workforce.

As the impact of the aging workforce is only starting to take effect, there has been little interventional research on workplace modification. However, in Japan the issue of the aging workforce is a priority and a number of studies have looked at workplace redesign for this group.

The noodle manufacturing industry in Japan is composed generally of small to medium sized enterprises.

With the shortage of young labour, many companies have found it hard to employ young labour and have been compelled to employ a large percentage of aged workers in what can be considered very physically demanding occupations.

In an attempt to redesign jobs to better suit older workers Hasegawa & Matsumoto (1995) evaluated the effect of changes to working procedures and organisational systems in noodle making.

Changes included the elimination of manual lifting of raw material, and the placement of product inspection systems to ensure comfortable worker posture during this process.

The results were positive, indicating improved supervisory tasks, workload decreased, and productivity and efficiency.

Job redesign was also implemented in a plastic manufacturing company that predominantly employed middle-aged and older workers.

When the company was first designed consideration was not given for human engineering or labour physiology of the aging worker.

As a consequence of complaints from aging employees, employers found it necessary to develop better work practices. Many of the improvements were achieved through removal of the physical demands placed on aging workers as identified in the survey.

The employers did not attempt to replace the need for muscle strength with machines; the process was only partially automated. The changes enabled work tasks for middle-aged and older workers to better match their physical capacity, and resulted in enhanced worker productivity (Kimura & Kishida, 1995).

Evidence from Kumashiro and Masaharu (1999) revealed that in an ideal management situation the needs of aging workforce would be addressed.

However, despite the absence of the ideal workplace in most workplaces strategies such as assigning older workers to more appropriate tasks can be implemented without loss of productivity.

5.3 Detecting Cause of Injury

From evidence that aging may impact heavily on injury status further research is required to determine other causative factors pertaining to accidents.

For instance, human error rate in older workers resulting from equipment design, and the impact on productivity is yet to be determined. Similarly low productivity, low efficiency, and high injury rates at many workplaces can be attributed to either poorly designed equipment, workplaces, and/or environments (Garg, 1991).

A number of studies have been conducted to evaluate the best method of assessing workplaces to determine causes of injury, with the aim of implementing workplace redesign strategies that more safely include an aging workforce.

Ilmarinen (1992) highlighted that the first step to workplace redesign was to identify the source of the problem.

This would require that data collection processes be based on the age and health profile of the workforce, and should include information on worker ability, job demands, and the imbalance between work demands and worker capacity.

5.4 Matching Worker and Task

In most workplace settings job demands for the older worker remain unchanged. This situation continues despite information which suggests that the more unstable the balance between an individual's capacity and job's demands, the greater the risk of a wide range of undesirable outcomes, more specifically the greater the risk of occupational accidents (LaFlamme, 1996).

In a review of the changes in mental capacity with aging Garb (1991), indicated that the age of workers on a job could be related to the complexity of the task.

For instance, younger workers are considered by the author to be more suited to complex jobs that require greater perceptual demands and jobs that require extreme attention to detail or that make severe demands involving sustained care and concentration.

In contrast, older workers may cope more effectively with slower paced mental and physical tasks.

Evaluating the physical demands of jobs is important in assessing worker-job compatibility, and a specific jobs analysis needs to be performed to determine:

- the tasks that are required by each specific job
- the physical, mental, and physiological characteristics necessary to perform the tasks.

The next step is to determine which job related tasks should be simulated in a worker task test.

This assessment should consider the frequency of the task, the critical role of the task in the job, and the skill levels required. The development of tests assessing physical capacity in relation to demands can be utilised as part of employee medical assessment (Davis and Dotson, 1987).

Job assignment can be adjusted by employers, so that older workers can work in self-paced predictable jobs that put a premium on coordination and dexterity rather than strength and endurance (Kumashiro & Masaharu, 1999).

Ergonomics researchers have suggested many equipment and workplace design modifications can be made to adjust for age related deficits.

For example, to minimise problems with attention span, irrelevant details on control panels and switches can be eliminated or masked. To compensate for visual losses, illumination of the task can be increased, the contrast between letters and background can be magnified, and highly contrasting colours can be used on instrument panels (Spirduso, 1995). T

To maximise work performance adjustments to enhance the workplace environment for older workers with reference to their age related physiological and psychological changes should be implemented and a summary of an age/task matching process is shown in Table 1 (Spirduso, 1995).

6.0 Health maintenance

Although job redesign may be considered impractical in some operations, programs to monitor and optimise the health and fitness of the older worker can be implemented with beneficial outcomes for worker and employer.

Health promotion programs in the workplace however may have limited success particularly when such programs lack management support. Cooperation between workers and management is critical to the success of the program, together with

Table 1. Modifications to enhance workplace environment for aging workers. (Spirduso, 1995).

Age related changes	Workplace/environmental adjustments
Decreased joint mobility Reduced elasticity of tissues	Avoid jobs that require or have - elevated arm activities - prolonged unusual postures - large wrist deviation to apply force using tool Position objects, controls, displays to minimise prolonged flexing, bending and stooping Adjust furniture to individual anthropometry - seats in vehicles - office furniture Design seats to reduce vibration - low frequency vibration (truck earth moving equipment, mining) - large wrist deviations to apply force using tools
Loss of strength	Avoid - controls and tools that require high strength - lifting, lowering, pushing, pulling, bearing loads - lifting loads >20percent maximum of young workers - lifting rapidly Design tasks so that - load is kept close to body - task does not require bending, stooping, or twisting - adequate rest is provided between lads - task assures good foot traction Teach workers correct mechanics of lifting and pushing
Reduced work capacity	Jobs requiring energy expenditures should not exceed 0.7 (men) or 0.5 (women) L/min oxygen consumption
Slowed perception and decision making Attention deficits Memory deficits Difficulty with mental transformations	Provide - longer training sessions - practice with written instructions - videotapes of desired performance - increased signal to noise ratio Assign older workers to - tasks which work is previewed rather than reacted to - tasks that are predictive rather than novel
Visual deficits Acuity	Provide - 50percent more illumination for workers 40-55 years - 100percentmore illumination for worker > 55 years - increased task contrast on control panels, writing on labels - increased display letters and symbols - reduced glare
Colour discrimination (blue/green)	Omit blue/green discrimination
Less tolerance for heat	Reduce heat stress index in workplace
Less tolerance for cold	Maintain optimum worksite temperature
Hearing loss	Increase signal to noise ratio in tasks that provide audible cues or instructions
Greater incidence of low back pain (LBP)	Provide job training to prevent LBP - risks on job - basic knowledge of body mechanics - specific motions to avoid - planning job activities to minimise back stress - of-the-job injury prevention
Increased risk of falling	Eliminate slippery walkways Mark steps or ramps Illuminate workplace adequately
Slower rehabilitation from injury or disease	Allow more gradual return to full work load Allow rotation between light and heavy jobs to phase in work requirements Provide information regarding proper rehabilitation and return to work
Tendency toward inactivity	Avoid paced work Give worker control over work load Emphasis accuracy rather than speed Provide fitness programs Encourage employees to use fitness programs

The role of physical activity for maintaining work ability during aging was evident in a 10-year follow-up study of aging municipal employees.

Deterioration and improvement in work ability was assessed in a sample of subjects aged from 51-62 years.

An increase in brisk physical training at least twice a week was one of the three most powerful predictors of improved work ability during the 10 years.

However the decline in brisk training was one of the four most powerful predictors of decreased work ability during the 10 years.

The effects of physical activity on work ability were independent of work type (physical, mental, or physical-mental work) and gender (Ilmarinen et al, 1997).

A randomised trial comparing physically active adults aged 35-60 years to sedentary adults of the same age found that over the period of two years there was no decline in average work ability in the active adults; however, there was a decline in the sedentary groups (Smolander et al, 2000).

Research indicates that adults who regularly participate in physical activity can maintain superior muscular endurance for many years, an accomplishment that enables them to continue working.

One of the clearest findings in the literature on strength and aging is that disuse accelerates aging. Most of the decline seen in strength and muscular endurance, at least to the age of 70 is due more to disuse of the neuromuscular system than to aging (Spirduso, 1995).

6.3 Injury Rehabilitation

Although older workers recover from injury more slowly than their younger counterparts, the number of days lost due to severe injury may be reduced if they are educated on the importance of early participation in rehabilitation programs.

Lustead (1993) found that although return to work took longer for older workers with back injuries the time could be significantly reduced if the worker was referred for rehabilitation without delay.

Emphasis on immediate rehabilitation and training in safe working practices for mine workers experiencing all types of injury, especially the knee, multiple site, and back injuries, should be an aim of any strategy to prevent severe injuries and/or control the severity of injuries (Hull el al, 1996).

It is recognised that all miners will not necessarily have access to the most effective treatment regimes, thus making injury prevention strategies critical to reduction of the personal and social cost of injury.

7.0 Conclusion

Research indicates that older workers will dominate the Australian workforce during the next decade.

The Australian mining industry is no exception to this trend and new strategies are required to maximise utilisation of the experience and skills of the older worker, while at the same time reducing the risk of injury.

Such strategies might include job redesign, more effective matching of physical and mental capability with job and task demands and specific health appraisal and fitness programs.

Further research is required in the mining industry to identify the needs and injury profiles of older workers and to assess the efficiency of current strategies to support the older worker. Additionally, intervention studies are required to examine the potential for job redesign, fitness enhancement, and their relationship to productivity and health related issues.

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THE INTERMITTENT HUSBAND -

IMPACT OF HOME AND AWAY OCCUPATIONS ON WIVES/ PARTNERS

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Abstract

Working and living away from home is common in many occupations including the military, sales, construction, mining and transportation. Frequent partings and separations place strain on those leaving as well as those staying at home.

In Australia, particularly in Queensland, the expansion of fly in/fly out mining operations has increased the incidence of this type of work-related absence.

This paper will examine the impact of home and away occupations across various industries with particular emphasis on the experiences of Great Barrier Reef (GBR) pilots. These pilots spend three weeks or more away from home at any one time while guiding ships through the Barrier Reef region.

Thus an investigation was designed to examine the impact of these work practices on wives and families.

Analysis of a survey of quantitative and qualitative data from 35 wives (response rate 60 percent) indicated respondents were relatively older (> 51 percent aged more than 50 years), well-educated and generally well-satisfied with married life. Of the respondents, 68 percent were currently employed and 22 percent had children under18 years. Concern regarding the impact of the physical risks and fatigue of pilotage work on their husbands was reported by 70 percent of respondents.

The home and away nature of pilotage work was linked to the experience of stress by the majority of participants at least some of the time. For instance, 60 percent of the sample reported difficulties coping with stress - with altered eating habits being predominantly used as a coping mechanism.

From the two measures of psychological well being used in this study, approximately 14 percent of the sample was anxious at the time of the study.

Nine percent of respondents were considered to be depressed. In comparison, normative data indicates approximately 3 percent of the adult population suffers major depression.

A substantial number of wives perceived a lack of emotional or informational support. Recommendations from the study included the use of the email system for contact with absent husbands/fathers and for the establishment of a support group for wives/families of pilots.

The mode of operation in mining is changing in favour of fly in/fly out or drive in/drive out work practices.

However, there is currently little information, specific to the mining industry, on the impact of home and away work practices on family. Consequently, inferences will be made from these results to fly in/fly out mining operations as a basis for further examination of this problem in future research.

Key words: home-and-away occupations, work-related family separation wives, anxiety and depression

1.0 Introduction

Research involving the impact of home and away occupations has tended to focus on those who leave, rather than those who stay at home. Thus, the effects of regular partings and reunions on wives and family members left at home has been less frequently acknowledged.

Riggs (1990) suggested that families experiencing work-related absences fall into three categories: military, corporate (white collar executives) and non-corporate (workers in transportation, sales, construction, exploration, mining and fishing industries). The literature has only dealt briefly with the impact of home and away work practices on families and not surprisingly, more is known about the effects of separation in military settings than in other sectors.

The occurrence of work-related absence from home is difficult to determine from official data sources. Australian census data indicates that approximately 1 million workers are employed in mining, transportation, construction and, military sectors.

A sizeable number of these workers are potentially involved in regular/irregular work-related absences (Australian Bureau of Statistics, 1998). In the United States, Riggs (1990) estimated that 34 percent of the civilian labour force in the United States was involved in work situations involving absences from home. It is likely that a similar percentage of Australian workers would be involved in home and away occupations, particularly given the relative international isolation and the vast physical size of the country.

According to Morrice and Taylor (1978) home and away occupations are characterised by a parting and reunion cycle providing a recurring crisis and a uniform pattern of feelings.

This recurring cycle includes tension and tearfulness on a husband's departure, return to normal, followed by feelings of depression, sadness, anger and recrimination towards a husband during the cycle and on his return.

These authors were one of the first groups to document the impact of home and away work patterns on the family. Morrice and Taylor were attracted by what appeared to be a recurrent pattern of clinical symptoms of anxiety and depression in women whose husbands were employed in the off-shore oil industry.

Study results indicated that while the general health profiles were similar in on-shore and off-shore wives, the off-shore wives experienced increased levels of anxiety and depression related to frequent separations from their husbands. In most situations, the wives were able to successfully cope with their husband's absence and thus, the anxiety and depression were not significantly problematic.

However, approximately 10 percent of off-shore wives exhibited ineffective coping strategies and were classified as suffering from 'Intermittent Husband Syndrome' (IHS). This term was coined by Morrice and Taylor (1978) and describes a triad of symptoms: anxiety, depression and sexual difficulties, which occur as a result of frequent partings and reunions between a wife and husband.

Australian mining is moving from the traditional 'company' to home and away operation. Information from the Australian mining industry shows that over past three decades mining companies have moved towards long distance commuting (LDC) and fly in and flyout (FIFO) workforces rather than building 'company' towns close to mine sites.

A total of 41 FIFO mines opened between the periods of 1980-1991, with 30 since 1987 (Storey & Shrimption, 1991). Currently, 63 FIFO mining sites are operating in Australia. LDC has been coined as employment where work is so isolated from the homes of the workers that employees spend a fixed number of days working at the site, and a fixed number at home.

In addition, all food and lodging are provided at the worksite (Storey & Shrimption, 1991). A mine is classified as LDC if 50 percent of the employees are accommodated at the work site for the duration of their rotation (Hogan & Berry, 2000).

The use of LDC in the mining industry is the result of trends that have increasingly favoured its use over the construction of new mining towns. These include relative costs of LDC operation compared to conventional mine towns; the social economic and political limitation of mining towns and technological changes that have made commuting safe.

Furthermore, changes in the regulatory environments tend to make LDC more attractive than new town construction for companies, indigenous people, and governments alike (Storey & Shrimption, 1991). Changes in regional mining employment in Australia have been highlighted by ABS census data (ABS, 2000).

Between 1986 and 1996, mining employment increased in capital cities and coastal regions, and decreased in other metropolitan, inland remote regions. The 10 percent rise in coastal employment was partly due to the shift towards LDC.

Results of mining studies in Canada and Australia have identified that little is known about the social impact of LDC on wives and families (La Forte, 1991; Houghton, 1993). Some evidence from mining indicates that stress in wives of miners who travel long distances has been reported to be greatest with short rotations (seven days on, seven days off; compared to 14 days on and 14 days off).

Burnout in this situation can occur at twice the speed. After a seven day separation, time is needed to adjust to one another. It can take up to two to three days to bond again. The days before departure are often filled with heightened emotions. Thus, a large proportion of the husband's time spent at home is lost due to readjustment issues (La Forte, 1991).

Difficulties with the upbringing of children have also been noted. In a review of long distance commuting in the mining industry: a wife's point of view, La Forte (1991) highlighted that discipline is responsibility of the wife while the husband is away.

When the husband returns he wants to maintain a hero's image and deters from disciplining children. This can create behaviour management problems with children and conflict between wife and husband.

The in/out lifestyle of LDC can impact heavily on the wife/partner. Issues such as working outside the home, social mingling, and sexual needs being met have been raised. These problems are largely due to living in a cycle (seven days, nine days, and 14 days) as opposed to normal day to day patterns.

Working outside the home is nearly impossible for some wives. For instance, the additional work load and the upbringing of the children places restrictions on the wife that can lead to resentment and marital conflict. LDC has been associated with changes in sleeping patterns, stress related hair loss, increase in minor illnesses such as colds, headaches, flu and mood-swings (La Forte, 1991).

Although work related travel does have drawbacks towards family life, in some situations it is seen as advantageous. For example, miners who choose to commute long distances enables their wives and children to continue living in urban centres instead of being uprooted and shifted to remote mining communities.

'Spouses do not have to give up their own existing careers, friends or activities; children do not have their education disrupted; a worker losing his job does not have to automatically move house (as is customary in a company town); and wives do not have to put up with the boredom and loneliness of remote locations (Jackson, 1987).

Additionally, the blocked work schedules of LDC allow for more extensive periods of recreation time, thus a greater amount of time (and quality of time) that can be spent with family than in 'normal' family situations (Houghton, 1993). When the LDC spouse is away, children develop more outside interests, helping them to cope when one parent is away (La Forte, 1991).

Most of the evidence relating to work-related absences comes from the military literature.

Military families are regularly separated with absences of six months not uncommon. In a typical military family, the major responsibility for normalising a family's physical, social and emotional behaviour frequently becomes the responsibility of the wife.

Evidence from the military literature indicates that 'waiting military wives' report increased demands of caring for the family, increased number of illnesses, loneliness, sexual frustration, anger and frustrations at their husbands departure (Riggs, 1990, review article).

A study examining the role of organisational support in army life during periods of separation revealed that lower ranking officers reported lower family adjustment than older, higher ranking officers. Additionally, the study identified several organisational resources which were effective in alleviating the negative effects of family separation.

These included: the level of soldier's morale, satisfaction with available resources to communicate with home and perceptions of leader support for family difficulties (Rohall et al 1999). The impact of family separations on divorce rates has been inconclusive.

However, a recent study exploring the impact on divorce rate of military deployment during the Gulf War revealed that deployment of male soldiers had no significant effect on marital dissolution. In contrast, the deployment of female soldiers led to a large and statistically significant increase in divorce rates suggesting deployment of women placed a marked strain on marriages (Angrist & Johnson 2000).

There is some evidence of the impact of work-related absence on children available from the military literature. In a review of some of the studies Riggs (1990) indicated that the parental absences seem to result in feelings of tension and anxiety prior to the departure or arrival home of the parent, a variety of behavioural problems and somatic complaints that mirror the departure of a parent had the potential for poor parent child relationships due to the intermittent periods of absence.

Information from transportation sectors supports the experiences of mining and military wives. Studies have shown significantly lower levels of well being and a higher incidence of depressive mood in aircrew wives compared with ground crew wives (Rigg & Cosgrove, 1994).

For instance, increased domestic role overload (including being like a one parent family, difficulty in involving the husband in things he has missed while away, isolation and feeling rejected when the husband returns home tired) were identified as the greatest source of stress on aircrew wives (Cooper & Sloan, 1985).

Similarly, studies of seafaring groups have revealed increased domestic stress on wives and families due to the husbands/fathers home and away work (Foster & Cacioppe, 1986; Parker et al., 1997; Shipley & Cook, 1980; Sutherland & Flin, 1989).

Levels of stress and tension appear to heighten particularly in the first seven to10 days during the transition between home and sea and vice versa. One of these studies involving a survey of 52 wives of Australian seafarers indicated that 83 percent of the wives experienced stress when their partner was either due to return home or to sea.

Moreover, 79 percent of children were perceived by their mothers to experience stress prior to and after the arrival home of their father (Foster & Cacioppe 1986). Hence, it is apparent that the home and away nature of seafaring work impacts on all family members.

Home and away patterns associated with marine pilotage also appear to be disruptive to family life. For instance, previous studies investigating English (Shipley & Cook, 1980), Dutch (de Vries-Griever, 1982) and Australian marine pilots operating in the Port Phillip region (Berger, 1984) have acknowledged the disruptive effects pilotage work can have on the lifestyle and family life of pilots, and the importance of a stable family situation on pilotage performance.

The work practices of Great Barrier Reef pilots frequently require pilots to spend considerable blocks of time away from home. These periods of separation may last anywhere up to several weeks. The pilots' wives input was considered highly relevant since anecdotal information from the industry suggested the uncertainty of pilotage work placed additional strain on wives and families. Moreover, previous data on Australian seafarers raised concern over the pressure on wives of having responsibility for the household and family for extended periods during a husband's absence (Parker et al., 1997).

The present paper provides data on the experiences of the wives of Great Barrier Reef pilots. The data is based on an investigation of the impact of home and away work patterns of pilots on wives and families including an examination of the degree of marital satisfaction, anxiety and depression.

2.0 Methodology

Sample

The wives/partners of 58 Great Barrier Reef pilots were surveyed to examine the impact of the home and away nature of marine pilotage work on wives/partners. Participation in the study was voluntary and anonymous. The study was conducted with approval from the Queensland University of Technology Research Ethics Committee.

Questionnaire development and distribution

A questionnaire was developed consisting of 17 questions (100 items). This paper addresses the following issues:

(i) demographic characteristics

(ii) marital satisfaction (dyadic adjustment)

(iii) social support

(iv) psychological well-being (particularly the experience of anxiety and depression).

The item content was based on studies of the wives of other situations of work-related absences (Cooper & Sloan, 1985; Rigg & Cosgrove, 1985; Taylor et al., 1985), with study specific measures based on previous maritime investigations (Shipley & Cook, 1980; Berger, 1984; Parker et al., 1997).

Pilot testing of the questionnaire was undertaken on a convenience group of four women with husbands in home and away occupations: their comments were incorporated into the final questionnaire.

Questionnaire distribution and reminders

Questionnaires (including an information page to explain the purpose of the study and a stamped-addressed envelope for returns) were distributed through the pilotage companies and posted to the home addresses of participants. A reminder system was implemented consisting of two individual reminders to each participant.

Measures

Demographics

Items in this section included information on age, marital status, education, number and ages of children and employment status.

Marital satisfaction: Spanier Dyadic Adjustment Scale

The Spanier Dyadic Adjustment Scale (Spanier, 1976) is designed to assess the quality of the relationship of either married or cohabiting couples and comprises four interrelated sub-scales (Dyadic Consensus, Dyadic Cohesion, Dyadic Satisfaction and Affection Expression). Seven items assessing Dyadic Satisfaction were used.

Previous reports indicate sub-scales can be used independently without losing confidence in either the reliability or the validity of the measure. Using Cronbach's alpha as the reliability estimate Spanier (1976) reports an overall scale reliability of 0.96 with a reliability score of 0.94 for the Dyadic Satisfaction. Respondents were asked to rate their responses on a five point Likert scale ranging from 'all of the time' (scale = 1) to 'never' (scale = 5). The reliability of the scale was determined using Cronbach's alpha. This was a very acceptable 0.83.

Social support – emotional or informational

There are two broad categories of social support: structural and functional support. The 19 measures used to assess the levels of functional support covered four categories: tangible support, affectionate support, positive social interaction and emotional or informational support (Vaux, 1988). In addition single items provided an estimate of structural support or the perceived size of the social network. For all scales, responses were coded on a five-point Likert scale ranging from 'never' to 'all of the time'. In this paper the measures for emotional or informational support are reported.

Psychological well-being: anxiety and depression

The Delusions Symptoms States Inventory (DSSI) (Foulds and Bedford, 1978) was used to measure levels of anxiety and depression. This is a brief, 14 item measure which contains two seven item sub-scales assessing levels of anxiety and depression. This measure was selected because it provides a clinically relevant measure of both anxiety and depression. The DSSI has been validated in adult Australian populations (Boyle, 1993; Henderson et al. 1981; Keeping et al.1989).

Respondents were asked to rate their feelings, during the last week, on each of the items on a five point Likert scale ranging from 'all of the time' (scale = 1) to 'never' (scale = 5).

Additional comments

The questionnaire also provided space for additional comments to enable wives/partners to elaborate on issues in the structured questions or to raise other pertinent points not covered in the questionnaire.

Data analysis

The quantitative data was analysed using SAS-PC. Standard univariate statistics were used to describe the responses. Factor analysis, using the principal components method to extract the initial factors and a promax (oblique) rotation method, was used to help identify constructs underlying a series of questions dealing with knowledge, attitudes and beliefs. Further item analysis involving assessment of the reliability of scales and the interpretability, was undertaken before the scales were finalised.

Cronbach's alpha coefficients were calculated to determine the reliability of each of the aggregate scores used in the report. Scales showed a high level of reliability with Cronbach's alpha coefficients for marital satisfaction, anxiety and depression being 0.83, 0.92 and 0.84, respectively. The reliability of the social support scales was also very acceptable: emotional or informational support 0.98

To facilitate interpretation of the questionnaire and to provide a clearer understanding of the context within which responses to questionnaire items were made the qualitative data was analysed by examining the comments for recurrent patterns and themes.

3.0 Results

Participation

A total of 35 wives/partners of Great Barrier Reef Pilots participated in the study, giving a response rate of 60 percent.

Table 1.0 Demographic Characteristics of the Sample

Variable	percent
Age	
Less than 50 years	48.6
50 years or older	51.4
Marital Status	
Currently married	94.3
Never married	2.9
Separated	2.9
Level of Education completed	
High School	40
Technical School	28.6
University Graduate	20
Postgraduate Degree	11.4
Employment Status	
Currently employed	68.6
Children	
At least one child 18 years or less	22.9

The socio-demographic characteristics of the respondents are shown in Table 1.0. The table reveals approximately 49 percent of the sample were aged 50 years or younger. The majority of respondents were currently married. The women participating in the study were well educated, with just over 30 percent having a university or postgraduate qualification. The majority of the sample was employed (approximately 69 percent).

From the qualitative data it was evident that for many of the women, participation in the paid workforce was directly related to changes in pilotage operations and a consequent drop in family income. Several women felt they had, in fact, been 'forced' to return to the workforce to supplement the family income. Some of the older women who had been out of the paid work-force for 20 or more years, had found this return difficult and stressful, were unable to return to jobs they had been trained for, and now worked in low skilled employment.

information support is shown in Table 3.0.

The majority of respondents (71 percent) believed that there was someone that they could count on to listen to them at least some of the time. Additionally, most respondents believed that they had access to someone for advice during a crisis (61 percent); someone who could provide them with information to help them understand a particular situation (64 percent); someone to confide in (68 percent); someone to provide wanted advice (59 percent); someone to provide assistance to deal with personal problems (53 percent) and someone who was understanding (65 percent).

However, approximately 53 percent of respondents did not believe that they had access to someone to share their most private thoughts with.

Table 2.0: Distribution of scores across the seven items comprising the marital satisfaction scale.

Item	All the time percent	Most of the time percent	Some of the time percent	Rarely percent	Never percent
1 In general, would you say things between you and your partner are going well?	0.0	37.1	54.3	2.9	5.7
2 How often do you think about divorce, separation or termination of the relationship?	0.0	2.9	11.4	25.7	60.0
3 How often do you or your partner leave the house after a fight?	0.0	0.0	0.0	25.7	74.3
4 Do you find it easy to confide in your partner?	42.9	42.9	5.7	2.9	5.7
5 Do you ever regret that you married or lived together?	0.0	0.0	5.7	17.1	77.1
6 How often do you and your partner quarrel?	0.0	5.7	31.4	54.3	8.6
7 How often do you and your partner 'get on each	5.7	5.7	34.3	51.4	2.9

Marital satisfaction

The Spanier Dyadic Adjustment Scale was designed to assess the quality of a relationship for both married and cohabiting couples.

The distribution of responses to this series of questions was skewed towards the end of the scale indicating satisfaction with the dyadic relationship (Table 2.0). Only two respondents (6 percent) believed that things were never going well between themselves and their partner. One respondent (3 percent) was considering divorce. A further 9 percent expressed difficulty confiding in their partners Table (2.0).

Emotional or informational support

The item content and distribution of scores comprising the measure of emotional and

The numbers of women reporting a perceived lack of emotional and information support was substantial.

The qualitative data provided some insight into the issue of availability of social support. The qualitative comments indicated that those respondents who lived closer to family and relatives reported greater levels of social support than those who have had to move away from family for work purposes. Several respondents considered this dislocation of themselves and their children to be a major form of stress.

Family, rather than friends, appeared to be the most important source of social support for a number of women.

However, at least one women who had relocated to another state reported that good friends and neighbours were important sources of support.

Those respondents who were geographically distanced from family support to maintain this link commonly used telephone contact.

The scores for all items were skewed towards the end of the scale indicating normality. However, a small number of respondents scored towards the negative end of the scale.

A response of either three, four or five (that is, a report of experiencing a symptom, some, most or all of the time) to any item was considered equivalent to experiencing a particular symptom. On this basis, the most frequently occurring symptoms of anxiety included 'worrying about every little thing' (44 percent) 'having a pain or tense feeling in the neck or head' (32 percent) and 'being kept awake at night due to worry' (23 percent). Five respondents or 14 percent of the sample reported experiencing four or more symptoms and can be considered to be experiencing high levels of anxiety.

Depression

Table 5.0 presents the item content and distribution of scores for the seven items included in the DSSI measure of depression. The distribution of scores on this measure of depression was skewed towards the end of the scale indicating normality.

However, a small number of respondents scored towards the negative end of the scale. By combining responses where respondents have reported the experience of a symptom 'all', 'most' or 'some of the time', the most frequently occurring symptoms of depression included feeling 'so miserable that I have difficulty sleeping' (26

Table 3.0. Distribution of scores for the eight items comprising the measure of emotional or informational support.

Item	Never percent	A little of the time percent	Some of the time percent	Most of the time percent	All of the time percent
1 Someone you can count on to listen to you when you need to talk	5.9	23.5	4.7	32.4	23.5
2 Someone to give you good advice about a crisis	11.8	26.5	17.6	26.5	17.6
3 Someone to give you information to help you understand a situation	12.1	24.2	15.2	27.3	21.2
4Someone to confide in and talk about yourself or your problem	5.9	26.5	20.6	32.4	14.7
5 Someone whose advice you really want	11.8	29.4	14.7	23.5	20.6
6 Someone to share your most private thoughts with	38.2	14.7	8.8	23.5	14.7
7 Someone to turn to for suggestions about how to deal with personal problems	17.6	29.4	11.8	26.5	14.7
8 Someone who understands your problems	20.6	14.7	23.5	26.5	14.7

percent); feeling 'depressed' (23 percent) and feeling that 'the future seems hopeless' (20 percent).

4.0 Discussion

This study was one of several conducted during an extensive investigation of the fatigue aspects of the work patterns of Great Barrier Reef pilots and as such provided insight into the social and psychological impact of home and away work patterns on wives and families. The wives' experiences were considered extremely important given the intimate relationship that exists between a worker's home life, work situation, work performance and well being (Cooper & Sloan, 1985; Karlins et al, 1989).

Generally, the study results demonstrate extra hardships on those at home when a husband or father is involved in work-related absences. While direct comparisons with other industries are difficult, in most aspects, the study results were broadly consistent with the experiences of wives in other occupations involving home and away work patterns such as airline workers (Rigg & Cosgrove, 1994), offshore oil industry (Sutherland & Flin, 1989), other maritime sectors (Shipley & Cook, 1980; de Vries-Griever, 1982; Berger, 1984; Parker et al., 1997), military (Rigg 1990), and mining sectors (La Forte, 1991; Houghton, 1993; Storey & Shrimpton, 1991; Hogan & Berry, 2000).

Many of the present wives experienced stress due to the home and away nature of pilotage work and felt strongly regarding the reasons for their return to the workforce. A substantial number of wives perceived a lack of emotional or informational support in their lives, and at the time of the study a considerable percentage reported depression.

The current data should be interpreted conservatively due to the small sample size (n = 36). However, the 60 percent response rate was generally comparable with that in similar studies involving postal surveys to wives in other home and away situations. For example, postal surveys to the wives of commercial airline pilots (Cooper & Sloan

Table 4.0: Distribution of scores of the seven items comprising the DSSI measure of anxiety.

Item	All the time percent	Most of the time percent	Some of the time percent	Rarely percent	Never percent
1 I have been worried about every little thing*	5.9	0.0	38.2	20.6	35.3
2 I have been so worked up that I could not sit still*	2.9	0.0	8.8	26.5	61.8
3 For no good reason I have had feelings of panic**	0.0	0.0	12.1	21.2	66.7
4 I have had a pain or tense feeling in my neck or head	5.9	2.9	23.5	20.6	47.1
5 Worrying has me awake at night	2.9	2.9	17.6	32.4	44.1 kept
6 I have been so anxious that I could not make up my mind about the simplest thing.	2.9	0.0	11.8	17.6	67.6
7 I have been breathless or have had a pounding of my heart.	0.0	0.0	8.8	20.6	70.6

Missing values *n=1; ** n=2.

1985) Australian seafarers (Foster and Cacioppe 1986) off shore oil rig workers (Taylor et al. 1985) provided responses of 56 percent, 40 percent and 70 percent, respectively.

Demographic results revealed the majority of women participating in the present study were married, well educated, and approximately 70 percent were employed. The number of wives employed was higher than broadly comparable Australian population data indicating 58 percent of women are in the workforce (Australian Bureau of Statistics, 1998).

The percentage of pilots' wives in the workforce was also higher than data from earlier studies of workforce participation by spouses in other home and away situations (Cooper & Sloan, 1985; Foster & Cacioppe, 1986; Taylor et al, 1985). The older age category of the present wives and absence of young children (only 23 percent of the sample have children aged 18 years or younger), may partly account for the higher workforce participation.

Developing one's career has been associated with greater life and job satisfaction in working wives of airline pilots (Cooper & Sloan, 1985); however, the underlying tone in the pilots' wives comments strongly suggested that work was due to financial pressures and not by choice.

Home and away work patterns across industries appear to place relationships at risk. Despite approximately 50 percent of the present sample reporting moderate to high levels of marital satisfaction, almost one quarter of the women (23 percent) participating in this study appeared to be concerned about the home and away nature of their partner's work being a risk to their relationship.

This figure was somewhat less than the 42 percent of wives of Australian seafarers reporting concern over marital risk from work-related absences (Foster & Cacioppe, 1986). Likewise, a study of aircrew wives revealed participants were concerned with the ever-present risk to relationships of extra marital affairs (Rigg & Cosgrove, 1994).

In contrast a military study showed that although female soldiers are less likely than male soldiers to be married (49 percent versus 63 percent) they are more likely to get divorced or separated (17 percent versus 8 percent). This finding indicates that the deployment of female soldiers was stressful for marriages, while the wives of deployed men were able to adapt to their husbands absences (Angrist & Johnson, 2000). This maybe due to the husband remaining at home having to take on what is considered to be more feminine roles.

The finding that a considerable percentage of the current sample perceived a lack of emotional or informational support is concerning given the major responsibility assumed by a wife during her husband's absence. Considerable evidence now indicates the importance of social support to quality of life and to the ways in which individuals cope with stressful situations (Thoits, 1995; Vaux,

Table 5.0: Distribution of scores on the seven items comprising the DSSI measure of depression

Item	All the time percent	Most of the time	Some of the time	Rarely	Never
1 I have been so miserable that I have had difficulty sleeping*	2.9	5.9	17.6	20.6	52.9
2 I have been depressed*	2.9	5.9	17.6	29.4	44.1
3 I have gone to bed not caring if I never woke up*	0.0	2.9	2.9	11.8	82.4
4 I have been so low in spirits that I have sat up for ages doing absolutely nothing.*	2.9	5.9	0.0	14.7	76.5
5 The future seems hopeless*	2.9	0.0	17.6	11.8	67.6
6 I have lost interest in just about everything	3.1	0.0	6.3	25.0	65.6
7 I have been so depressed I have thought of doing away with myself	0.0	0.0	2.9	1.8	85.3

Missing values * n=1.

1988; Cohen and Wills, 1985).

Social support is believed to promote well-being either directly, by promoting well-being regardless of the level of stress the individual is experiencing; or indirectly, by 'buffering' or attenuating the stressor. The importance of a close confidant for the seafaring wife has been previously reported. Foster & Cacioppe (1986) indicated 80 percent of wives of Australian seafarers had a close friend in whom they could confide, however these respondents pointed out that unless the person was familiar with the seafaring life, their concerns could sometimes be misunderstood.

The qualitative data provided some insight into the issue of availability of social support. These comments indicated that those respondents who lived closer to family and relatives reported greater levels of social support than those who have had to move away from family for work purposes.

Several respondents considered this dislocation of themselves and their children to be a major form of stress. Family, rather than friends, appeared to be the most important source of social support for a number of women. However, at least one woman who had relocated to another state reported that good friends and neighbours were important sources of support. Those respondents who were geographically distanced from family support to maintain this link commonly used telephone contact.

Difficulties in planning and involving partners in social events appear to be a common problem in home and away occupations (Rigg & Cosgrove, 1994; Foster & Cacioppe, 1986; Taylor et al., 1985). The present wives considered that their level of involvement in social situations in the community was greatly influenced by the uncertainty of being able to plan ahead for social events and whether or not their husband would be at home or on leave.

Moreover, the reintegration of the absent member into family life again is associated with feelings of relief, excitement and tension. Communication is also difficult due the different experiences of both parties during separation (Rigg, 1990).

Levels of both anxiety and depression in the present sample were notably higher than population figures. By comparison, 14 percent of the current sample was classified as anxious; prevalence rates for anxiety disorders in the adult population have been estimated at between seven and 15 percent (Freedman, 1984).

Similarly, the prevalence of depression was 9 percent in pilots wives compared with a figure of 3 percent assessed across approximately 20 studies conducted since 1980 (Wittchen et al., 1994). However, the shorter term, six month to one year, depression prevalence rate was approximately 6 percent. The range across studies was from 2.6 to 9.8 percent.

Previous studies have reported the occurrence of symptoms of anxiety and depression and lower levels of well-being in the wives/partners of men involved in work-related absences (Morrice and Taylor, 1978; Taylor et al., 1985; Rigg and Cosgrove, 1994). The frequent partings and reunions associated with these work practices manifest in symptoms of anxiety and depression and have also been used to classify sufferers of 'Intermittent Husband Syndrome' (Morrice and Taylor, 1978; Taylor et al., 1985; Rigg and Cosgrove, 1994).

Research examining the psychosocial effects of frequent partings on off-shore wives revealed that these wives experienced greater levels of anxiety than a comparative group of onshore wives. However, the increased anxiety occurred only while their husband was off shore (Taylor et al., 1985).

Additionally, the levels of anxiety associated with partings and reunions tended to decrease as wives became more 'experienced,' that is, had been with their partner for longer periods of time (Taylor et al., 1985). However, It was notable that a considerable percentage of the present wives still experienced stress from the home and away nature of their husband's work. This occurred despite their husband having spent up to 30 years in the general maritime sector prior to joining the pilotage service.

5.0 Conclusion

The impact of home and away work patterns on the pilots' wives was consistent with the experiences of wives in other home and away settings. It was clear that a support group for pilots wives would enable communication with others in the same 'boat', particularly in light of the scattered home locations along the Queensland coast.

Present levels of anxiety and depression and the reported lack of support for the group are concerning given the extensive experience by the current group in home and away situations and reinforces the need for counselling and support services. Co-operation between industry and family professionals will enable families experiencing the negative effects of work-related absences to feel added support.

In their more detailed qualitative responses, several women pointed out that they knew what to expect from life before they married a seafarer. They knew that they would have to cope with a life spent, at least in part, separated from their partners. In their opinion, they do cope.

6.0 Future directions

Additional research is needed particularly in view of: the relationship between a happy family life and worker productivity; the huge financial importance of the mining industry to Queensland economy; and the likely expansion of FIFO mining operations.

This paper has presented common findings across families who experience work related routine absence.

From an industry standpoint several issues also emerge: Do mining wives experience similar problems? Does the industry have a support program in place? What is the utilisation rate of this program? What are the 'best practice' options for FIFO families? Does successful family coping increase worker productivity? Do family needs differ across the various mining sectors?

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ARRB PRO-ACTIVE FATIGUE MANAGEMENT SYSTEM

Nick Mabbott ARRB Transport Research Ltd

Operator fatigue has attracted a great deal of attention over the past two decades. Within this time, numerous technological and managerial solutions have been offered to various industries.

The constant highlighting of the issues must surely be having some impact on the workforce, however, positive outcomes are rarely shown. Similarly, although technology abounds, the system that appears to get most usage – the 'dead man's handle' in trains – is said to be far from minimising the risk associated with becoming tired on the job.

The ARRB Pro-Active Fatigue Management System utilises fatigue education with ongoing performance management supported by the ARRB Fatigue Monitoring Device. The fatigue management aspect couples fatigue research, education and training into a system of pro-actively managing operator performance.

It commences with training that highlights the most pertinent performance issues in a short session directed at what is relevant to the mining environment. The training provides personnel with materials to take home to conduct their own sleep research for inclusion into their personal fatigue management profile.

The information collected from this exercise is added to the first (approx.) six weeks of data collected from the fatigue monitoring device that has been installed into the haul trucks. Each personnel has their data analysed and a performance profile is generated to assist in the management of their performance.

Countermeasures are discussed where appropriate with each individual. At regular intervals, the data for each personnel is revisited and an updated performance profile developed. This unique system offers a very practical combination of fatigue education, training and feedback support from technology. It takes a risk management approach to fatigue by addressing the issues at a grass roots level.

1 Background

Operator fatigue has attracted a great deal of attention over the past two decades. Within this time, numerous technological and managerial solutions have been offered to various industries. The constant highlighting of the issues must surely be having some impact on the workforce, however, positive outcomes are rarely shown. Similarly, although technology abounds, the system that appears to get most usage – the 'dead man's handle' in trains – is said to be far from minimising the risk associated with becoming tired on the job.

In 1999, ARRB Transport Research Ltd. were commissioned by the Australian Coal Association Research Program (ACARP) to conduct a review of local and international technology that would be useful for monitoring heavy vehicle operator fatigue in open cut coal mines.

The report (Mabbott, Lydon, Hartley & Arnold, 1999) described several devices that were examined for their implementation into open cut coal mines. Similar research was later conducted for the long distance heavy transport industry for the National Road Transport Commission (Hartley, Horberry, Mabbott & Krueger, 2000). Both reports noted the lack of practical devices available for implementation into environments utilising heavy vehicles in rugged terrain.

2 Fitness for the entire shift

Fitness for duty testing is unfortunately limited to the number of times an employee is tested for fitness levels. The usual practice is to test at the start of the shift only. Although some supporters of fitness for duty testing are advocating more tests (eg at lunch and some other down times), this will often require a trip back to the buildings where the fitness for duty tests are housed. It is hard to argue the cost/benefit of such an action without the necessary validation data to substantiate the action.

Research has shown that the human can (in times of drowsiness) pull together a certain amount of resources to achieve an endpoint if thought necessary. For example, even sleep-deprived subjects can perform tasks for up to 15 minutes in duration (Arnold & Hartley, 1998).

If one can reflect on periods whereby they felt very tired, they may also recall having smaller periods of feeling reasonably alert. Therefore, when we find ourselves nodding off at the conference, we also find we can 'pull ourselves back together' for short bursts. Electroencephalograms (EEGs) have shown this to be caused by shifts in brain waves.

For example, Khardi and Vallet (1995) noticed alpha and beta activity through normal operating conditions, then shifting to alpha and theta activity. The shift coincided with impaired driving. What this means is that when a driver is feeling tired, they might become alert after a while, become drowsy again, become alert again, and so on.

The amount off additional resources that an individual can muster when feeling drowsy will depend upon many variables (eg time of day, time since last sleep, etc). The basic fact is that if an operator of machinery is feeling tired, they are a liability to the company. Research has shown that a simple break will not restore alertness.

Lisper, Laurell and van Loon (1976) showed that drivers falling asleep, being woken and given a five-minute break, were asleep again in an average of 24 minutes. A brief nap may be all that is needed to restore alertness to an individual.

3 The ARRB fatigue monitor

ARRB Transport Research Ltd. has developed a device that can measure operator alertness levels through the operator's reaction to a visual and audible stimulus. It does this in real-time (while the operator is working) and throughout the whole working shift. It has the capability to acknowledge reductions in alertness levels and allows an intervention strategy to counter the effects of driving fatigued. This is made possible by alerting significant others to the fact that the operator is becoming drowsy.

Stimulus-reaction tasks have been used in research studies to measure several functions of humans. One such function is human performance decrements such as that displayed during periods of operator fatigue.

Research has shown that simple stimulus-reaction tasks can become automated to the extent that an operator can still respond rapidly even when in a decreased state of alertness. By using two stimuli lamps instead of one, the simple reaction task becomes a forced decision task. Decisions are a much harder task than simple responses for individuals during periods of tiredness. Therefore, a slower response would suggest a fatigued state.

The concept and specifications for the operation of the fatigue monitor were relayed to the builder of the device – Romteck Pty Ltd. Romteck engineers worked closely with the ARRB project leader to develop the device to make it applicable to the mining industry. It was trialed in three mines, whereby many glitches were taken out of the system and improvements to the devices were born.

Electronically, the fatigue monitoring system consists of the following components:

1 a PC with Romteck communications module
2 a talk through repeater (if required)
3 a fatigue monitoring unit.

These three main components work in unison to make up the complete monitoring system. The fatigue monitoring unit consists of a 'stimulus' enclosure and a control module. The control module (the heart of the vehicle system) houses a Romteck Delta IV series microcontroller board incorporating a Motorola 32 bit microprocessor.

This board controls and monitors all the functions of the vehicle monitoring system. Attached to it are a Dallas Touchkey reader, inputs from vehicle park brake and reversing signal as well as heavy-duty response buttons from the front of the unit. It also controls the two stimulus lights (mounted in a separate module) as well as a piezo buzzer.

A separate connection to a FSK data radio, which allows data to be routed between the vehicle and the base PC, makes up the last of the in-vehicle system.

The radio unit is generally connected to a 4.5dB UHF whip antenna. The entire system runs on 12V DC. All components are housed in a rugged tamper-resistant enclosure. The stimulus lights are mounted in a separate module that connects to the main module via an umbilical cable.

The in-vehicle system communicates to the base PC via a talk through repeater site. One trial site comprised a Romteck RM1000RR talk through repeater unit. This unit is a 2U rack enclosure and consists of all equipment required for a complete talk through repeater unit including 2 data radio's, a Romteck data switch unit and duplexor. The install is usually complemented with a dipole or co-linear antenna mounted on an adjacent mast.

At the PC end, a Romteck communications module is connected for the purpose of communicating with the PC on a RS232 connection and formatting this information in a suitable manner to send through a data radio unit via the repeater to the remote vehicle units. The communications module consists of a FSK data radio, PC interface and power supply.

3.1 Normal operation

The stimulus-reaction device operates in four defined stages. Under normal circumstances (and the operator is wide awake) the device will present a light and audio stimulus every seven to 10 minutes apart. If the operator reacts within a short time, nothing else will happen and another stimulus presentation will occur within the next seven to 10 minutes. Stimulus presentations are random in time and for left and right stimulus light.

3.2 Slow or wrong responses

If the reaction to the light stimulus is slightly slower than normal, or if the wrong reaction button is pressed (eg left stimulus light – right reaction button), the device will automatically speed up the period of time between stimulus presentations. The next presentation will occur within 4 to 7 minutes apart, based upon the notion that more testing should be carried out if the operator is getting tired.

3.3 Slower responses

If a reaction to the stimulus light is considerably slower, the device will again speed up the time between tests. However, on this occasion the next stimulus presentation will occur within the next two to four minutes and an alert will be sent to the supervisor.

At this stage, the device has determined that the operator is at risk of becoming sleepy enough to possibly cause an accident. The supervisor should contact the operator on the radio to discuss possible countermeasures to the current state of lowered alertness.

3.4 Extremely slow responses

Extremely slow responses to stimulus presentations will cause the device to emit a warning buzzer sound in the vehicle cabin. This is not designed to increase alertness levels but to advise that the operator has responded extremely slow or missed the stimulus altogether.

The supervisor will also receive a warning message that will prompt immediate action. It is at this stage that the operator should no longer drive the vehicle without first having a rest/nap/sleep. Until the supervisor acts on the warning message the fatigue monitor will test reactions every minute.

3.5 Faster responses

There are likely to be occasions whereby the reactions to the stimulus presentations were slow for reasons other than fatigue. For example, an operator may have been focussing all of their attention on something within their visual field, thus not seeing the stimulus light immediately. In this case, the next stimulus presentation will be sooner than seven to 10 minutes apart dependent on the reaction time. If the operator then responds quicker, the stimulus presentations will slowly move back out to the normal seven to 10 minutes apart. Therefore, the quicker operators react to the stimulus presentations, the fewer tests will have to be conducted on that shift.

3.6 Disabled when reversing and with park brake applied

In either a reverse movement or when the vehicle is not in motion (stopped, loading or tipping), the fatigue monitoring device will be disabled so that operators are not tested as they may be looking elsewhere. The device's internal clock will continue to run during the period of disablement, however, no stimulus presentations will be made.

3.7 Safety

Operator safety has been given highest priority within all parameters of the trial. The research team has given priority to safety in every step of the development of the fatigue monitoring device, through their skills in ergonomics and human factors. The device is non-invasive and will neither distract nor cause high mental workload for the operators.

3.8 Touch key

On top of the reaction box is a receptacle for the 'touch keys' that will be used to identify the operator using the fatigue monitoring device. The use of this will be explained in the next section (Logging onto the device).

3.9 Logging onto the device

Each operator that will be utilising the fatigue monitor will be issued with their own personal 'touch key'. Each time the operator uses the vehicle, they must touch their key onto the receptacle on top of the reaction box. When they do this, it will emit a beep indicating that they have logged on.

It will also identify the operator and enable the system to use their personal reaction time data. When they have finished operating the vehicle, they will need to log off by touching the key onto the receptacle again.

When logging off, the device will emit three short pip sounds to indicate the trial has finished.

If the operator forgets to log off at the end of operating the vehicle, one of two things will happen. If the next operator is part of the trial and he/she touches their key onto the receptacle, the device will automatically switch to their data. Nothing more will need to be done. If the truck is turned off, the operator will automatically be logged off.

3.10 Supervisor warning messages

In the event that an operator responds in a slow manner, the device will emit a warning message via a radio link to a control/dispatch room. The warning will be shown on a computer monitor that will highlight the warning. In the case of successive warnings, it will rank the warnings in priority. The supervisor (or assigned personnel) should contact the tired personnel and discuss possible countermeasures for the operator. It may simply be changing crib breaks with other personnel or moving onto a less risky task.

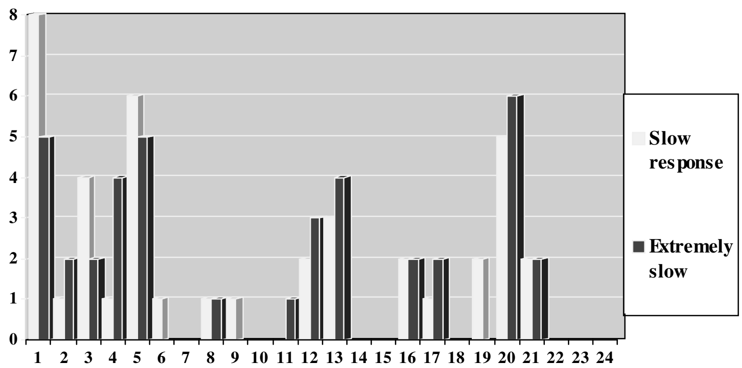
4 The pro-active fatigue management system

The Pro-Active System comprises the fatigue monitoring device together with fatigue education and ongoing management. The fatigue management aspect couples fatigue research, education and training into a system of pro-actively managing operator performance. It commences with a 2-hour training session that does not bombard personnel with information that they will feel they do not need and will not retain. Rather it highlights the most pertinent issues in a short session that will be directed at what is particularly relevant to the mining environment.

The training session leaves the personnel with materials to take home to conduct their own sleep investigations for inclusion into their personal fatigue management system. The information collected from this exercise is added to the first (approx) six weeks of data collected from the fatigue monitoring device that has been installed into the haul trucks. Each person has his or her data analysed and a performance profile is plotted. A report is generated to assist the personnel to manage their performance. The report will contain advice on practical countermeasures to help manage performance.

Personnel are monitored continuously to ensure the fatigue management is supporting good performance in the vehicles. Once this is achieved, a decision is made whether or not the personnel remains using the fatigue monitoring device. The data shown in the chart below illustrates the number of times an operator has become tired (vertical axis) by the time of day (horizontal axis). This data is utilised to develop personal performance profiles.

At six, nine and 12 months, the data for each personnel is revisited and reports will be forwarded to each personnel that has a performance issue.



Data collected from devices to plot performance of operators. This is utilised to pro-actively manage operator performance. Note: Numbers on horizontal axis are hours of the day.

Countermeasures will also be discussed. At 12 months, a report to the mine will be made on the overall performance of the employees and the system as a whole.

The Pro-Active Fatigue Management System saves the mine paying the full cost of using the devices as a leasing arrangement is offered. A cost is charged per system and all maintenance will be carried out by ARRB staff or their contractors. A spare device will be provided so that a quick change in and out can be made and the unit sent to ARRB/Romteck for maintenance.

5 Benefits to mining

The most immediate benefit will be a reduction in the number and severity of fatigue-related crashes and incidents (fatigue-related crashes are generally more severe as avoidance manoeuvres are not used). The workforce should become healthier if they utilise what they have learnt and performance should increase.

Other savings may be realised through operators taking more care of their vehicles (past research has shown that tired operators do not always treat company vehicles as well as they would if they were not tired). Having the ARRB Pro-Active Fatigue Management System in place also supports the legislative requirements of providing a program to enhance 'fitness for duty' of employees.

6 Summary

6.1 Originality and ingenuity of the solution

The origins of the project were to determine what practical fatigue management devices were available for use in real-time driving operations in open cut mines. Many practical additions were made to a simple stimulus-reaction device that would present a stimulus and cause a buzzer to sound if it was not reacted to.

The ingenuity came from closely working with industry and determining what was necessary to both monitor operator performance and work practically in the mining environment. Several additions were made through responses gained within the three trials.

6.2 Original program

In the initial program, two trials at open cut mines were planned. There were problems with gaining the adequate support at one mine and as luck would have it, some of the equipment was crushed in an accident whereby a dozer reversed over a small vehicle containing a data collection unit.

For these reasons, a third trial was initiated to collect additional data. This was very successful in finalising the validation of the device. The Industry Monitor for the Australian Coal Association Research Program (the funding body) responded with:

I have reviewed the final report draft and I am pleased to advise, in my capacity as industry monitor, that I am satisfied Stage 3 of this project has been successfully concluded and reported. The project has delivered its stated objective - that being the trial of the fatigue monitor at selected mine sites and determination of its capability to monitor operator fatigue. It was evident that the technology developed by the ARRB, and its application using the device, will monitor fatigue and detect a tired operator.

I am confident that the experience gained throughout the trial will enable the ARRB Transport Research group to develop a commercial version of the device suitable for the open cut mining industry.

I believe the only outstanding issue of any consequence is the possible exposure of alert operators to constant monitoring which if not addressed during commercialisation or implementation, may see a gradual reduced acceptance by operators.

The device has demonstrated that it is capable of detecting a tired operator and in this respect offers industry with a means to reduce fatigue related incidents, thereby promoting safe (controlled) operation of mobile mining equipment at all times.

This device coupled with the proposed Fatigue Management Program developed by the ARRB potentially offers industry the means to pro-actively monitor operator fatigue and successfully manage this issue.

I wish to note the enthusiasm and perseverance of Mr Nick Mabbott in leading stage 3 of this project, often in trying circumstances. Operating mines are not always the most ideal environment to conduct trials of this nature, but the experience gained by both researcher and ACARP representatives has been invaluable in the development, operation and testing of the device.

Given the ongoing and committed efforts of the ARRB Transport Research group throughout stage 3, I have every confidence that they will be successful in their endeavours to commercialise the device.

Robert Spencer - (Industry Monitor for ACARP Project C9032)

Chief Mining Engineer

Mt Arthur Coal Pty Limited

6.3 Occupational health and safety record.

The complete Pro-Active Fatigue Management System has only recently been completed, the most recent development being the fatigue management training package. As such, the occupational health and safety record is somewhat short.

During the trials, operators that were detected as becoming tired changed crib breaks with others or changed onto less hazardous work tasks.

Performance profiling also allowed one operator to be counselled in his diet and eating regime. It appeared that the operator was getting tired between 8pm and 9pm after eating a large three-course meal with his family prior to shift commencement at 6pm.

He has since changed this regime and is performing better. It is expected that a huge safety benefit will be noted by any mine or rail organisation that utilises the Pro-Active Fatigue Management System.

6.4 Benefit to the community

Benefits to the community will be manyfold. The immediate benefit is the early detection of lowered performance of operators of dump trucks in open cut mines. Over the long term, the fatigue management education, together with feedback from the devices, will create a better performance level of operators and bring about healthier lifestyles.

This will also impact on the families of the workers. Another major benefit will be an increase in safety on roads whilst operators drive home at the end of considerably long day and night shift operations. Significant savings to the community will eventually be recognised from reduced accidents and incidents normally attributed to fatigue.

6.5 Simplicity of the engineering solution

The engineering solution to the fatigue problem in the mining industry was reasonably simple. At the level of operator usage, the operator merely reacts as quickly as possible to an audible and visual stimuli. Nothing else is required.

6.6 Use and development of innovative design and construction

The design was innovative in that it produced a simple engineering and psychological solution to a very technical and hard to address problem – operator fatigue. Past educational and engineered attempts have been made to address fatigue in many workplaces, with very limited success. Much of the success to date and that expected arises from the combination of the engineering solution together with the management of operators' performance levels.

6.7 Co-operation with other disciplines and professions and effective use of industry consultation

The ARRB Pro-Active Fatigue Management System was developed utilising information and experience from psychology, ergonomics and engineering. The ARRB Project Leader for the project is a psychologist with expertise in fatigue management. The device and system concept were developed by him and relayed to Romteck engineers for building. A reasonable amount of ergonomics of the design was necessary as the devices had to be user-friendly in the cabs of dump trucks.

Considerable consultation with the mining industry was gained through the trials at three distinctly different mining operations and from the ACARP Industry Monitor. Many other individuals from mining organisations were also consulted regarding the operation of the devices.

6.8 Attention given to the needs of users

Considerable attention was given to the needs of operators that might involved in the Pro-Active Fatigue Management System. The design of the device is such that it is safe, effective and practical to use from an operator's perspective. The management component is conducted by ARRB staff, reducing the need for mining personnel to investigate data and arrive at solutions.

This then frees their time to combat other potential sources of injury within the work environment. It also assists to provide the organisation's 'duty of care' for providing safe systems of work.

6.9 Summary

The Fatigue Management Device is one component in the ARRB risk management system, and its main use is to provide feedback as an aid to operator assessment and training, and to allow ongoing monitoring of system performance.

It is NOT a stand-alone device intended to be used as a 'dead man's handle'; that is in a similar manner to the systems used in the rail industry to stop the locomotive if the event that the operator becomes incapable for any reason. The goal of the ARRB system is to prevent situations in which operators experience fatigue related incidents – not to reduce the effect of incidents that occur.

In summary, the package takes a risk management approach that traces back from the immediate causes of fatigue incidents to examine the basic causes and to identify controls that can operate at the level of those basic causes.

The resulting system educates supervisors and operators about fatigue, provides base-line data on individual operators' diurnal rhythms, designs strategies for individuals to minimise the risk of fatigue incidents, and provides an ongoing high level monitoring of the performance of the risk management process.

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EVOLUTION NOT REVOLUTION,

RISK MANAGEMENT OF SHIFTWORK

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1 Abstract

The new mining legislation and regulations in both Queensland and New South Wales are based on risk management frameworks. The management of risks associated with shiftwork has not been systematically investigated and controls need identification. This paper outlines the development of a risk management tool for shiftwork resulting from extensive research in the mining industry.

The research has built on the current limited available knowledge by undertaking a study of current practice to identify processes for risk management and control. This has included the use and evaluation of sleep and alertness logs, and lifestyle questionnaires to identify the work and non-work factors affecting the management of shiftwork. Accident and incident data has also been evaluated. A matrix for assessing risks associated with shiftwork and fatigue has been developed and trialed at a number of sites. This matrix is based on risk management processes outlined in AS4360 and allows for site-specific variations in terms of people, equipment and environment.

2 Introduction

As part of the process to manage the risks associated with shiftwork, Simtars is completing an Australian Coal Association Research Program (ACARP) funded research project to develop a risk management framework for the mining industry. The risks associated with shiftwork are multifactorial and include fatigue, exposures to hazardous substances and health issues. Of these, fatigue is the focus of the project.

Mining regulations for coal, mining and quarrying industries in Queensland require the risk management of hazards associated with mining. One area that is covered in both sets of regulations is fitness for work. This is covered within the *Coal Regulations* **Part 6 Division 1**, and the *Mining and Quarrying Regulations* **Part 9 Division 1** which require the development of a safety management system to manage fatigue. Risks associated with fatigue cannot be effectively managed unless they are identified and understood.

The fundamental and interrelated causes of fatigue in workplaces are:

- The time of day that work takes place
- The length of time spent at work and in work related duties
- The type and duration of a work task and the environment in which it is performed
- The quantity and quality of rest obtained prior to and after a work period.

Symptoms of fatigue include tiredness even after sleep, psychological disturbances, disinclination to work and general loss of vitality. This may lead to chronic disruptive sleep patterns and body systems alterations (gastric ulcers etc).

From a safety and health perspective, fatigue is most appropriately conceptualised as either work-related or non-work-related.

(a) Work related fatigue

Examples of work related fatigue might arise from situations requiring concentrating for extended periods during work hours, working in temperature extremes or working in high-risk situations.

Levels of work-related fatigue may be considered to be more similar across different individuals performing the same tasks than non-work related fatigue. This follows because there are fewer variables for individuals doing the same task in the same environment than in a non-work situation. Work-related fatigue can be managed at an organisational level.

(b) Non-work related fatigue

Examples of non-work related fatigue include sleep disruption due to ill family members, stress associated with financial difficulties or domestic responsibilities, or many other factors.

Non-work-related fatigue, because of all the different circumstances, will be highly variable between individuals and is dependent on a person's environment in addition to their physical and mental attributes. Non-work-related fatigue is best managed at the individual level.

One of the difficulties of establishing the risk associated with fatigue in the mining industry has been the lack of data and information available on the work related and non-work related factors affecting fatigue.

3 Risk assessment process

3.1 Objectives

As shown in Figure 1, the objectives of the project are to identify and control the factors leading to fatigue in the workplace and to identify and control the risks associated with fatigue within the workplace.

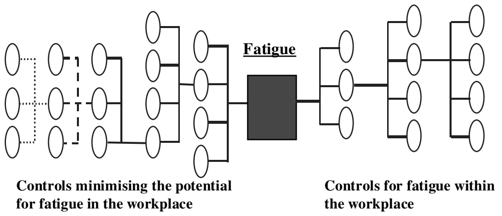


Figure 1 Objectives of ACARP project

The first step of the process involved the development of an acceptable definition of fatigue. Definitions of fatigue range the very simple to the overly complex. The following definition has been agreed upon by all participating mines in the project.

'Fatigue is caused by physical or mental exertion or insufficient sleep that results in a markedly reduced performance or reduced ability to carry out a task'

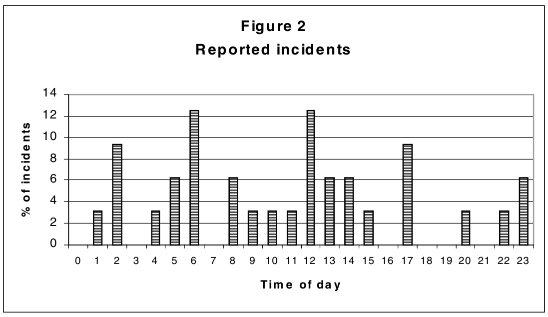
3.2 Methodology

(a) Data gathering

(i) Site information

One of the first steps of the project was to identify issues currently present at the mine eg:

- roster details
- production techniques
- accident and injury information related to shiftwork - an example is shown in Figure 2 which shows the percentage of reported incidents related to the time of day.



(ii) Worker information

Due to the limited available information on the factors leading to fatigue in the mining industry, the other major data gathering method was to identify and quantify work and non-work related factors leading to fatigue. This data involved two major parts.

Part one involved the distribution of a 38 point lifestyle questionnaire to all persons involved in the project (in the majority of circumstances this involved nearly every person on site, workers and management).

The questionnaires were distributed prior to the fatigue training. The questionnaire was divided into five main sections:

1 General demographic data (age, sex, marital status etc)
2 Diet and alcohol
3 Physical activity and exercise
4 Cigarette smoking and other drug use
5 Work environment (overtime, tasks etc).

Part two of the project introduced the sleep and alertness log books. The log books were designed to be kept for a minimum period of 14 days. During this time individuals were required to keep track of sleep quantity and quality, alertness and tasks performed during work periods. These log books were able to be modified to suit the roster rotation at different mine sites.

The sleep log comprised two sections:

- sleep ruler - a 24 hour visual analogue scale on which the subjects were asked to indicate with an X the time they went to sleep and with a U the time that they woke from the ***major sleep*** of the day
- sleep scale - Sleep quality was assessed using self-assessment. Participants were asked to rate the sleep quality on a scale of one through 10.

The alertness log was designed as a tool to measure the subjective alertness levels of the subjects on an hourly basis during work time only. In addition to the alertness levels individuals were also asked to record the ***main*** task performed during that hour.

(b) Fatigue training

A one-hour fatigue management training session was delivered to all persons participating in the project. The training session was designed to assist the individual to self manage fatigue and identify fatigue in others. This training provided participants with the following information:

- what is fatigue
- identification and management of the work related causes of fatigue
- identification and management of the non-work related causes of fatigue
- legislative obligations.

(c) Risk assessment

The results from the data gathering were used as supporting data for the risk assessment.

The risk assessment matrix was based on AS/NZS 4360:1995 – Risk Management. The risk assessment process was divided into:

- risk analysis – the systematic use of available information to determine how often specified events may occur and the magnitude of their likely consequences
- risk evaluation – the process used to determine the risk management priorities by comparing the level of risk.

Site representation at the risk assessment comprised:

- a minimum of two persons from each roster cycle on site
- management representative
- union representative.

The assessment of the factors causing fatigue covered the following areas:

(i) Work related

- the work arrangement, equipment and work environments likely to cause fatigue. These included tasks, breaks, work conditions and schedules.

(ii) Non – work related

- the human factors likely to cause fatigue.

These were in terms of lifestyle, health, awareness and culture

- the environmental factors likely to cause fatigue. These included accommodation conditions, time of day and community factors.

The following classifications were used for the risk assessment. These classifications are based on AS/NZS 4360:1995, Risk Management and were modified to suit the project. Modifications to the basic matrix occurred after initial trials at two mine sites. The modifications involved the removal of the descriptives for the consequences and likelihood. After the modifications were made participants in the risk assessments found it much easier to appoint a consequence and likelihood.

Consequences

1 = no fatigue resulting
2 = low levels of fatigue not affecting activity
3 = level of fatigue will cause moderate level of impairment
4 = high level of fatigue causing significant impairment
5 = very high level of fatigue causing serious impairment and/or leading to sleep

Likelihood

A = fatigue is expected to occur in most circumstances
B = fatigue will probably occur in most circumstances
C = fatigue should occur at some time
D = fatigue could occur at some time
E = fatigue may occur only in exceptional circumstances

Table 1 demonstrates the risk analysis matrix used.

The analysis was based on information supplied by workers and management during the risk assessments. This allowed a 'raw' ranking of the factors causing fatigue based on the understanding and knowledge of the participants of the risk assessment. It did not take into account current controls nor the information available from other sources.

The next step involved an assessment of the current controls (both formal and informal) in place to manage fatigue. This allowed identification of 'residual' risk.

The information available from the questionnaires and logs was taken into account. This allowed the ranking of the risks to be confirmed or re-evaluated as necessary.

(d) Risk management

Using the results of the risk assessment, potential controls to manage the risks were identified. Where contributory factors were analysed to be of low or moderate risk, additional control options were not considered.

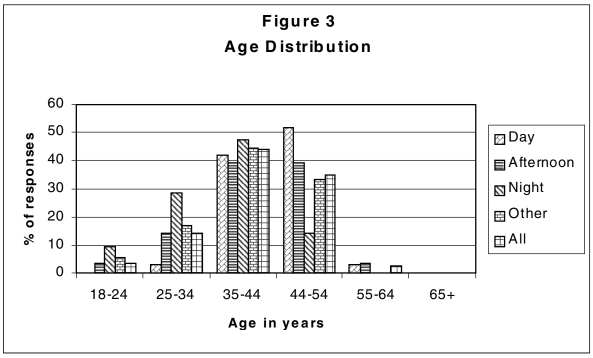
Risk treatment options were identified at the:

- corporate level
- site level
- shift level
- individual level.

Four of the project sites proceeded with the development of draft standard operating procedures and an additional mine went on to complete a roster redesign workshop.

3.3 Results

A total of six mines in Queensland and New South Wales have participated in this project. The number of questionnaires distributed across these four sites totalled 459. Some examples of the results of the questionnaires are shown in Figures 3 to 10.



The age distribution as shown in Figure 3 was fairly consistent across sites. The time spent in the coal industry demonstrated the experience of most workers as shown in Figure 4.

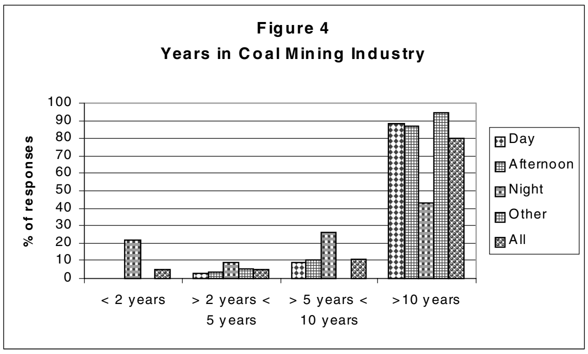


Table 1
Qualitative Risk Analysis Matrix

Likelihood	Consequences				
	1	2	3	4	5
A	S	S	H	H	H
B	M	S	S	H	H
C	L	M	S	H	H
D	L	L	M	S	H
E	L	L	M	S	S

H = high risk in terms of contributing to fatigue, research and planning required at high level
S = significant risk in terms of contributing to fatigue, attention needed
M = moderate risk in terms of contributing to fatigue, responsibilities must be specified
L = low risk in terms of contributing to fatigue, manage by routine procedures

Dietary intake across the six project sites were generally within the National Guidelines for Australians however, intake of saturated fat was for some sites consumed in excess. Alcohol consumption varied across sites and workgroups.

The majority of respondents indicated that exercise was difficult to find time for when trying the balance the needs of work and home life when on shift work.

However, for those that were able to make time to exercise all were within the recommended guidelines for exercising. Cigarette smoking across all project sites varied but overall was consistent with the industry average of 27 percent.

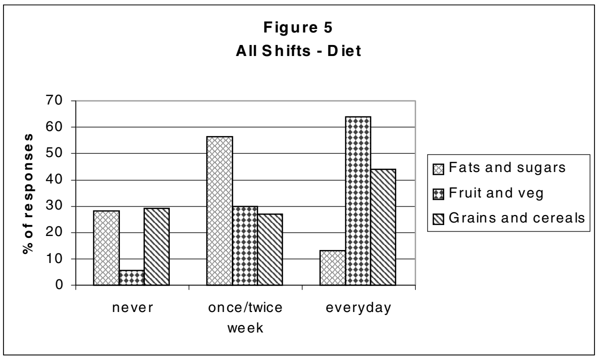


Figure 5
All Shifts - Diet

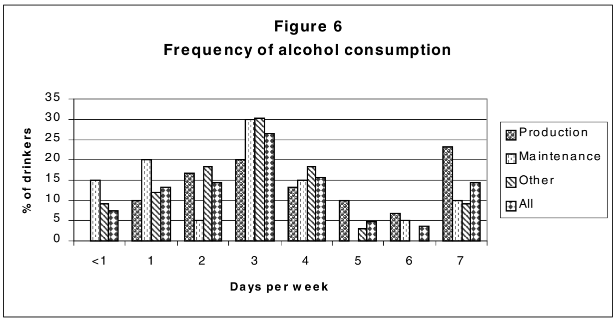


Figure 6
Frequency of alcohol consumption

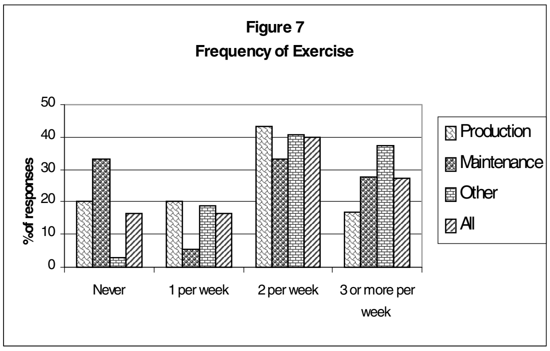


Figure 7
Frequency of Exercise

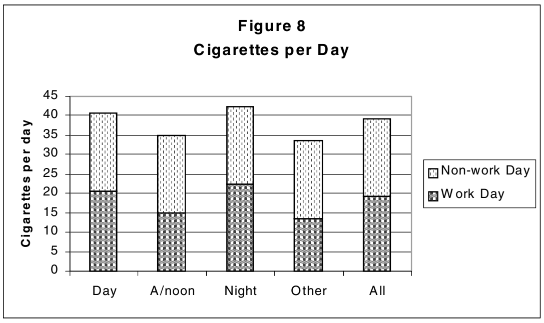


Figure 8
Cigarettes per Day

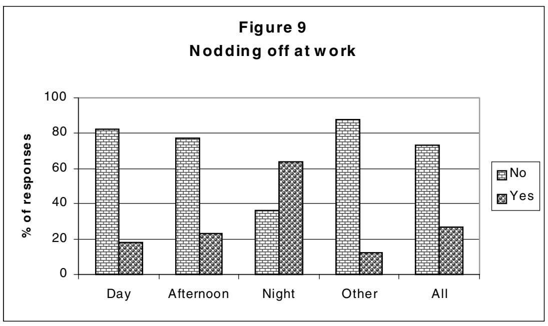


Figure 9
Nodding off at work

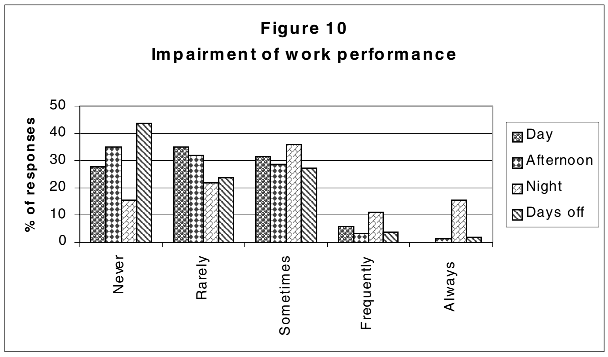


Figure 10
Impairment of work performance

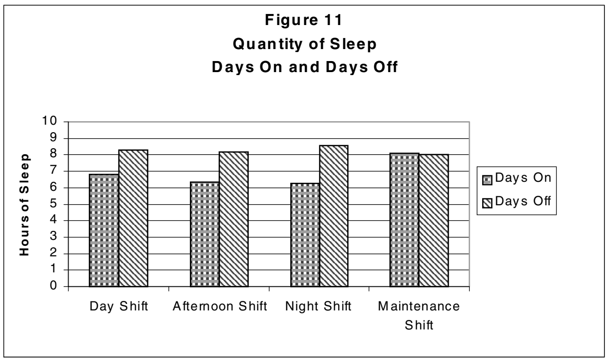


Figure 11
Quantity of Sleep
Days On and Days Off

By far some of the most disturbing statistics came from the questions which asked 'Do you ever nod off at work' and 'Does tiredness effect your work performance' as seen in Figures 9 and 10. Approximately 65 percent of night shift workers at one mine (Figure 9) stated that they nod off regularly while at work.

Of these, 25 percent stated that they were operating either mobile or stationary equipment at the time. Results from one mine indicated by Figure 10 show that often on afternoon and night shift workers feel as though their work performance is impaired by tiredness.

The results from the Sleep and Alertness logs are shown in Figures 11,12 and 13. Completed sleep and alertness logs over the four sites were 73. Modifications to the sleep and alertness diaries have been made after a low response rate from initial trials. Participants were given the option to implement the sleep log only or use the combination of sleep and alertness.

Sleep diaries are analysed in terms of quality and quantity of sleep. Figure 11 displays quantity of sleep results comparing on and off roster averages across all shift types. Results can be displayed as the differences in alertness levels between first and last shift as shown in Figure 12 and as an overall average across all shifts as shown in Figure 13

Examples of the results of the risk assessments for two mines are shown in Tables 2 and 3.

Although there was some variation from mine to mine, generally, the high and significant risks for work related factors fell under the following areas:

- work arrangements
  - roster
  - overtime

- breaks
- time of travel
- change to roster
- work conditions
- tasks
- physical work environment
- stress.

Examples of this are shown in Table 2.

Table 3 shows some examples of the non-work related factors that were rated high or significant risk. Again there was variation from mine to mine but generally there was a level of consistency.

Tables 2 and 3 show the residual risks once the current formal and informal controls were taken into account. In some instances the informal controls that were identified were significant in controlling fatigue but the mines did not appreciate their importance.

The information from the questionnaires was taken into account to confirm or indicate the need for re-evaluation as necessary. Where contributory factors were analysed to be of low or moderate risk, additional control options were not considered.

These risks were supported by the information gained from the data sources or the experience and knowledge of the risk assessment team. Some of the risks are associated with any 24 hour operations eg time of day and associated circadian rhythms.

Additionally, some of the controls identified were put in place to control other workplace hazards eg road maintenance. Consequently, the control of fatigue is a side issue. The limited effectiveness of some of the controls identified results from the original reasons the control was initiated.

This means that even if controls minimising the potential for fatigue are in place, there is a residual risk that workers will become fatigued during work operations. Therefore, controls need to be put in place in two areas as shown in Figure 1.

Some risks can be addressed only by information and training. Employers need to provide access to information that allows their employees to make informed lifestyle choices. By providing relevant and accurate information, employers are more likely to minimise the impacts of non-work related fatigue on work activities.

Results varied from site to site with consideration of the following variables:

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The information from the questionnaires was taken into account to confirm or indicate the need for re-evaluation as necessary. Where contributory factors were analysed to be of low or moderate risk, additional control options were not considered.

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Table 2
Work Related High Risk Factors

Mine A	**Mine B**
Body clock versus work pattern	Night - body clock including start and finish time
Shift time – length of time at work	Afternoon Finish 12 am
Overtime – running on other shifts	Day Start 6am/finish time 1pm+ travel time
Noise and vibration	Working in excess of specified max overtime (in conjunction with production targets)
Cabin conditions	Timing and unpredictability of overtime –pre or post shift
Work postures	
Number of shifts in a row	
Heat and humidity	
Time of start/finish of shift	

Table 3
Non-Work Related High Risk Factors

Mine A	**Mine B**
Lack of sleep – mental state eg worry	Second job (10% of workforce)
Sleep disorders – physiological Eg Sleep apnoea	Sleep disorders
Other medical problems	Family understanding/ management of shiftwork
Drugs and medication	
Travel time	Family commitments
Use of alcohol	

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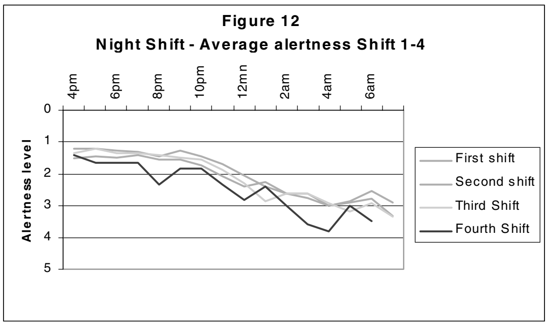
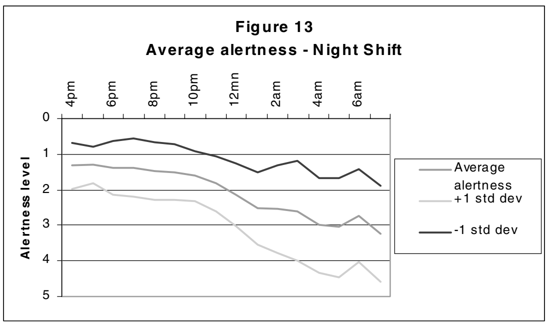
Results varied from site to site with consideration of the following variables:

- community, commuter or site based operation
- age of operation (older mines tended to have older workers).

Two of the participating mine sites proceeded with the development of draft standard operating procedures for fatigue and shiftwork, based on the results of the risk assessment. The major headings for the SOPs included:

- definition of fatigue
- accountabilities for fatigue management for SSE, supervisor, employee, contractors and visitors
- hours of work and rostering arrangements
- maximum hours of work
- number and length of rest breaks (both within and between shifts)
- maximum number of hours to be worked in a week or roster cycle
- maximum number of extended shifts in a row
- shift start time
- roster details
- overtime
- rotation of tasks





- physical environment
- education and awareness
- employee assistance program
- personal fatigue critical tasks
- administrative controls
- management of the fatigued worker
- audit and review

One site proceeded with a roster design workshop. The roster design process was divided into:

1 Background
- identification of health and safety requirements
- identification of operational requirements including different workgroups;
- identification of other worker requirements.

2 Roster design concepts
- shift length
- total hours
- shifts in cycle;
- overtime arrangement
- other factors impacting.

3 Evaluation of existing roster
The rosters are evaluated considering the following aspects.
- fatigue
- breaks between and within shifts
- travel time
- financial aspects of change to hours of work and overtime
- social impacts
- community
- operational requirements

4 Recommendations for new roster
The results of the risk assessment were used to underpin the changes to the rosters at this site.

4 conclusion

The results of the risk assessments undertaken at the mines have shown the value of using a risk assessment framework to identify the risk factors leading to fatigue. It allows the residual risks to be estimated and consequently additional controls to be implemented.

Development of shiftwork and fatigue management systems has been made easier by using the risk assessment process. The current risk assessment framework needs adjustment to allow for the synergistic effects of the inter-relationships of many of the factors leading to fatigue.

The risk assessment process is able to be tailored to suit mine specific needs or already existing systems. The nature of the subjective data gathered from the questionnaires and the sleep / alertness diaries are able to easily fit in with any risk assessment methodology.

Although still in development, the risk assessment framework will improve the process of complying with the new health and safety mining legislation to control the effects of shiftwork and fatigue at minesites in the Coal, Metalliferous and Extractive Industries.

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FITTING WORKERS TO JOBS AND JOBS TO WORKERS

Jenny Legge, Physiotherapist

Musculoskeletal injuries cost companies millions of dollars every year in reduced productivity, replacement wages, medical costs, lump sum payments and performance-based workers compensation premiums.

The 'JobFit System' is a tool that can be used to reduce these costs. The 'JobFit System' is a task analysis database that can be used to facilitate an early return to work for injured workers, as well as assist in the risk management process of pre-employment screenings.

Therefore, this system has the potential to not only reduce the costs of musculoskeletal injuries but also the number of them.

What is the 'JobFit System'?

The 'JobFit System' is a database program containing easy-to-understand objective information about the physical demands of work-related tasks and the physical capabilities of workers.

The two databases can be compared to provide a variety of reports indicating matches and mismatches for particular tasks and individual workers.

The reports provide readable and practical information, without medical jargon, that can be applied immediately.

In response to industry requests, the 'JobFit System' now also contains a medical database for recording pertinent information such as assessment scheduling and plans of action.

How can the 'JobFit System' save me money?

The 'JobFit System' has a number of immediate applications:

- screening tool in the selection of new workers
- facilitates an early return to work for injured workers
- manages worker's health and wellness
- easy identification of manual handling risks

Planned future applications include an export function for statistical analysis and comparative reporting for monitoring injured workers' progress.

Assistance in the pre-employment process

Employers have a responsibility to ensure, as far as reasonably practical, that each employee whilst at work is safe from injury and risks to their health (Worth, 2000).

Much of the focus has traditionally been on designing/altering the demands of a job to better match them with the capabilities of the workforce.

Sometimes however, there comes a time where further changes in a job are either cost-prohibitive or technically infeasible at that time.

An alternative approach is to consider matching workers to the job demands on the basis of their physical abilities (Anderson, 1999).

To ensure that a pre-employment functional assessment (PEFA) will truly assess an individual's ability to do a job you need a thorough job analysis with clear, objective and detailed data of the key physical requirements of the job for which the applicant is applying, from which to design your assessment and make your final decision.

The 'JobFit System' database contains this information and is transferable across sites thus saving companies valuable time and money.

The emphasis of a PEFA should be on objective information such as an individual's ability to perform the job rather than speculative conclusions such as risk of injury that may occur in the future (Anderson, 1999).

For a worker to be judged capable of safely performing the required tasks, their capabilities must be equal to or greater than the job demands.

This is determined by matching their capabilities against the chosen job demands using the same range of values (Worth, 2000).

The 'JobFit System' achieves this by matching two identical sets of data values and indicates a match if the worker's abilities are either equal to or greater than the required physical demands.

The displayed information is broken down into manual handling tolerances and postural tolerances so that the operator can clearly identify where the mismatches lie to determine if further action, such as physical conditioning, can be applied to enable the worker to safely perform the desired tasks.

Both management and workers benefit from pre-employment functional assessments in the form of increased productivity and improved safety (Rice, 1999).

Rehabilitation benefits

An appropriate and detailed job analysis, such as the 'JobFit System' database is needed to enable the comparison of a worker's functional capabilities with the physical demands of a job. From this comparison, it is then possible to:

- set goals for a graduated return to work
- identify needs for further intervention
- determine what modifications to the process

methods or equipment may enable the worker to participate in the job safely
- identify a range of jobs within the worker's safe current abilities (Rankin, 2000).

The comparative reports also enable the workplace to monitor the injured worker's progress.

This enables an earlier return to work resulting in decreased replacement costs and a reduction in the overall cost of the claim.

Effective claims management means that employers can increase their savings by reducing the duration of a claim as much as decreasing the incidence of others (Grant, 2000).

The 'JobFit System's' objective determination of a workers abilities in comparison to the task requirements supports the employers decision regarding the availability of suitable duties, as well as demonstrating their ability or willingness to provide them to both their workforce and the insurer.

The system's methodology also changes the focus from the workers incapacities (eg can't lift more than 10kg, no bending) to one of capacity - focusing on areas of ability rather than those of inability or disability.

This changes the worker's and employer's overall outlook from a negative one of 'the glass is half empty', to a positive, proactive one of 'the glass is half full.'

The operator simply enters the worker's medical restrictions and the 'JobFit System' extrapolates the data to display the worker's safe postural and manual handling tolerances at various frequencies based on the Strength-Endurance Continuum (WorkHab Australia, 1998) for comparison with their job demands.

The objective data matching of the 'JobFit System' also takes the 'guesswork' out of the hands of people with decreased knowledge of the worksites, such as offsite medical personnel and rehab co-ordinators that do not have prior 'hands on' experience.

It also provides a baseline for the return to work process and gets the issue of physical ability out of the way so that we can perhaps deal with other issues that may be hindering the early return to work process such as previous work performance difficulties, conflict with supervisors, personal difficulties, psychological and social difficulties (McKie, 2000).

Efficient health and wellness management

Due to industry demand, the functions of the 'JobFit System' have been expanded to provide medical assessments and screening schedules at the operator's fingertips.

The 'JobFit System' monitors the workforce's schedules for industry medicals, health surveillances and checks (eg hearing, vision, lung function, skin cancer) as well as keeping a record of wellness factors such as fitness level, exercise and smoking habits for statistical research.

Risk Management Tool

The 'JobFit System' task summaries allow key stakeholders to rapidly identify components of an individual's job that have a high manual handling risk. This is the first step in implementing risk management control measures in the reduction of manual handling injuries.

How does the 'JobFit System' work?

Practical demonstration

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Jenny Legge is a registered physiotherapist with seven years experience in occupational health and injury rehabilitation both in Australia and overseas. She has been involved in the coal mining industry since 1998.

Based in Mackay, North Queensland, Jenny is a registered provider of the 'WorkHab Australia' Functional Capacity Evaluation enabling her to assist industry with their rehabilitation and injury prevention activities through the performance of objective tests and worksite assessments, the establishment of suitable duties plans and the presentation of the popular 'Fit.2.Work Manual Handling & Injury Prevention Program.'

This exposure has allowed her to see the difficulties that industry faces with selecting the right workers for the job and returning injured workers to suitable employment.

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A review of the requirements for the testing of

THE STRENGTH OF VENTILATION STRUCTURES TO BE USED IN QLD MINES

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Abstract

The regulations in Queensland require that ventilation structures conform to strength requirements in terms of the overpressures that they can withstand. Prior to the enactment of the regulation on 16 March 2001 the testing of Ventilation control devices were described in an approved standard. As this standard did not however fully cover the testing of all the ventilation devices due to the availability of suitable methods a need arose to review suitable methods that could be used to determine the strength characteristics of ventilation structures.

To test these structures at the presently available facilities in the world is costly and difficult for manufacturers developing new designs. This has created the need for alternative processes that include both destructive and non-destructive methods. There has been a move throughout the world to different types of testing processes for seals.

This paper reviews the newer method used throughout the world and uses them as a basis for reviewing the test requirements of structures to be used in Queensland.

Based on the purpose of the ventilation devices a set of leakage criteria to be used in an adapted standard has been derived for stopping and other ventilation devices.

To ensure conformity with such a proposed standard the overpressure against which the structures are tested against is also reviewed and processes proposed that would make the testing of ventilation control devices significantly cheaper while still in line with the best practice used in international organisations.

1.0 Introduction

The underground explosion at Moura No2 mine on 7 August 1994, presented challenges to mining engineers that had not been formally addressed previously throughout the world. Soon after the first explosion the mine tube bundle gas monitoring system proved to be partly operative .

The gas analysis showed that in addition to the predictable high levels of carbon monoxide throughout the mine, there was a large area where the atmosphere contained high level of methane and reduced oxygen levels .

The atmosphere was potentially explosive and prevented rescue teams from entering the mine .The low levels of oxygen also prevented the possible escape of other persons from a large portion of the mine.

The gas monitoring data strongly indicated that the explosion had breached multiple seals. Two days after the first explosion, a second and more violent explosion occurred.

The failure of the seals significantly increased the risk to the chances of survival for the mineworker's underground at that time. The efforts of Task Group 5 concentrated on establishing practical design criteria to assist mining engineers minimise these risks

The purpose of any ventilation structure, including a seal, is to separate the mine into different areas with regard to airflow and the general atmosphere in that area. In the case of structures like stoppings, curtains, aircrossings and regulators the main purpose is to separate intake air from return air in the process of ventilating the mine. Seals on the other hand separate worked out areas

Table 1. Strength criteria for ventilation structure to be used in Queensland mines

Design Criteria	Location
Type A (2 psi) 14 kPa	Limited Life Production Panels
Type B (5 psi) 35 kPa	Main Roadways
Type C (20 psi) 140 kPa	Sealed Areas
Type D (50 psi) 345 kPa	Sealed Areas in the event of explosive conditions.
Type E Pressure Relief (10 psi) 70 kPa	Surface Infrastructure

of the mine from the accessible part and on the whole are structures that play a longer-term role.

These structures, apart from separating the parts of the mine, also have to ensure that if any occurrence happens in one part of the mine the sealed atmosphere it is contained there and is unable to enter other parts.

Even though seals have a different primary role and have to contend with significantly more serious occurrences than normal ventilation structures they can still be considered to be a ventilation control device.

The Queensland Mining Regulations require that all ventilation structures in a mine have to conform to certain strength requirements.

These strength requirements are expressed in terms of the overpressure that the structure has to withstand. Previous to the introduction of the Coal Mining Regulation on 16 March 2001 there had not been any recognised testing criteria method to which ventilation devices (excluding seals) could be conducted, The previous approved standard did not cover the testing of ventilation control devices (VCDs) for leakage of ventilation sufficiently.

Queensland is unique in that it has regulated the strength of ventilation structures in addition to seals. These strength requirements that are set according to the different areas in a mine, are presented in the following table.

These criteria were developed as a result of the Warden's Inquiry into the circumstances surrounding the explosion that occurred at Moura No.2 mine in August 1994.

All of the recommendations made were acted upon by various Task Groups. The above criteria was developed by Task Group 5 and its main purpose was to establish a standard for ventilation control devices to ensure a high level of survival of mine workers following a fire or an explosion.

The sealing structures had to contain the explosion to the area in which it occurred and not increase the contamination of the mine airways with the previously sealed atmospheres.

The ventilation structures had to be partly functional after the incident. If the ventilation structures could survive the overpressures resulting from explosions, then the airflow in the mine would not be severely disrupted and workers surviving the incident would be able to reach fresh air much more quickly than what would be the case if the structures were completely destroyed, as would be the case when they had no explosion resistance.

To comply with the requirements of the law, as well as ensure that the structures in a mine are fit for purpose, there is a need to determine the strength of ventilation structures.

This paper compares the methods that are being developed and used and indicates the suitability of these methods for future use.

2.0 Testing of structures for use underground.

In the development of ventilation structures for use in the underground environment there is a process that needs to be followed.

This process conforms to most other needs driven developmental processes in the engineering field. The setting of strength requirements of a ventilation structure is usually done by or under the auspices of the legislators or the organisations that set standards. These requirements are based on a prediction of what would be the performance criteria for the device to reach a desired outcome. In the specific case of ventilation structures, the criteria are in terms of the forces that a structure would have to withstand so that it could still fulfil its function, or part of its function, after being subjected to these forces. In the USA, it has been stated by Mitchell (1997) that because no one can foretell what forces might be exerted on bulkheads due to explosions in isolated areas, studies should be directed at preventing flames from propagating into sealed areas and minimising gas flows into the path of the flame.

The next step in the development of a seal to be used in the mine is to design the seal according to good structural engineering practice to satisfy the requirements. This is usually done by the organization that is going to construct the seal or develop such a structure as a commercial venture. The seal design is then tested by constructing it in a suitable gallery and subjecting it to the overpressure as specified in the requirements .In the USA seal designs have been developed and approved using test galleries. The seal designs in Australia have mostly been developed as commercial ventures and until fairly recently been tested at the Lake Lynne Experimental Mine (LLEM). During the last few years' tests to determine the strength of seal designs and other ventilation control devices have also been conducted in Australia and in South Africa.

The fourth aspect of the process is when the erected seals themselves are being tested in situ. In work done by Oberholzer (1997) in determining the strength characteristics of refuge bay bulkheads it became very clear that while the design aspect was important, the way that this design was implemented in the underground environment was of greater value in determining the performance of the structure. This rationale was further supported by observation of the deleterious effects that the mine environment could have on these structures. This led to the conclusion that to determine what the characteristics of the structure were, and especially over the longer term, a method would have to be devised to test the structures in situ. The feasibility of non-destructive testing was investigated to satisfy this need.

3.0 Destructive test methods.

The methods used to test seals have basically been derived from the technology as developed in the USA at the Lake Lynne Experimental Mine. These methods have not only been used to test structures for the use in the USA, but have also been used to test structures intended for use in Australia.

There is a plethora of literature that describes the testing methods, the results and the seal designs emanating from this facility. Traditionally testing has been conducted by using large-scale explosions resulting in overpressures in the 20-psi range in the mine passages to test ventilation structures.

The testing of seals up to now has been done by using an actual seal and subjecting it to the closest simulation of a underground explosion that is possible. There is no practical way whereby the actual conditions of an underground explosion in a mine can ever be created, therefore use had been made of explosion galleries using methane explosion to create the overpressure.

By varying the mixtures and amounts of gases used in the explosion, different overpressure can be obtained.

The strength criteria for a ventilation control devices is usually given in terms of this overpressure. After the structure has been subjected to this overpressure there are basically three outcomes.

- The structure is completely undamaged and in the same conditions as it was prior to being subjected to the overpressure. No evidence of change can be noted in this case
- The structure is evidently destroyed. It has been demolished, broken and moved to the extent that it does not exist as a structure
- It shows evidence of change, possible cracking but not to the extent that it has evidently been destroyed.

It is in the latter case where the leakage criteria are used to determine if the structure has withstood the overpressure event or not. Through usage this leakage criteria has become the ultimate determinant of success or failure of the structure.

As the purpose of a seal is to stop flames from propagating into sealed areas and minimising gas flows into the path of the flame the allowable leakage is very low.

Testing of ventilation structures was conducted locally under the auspices of an ACARP funded project (Pearson et al, 2000). Although the Testsafe facility at Londonderry, which is basically a surface structure, was found suitable to test ventilation structures requiring lower overpressures it was not deemed suitable to test seals requiring an overpressure of 140 kPa and above.

This means that structures in this range still have to be tested at LLEM. The lower range tests conducted in the Testsafe facility correlate well with those done at LLEM and is considered adequate for proving compliance with the requirements of the Queensland mining regulations.

4.0 Non-conventional destructive test work

During the past two to three years various parties conducted destructive tests to develop methods that would not require the use of a gallery or even explosion to obtain the overpressures.

The following are examples where these innovative methods have been used with success. The success of these testing methods put the use of galleries as prescribed in the old approved standard in a completely new light.

Case 1

Two chambers for testing containment walls and seal strengths were constructed at the NIOSH Lake Lynn Experimental Mine (Cashdollar, 2000).

The intention was to develop more easily executable tests for seal testing as well as to establish the technology to satisfy the need to evaluate these structures at the mine site in the future. The first chamber is approx. 2m high and the second approx. 4m high. In these chambers, seals can be tested through using water (hydrostatic pressure) and methane explosions .

These chambers were commissioned during the latter part of 1999 with most of the work focussing on either compressed air tests or methane explosion testing.

Even though the time period in these test seem to be slightly longer than in the case of the conventional test the new result correlate well with the older ones.

Case 2

In South Africa a collaborative effort between manufacturers, mines and the CSIR Miningtek was implemented to develop other evaluation methods. The overpressures were to be achieved using either compressed air or the hydraulic pressure resulting from a static water head.

To make the test more representative the evaluation methods were devised to be used within a mine where the structure was constructed under mining conditions.

In these tests the following methods were used to achieve the required overpressure pulse.

- Uncontained compressed air
- Contained compressed air
- Uncontained but sealed hydraulic pressure
- Contained methane explosion.

In all the cases the seal was constructed in such a way that an enclosed void was created behind the structure.

Tests with compressed air did not succeed in reaching 140kPa pressure as the nature of the coal strata caused leakage to occur at such a rate that no pressure higher than 40kPa could be obtained.

The compressed air system could not transfer the air at a fast enough rate to compensate for the outflow of air. Further to this, it was found that when cracks started to form in the structure, the air leakage increases to the extent that very little force can be applied to the wall.

In an effort to circumvent the problems experienced with previous tests it was proposed to create an airtight pressure bag of the correct size and strength to assist in preventing air leakage when cracks were formed.

In this test with the containment bag the maximum pressure increased to 80kPa before failure of the containment bag occurred.

The most successful tests with compressed air were conducted at the Douglas Colliery in South Africa where a wall that was very well sealed off and constructed in very competent strata was able to withstand 125kPa prior to the formation of cracks, which stopped a further increase of the overpressure.

Successful tests using water were conducted at the Koornfontein mines, South Africa, where a seal was constructed in such a fashion that the void behind the seal was sufficiently watertight that the outflow of water could be kept to a minimum.

By filling the void through a borehole to surface, the required pressure could be obtained and the pressure at which the seal started breaking could thus be determined quite easily.

In both of these methods the slow application of static pressure could be applied with success to determine the strength of the seals.

A further innovative testing method was conducted when a special gallery was built underneath an old bridge across a dry riverbed.

Access to the chamber was gained by means of a manhole and steel door. The bridge consisted of I-beams, steel reinforcing and concrete of unknown design or strength.

To reinforce the resistance of the structure to withstand the pressure in the chamber an amount of fill material was placed on top of the bridge.

The quantity was calculated as if the bridge had no inherent strength. The gallery was equipped with static pressure sensors to measure the increase in pressure.

A methane explosion was used to obtain the required overpressures. All the tests were done with a volume of 31.5 m^3 air-methane mixture of between 9 and 9.5% per volume.

The mixture was ignited by using three fuse caps in parallel. The ignition simultaneously triggered a PC based data acquisition system. Data for the pressure rise over time was stored in a data file, which was then imported into a commercial spreadsheet package that could be used to generate a graph of pressure rise against time.

Due to the configuration of the test chamber it was impossible to do the leakage test as required by the MSHA test protocol.

This is not seen to be insurmountable problem as the use of a compressor and the extrapolation of the curve could allow for adequate leakage testing to be done.

The maximum overpressure reached in the first test was 141.8kPa with a maximum deflection of 20mm. In the second test, the failure of the manhole and the roof structure resulted from a maximum over pressure of 144.3kPa.

Although the test gallery was destroyed during the last test it nevertheless proved that the seal that was being tested withstood the overpressure obtained from the methane explosion.

What these tests further proved is that a cost effective gallery can be constructed and that, by using a contained methane explosion, the overpressures necessary to test seals can be obtained.

It is anticipated that due to the confined nature of such a test chamber significantly higher pressures could be achieved if it was required.

Case 3

Tests using commercial explosives to create the overpressure have been conducted by a Queensland firm in a metal mine in Western Australia. In these tests the expending gases of a charge of explosives was used to create the overpressure on the structure .

As these tests were very well instrumented, the pressure pulse was well determined. It was found to be less than 0.3 of a second, which is considerably shorter than the pressure pulse lengths as obtained with methane mixtures that are in the order of a second or longer. It has been determined that by using a slower commercial explosive pulse lengths of significantly longer duration can be obtained.

What these test has proved is that the destructive testing of structures need not be confined to be done in galleries but can be done in any place where the appropriate overpressure can be generated and where the leakage through the structure can be measured.

5 Non-destructive testing

The requirement for non-destructive testing arose from the need for a less costly method to test prototype designs and the need of the mines to ensure that the structures that have been installed in their mines conform with, and continue to conform to the set requirements.

Simtars has completed an investigation into the feasibility of developing non-destructive testing methods that can be used to test ventilation control devices.

This work forms part of an ACARP sponsored project. (No C10014- Develop testing methods that will allow for the in-situ testing of ventilation structures in coalmines. Phase one – Identify suitable testing methods.)

To be able to assess the ventilation structures in a mine without affecting its strength the use of non-destructive methods is required.

The condition of a ventilation device is presently determined by how effectively it separates two parts of a mine and therefore leakage criteria is quite rightly used as the deciding factor.

Using leakage as the criterion is suitable to define the performance of a structure after it has been subjected to an overpressure but is, however not adequate to describe the state of a structure and its immediate surroundings.

It is thus necessary that other accepted criteria will have to be established to describe the condition of the structure.

These acceptance criteria will then have to be formulated in terms of physical characteristics or in terms of how they are allowed to change after the structure has been subjected to the overpressure.

These descriptive characteristics will not be restricted to the structure only but will include the system linking the structure to its environment as well as the conditions of the environment.

One of the most critical aspects would be to relate the physical characteristics with the leakage criteria. The state of the structure that would result in an acceptable or unacceptable leakage criteria would have to be determined in terms of the descriptive characteristics.

This is presently seen to be the biggest hurdle to the achievement of a satisfactory outcome of the process. The matter is exacerbated due to fact that this relationship will have to be done for all the different types of ventilation structures types being used by the mining industry.

It is also foreseen that although a significant portion of determining the relationships can be done at the hands of structural engineering practice it would still have to be confirmed through actual testing. Only then will it be possible to determine if a structure is acceptable or not in terms of the physical characteristics.

The use and suitability of these methods will have to be tested and the level of confidence that can be attributed to the results determined.

Only when both the relationships between leakage and the physical characteristics and between the physical characteristics and non-destructive measurement parameters are determined will the process be suitable for the adjudication of the condition of a seal with regard to its strength.

The challenges with regard to the testing of prototype structures now becomes significant. This is because the criteria that will be used to determine if a structure has passed the compliance test will be based on the design that is used, the materials involved and the method of construction.

Primarily these criteria will set out to determine if the design is adequate and then if the structure under investigation complies with the design.

There is no present method apart from controlling the design process or simulating the design of the structure that would enable non-destructive methods to predict how a structure will perform.

This leads to the finding that non destructive testing processes will, over the shorter term, only be suitable to test the conditions of a structure the design of which has been proven in a destructive test process.

6 Determination of the criteria for ventilation devices

In order to develop criteria for ventilation control devices two aspect had to be considered. The obtaining of the required overpressure and proving that the structure remained within the allowable leakage criteria would indicate that the structure has survived or withstood the overpressure.

Latter day work has shown that different methods of obtaining the overpressure can be used however the leakage criteria for seals presently being used at the LLEM are deemed not to be practical for VCDs in Queensland.

It was therefore proposed that leakage criteria should be developed in keeping with the intent for establishing strength specifications the structures. The overpressure requirement will thus impact on the testing method and the leakage criteria will determine if the structure has passed or failed.

As the intent of specifying the strength of the ventilation devices was to ensure that they would be strong enough so that sufficient airflow to the sections can be restored or maintained after the occurrence of an incident.

If the airflow can be maintained or restored such that a worker exiting the mine can reach fresh or uncontaminated air as soon as possible, the structure would have fulfilled its purpose. This might typically be around 30 minutes with the use of oxygen self-rescuers.

A further motivation for a less stringent leakage levels is that in many cases the air leakage of newly built ventilation control devices (stoppings) would not comply with the NIOSH seal leakage criteria even before being subjected to an overpressure.

By calculating the maximum leakage that would allow air to reach the face in time, a new set of leakage criteria has been developed and is recommended for use when evaluating ventilation structures after being tested in a gallery.

7 Overpressure requirements for testing

The levels of overpressure defined in the regulation(schedule 4), requires the test methods at the internationally accepted test galleries.

The majority of the testing work on which the present criteria for Australia, as well as South Africa, are based upon was conducted in the Lake Lyne experimental mine (LLEM) and Bruceton facilities. The basis of developing seals and determining their ability to withstand certain overpressure has been based on an unconfined methane explosion in mine workings.

Although test has been conducted with gunpowder added to the fuel the majority of explosion test have been done with methane and methane and coaldust mixtures.

It would seem that it is very difficult to exceed the 20psi or 147kPa level purely with an uncontained methane explosion.

The factors that determine the peak loading on the bulkhead is the explosion intensity, the passage length between the bulkhead and the explosion source and the orientation of the bulkhead with respect to the passage in which the explosion occurs.

On first contemplation it might be expected that the damage caused by an explosion would depend simply on the peak pressure that was generated.

Table 2 Comparison between the periods of vibration of structural elements, and duration of pressure pulses. (Harris, 1989)

Structure	**Period** (milliseconds)
Concrete floors	10-30
Concrete walls	10-15
Brick walls	20-40
Explosion type	Duration (milliseconds)
Confined gas explosion	100-300
Pressure wave from the detonation of an explosive charge	1-10
Pulse length –Londonderry	2000
Pulse length LLEM	500
Pulse length LLEM large chamber	8000

(This in a way is what is implied through the use of 'overpressure'.)

However the response of structures to the pressure loading generated by the explosions is more complex.

An explosion produces a pressure loading that varies with time and the response of the structure to this load is in itself time dependant.

What this means in simple terms is that the response to an explosion will be determined by the peak pressure generated and upon the ratio of the time period of the imposed pressure load t_d and the natural period of vibration of the structure Tn.

The ratio t_n /Tn determines how the structure will 'feel ' the application of the overpressure.

Three basic types of response can be defined. (Harris ,1983)

1 t_d > Tn
Where the duration of the overpressure is longer than the natural period of vibration.

In this case the loading on the structure will effectively be equivalent to the static loading.

2 t_d @ Tn
The duration of the overpressure is about the same as the natural period of vibration. In this case the loading experienced would be effectively equivalent to a static loading of a magnitude greater than the peak overpressure generated in the explosion. The equivalent static pressure can be up to P/2 time the magnitude of the incident overpressure.

3 t_d < Tn
The duration of the overpressure is shorter than the natural period of vibration. In this case the structure will not be able to absorb the energy of the pulse and the pressure will be partially absorbed and the loading experienced will be equivalent to a static loading of a magnitude lower than the static loading.

Expressed in a different way this means that under these conditions a structure could withstand a higher-level pressure pulse of very short duration that it would under static load conditions.

The length of the explosion pulse used to test the ventilation control device is thus of great importance.

In the following table the natural period of vibration are compared with the pressure pulses from different types of explosions.

From the above it is thus evident that when seals and ventilation control devices are tested by subjecting them to the most probable overpressure that they might have to cope with, a gas explosion, the pulse duration of the explosion will be longer than the natural period of the structure.

A static load can thus simulate the load of the pressure on the structure.

Where commercial explosives are used to simulate the overpressure pulse care will have to be taken to ensure that the pressure pulse is of sufficient duration to well exceed the natural period of vibration.

Any overpressure pulse that is used for the testing of the structures and that has a pulse length that exceeds that of the natural period of vibration of the structure being tested would be suitable to obtain the required loading .(In practice this pulse length is usually longer than 100 milliseconds in length and should be approximately the same as what would be obtained by using either a contained or uncontained air/ methane gas explosion.

7 The leakage criteria

The leakage that is measured through the structure after it has been subjected to an overpressure is taken as indicative of the competency of the structure.

As the leakage is determined by the ability of the structure to resist the flow of air through it the leakage criterion can be replaced by the resistance of the structure to determine its ability to seals of the flow of air.

The relationship between the pressure difference and the flow between two points are determined by the resistance (Atkinson's resistance) and is presented by the well-known square law.

$p = RQ^2$

Where p is the pressure difference in Pascal, Q is the volume of airflow in cubic meters per second and R is the resistance in Ns^2/m^8

Because of the highly non-linear relationship between the area available for flow and resistance, the resistance for structure can vary from one or two Ns^2/m^8 to literally thousands of Ns^2/m^8.

The relationship between the resistance and the size of the hole is given by;

$R \propto 1/d^5$

Where d is the hydraulic mean diameter of the opening.

In the calculation of ventilation flow it is this resistance that is of importance. Reality is that in the test situation it is impossible to directly measure the resistance of a damaged structure and the best way of determining it is to determine the leakage of air through the structure.

At Lake Lynne and in other instances where this has been tested, the pressure differential to create airflow over the structure is created by using a fan. A manometer measures the pressure differential. By installing a brattice or structure with a small hole of known dimensions in the airway the flow of air through this hole give the volume or quantity.

The hole is usually rather small as the flow of air through the seal is small and sufficient airspeed

Table 3 Leakage rates for seals according to the USBM criteria

Pressure difference in kPa	Airflow in m^3 per cubic metre
<0.25	<0.05
<0.50	<0.07
<0.75	<0.10
>0.75	<0.12

has to be obtained so that the flow can be measured by means of an anemometer.

It has become practice to present the acceptability levels in the form of leakage criteria in the form of a set pressure differentials and airflows.

It can safely be assumed that no changes will be brought about in the resistance of the structure in the testing process due to the presence of the brattice and therefore by using a curve representing the airflow relationship for a particular resistance, a whole range of testing criteria can be developed to suit the fan in the testing facility.

To develop the leakage criteria to be used for ventilation structures other than seals simulation exercises using resistances were done. Following consultation within the mining industry the following scenario was chosen:

- The VCD structures will form part of a panel of 3km in length.
- The size of the roadways would be 5 by 3 metres.
- The amount of air entering the section would be 50 cubic metres per second.
- Every VCD (stopping) in the panel will have the same leakage characteristics.
- No compensation for the attenuation of the explosion down the roadway would be made .
- The duration of the self-rescuer would only be 30 minutes and that a person can cover a distance of about 600 metres in that period. (For purposes of this calculation the placement of workers throughout the section is not taken into account)
- It is also assumed that when an explosive incident occurs it pollutes the whole panel.

In this exercise the critical value that had to be determined was the ratio of residual air in the last through road to the air entering the section.

This value should be such that it will allow the workers to be in clean air at 600 metres distance from the face and after 30 minutes.

In calculating the ratio it is further assumed that the contaminant gases will move in a plug through the headings and the ventilation flow will not dilute it and thus have a drag out effect.

Once the required residual flow has been calculated then the required resistance to obtain such airflow can be calculated. This in turn would give the maximum leakage that could be allowed in each stopping.

It should be noted that this value is not the value that would be accepted in the normal operating underground environment.

The value would be used as the criteria to determine if a stopping has withstood the effects of the overpressure after it had been subjected to a destructive test.

An initial exercise was used to obtain an order of magnitude result of the residual flow at the end of the panel that would be able to satisfy the fresh air criteria. A 3000m long panel consisting of two parallel roadways spaced 30m apart. In this panel 29 cut-throughs were placed at 100m intervals. Each cut-through had a 100 percent regulator placed in it. By changing the resistance of the regulators, thereby simulating the damage that the stopping had undergone, the amount of air reaching the face could be simulated. The resistances of the stoppings thus became the independent variable with the residual flow at the front of the panel the dependent variable.

Table 4 Leakage rates to be used in testing ventilation control devices (other than seals)

Pressure differential in Pascal	Flow of air in cubic metres per second.
10	0.271
50	0.606
100	0.857
150	1.049
200	1.211
300	1.484
400	1.713
500	1.915
600	2.098
700	2.266
800	2.423
900	2.570
1000	2.709

As all the stoppings in the simulation had the same value the results obtained gave a relationship that could be used to approximate the most suitable maximum leakage, or resistance, value.

It was accepted that this would not be the final value used but would give a very good indication of the allowable leakage that would ensure the fresh air to reach sufficiently into the panel.

Based on this initial exercise it was indicated that a residual flow of about 5.0 cubic meters per second in the last through road would be sufficient but that with a safety margin 9.9 cubic meters per second would be appropriate.

Using the accumulated time for air to move at each stopping the calculations were redone. This facility is available on the simulation package when the fresh air is used as a contaminant.

These calculations confirmed that a residual airflow of around 10 cubic meters per second would be sufficient to ensure that a worker could reach fresh air.

Making one of the airways into a belt road with the commensurately higher resistance an additional simulation was done to prove the validity of the figures.

Once the resistance characteristics of the stopping were determined they could then be used as the maximum leakage in a test that would be allowed for a stopping.

The resistance can also be stated in terms of a hole in the stopping. This should not be seen as being indicative of the damage but should be used as an indication only.

Using the formula for regulators areas the area of the regulators that will coincide with the resistance criteria of the stoppings is 0.378 m^2.

This is significantly larger than the area of a regulator that can be used to obtain the USBM criteria. Such a regulator for tests at LLEM would be 0.0042 m^2 in area.

In practical terms the criteria determined by this exercise indicates that a section with a set of holes through the stopping in the order of 0.378 m^2 each will still result in air reaching the face.

Using these results the following table sets out the criteria in terms of pressure difference and airflow that would be required to test the ventilation control devices are set out below in tables 3 and 4.

If the airflow through the actual stopping (after it has been tested) at a certain pressure difference exceeds that given by this graph then the stopping has failed the test

Table three presents the leakage rates as used in the LLEM test and is to be used for all seals.

The following leakage levels for ventilation control devices other than seals have been set to ensure the highest probability of maintaining a sufficient flow of air after the occurrence of an event in a mine.

8 Conclusions

The new and innovative methods for destructively testing seals and other ventilation structures are potentially viable alternatives. It can be foreseen that the testing of such structures will be done in smaller purpose built galleries or in special areas of mines.

This may lead to a reduction in the cost of testing. In all cases it will be critical that the quality of the instrumentation and competence of the persons conducting the test is documented and able to be subjected to re-examination

The use of non-destructive testing has application and merit in determining the state of ventilation structures in mines as well as determining the quality of installation.

It is however not seen as a method that in terms of both cost efficiency and reliability can be used to test innovative prototype structures.

The relaxed leakage rates for use with ventilation structures will be recommended for incorporation into the proposed Recognised Standard for the testing of ventilation control devices

This standard will also consider the use of innovative and alternative testing processes with the proviso that an organisation with the necessary competence to conduct the test conducts or oversee these tests.

In reviewing the testing methods better and more cost-effective methods of ensuring a higher standard of ventilation control structures may be developed in the near future.

9 Acknowledgements.

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SAFE ESCAPE FROM

LONGWALL DEVELOPMENT SECTION IN CASE OF A BELT FIRE

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Abstract

When a fire occurs outby a working area, the immediate safe evacuation of miners from the mine should always be the first action during the rescue operation.

However, many times, the dedicated escape ways for the evacuation of the miners become contaminated by the by-products of fire from adjacent entries.

The purpose of this paper is to present the ventilation-control process that would keep escape way free from contaminants and, thus, available for travel. A few scenarios of mine belt fires in longwall development entries are analysed, and discussed.

To perform these studies, a mine-fire simulator (MFS) named 'VANTGRAPH' was used. This software provides a dynamic representation of the fire's progress (in real-time) and gives a colour-graphic visualisation, of the spread of combustion products, oxygen, and temperature of the gases throughout the ventilation system.

This presentation, for the Queensland Mining Industry Health and Safety Conference, based on paper published by Wala (1996), however, this time the new mine-fire simulator 'VENTGRAPH', with modified fire's parameters was used.

Also presented and discussed are ways in which the MFS can be used as a training and teaching tool for miners and, particularly, for ventilation and safety specialists.

Introduction

Despite remarkable improvements in mine-safety procedures, coal-mine fires remain among the most serious hazards in underground mining. How much of a threat that a fire presents depends upon the nature and amount of material ignited, the ventilation system arrangement, the duration of the fire, the extent of the spread of combustion products, the ignition location and, very importantly, the time of occurrence. The response to the fire by mining personnel will depend upon all of these factors.

Then a fire occurs outby the working section, the immediate safe evacuation of miners from these areas should always be the first action during the rescue operation.

Usually, the intake entries are dedicated as the primary escape ways from the working section. In many cases, the dedicated escape ways are contaminated with fire by-products from abutting entries, (eg a belt entry) due to leakage through stoppings. Therefore, it is important to keep these escape ways unobstructed and free from contamination.

As suggested by Mitchell (1990), miners escaping from a mine fire should erect a check curtain in the intake escape way. The check curtain should be close to the face to reduce smoke infiltration from an abutting entry that is on fire.

In 1991, Kissell and Timko investigated the use of a parachute stopping which could be rapidly activated to prevent spreading of contaminated air. The data collected during their study indicated that the pressure of the intake escape way increased after installation of the parachute, thus preventing smoke infiltration from the adjacent entry and making the escape ways available for travel.

In their conclusions, Kissell and Timko said, 'It is not possible to reliably forecast the degree of pressure unbalance and leakage created by mine fire. However, during the early stages of a fire when miners should be making their escape, checking off the intake escape way will serve as a viable way to improve safety.'

They also noted that, because of complex interrelationships between the mine ventilation system and a mine fire, it is difficult to predict the pressure unbalance and leakage created by a mine fire.

Depending on the rate and direction of dip of incline of the entries (dip or rise), reversal or recirculation of the airflow could occur because of convection currents (buoyancy effect), and constriction (throttling effect) caused by the fire.

This reversal jeopardises the functioning of the ventilation system, whose stability is critical for maintaining the escape ways free from contamination and therefore available for travel.

The major goal of this paper is to analyse and visualise underground mine fire scenarios that control fire contaminants and maintain safe escape ways. To perform these studies, the authors used a mine-fire simulator (MFS). It utilised a colour-graphic visualisation of the spread of combustion products, oxygen, and temperature throughout the ventilation system and provided a dynamic representation of fire progress.

During the simulation session the user can interact with the ventilation system (eg implement check curtains, breach stoppings, and change fan characteristics) to study different ways of controlling the system.

In studies conducted by Goodman and Kissell (1990), who used risk analysis on reducing the dangers associated with escape from an underground mine emergency, it was shown that one of the most important factors in saving lives during a mine fire is miners' training.

Therefore, this paper also presents and discusses ways in which the MFS could be used as a teaching and training tool for Mining Engineering students and ventilation and safety specialists (Wala, 1992). In particular, training that concerns the probable behaviour of mine ventilation systems during a fire is of utmost importance.

Capability of the mine-fire simulator (MFS)

The MFS used to perform these studies was developed by Trutwin, Dziurzynski, and Tracz (1992). The program, coded in Pascal, combines three distinct modules:

- a conventional program for mine ventilation network calculations
- a program to simulate the fire development (real-time heat and product-of-combustion simulator)
- a program to calculate the air temperature changes due to a fire.

The purpose of this simulator is to predict the behaviour of the ventilation system in the case of a fire.

For clear and convenient display of the calculations results, the MFS provides a dynamic (animated) representation of the fire's progress, including a colour-graphic visualisation of the spread of combustion products, the temperature, the flow and other parameters throughout the ventilation system in real-time.

This program also enables the simulation of other fire-controlling actions, such as changing an emergency check curtain, opening or closing a regulator (door), breaching a stopping, and changing the fan characteristics.

All of these changes can be simulated at an arbitrary instant, which allows for the testing of various fire-control and suppression strategies.

These capabilities of the MFS, take advantage of the full power of the computer to design the safest ventilation system, to serve as an advisor during a real emergency action, and for instruction and training of mining personnel.

Validation studies of the MFS were performed using data gathered from a real mine fire (Wala et al (1995).

The MFS program is fully interactive. All data are entered from the keyboard during program execution. Input is simplified to such an extent that basic computer skills are sufficient. The user is precisely menu guided throughout the simulation session.

The usefulness of the MFS to analyse, diagnose, and explain certain situations when controlling ventilation for determining miners' safe escape route(s) from the section in case of fire will be presented later.

Description of the studied ventilation systems

Two different scenarios for a longwall development entries are investigated. Both represent the three-entry system with a standard single-split ventilation. The difference between the two scenarios is the incline of the entries.

Figure 1 depicts a typical three-entry, single-split ventilation arrangement. The intake air reaches the faces through the belt entry, which is adjacent to a solid barrier pillar (requires approved 101-C Petition for Modification of Section 75.326 of Title 30, CFR), and through the middle intake entry dedicated as a primary escap eway.

This primary escape way is isolated from the belt/track and return entries by rows of permanent stoppings. A man-door is installed in every fifth stopping.

The belt/track entries are assumed to be 7.3m (24 ft) wide, while all other entries are assumed to be 6.4m (21 ft) wide. A mining height of 1.5m (5 ft) is used in all calculations. Friction factors used to calculate airway resistance were determined from data collected during ventilation surveys performed by the author and are as follows:

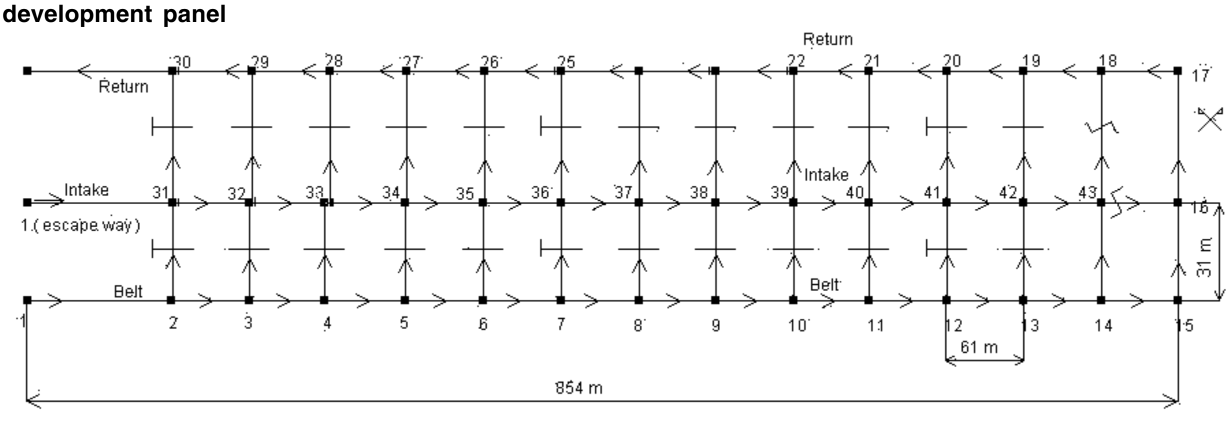
- intake entries: 0.00835 kg/m^3 **(45 x 10E-10 lb min^2/ft^4)**
- return entries: 0.0167 kg/m^3 (90 x 10E-10 lb min^2/ft^4)
- belt entries: 0.0426 kg/m^3 (230 x 10E-10 lb min^2/ft^4).

The pillar centres were assumed to be 61m (200 ft) by 30.5m (100 ft).

To present how the buoyancy, throttling, and stoppings' leakage affect the availability of escape ways for travel in case of fire, this system is tested as horizontal and incline (rise 10 percent toward the face) with medium air-tight stoppings.

The resistance assumed for such a stopping is 500 N s^2/m^8 (4480 x 10E-10 in. min^2/ft^6), which means that if differential pressure across the stopping is 25 Pa (0.1 in. WG), the leakage is 0.22 m^3/s (465 cfm). The resistance assumed for the stoppings with the man-

Figure 1 Schematic of the three-entry, single-split ventilation arrangement for longwall development panel



doors is 100 N s^2/m^8.

For the purpose of exaggerating the problem the resistances for two stoppings in the system were assumed lower. Lower resistance indicates stopping damage. The resistance of the damaged stopping between notes 3-32 (see Figure 1) is 30 N s^2/m8 (269 x 10E-10 in. min^2/ft^6) and for stopping between the notes 34-27 is 50 N s^2/m^8 (448 x 10E-10 in. min^2/ft^6).

The total length of the tested longwall development section is 854m (2800 ft), as shown in Figures 1.

To generate a proper amount of an airflow through the system, a differential pressure equal to 250 Pa (1.0 in. WG) across the intake and return, at the mouth of the development section, was introduced.

Simulation exercises

The purpose of performing these exercises is to visualise how the ventilation controls could be used to maintain the escape ways free from contaminants and available for travel in case of fire. These simulation exercises were carried out for the three-entry, single-split ventilation system for the longwall development panel with horizontal and incline (rising, ascentional) entries.

Hands-on experience with the simulator has potential for improving mine workers' understanding of mine fires and ventilation interactions. For example, the placing of a check curtain (parachute stopping) in an intake near the face, and the resulting changes in mine ventilation and the fire's behaviour, can immediately be viewed in real but accelerated time. Also, the buoyancy and throttling effects on the ventilation system can be directly observed.

- The fires simulated for all exercises have the similar characteristics:
- they are located in the belt entry, 800m (2700 ft) outby the face
- coal, of heating value equal 29,000 kJ/kg (12,500 Btu/lb), is on fire
- fire is spreading (building-up) with a given time constant to reach the visible fire area of 65m^2 (see Figure 2 graph A_f(t)), according to a study carried out by Dziurzynski and Tracz (1994), the relationships between the fire area and the visible fire area can be described by a proportionality factor

· time constant of the fire development is 1200 second (fire growth rapidly in purpose to accelerate time of the whole rescue action)

· intensity of fire, ie, the amount of coal burning during the fire, is shown in Figure 2 as a graph I(t)

· during the oxygen-rich stage of fire, the combustion gases CO and CO_2 are produced in a CO:CO_2 ratio of 1:10 are produced.

Exercise 1

Single split, horizontal entries. The objective of this exercise is to demonstrate how to prevent infiltration of the fire's contaminants into the primary escape way in the longwall development panel with horizontal entries. For this arrangement, this goal can be achieved in the following two ways:

- by pressurising the intake entry by erecting a check curtain (parachute) close to the face (eg branch 42-43), as shown in Fig 3
- by lowering the pressure inby the fire by checking off the belt entry outby the fire (eg branch 1-2), again as shown Fig 3.

Besides lowering the pressure inby the fire, the second action also reduces the oxygen provided to the fire. This oxygen reduction could lead to a fuel-rich type of fire, requiring special attention.

With concern for the time required for implementation of these two approaches for making the escape way available for travel, the first alternative is more favourable. However, sometimes the second solution is recommended, especially when entries are inclined. This case will be discussed during the next exercise.

Figure 3 depicts the tested three-entry, single-split ventilation system with horizontal entries, with the fire located in the belt entry. In particular, this figure shows the flow and carbon monoxide distribution in the

Figure 2 The growth of the fire area and intensity of the fire

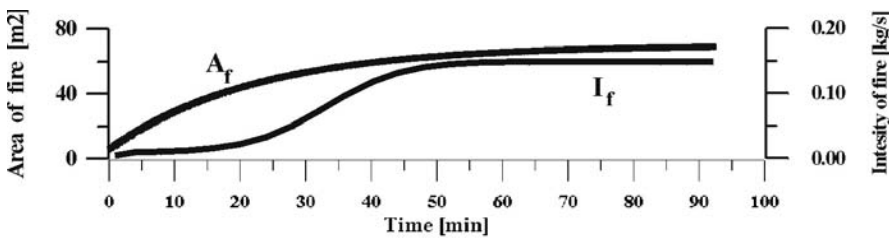
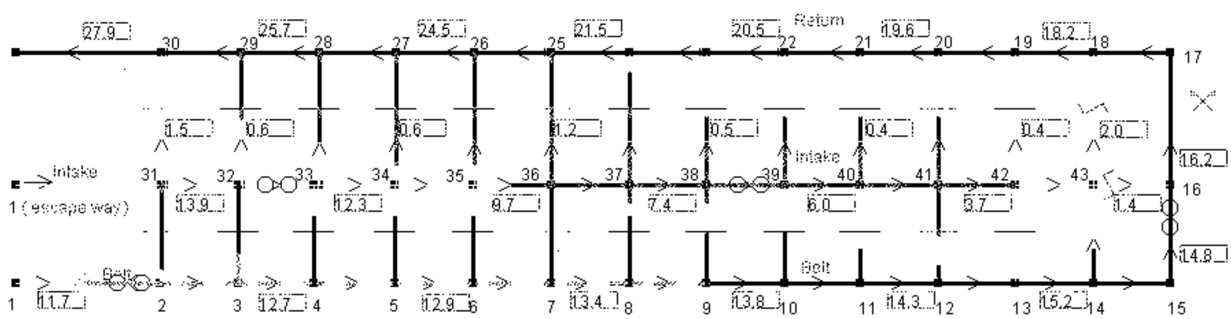


Figure 3 The flow of gases in m^3/sec and carbon monoxide concentration (thick lines) 45 min after fire's ignition



system 45 minutes after the fire's ignition.

The numbers in the small boxes display the flow of gases in m^3/s. The thick lines depict branches containing carbon monoxide. These lines, displayed in colours on the computer screen (or produced on printer), could indicate concentrations of oxygen, combustion products or the temperature of the gases.

Figure 4 shows transients of carbon monoxide in the ventilation system caused by the fire and by implementation of the check curtain (parachute) outby the face area.

This check-off curtain was erected 40 minutes after the fire started and 15 minutes after concentration of carbon monoxide in the face area reached 15ppm. Carbon monoxide concentrations were measured by sensors located at points A, B, C, and D, as shown in Fig 3.

Figure 5 depicts transients in the same ventilation system as details above, with one exception: the check curtain was erected outby the fire in the belt entry. In this scenario, it was shown that by lowering the pressure inby the fire, the escapeway could also be kept free of combustion gases.

Exercise 2

Single split, incline entries. The objective of this exercise was to demonstrate the interrelationships between the mine ventilation system and mine fires in a mine with incline (rise) entries.

It is well known that heat generated by the mine fire, especially a severe open fire in a mine with incline entries, can affect the stability of a ventilation system by buoyancy (natural ventilation pressure) and throttling.

These effects can range from flow-constriction, smoke rollback to a complete reversal of flow. The consequences can be disastrous, because entries designated as escape way (and presumed to be free of contamination) can fill quickly with toxic fumes, gases, and thick smoke.

To effectively use ventilation control to assist miners to escape, mine operators, mining engineers, miners, and safety and ventilation personnel must have a thorough understanding of relationships between the ventilation system and a mine fire. And they must be capable of applying this knowledge to the particular mine and location where they work.

Figure 6 depicts the same layout for the longwall development panel used in Exercise 1, except

Figure 4 The transients in the system with horizontal entries and check curtain being erected in the intake close to the face. The graphs in Figure 4 show that by checking off the intake entry close to the face area, the infiltration of the fire by-products into the escape way could be prevented. Similar results were observed during the study carried out by Kissell and Timko (1990).

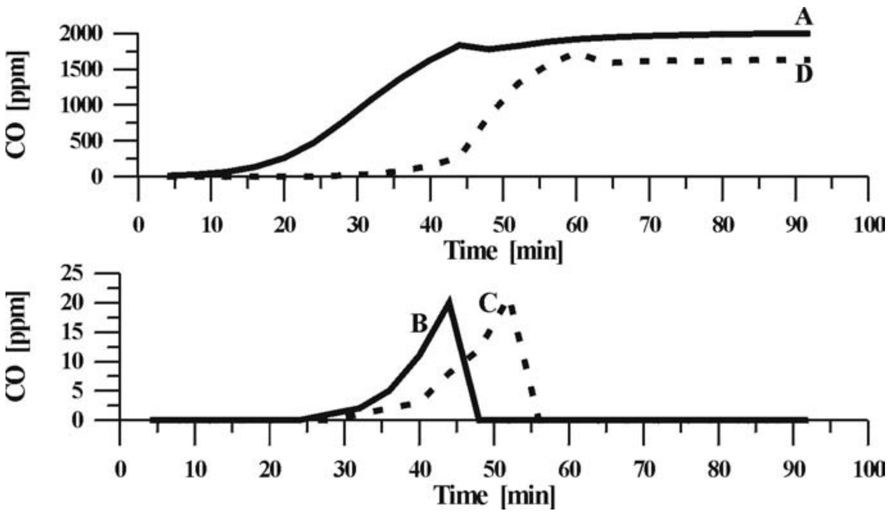
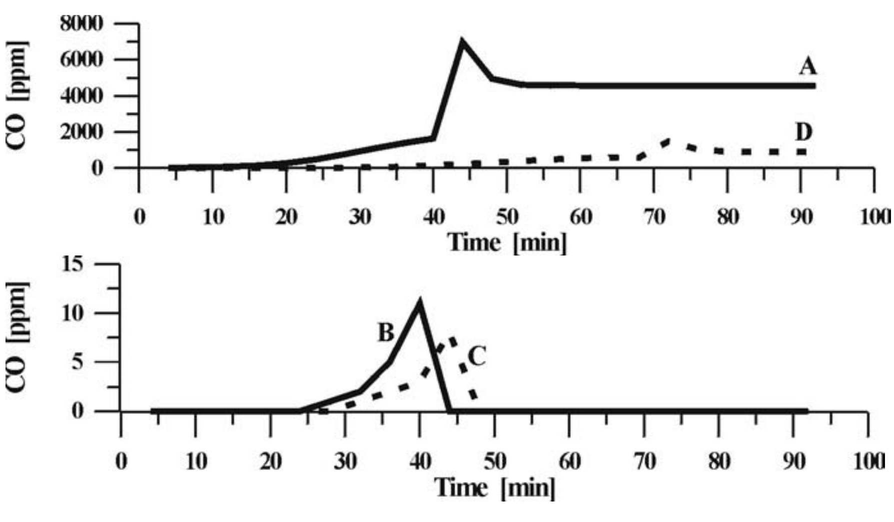


Figure 5 The transients in the system with horizontal entries and check curtain being erected outby the fire in the belt entry



that the entries rise 10 percent toward the face.

As in Exercise 1, to exclude fire by-products from the primary escape way, the check curtain (parachute) was installed in the intake entry outby the face area 40 min after the fire's ignition and 15 min after the concentration of carbon monoxide reached 15ppm in the face area.

The carbon monoxide (the thick lines) and the flow distribution 45 minutes after the fire's ignition, are also displayed in Fig. 6. The transients in this ventilation system caused by the fire and placement of the check curtain are shown in Fig. 7.

A comparison of Figs. 4 and 7 indicates that the same control procedure affects these two systems differently. This is because of the buoyancy in the mine with the inclined entries.

These two figures depict the mechanics of the buoyancy and its interaction with ventilation controls for horizontal and inclined system.

In the case of the incline system, where the natural ventilation pressure builds up mostly in the incline belt entry, implementation of the check curtain in the intake entry close to the face dose not help to keep the escape way free of combustion gases.

As shown by graphs B and C in Fig. 7b, the concentration of carbon monoxide in the intake entry (primary escape way) reached 200ppm.

The objective for the next simulation study was to display the behaviour of he ventilation system as a responses to the following control scenario:

- 25 min after fire ignition, the CO concentration in the face area reaches 15ppm;
- 15 minutes later (40 min after fire's ignition), a check curtain is installed outby the face in intake entry (primary escape way)
- utilising a Self-Contains Safe Rescuers, miners escaped from the section through the intake escape way on battery-powered portal bus
- 60 minutes after fire's ignition, the miners (after they were outby the fire) erect the check curtain to make the fire area accessible to fire fighters.

Figure 8 depicts the flow distribution and carbon monoxide concentration in the system, 70 min after fire's ignition.

Figure 9 depict the transients of the carbon monoxide. Figure 10 depicts the flow rate changes (due to the fire and control process) measured by sensors A, B, C, and D in branches 1-2, 32-33, 38-39, and 15-16, respectively.

It was found that, during these simulation exercises that placement of the check curtain outby the face in the intake entry, during the early stage of the fire, does not keep the escape way free of combustion gases.

Implementation of the check curtain outby the fire in the belt entry could only keep the escape way free of

Figure 6 The flow of gases in m^3/s and carbon monoxide concentration (thick lines), 60 minutes after fire's ignition

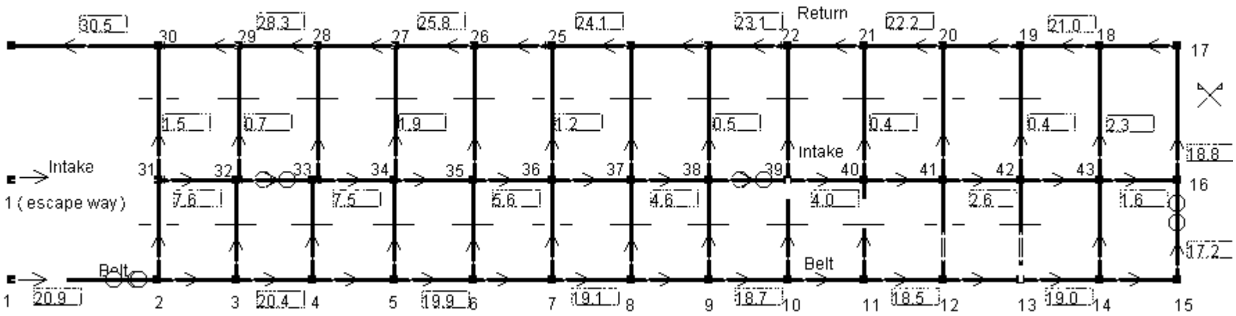
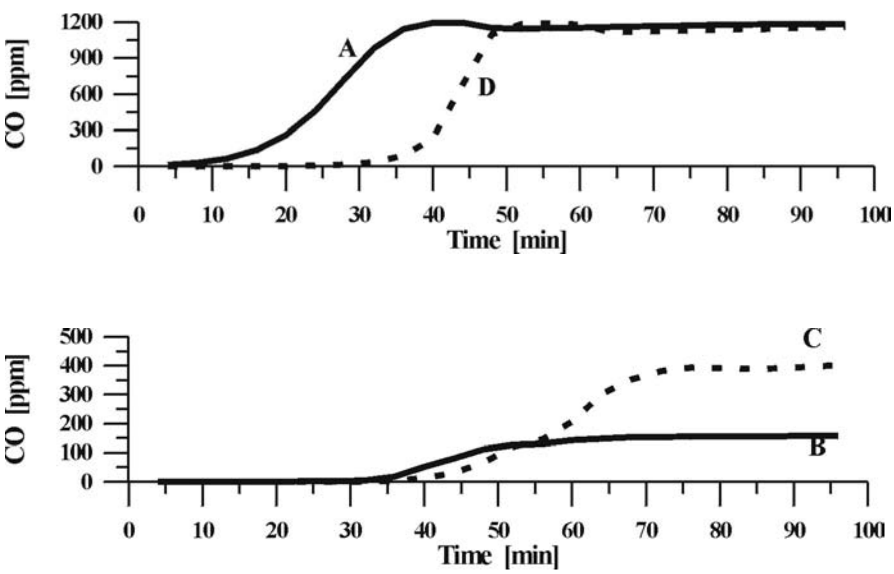


Figure 7 The transients of carbon monoxide in the system shown in Figure 6



combustion products.

Conclusions

Mine emergencies and disasters are rare events in the experience of individual miners, and this is as it should be.

However, a consequence fact is that the majority of underground coal miners in the United States have little or no chance to practice their decision-making skills in actual mine fires.

Thus, well-designed computer simulation exercises, based on actual mine fires and the actions of miners during these emergencies, may be useful for teaching, maintaining, and assessing miners' proficiency in critical self-rescue and escape skills.

Training mine personnel in the wise and proper use of mine-ventilation controls to aid the escape from fires remains a largely undeveloped area.

Little systematic instruction is available for this complex area. The mine fire simulator implemented in Computer Assisted Instruction (CAI), (Wala 1992), shows much promise as a means to provide such training.

When fully developed, the CAI system might be used for teaching and training mining engineers and safety and ventilation personnel who are responsible for ventilation arrangements during fire fighting, mine rescue, and recovery.

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Figure 8 The flow of gases in m^3/s and carbon monoxide concentration (thick lines), 90 minutes after fire's ignition

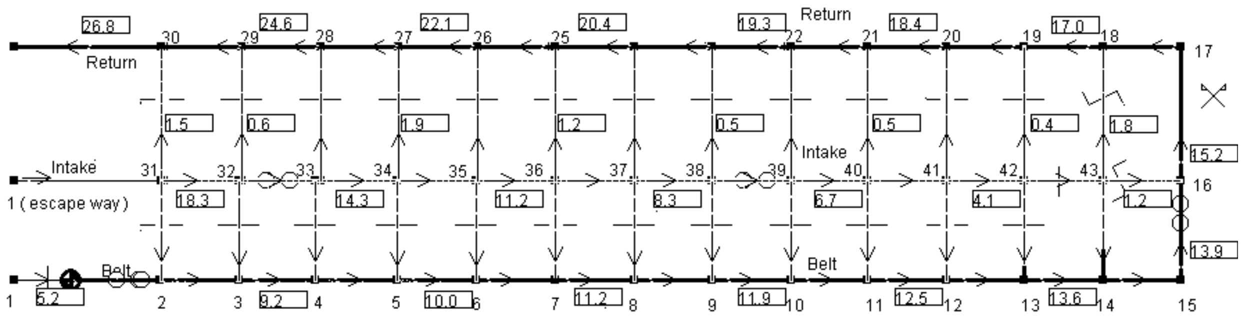
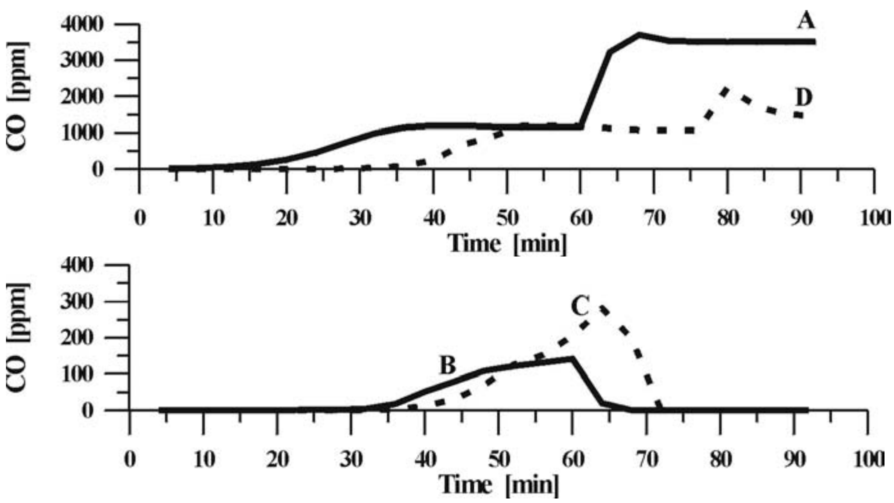


Figure 9 The transients of carbon monoxide in the system shown in Figure 8



Journal, Maclean Hunter Publishing Co., Vol. 96, No. 3, March, pp. 75-77.

3 Kissell, F.N., Timko, R.J., 1991, 'Pressurization of Intake Escapeways with Parachute Stoppings to Reduce Infiltration of Smoke,' *Proceedings*, 4th U.S. Mine Ventilation Symposium, Morgantown, WV, June, pp. 28-34.

4 Mitchell, D.W., 1990, *Mine Fires - Prevention, Detection, Fighting*, Maclean Hunter Publishing Co., Chicago.

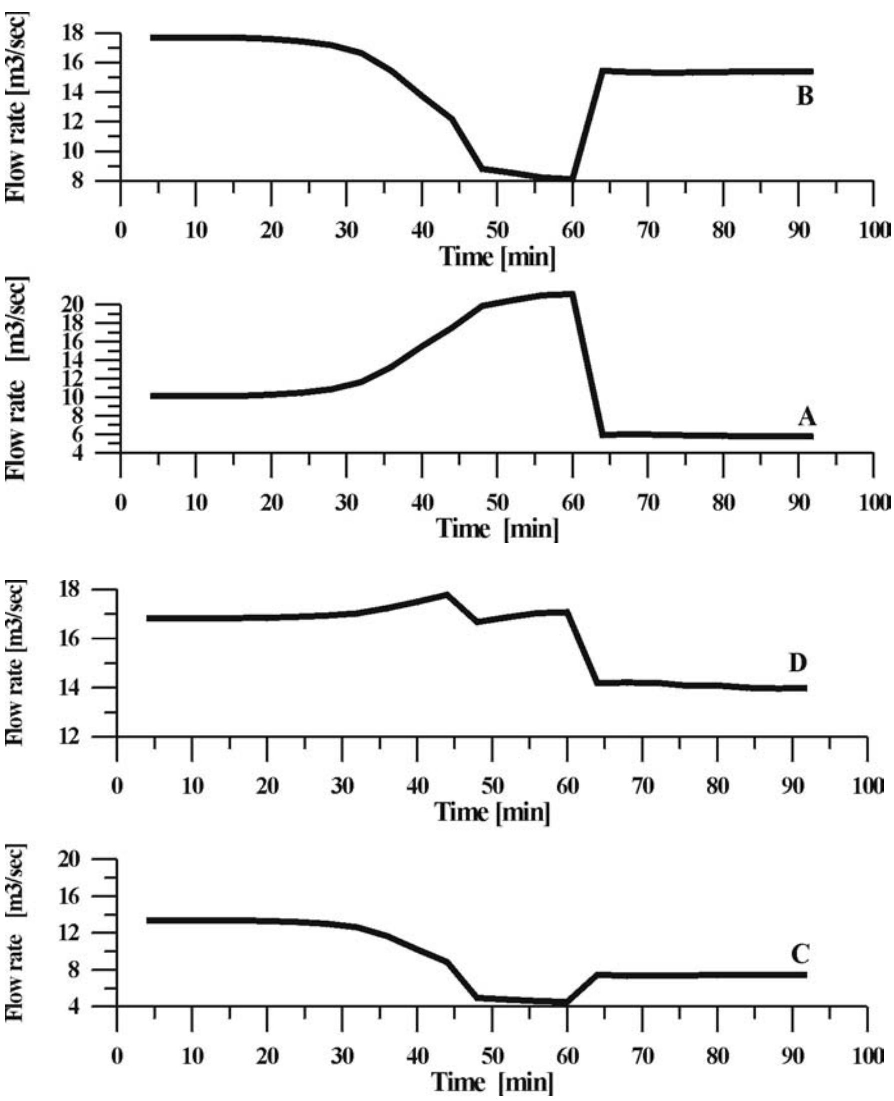
5 Trutwin, W., Dziurzynski, W., and Tracz, J., 1992, 'Computer Simulation of Transients in Mine Ventilation,' *Proceedings*, 5th International Mine Ventilation Congress, Johannesburg, South Africa, October, pp. 193-200.

6 Wala, A.M., 1992 'Teaching Mine Fire Principles with Intelligent Computer-Assisted Instruction,' *Proceedings*, 5th International Mine Ventilation Congress, Johannesburg, South Africa, October, pp. 301-311.

7 Wala, A.M., Dziurzynski, W., Tracz, J., and Wooton, D., 1995 'Validation Study of the Mine Fire Simulation Model,' *Proceedings*, 7th U.S. Mine Ventilation Symposium, Lexington, KY, June, pp. 199-206.

8 Wala, A.M., 1996, 'Controlling Ventilation for Safe Escape from Coal Mine Fires,' *Mining Engineering*, April, pp. 61-66.

Figure 10 The flow changes in the system due to the fire and control process



THE ROLE OF THE INDIVIDUAL IN FATIGUE MANAGEMENT

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Abstract

While it is clear that the individual has a definite role in managing fatigue, little research has specifically identified those aspects of individual functioning that make for effective coping with fatigue.

This paper explores variations in how people cope with fatigue at work. Our exploration is informed by the theoretical framework that has evolved over the past two decades of research on coping with stress.

Three questions arise out of the applications of coping theory to fatigue management:

- Is it possible to identify variations in individual coping with fatigue risk at work?
- Are these variations linked to variations in the demands of the workplace, or to variations in stable personality traits?
- If it is possible to identify various styles of coping with fatigue risk, are these coping styles linked in meaningful way to different safety outcomes.

Results from nine Queensland industrial sites and 1651 people identified different styles of coping with fatigue that were linked to different safety outcomes.

Overall, the results suggest that coping plays a relatively dominant role in predicting fatigue risk at work and that a more deliberate coping style involving planning and organising one's life is linked to increased safety at work.

The evidence also indicates that rigorous work conditions elicit more deliberate coping responses but these may not mitigate the risk inherent to more rigorous workplace conditions.

Introduction

'Fitness for duty' is generally conceptualised as a set of mutual responsibilities shared between employers and employees. These mutual responsibilities involve the responsive design of the workplace and responsible personal management.

While it is clear that the individual has a definite role in managing fatigue, little research has specifically identified those aspects of individual functioning that make for effective coping with fatigue.

The present paper draws on data from 1651 people from nine Queensland industrial sites that go some way in identifying specific aspects of the role of the individual in effectively managing fatigue in the workplace.

A theoretical model

The broad theoretical model that has informed our work with fatigue in the workplace relies on the research literature on coping that has emerged over the past two decades.

The coping research developed as a reaction to questions about individual differences in stress response.

Reacting to earlier models of stress that emphasised the severity of life-events as predictors of stress response (ie Holmes & Rahe, 1967), the coping literature emphasised the importance of identifying those aspects of individual functioning that allowed some people to cope more effectively than others (Carver, Scheier, & Weintraub, 1989; Billings & Moos, 1981; Holahan & Moos, 1987; Lazarus & Folkman, 1984).

The coping research demonstrated that active or problem-focussed coping significantly moderates the adverse effects of stressful or negative life events on physiological functioning and well-being.

Active coping is the process of taking deliberate steps to meet the challenge that faces the individual.

Active coping includes:

- initiating direct action
- increasing one's efforts
- planning and organising action strategies
- restricting other activities that might compete with or inhibit effectively responding to the stressor
- actively seeking additional knowledge or social support (see Carver et al, 1989).

In contrast, avoidant coping involves:

- efforts aimed at reducing the tension created by the stressor
- or avoiding the real problem, eg smoking or drinking, getting involved in alternative activities, blaming others, and denying the importance of the stressor.

Other researchers (eg Lazarus & Folkman 1984) have described emotion-focussed coping as expending effort on coping with the immediate emotional tension that the situation generates for the individual rather than directing efforts towards meeting the challenge.

The evidence from the coping literature overwhelmingly supports the view that avoidant or emotion-focussed coping leads to poorer outcomes.

Although most stressors elicit both kinds of coping types, active or problem-focussed coping tends to predominate when people feel something positive can be done, whereas avoidant or emotion-focussed coping tend to predominate when people feel nothing can be changed or that the stressor is something that must be endured.

Such evidence suggests that situational cues determine the coping style an individual employs in a specific situation or environment.

However, a number of studies have linked traditional personality differences to coping style. Optimism, self-confidence, neuroticism, mastery and an internal locus of control have been linked to more effective coping (Scheier, Weintraub, & Carver, 1986; Parkes, 1984).

The individual who assumes s/he can influence the environment (an internal locus of control) inevitably enjoys better health than the individual who assumes s/he cannot influence their environment, that they are victims of the world around them and control is attributed to external forces or identities (Rotter, 1966).

Such results suggest that dispositional factors or preferred coping strategies determine particular coping responses.

Fatigue risk at work

We have conceptualised fatigue risk at work as arising out of the interaction between an individual and the workplace. Both workplace design and practice, and individual functioning can contribute to an unacceptable level of fatigue risk at work (see figure 1).

We have wanted to avoid the position that workplace factors alone, or alternatively, individual coping alone are the sole explanation for safety outcomes at work.

Potential workplace factors that might contribute to fatigue risk include the distribution of time at work (ie hours of work, roster design, breaks in shift), the nature of the work performed, and the conditions of the work environment including the social relationships.

Individual factors that might contribute to fatigue risk in the workplace include variations in coping with fatigue, aspects of lifestyle, hours of sleep, family support, and any physiological or psychological factors that might be predispose people to poor functioning at work.

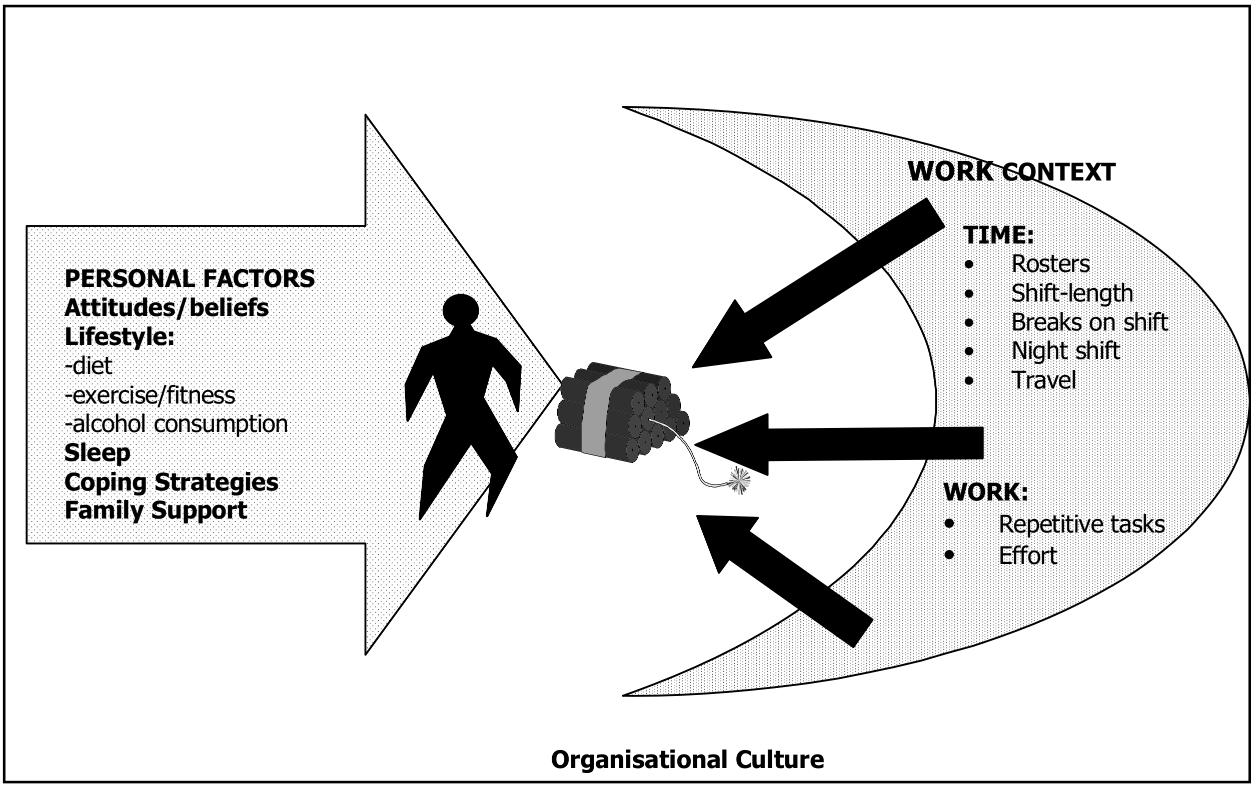
The critical task of safety personnel is to identify those aspects of the workplace, or of individual functioning that might make fatigue-related incidents or injury more or less likely to occur in the workplace, and then to introduce effective controls to reduce the risk.

It is suggested that little research has specifically set out to systemically explore individual factors that might contribute to fatigue risk in the workplace.

The 'coping' framework applied to fatigue

The application of the 'coping' framework to our understanding of fatigue in the workplace invites a series of questions about coping with fatigue. Firstly, there is a set of issues surrounding the question of whether it is possible to identify various styles of coping with fatigue in the workplace. And, if it is possible to identify different ways of coping with fatigue, to then isolate the defining characteristics of these potentially different ways of coping with fatigue.

A second question concerns whether these differences in coping might arise out of the differences in the work environment or from inherent individual differences. We could refer to these two types of differences as situational differences and dispositional differences. Situational differences in coping arise out of the nature of the situation in which people find themselves. On the other hand, dispositional differences arise out of the nature of the people rather than differences in the situation, and would be linked to stable personality differences.



A third and critically important question concerns the possibility of demonstrating links between the different ways of coping with fatigue and the specific outcomes of fatigue risk and safety at work.

Finally, a fourth question addresses the relative contribution of coping to fatigue risk when compared with other factors that might be linked to fatigue risk in the workplace.

Our work in industry

While the above research and questions have inevitably informed our thinking about the role of the individual in managing fatigue, our actual work has inevitably required a focus on a broader view of fatigue in the workplace.

Our investigations have essentially played the function of identifying those aspects of the workplace design and of personal functioning that contribute to fatigue risk in specific industrial operations.

The data reported below draws on questionnaire data collected from site-wide studies at nine different Queensland mines and one Queensland group involved in the power industry. At each site considerable care was taken to ensure either all personnel completed forms, or that a representative sample was drawn from each operation.

Summary of the results

A key question in each of these studies has been identifying the proportion of people who had personally experienced a near-miss over the past month of their work, that they believe was caused by fatigue.

In each study we examined those aspects that might make it more or less likely that people experience a fatigue-related near-miss. While other indicators of fatigue risk at work were used, this question seemed to come closest to real fatigue risk while at work.

Table 1 presents a summary of the sites, people involved in each study and the proportion of people at each site experiencing a near-miss.

A cursory examination of the above results suggests that underground operations may run a higher degree of risk than surface operations in terms of fatigue and safety.

However, the Site 9 open-cut operation stands out as an exception to this pattern.

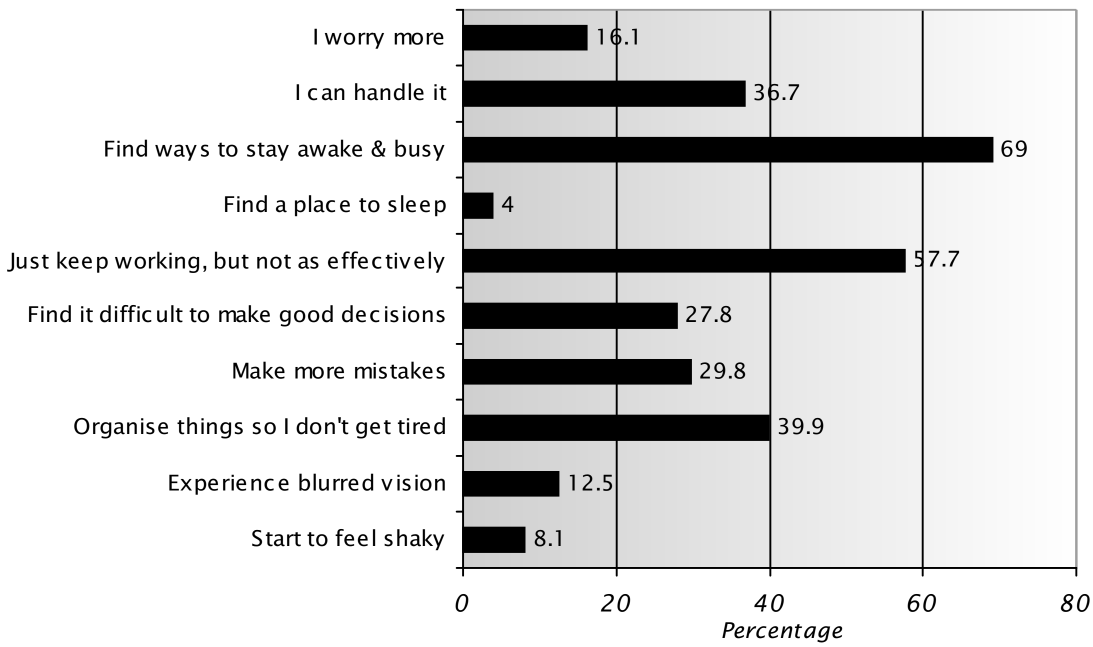
Identifying styles of coping with fatigue

In the first study we included 10 items in the questionnaire that represented a checklist of the various ways of coping with, or responding to the experience of fatigue at work. Respondents indicated

Table 1
Summary of sites and proportion of people experiencing a fatigue-related near-miss in the past month of work.

Site	Type of Industry	N	% reported near-miss	Year of study
1	U/G Coal	248	20.4%	2000
2	U/G Coal	92	30.3%	2000
3	O/C Coal	379	11.0%	2001
4	Power Dstribution	58	14.0%	2001
5	O/C Coal	200	10.7%	2001
6	U/G Metalliferous	178	20.8%	2001
7	O/C Coal	227	11.3%	2001
8	U/G Coal	138	20.3%	2001
9	O/C Coal	101	20.9%	2001
10	O/C Coal	30	3.3%	2002

Figure 2. Proportion of respondents adopting coping responses to feeling very tired at work



which of the items was typical of their functioning when they were really tired at work. We examined the data in a number of ways. Figure 2 presents the raw data from the sample. There were no differences between roster or work groups.

A cluster analysis of the data identified three quite different styles of coping with or responding to fatigue in the work place. Figure 3 presents the differences between the clusters on the coping items. Items were scored 0=not indicated or 1=indicated. Mean scores then represent the proportion of the sample indicating each item.

The first group differed from the other groups in being less symptomatic, more likely to plan and organise their life to avoid fatigue and to feel that they could cope with fatigue.

It is not surprising that feeling one could cope with fatigue was linked to more planning and organising.

The second group, while less symptomatic than the third group, were least likely to plan and organise their life to avoid fatigue and felt less confidence in their ability to cope with fatigue.

While the third group were clearly more symptomatic, they were most likely to 'just keep working' when they were really tired at work.

Subsequent analyses indicated that 11.5 percent of cluster 1 people reported experiencing a fatigue-related near-miss in the past month.

This group could be seen as the active copers and were less likely to attribute their tiredness to the roster system. This group worked a longer shift in terms of hours than the other groups (average of 10.3 hours as opposed to 9.7 and 9.6 hours for groups 2 and 3).

One in four (24.5 percent) cluster 2 people reported a fatigue-related near-miss in the past month. They were more likely to report that fatigue was a major contributor to accidents than cluster 1, and less likely to agree that they could work effectively even when tired. Further, cluster 2 people reported working shorter shifts than cluster 1 people.

Nearly half (47.4 percent) of cluster 3 people reported a fatigue-related near-miss in the past month. Clearly, this group reported more symptoms of fatigue, they were most likely to agree that fatigue was a major contributor to accidents, but tended to work the shorter shifts.

Cluster 3 people were most likely to attribute their tiredness to the roster. Safety was more a product of coping than of rosters and shift length.

These data provide an initial response to our questions one and three. It does seem possible to identify different styles of coping and to identify specific characteristics of these various styles.

Further, these differences seem to be related in meaningful ways to fatigue risk and safety at work.

Planning and organising seems to play a critical role in discriminating between those people who cope well and those who don't cope as well with fatigue. Planning is typically seen as a major component of active and problem-focussed coping and has been associated with optimal outcomes (see Carver et al, 1998).

The data also suggests that a minority of people may be more symptomatic of fatigue and that increased symptoms of fatigue is related to increased fatigue risk at work in spite of planning and organising.

Descriptions of coping style

In the past four studies we have included a question where we simply asked people if they had a strategy to minimise fatigue risk, and if so to describe their way of managing fatigue. In one project we distributed the same questionnaire across three sites for responses from 466 people. We received 368 descriptions of personal fatigue management. These 368 comments are summarised in

Figure 3. Mean scores on reported symptoms/coping strategies of each cluster. (cluster 1 (n=122); cluster 2 (n=104); cluster 3 (n=19))

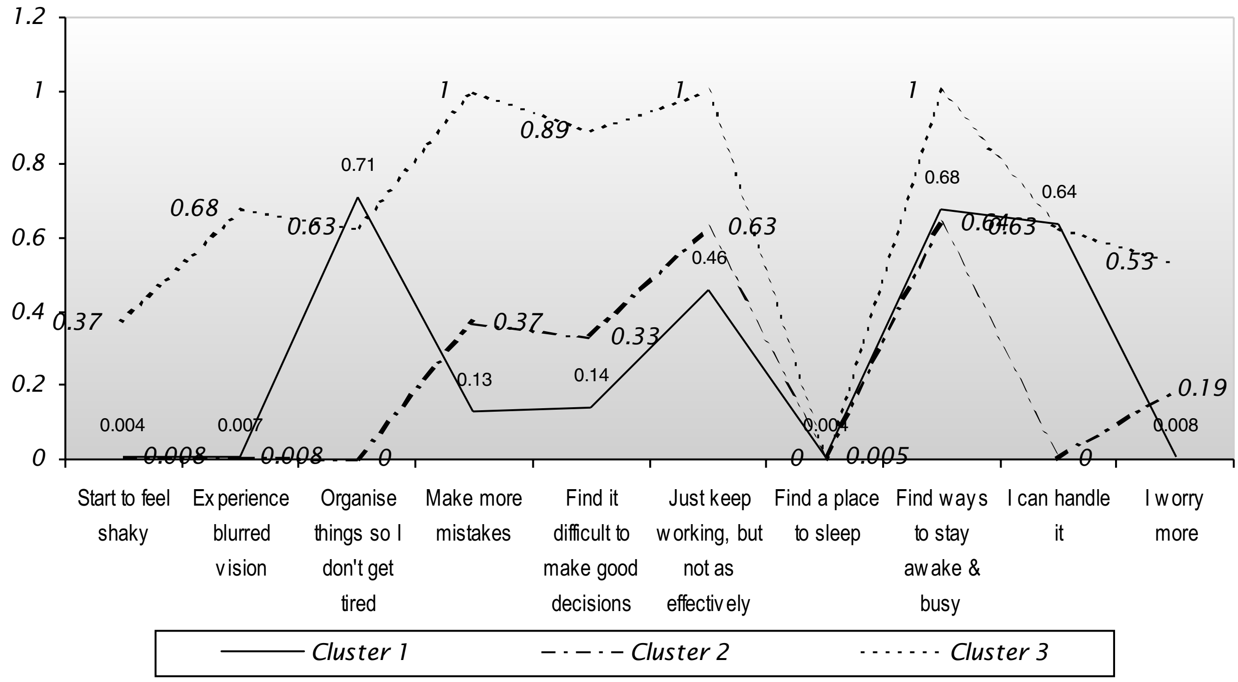


Table 2

The comments fell into three quite different approaches to managing fatigue at work. Preventative strategies involved the active planning to prevent fatigue – ie managing lifestyle, time-off and the job. On the other hand reactive strategies responded to the experience of fatigue by seeking stimulation (ie drinking coffee, splashing water on face, cat-naps during crib time etc.

A more complete view of each type of strategy can be gained by reading Table 2 above. In addition to the preventative and reactive approaches to managing fatigue, there were 50 comments that essentially indicated the individual had no strategy for managing fatigue or assigned responsibility for personal fatigue to someone else.

Subsequent analyses revealed meaningful differences between the coping styles if these analyses were conducted within roster groups. Table 3 summarises these differences within a four on/four off rotating roster group. In addition, near-miss rates are reported for the seven on/seven off roster group from Site 8.

As one would expect, the evidence suggests that people who describe a preventative strategy for managing fatigue tend to do better on other measures as well.

Differences in coping across sites

Differences between the three operations in this

Table 2.
Conscious strategies of fatigue management currently adopted by sample

Conscious strategy to minimise fatigue	Frequency
Preventative Strategies	
1) Managing self (Lifestyle management – sleep, health)	
By actively managing sleep time	109
Manage sleep environment	1
Exercise regularly	11
Constant consideration to nutrition ie. diet/fluids	20
Avoiding/limiting alcohol during the week	11
2) Managing time off	
Limiting activities when on a tour	11
Relaxation, reading, meditation, spend time with family	17
Rest on days off	5
Preparing the day before tour starts – ie take it easy and rest	6
Catch up on sleep on days off	3
3) Managing the job	
Planning time and tasks - setting objectives, sharing responsibilities,	19
Change job/tasks throughout shift ie. task rotation	22
By keeping moving and always doing something, keeping busy	18
Regular short breaks	18
	271
Reactive Strategies	
1) Seeking stimulation or relief from symptoms	
Stimulation seeking: exercise, wash face, coffee, chew gum, crib, walk	19
Cat nap in break or crib time	11
Yes, cut days short if necessary	3
Pacing self, take it easy	6
2) Attempts	
Try to but things always throw plans out, phone calls etc.	3
Find it harder as I get older	1
Yes have a bit of heart	1
Yes, stop when tired	2
	47
No Strategy	
No	46
No as there is always pressure from supervisors to complete work ASAP	1
No, need more sleep	1
You can't	1
You cannot manage your time when you don’t get enough time to do anything	1
	50

same study revealed useful information about coping. Figure 4 presents data on the proportion of people at each of the three sites (regardless of roster) who reported a fatigue-related near-miss in the past month of their work.

While the differences between sites 7 and 8 might be explained in terms of differences between underground and open-cut operations, site 9 represents an anomaly in the data.

Additional analyses revealed no differences between the three sites on measures of the distribution of time at work (ie length of shift, hours between waking and arriving home after work, longest shift in past month), on reports of hours of sleep when working night-shift, day-shift, on days off, or on measures of lifestyle (ie alcohol consumed, ratings of diet, and family support).

A potential explanation of the quite high rate of near-misses at site 9 may lie in the coping style adopted by site 9 people. Figure 5 shows mean scores on a four-point scale for the item 'I have developed effective strategies for coping with fatigue.'

The results from figure 5 indicate that the site 9 group were least likely to report having developed ways of coping with fatigue than people at sites 7 and 8 ($F=4.5$, $p < .01$), and more likely to report finding coping with fatigue very difficult ($F=2.9$, $p < .05$). Further analyses examined the proportion of

Table 3

Differences between groups adopting various fatigue management strategies.

Preventative Strategies group:

- score higher on 'Plan and organise to avoid fatigue'
- consumed less alcohol
- reported more family support
- reported more hours of sleep on night shift
- 16.5 percent of group reported experiencing fatigue-related near-misses in past month (four on/four off roster)
- 36 percent of group reported experiencing fatigue-related near-misses in past month (seven on/seven off roster)
-

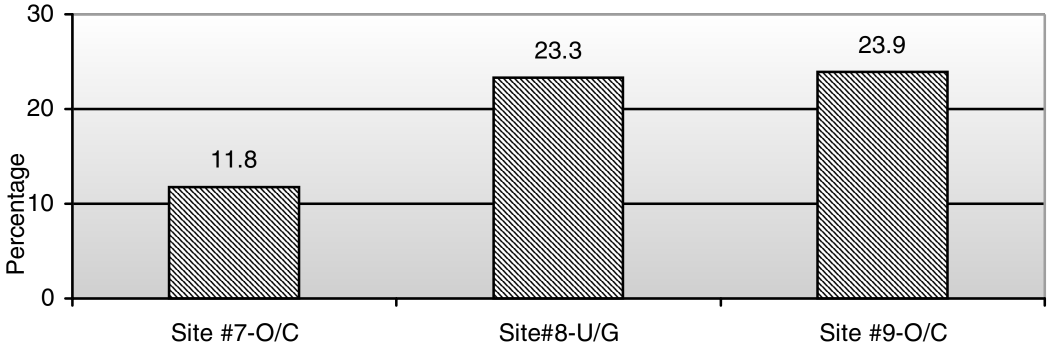
Reactive group:

- more likely to attribute personal fatigue to worry/stress about personal and/or family issues and sleep deficits
- 15.8 percent of group reported experiencing fatigue-related near-misses in past month (four on/four off roster)
- 37.5 percent of group reported experiencing fatigue-related near-misses in past month (seven on/seven off roster)

No Strategy

- scored lowest on measure to plan and organise to avoid fatigue
- more likely to attribute fatigue to weather and environmental conditions and repetitive nature of work
- less experience with shift work
- 27.3 percent of group reported experiencing fatigue-related near-misses in past month (four on/four off roster)
- 57.1 percent of group reported experiencing fatigue-related near-misses in past month (seven on/seven off roster)

Figure 4 Proportion of people at three sites who experienced a near-miss



people at each site adopting various strategies for coping with fatigue, ie preventative, reactive or no strategies. The distribution of coping styles across the three sites is presented in figure 6.

The majority of people at site 7 reported adopting preventative strategies for managing fatigue.

They were more likely to plan and organise their sleeping and rest time and work tasks in order to avoid fatigue. In contrast the most common method for managing fatigue at site 9 was a post-event reaction to fatigue.

The proportion of people adopting a reactive strategy was significantly higher in the Site 9 group than the other two groups.

The above data seems to offer support for a dispositional view of coping - ie people have a preferred method of coping and that is related to how safe people are at work.

However, the role of workplace design should not be understated. Differences between the coping strategies appeared only within roster groups rather than across roster groups, which might indicate the importance of situational changes in coping style among employees. Across site comparisons are invariably difficult because of the many subtle differences between sites and organisations.

However, the site 8 operation included two quite different rosters within the one operation.

Coping with fatigue and situational factors

It is important to note that both open-cut operations operated on a four on/four off roster. In contrast, the production group at the underground site 8 operated on a seven on/seven off roster while the maintenance crews operated on a permanent day-shift roster, five on/two off.

Figure 7 presents differences between the two roster groups at site 8 in the proportion who reported experiencing a fatigue-related near-miss in the past month.

Figure 8 presents data describing the proportion of each roster group in the underground adopting various strategies for coping with fatigue. Staff and administration roles were removed from the data for these analyses.

Clearly the rotating seven on/seven off group were more vulnerable to experiencing a fatigue-related near-miss than the permanent day-shift people. Further, it is unlikely that the differences in tasks between the two groups would explain all of the safety differences between the two groups. The results of figures 7 and 8 bring evidence to the question of whether the differences in safety between the roster groups can be explained in terms of variations in

Figure 5. Mean scores across the three sites on coping items

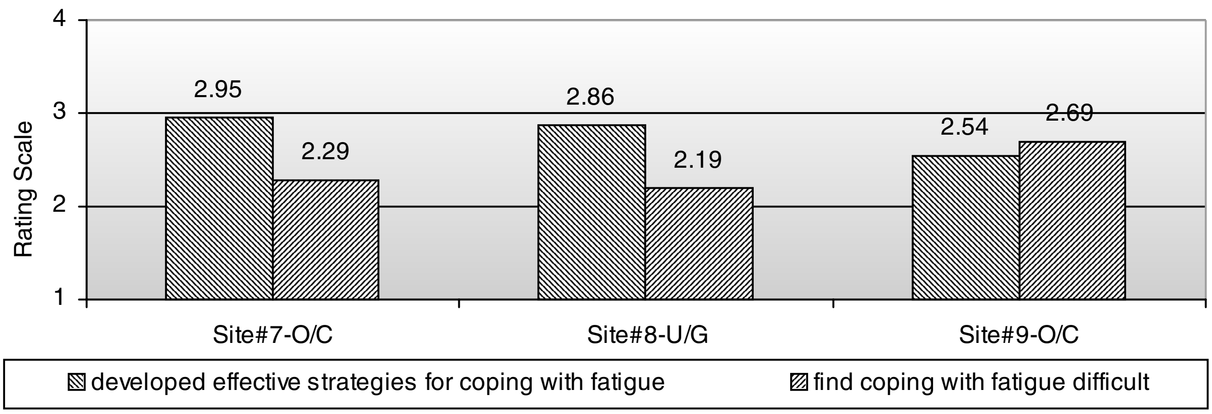
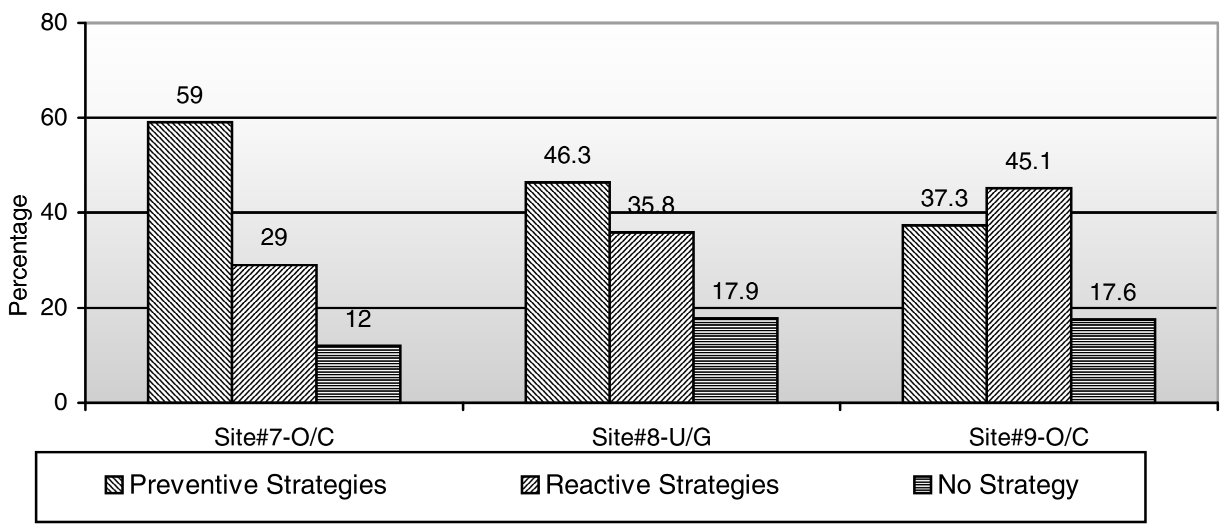


Figure 6 Proportion of people from each site adopting various coping strategies



predisposition and preferred coping style, or because of situational differences.

The evidence from site 8 supports a situational explanation for differences in coping and safety between roster groups.

Within the seven on/ seven off roster group coping differences seem to be a response to the situational demands of the rigours of the roster design, whereas in the five/two permanent day shift roster group, presumably the demands of the roster are less allowing for less deliberate coping strategies.

On the basis of this interpretation of the results, the increased fatigue risk of the seven on/seven off group appear to be driven by situational (roster) demands rather than coping deficiencies.

The seven on/seven off people were more at risk in spite of their attempts to cope more deliberately.

While the above results clearly reveal the importance of individuals adopting a deliberate and conscious strategy to prevent fatigue in the workplace, these results also demonstrate the importance of workplace design.

There are some groups of people that are clearly more at risk than others because of the design of their workplace rather than poor self-management.

Predicting fatigue-related safety at work

In order to address the fourth question, a path analysis of the data provided some sense of the relative contribution of these factors to fatigue risk and workplace safety.

Again, the data from site 8 was particularly useful as the variation in rosters for operational roles on the one site allowed for an evaluation of the variations in rosters as a predictor of fatigue related safety in the workplace.

In path analysis standardised beta coefficients comment on the relative strength of predictors in a subset of the population (see Asher, 1983).

Table 4 lists the measures that were entered into two regression equations with the experience of a fatigue-related near-miss over the past month of work as the dependent variable.

The first regression equation calculated the

Figure 7 Proportion of underground people on various rosters who report a fatigue related near-miss in the past month

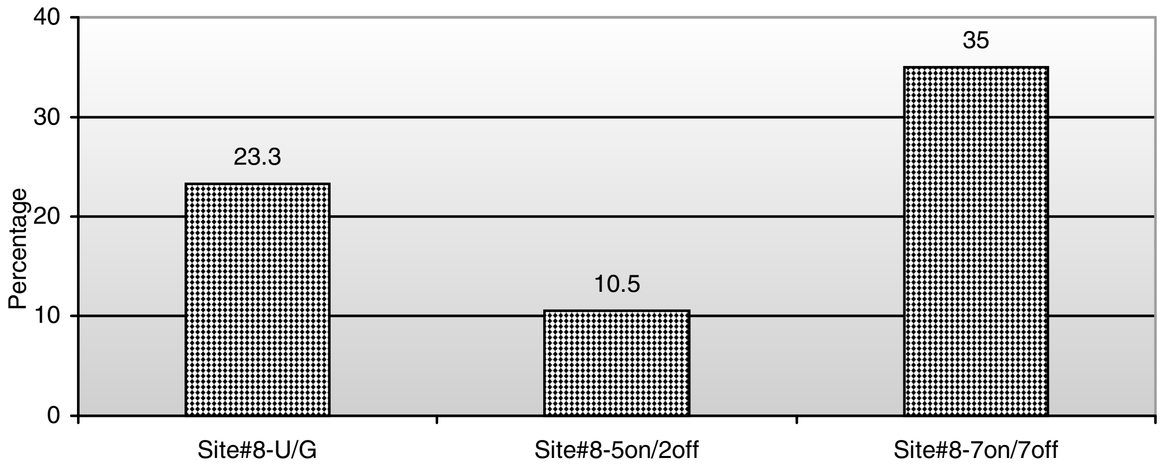
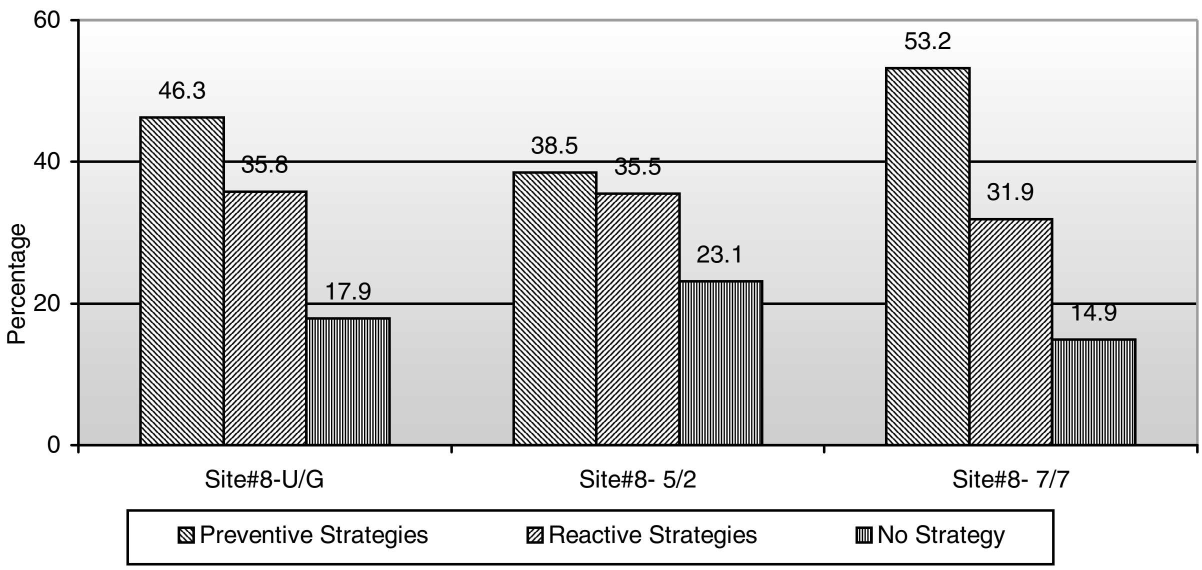


Figure 8 Proportion of people adopting various coping styles, by underground roster groups



contribution of workplace factors and the second regression equation calculated the contribution of personal factors to fatigue-related near-misses at work.

A series of correlations between workplace and personal factors and the experience of a fatigue-related near-miss provided an initial view of the links to fatigue-related risk in the workplace.

In the regression equations, the least significant predictors were eliminated sequentially until only significant predictors remained in each equation.

Standardised beta coefficients for variables that remained significant in the regression equations are listed in Table 4.

The results of the regression equations indicated that personal factors and workplace design factors were equally important in predicting fatigue-related risk at work - both explaining 30 percent of the variance of fatigue risk at work.

Several aspects of the workplace design represent a significant fatigue-related risk for people at the underground operation of site 8, as follows:

- the seven on/seven off roster
- hours at work (time between waking and returning home)
- task rotation (need to practice more task rotation)
- the reluctance to report serious personal fatigue risk
- (links between travel and satisfaction with roster system and fatigue-related near-misses reduced to near zero once attitudinal items and coping items were considered)

In addition, several aspects of individual functioning were linked to the experience of a fatigue-related near-miss. These issues essentially revolve around:

- the ability of the individual to cope with fatigue
- the susceptibility of the individual to the symptoms of fatigue
- the effects of fatigue on personal motivation.

Discussion

The initial study at site 1 provided good evidence that people cope with and respond to fatigue at work in different ways, and that these ways of coping can be linked, in meaningful ways, to different safety outcomes. The early evidence suggested that planning ahead in order to avoid fatigue might play a vital role in successfully coping with fatigue and minimising fatigue risk at work.

The recent studies that asked people to describe their strategy for minimising fatigue risk at work revealed very useful information. The strength of these data lies in the fact that people volunteered the information and that our categorising the comments into preventative, reactive strategies or no strategy seemed to be linked to meaningful differences that reflected quite different ways of thinking about fatigue and its management, and were linked to different safety outcomes. Clearly the no strategy group were more vulnerable to fatigue risk at work, and may suggest that even the reactive strategies have an active component of doing something about fatigue risk.

The coping differences between sites 7, 8 and 9 were used to illustrate the links between individual fatigue management strategies and safety at work that one would expect to find. While these data support these hypothesised links we really have too few sites in the sample to define our results as conclusive evidence.

However, the results really do invite us to think carefully about the role of individual coping, particularly in the light of the lack of differences between the sites on the measures of the distribution of time, sleep and lifestyle. Coping and safety were the only substantial areas of difference across sites. However, it is important to recognise the inherent difficulties of across site comparisons.

It appears that individuals who described a preventative strategy for managing fatigue adopted a more deliberate approach to managing their lives - they slept more hours during the day when working night shift, consumed less alcohol, and reported more family support.

Organising the present in light of the planned future is inherently involved in prevention. Whether the preventative approach is linked to any predispositions remains a question for further investigation. The nuances of the data have suggested to me for some time that locus of control issues may drive much of the differences between these broad approaches to coping with fatigue within roster groups.

It is important to keep in mind the finding in the present study that situational factors were linked to coping responses. At site 8, people working the seven on/seven off roster were more inclined to adopt preventative strategies than people working the permanent day-shift five/two roster. It may be that within work environments where situational demands are relatively low, personality factors are the major determinants of how people cope with fatigue.

In contrast, when the work environment becomes more demanding, these situational factors emerge as the important determinants of how people cope with fatigue. The evidence from site 8 indicated that on the tougher roster, people were more likely to adopt more deliberate and preventative approaches to managing fatigue risk.

The path analysis of site 8 data was used to illustrate the relative contribution of workplace and personal factors to fatigue-related safety at work. As one would expect, the distribution of time at work is an important predictor of safety at work.

Extended hours at work can and do create a serious risk for people in the workplace. The ability to break these hours up with variations in work and a procedure for reporting serious personal fatigue risk seem important modifications to workplace practice at site 8.

But even in an environment that elicits more deliberate coping, a comparison of the standardised beta coefficients suggests that coping plays a more significant role than the roster for predicting susceptibility to fatigue risk at work.

To date our measures of coping have been fairly simple and categorical and therefore not allowed the development of path models using coping style data in our regression models. The development of interval measures (ie scales) of the different styles of coping with fatigue would allow us to gain a more detailed view of the links between coping and safety outcomes.

Table 4

Predictors of a fatigue-related near-miss at site 8 - Underground.

Predictor	r	standardised beta
workplace items (R^2=.30, F=7.4, p<.000)Hours of work		
Hours of work in normal shift	0.17ns	
Longest shift in past month	0.02ns	
Hours of overtime on a tour	0.04ns	
Average hours from waking until arriving home after work	-0.21*	-0.14*
Satisfaction with roster	0.36**	0.22**
Roster worked (1=5/2, 2=7/7)	-0.23**	-0.14*
Travel		
Hours of travel from home to work	0.16ns	0.14*
Share driving with others?	0.11ns	
If you travel more than one hour, do you travel immediately before starting work?	-0.01ns	
If you travel more than one hour, do you travel immediately after finishing work?	-0.18ns	
Reporting personal fatigue risk		
Report personal serious fatigue risk to supervisor?	-0.21*	-0.18**
Task rotation		
Do you use task rotation as a way of managing fatigue risk?	-0.27**	-0.22**
How often do you use task rotation?	0.29**	0.16*
Is task rotation helpful?	-0.02ns	
Personal Factors (R^2=.30, F=13.2, p <.000).		
Attitudes		
Fatigue is not really an important issue for people at the NCA project.	0.14ns	
Fatigue is a significant contributor to accidents/injury where I work	-0.29**	
I find coping with fatigue very difficult	-0.41**	-0.25**
I can work and function safely even when I am really tired	0.18*	
How tired I get at work is not the Company's business	0.04ns	
I have developed effective strategies for coping with fatigue	0.19*	
Typical Responses to Fatigue		
I start to feel shaky and/or experience blurred vision	-0.28**	
I make more mistakes and/or find it difficult to make good decisions	-0.26**	
I plan and organise my time so I don't get too tired at work	0.14ns	
I just keep working, but not as safely	-0.25**	
I find ways to keep myself awake and busy	-0.07ns	
I worry more	-0.26**	
I get so tired I don't care any more	-0.36**	-0.17*
I find myself slowing down and being less effective than usual	-0.37**	-0.17*
I have lapses in concentration	-0.30**	
I nod off momentarily	-0.42**	-0.19*
Sleep		
Hours of sleep on day shift	-0.07ns	
Hours of sleep on night shift	0.14ns	
Hours of sleep on days off	-0.21*	
Age and experience		
Age	0.01ns	
Experience with shiftwork	-0.12ns	
Lifestyle		
Do you exercise regularly?	0.01ns	
How would you rate your diet when you are on tour?	0.14ns	
Alcohol consumption, on tour and off tour	0.00ns	
Extent of family support and understanding of work and time away from home	0.01ns	

Note. * p < .05 ** p < .01 ns=not significant

We have plans to use the descriptions of coping strategies gathered in our recent studies to develop measures of each style of coping with fatigue.

Such scales will allow us to examine individually the contribution of some of the individual strategies to effective managing fatigue at work, and to test our initial categorising of the strategies into three broad styles of coping.

Further, such scale measures of each style would allow us to identify the relative strength of the links between each coping style and fatigue risk at work.

The coping literature has also suggested that coping varies with the degree of influence people believe they have over their environment.

Our ongoing conversations with people in fatigue management training sessions have suggested that coping with fatigue might also vary with the degree to which people believe they can influence decisions about their work environment.

Again, whether this belief is driven by situational factors or by personality factors remains to be tested. Locus of control as a personality variable seems an attractive explanation for why people may or may not believe they have some influence over their work environment.

We plan to include these measures of personality in future studies.

The above results have several implications for employees and employers.

Firstly, the results portray those actions that actually contribute to effective fatigue management and suggest that there are some things that individuals can do to cope more effectively with fatigue.

Training programs in fatigue management should describe those methods of effective coping in contrast with the characteristics of ineffective coping.

Secondly, selection procedures could include materials that specifically target individuals who are more or less likely to cope with fatigue.

In those operations where shift-work is a part of the role description, the individual's ability to cope with such rosters and shifts should be an important aspect of selection criteria.

Finally, the results add to the somewhat overwhelming evidence indicating there are some rosters that generate an unacceptable degree of risk for a majority of people, in spite of their best coping efforts.

Conclusion

The above results suggest that it is possible to describe different styles of managing fatigue in the workplace and these ways of coping with fatigue are linked in meaningful ways to different safety outcomes.

Clearly, planning ahead and organising one's life plays a critical role in effective fatigue management. We have evidence supporting the view that these differences in coping style might be linked to both situational and dispositional factors.

We have interpreted our data as indicating that individual coping plays a relatively dominant role in managing fatigue risk at work.

While the demands of rigorous work environments elicit more deliberate coping strategies, this improved coping may not eliminate the degree of fatigue risk involved in those rigorous workplaces.

There is clearly more work to be done in clarifying the role of the individual in managing fatigue risk at work.

There appears to be some ways of coping that are more effective than others and situational factors seem involved in eliciting variations in coping.

We have yet to clarify the links between stable personality factors and coping variations and to learn how these variations might be influential in different workplace conditions.

There is also a very important set of questions about implications for training and behaviour change that need to be addressed in order for us to engineer a safer workplace.

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OPTIMUM INERTISATION STRATEGIES

Rao Balusu[1], Patrick Humpries[2], Paul Harrington[2], Michael Wendt[1] and Sheng Xue[1]

Innovation success

The new optimum inertisation strategies developed and implemented at Newlands Colliery were highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing. During the field demonstration studies, the goaf atmosphere was inert by the time of closing the doors on the final seals, with oxygen concentration below 5 percent at all locations in the goaf.

Abstract

The main objective of the ACARP project was to develop optimum and effective strategies for inertisation during longwall sealing operations to achieve goaf inertisation within a few hours of sealing the panel.

The project has combined the detailed analysis of the performance of various inertisation field trials together with computational fluid dynamics (CFD) modelling of different inertisation operations in order to develop the optimum inertisation strategies.

The project work specifically involved review of the current inertisation practices, laboratory studies, CFD simulations, tracer gas tests, development of optimum strategies and field demonstration studies.

Analysis of the data from six review case studies showed that the traditional inertisation schemes were not effective in preventing the formation of explosive gas mixtures in three cases, and in the other three cases oxygen concentration levels were above 12 percent[for up to two days after panel sealing.

CFD modelling simulations and review studies indicated that just injecting inert gas through the MG or TG seals does not achieve the objective of quick inertisation of longwall goafs.

Based on the results of various simulations, an optimum inertisation strategy was developed taking into consideration the positive effects of various options and the field site conditions.

Field demonstration studies of the optimum strategy were conducted at Newlands Colliery. The new optimum inertisation strategies developed and implemented at Newlands Colliery were highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing.

Introduction

In underground gassy coal mines it is generally recognised that immediately after sealing a longwall panel, the atmosphere behind the seals may enter and pass through the explosive range. The duration of explosive conditions in the sealed longwall goaf ranges from a few hours to one or two days or even a few weeks, depending on the gas emission rate and goaf characteristics.

Therefore, any sealed area with methane as the seam gas has the potential to explode depending on the presence of ignition sources.

To minimise this risk of explosions, the modern practice in some of the Australian mines is to inject inert gas into the sealed goafs immediately after sealing the panel.

The specific objective of inert gas injection operations is to reduce the goaf oxygen levels below the safe limit of 8 percent or 12 percent before methane concentration reaches the lower explosive limit of 5 percent.

The traditional inertisation schemes usually involved just injecting inert gas through maingate (MG) or tailgate (TG) seals until goaf gas sampling results show that oxygen level was below 8 percent.

In many cases it was found that the goaf oxygen concentration was above 12 percent even after two to three days of inert gas injection and in some cases an explosive atmosphere was also present in the goaf during inertisation.

There was a need to optimise inertisation operations to reduce the goaf oxygen levels, thus reduce the explosion potential as quickly as possible during longwall sealing off periods.

The main objective of theACARP project was to develop optimum and effective strategies for inertisation during longwall sealing off operations to achieve goaf inertisation within a few hours of sealing the panel.

This research work was carried out under the Australian Coal Association Research Program (ACARP) project C9006, entitled ‘Optimisation of Inertisation Practice.’

The project has combined the detailed analysis of the performance of various inertisation field trials together with extensive computational fluid dynamic (CFD) modelling to develop the optimum inertisation strategies.

Field demonstration studies of the optimum inertisation strategy were conducted at Newlands Colliery in Queensland. A brief summary of the project work is presented in this paper.

Review of traditional inertisation schemes

Longwall goaf inertisation is being carried out in some of the mines in Australia on a regular basis to reduce the potential risk of explosions during the panel sealing-off period.

Traditionally liquid N_2 and CO_2 were used in most of the fire control inertisation operations.

However, it was difficult and expensive to procure large quantities of the inert gases for routine longwall sealing applications, particularly in mines located at remote places of Australia. In 1997, the Tomlinson Boiler low-flow inertisation device and a high capacity GAG 3A jet engine system were demonstrated to the Australian mining industry as new practical tools for inertising underground mine atmospheres.

The successful demonstration of these devices has improved the availability of inert gases for routine mine applications.

While the previous inertisation projects concentrated on development of inert gas generators, this project concentrated on development of an effective and optimum inertisation strategies using the available inert gases.

Over the last few years, there have been more than 10 applications of inertisation during longwall sealing operations.

The data review phase of the study involved collection of inertisation data from previous operations and field studies to collect data from the on-going inertisation operations at a number of longwall panels.

In total, inertisation data has been collected from 6 different longwall panels. These six panels had employed different inertisation schemes and cover three different mines with different gas emission rates and panel characteristics.

A comprehensive review of the inertisation data has been carried out to analyse the effect of different inertisation designs on goaf inertisation.

The effect of mine factors such as goaf layout, ventilation systems and inert gas composition on effectiveness of inertisation was also assessed.

Analysis of the data from some of the mines showed that the inertisation schemes implemented were not effective in preventing the formation of explosive gas mixtures near the longwall finish line for up to two days after panel sealing. In one case, the goaf atmosphere near the finish line fluctuated widely and the oxygen concentration was over the 12 percent level a number of times over the two week period after sealing.

Results from another mine showed that although the inertisation schemes employed at that mine were relatively more effective when compared with results of other cases, oxygen levels in the goaf were still above 12 percent for up to two days after panel sealing. Analysis of results from one of the typical case studies is discussed below.

In the typical inertisation practice, the inert gas is injected into the goaf generally through the MG seal immediately after sealing the panel.

Recently, some mines started the practice of injecting inert gas simultaneously into both MG and TG

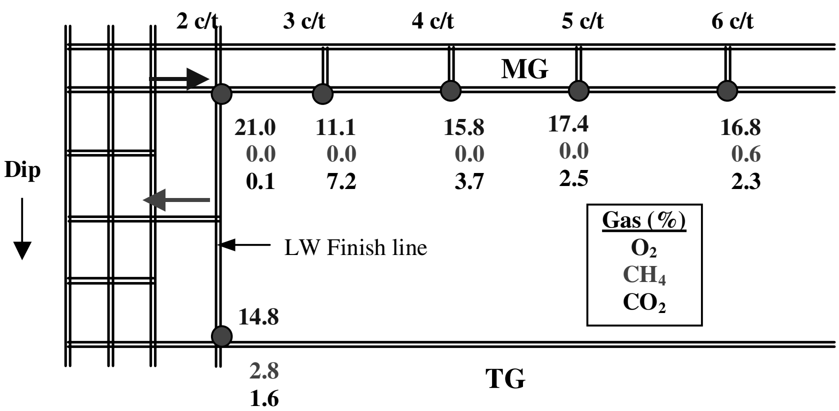

Figure 1 Gas distribution in the goaf – just before panel sealing in a typical case study

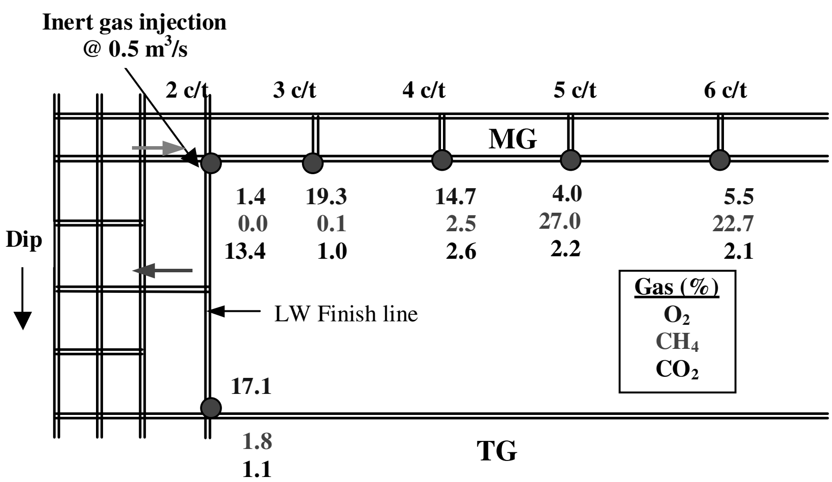

Figure 2 Gas distribution in the goaf – 6 hours after panel sealing, with traditional inertisation

seals or other seals depending on the oxygen levels at various locations around the goaf.

The inert gas generator is normally set up at a temporary surface site above the longwall and one or two 150mm diameter boreholes are drilled from the surface into the gateroads for inert gas delivery.

In the typical case study presented here, the maingate was used as an intake airway and the tailgate as return airway during longwall retreat operations.

Airflow quantity of 40 to 50 m^3/s had been maintained along the face during longwall extraction.

In this case, the panel orientation was such that the maingate intake was at a higher elevation compared with the tailgate roadway and the outbye tailgate corner was the point of lowest elevation.

Methane gas emission in the panel was relatively low at the rate of about 300 l/s. After sealing off the panel, Boiler inert gas was injected into the goaf through the MG seal for inertisation.

Goaf gas distribution at various locations around the longwall panel during the inertisation period is shown in Figures 1 to 3.

Figure 1 presents the goaf gas composition immediately before sealing off the panel and shows that the oxygen level was above the explosive nose limit of 12 percent even at 6 c/t, ie at 400m behind the finish line on maingate side.

Gas distribution in the goaf 6 hours after sealing the panel is shown in Figure 2. Comparison of Figures 1 and 2 shows that fresh air/oxygen from the face finish line area was pushed towards 3 c/t and TG areas after introduction of inert gas through the MG seal.

Figure 3 shows that the goaf O_2 level was above the safe limit of 12 percent, 12 hours after panel sealing. Results showed that the goaf became completely inert two days after panel sealing.

In another typical case study, inert gas was injected through both MG and TG seals, immediately after sealing off the panel. Gas composition in the goaf after one day of inert gas injection is shown in Figure 4.

Analysis of the results shows an increase in oxygen level to 15 percent at 3 c/t seal, which indicates that high O_2 concentration pockets were still present in the goaf even when inert gas was injected through both MG and TG seals.

The results from the review studies indicate that just injecting inert gas through MG or TG seals does not achieve the objective of quick inertisation of longwall goafs.

Analysis of results indicated that the effect of inert gas injection through the MG/ TG seals on gas composition at inbye locations of the goaf was negligible for up to two days after sealing. It was also noted that development of positive pressure in the goaf alone, even at 500 Pa, does not indicate goaf inertisation.

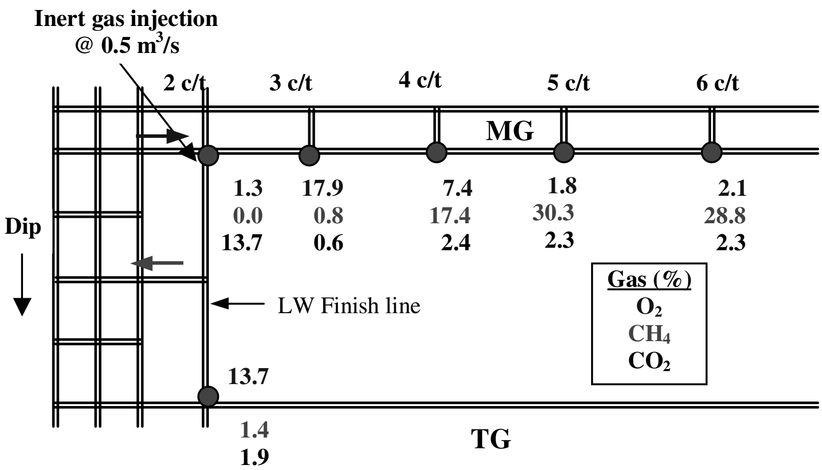

Figure 3 Gas distribution in the goaf – 12 hours after panel sealing, with traditional inertisation

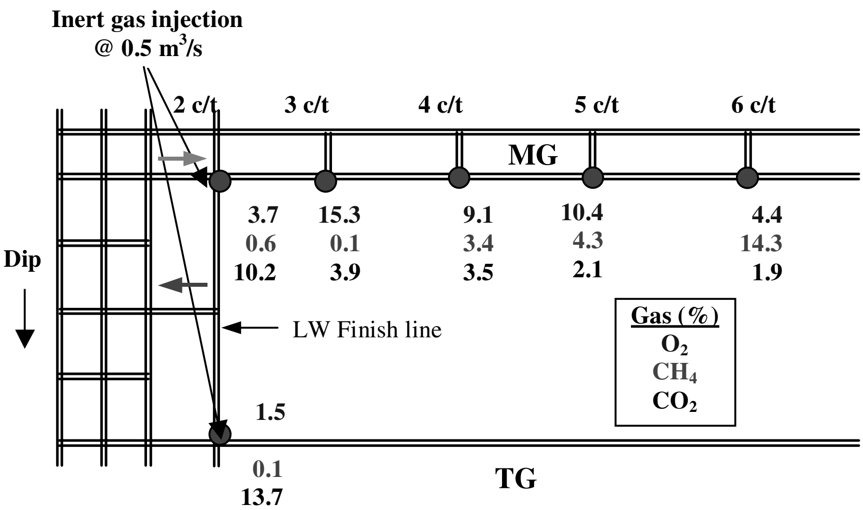

Figure 4 Gas distribution in the goaf – 1 day after panel sealing, with traditional inertisation

These review studies indicated that there is a need for optimisation of inertisation strategies to achieve the desired objective of goaf inertisation within a few hours of sealing.

Development of optimum strategies requires a detailed understanding of inert gas dispersion patterns in the goaf and their effect on goaf gas distribution.

A brief summary of the modelling studies carried out to improve our understanding of the effect of inertisation is presented in the following section.

Cfd modelling studies

The focus of the modelling exercise was to obtain a better understanding of the inert gas flow patterns in the goaf and qualitative analysis of the various factors involved in inertisation operations, in order to establish a scientific basis for design of optimum strategies.

Computational fluid dynamics (CFD) techniques have been used to develop the goaf models to study the inert gas flow mechanics in sealed longwall panels.

The modelling of the inertisation process in longwall goafs consists of a number of stages, including:

- field studies to obtain the basic information on panel,
- goaf geometries and other parameters
- construction of 3D finite element model of the longwall goaf
- setting up flow models and boundary conditions through user-defined subroutines
- base case model simulations
- model calibration and validation using field measured data
- extensive parametric studies and development of optimum inertisation strategies.

Base model simulations

Field studies were conducted in the beginning of the project to obtain the basic information on geometry of the longwall goaf, gas emissions, ventilation system, caving characteristics and inertisation practices and system details.

These initial studies also involved a detailed monitoring of the gas distribution changes in the goaf during standard inertisation operations in order to collect field data for base-case model calibration and validation purposes.

Information obtained from the above field studies was used to construct the base-case longwall inertisation model. The base model for the longwall inertisation studies was 1km in length along the panel, 205m in width and 50m in height to cover the immediate high porosity caving regions in the goaf.

The seam and roadways were 4m high and all roadways were 5m wide. Goaf gas emission was varied between 100 l/s and 600 l/s to represent typical longwall panels in highly critical low gas environments.

This was also equal to the gas emission rates of the panels used for model calibration and validation.

The maingate inlet was set at an elevation 20m higher than the tailgate return to represent the field case scenario.

A 'U' ventilation system was used in the base-case models, with the maingate as intake and tailgate as return roadway.

The distribution of goaf porosity was derived from results of typical longwall geomechanics models.

Pressure, flow rate and gas distribution in a typical longwall goaf were used to calibrate the initial models and further refine the distribution of goaf permeability.

The permeability distribution in the goaf ranged from 10^{-4} m^2 to 10^{-10} m^2. A standard two equation k-e model was used to estimate the turbulent transport through the flow region.

Flow through goaf was handled using custom written subroutines, which were added to the 'flow through porous media' modules of the basic code.

A number of subroutines were written to represent the goaf gas emissions and inertisation scenarios, which were then combined with the main FLUENT program to carry out the simulations.

Initial simulations were carried out using the base-case longwall inertisation model.

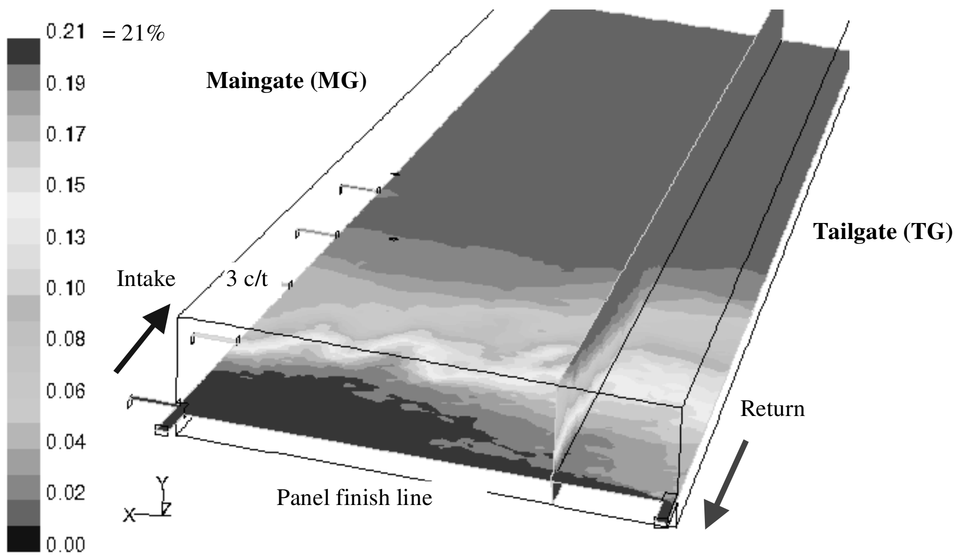

Figure 5 Oxygen gas distribution in the longwall goaf near the finish line – with 50 m^3/s airflow

Two sets of base-case simulations were carried out to represent the conditions during face bolting and panel sealing-off periods.

The intake airflow rate through the maingate was kept at 50 m^3/s in the first base case set, which represents goaf environmental conditions during face bolting period. In the second base case, intake airflow was reduced to 10 m^3/s to represent goaf conditions just before sealing off the panel.

These base-case simulations were carried out under different gas emission flow rates. Steady state modelling was carried out to simulate goaf conditions before the sealing off period and transient modelling techniques were used to simulate the sealed goaf atmosphere at regular time intervals after panel sealing.

The results of the base-case simulations in 3D view are presented in Figures 5 and 6, showing the oxygen gas distribution in the goaf under different airflow conditions.

The 3D view figures show two slices along the longwall panel. The horizontal slice is midway through the seam and the vertical slice is 50m from the tailgate rib.

In the colour coding scale of the figures, 0.21 represents 21 percent oxygen, ie fresh air composition.

Figure 5 shows the oxygen distribution in the goaf with first base case simulations, ie, with 50 m^3/s airflow and 0.6 m^3/s methane goaf gas emissions.

Results show that oxygen ingress into the goaf was more on the maingate intake side compared with tailgate return side.

For example, the oxygen level was around 20 percent on the maingate side and 16 percent on the tailgate side of the goaf at 60m behind the face.

Other important points to be noted from the results presented in Figure 5 are:

- The vertical section in the figure clearly shows the air/gas layering in the goaf with higher oxygen concentration near the lower working seam level. However, Figure 5 also shows that even though tailgate return was at lower elevation, the oxygen levels were higher in the maingate area. This indicates that during longwall retreat operations, ventilation pressures and gas emissions had a major influence on goaf gas distribution at working seam level near the face, compared to the effect of methane gas buoyancy forces.
- It is also to be noted that although the oxygen concentration levels were lower near the tailgate area, air penetration distance into the goaf was higher on tailgate side with 10 percent oxygen at 200m behind the face.
- Oxygen levels presented in the figure represents only goaf gas distribution near the bolted-up area of the panel near the finish line, but not a standard goaf gas distribution under normal caving conditions. (In normal caving zones, high oxygen concentration zone penetration distance into the goaf will be significantly less due to higher consolidation of the goaf material at the centre part of the panel).

In the second base case simulations, airflow in the panel was reduced to 10 m^3/s to represent goaf conditions just before sealing off the panel. Results of simulations are shown in shown in Figure 6.

Oxygen distribution presented in the Figure 6 shows that oxygen concentration levels and penetration distance were higher on the tailgate return side of the goaf.

Oxygen penetration distance extended up to 300m on the tailgate side of the goaf. This is in contrast to the oxygen distribution for first base case, presented in Figure 5, where oxygen concentration levels were higher on the maingate intake side.

Comparison of the results presented in Figures 5 and 6, shows that intake airflow rate and the consequent air velocity and ventilation pressures have a major influence on gas distribution in the goaf.

Reducing the intake airflow in the panel during chock recovery operations has considerably reduced the oxygen penetration on the intake side of the goaf and drastically changed the goaf gas distribution pattern.

In addition, reducing the intake airflow also resulted in extension of buoyancy force effect down to working

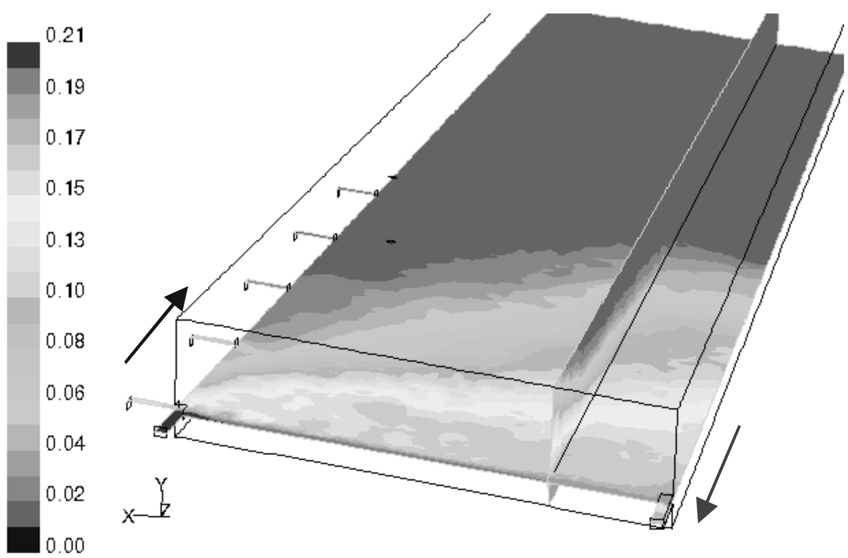

Figure 6 Oxygen gas distribution in the longwall goaf near the finish line – with 10 m^3/s airflow

seam level in the goaf.

Parametric studies

The base case CFD models were calibrated and validated based on the information obtained from previous inertisation studies and goaf gas monitoring. The validated models were then used for extensive parametric studies involving changes in inert gas injection locations, inert gas flow rates, seam gradients, and different inertisation strategies to investigate their effect on goaf inertisation.

Parametric studies were conducted under both steady state and transient conditions. Goaf conditions were simulated for up to five days after sealing of the longwall panel with various inertisation strategies.

Results from two typical parametric studies are presented in this paper.

(a) Effect of inert gas composition: The effects of two different inert gases on goaf inertisation were investigated in these parametric studies. In the first model, boiler exhaust gas was used as inert gas, whereas in the second model nitrogen gas was used for goaf inertisation. In both the models inert gas was injected through the MG seal at the flow rate of 1.0m^3/s. In both the models, seam gradient was set at 1 in 10 dipping towards the tailgate side. All other parameters were the same in both models. These modelling studies were carried out with transient parameters to simulate the goaf conditions immediately after sealing of the panel. Results of the simulations are presented in Figures 7 and 8.

Results show that there were no major differences in goaf gas distribution between the two cases under the modelled parameters. In both cases the oxygen level was reduced to only 14 percent after 24 hours of inert gas injection.

Results show that there was no major difference in effectiveness of boiler gas or nitrogen on goaf inertisation. These results indicate that although inert gas composition might have an effect on goaf inertisation under certain conditions, it is not the major factor that would make an inertisation process a success or a failure, particularly under sealed goaf conditions.

(*b*) Effect of inert gas injection location: The effect of two different inert gas injection locations on goaf inertisation was studied in separate models with transient parameters to simulate goaf conditions after panel sealing. In the first model inert gas was injected through the MG seal and in the second model inert gas was injected at 200 m behind the face (through 3 c/t seal) on the maingate side. Inert gas was injected at the rate of 0.5 m^3/s in both the models. All other conditions and parameters were the same in both cases. Oxygen distribution in the goaf for both models after 24 hours of inert gas injection is presented in Figures 9 and 10

Results show that different inert gas injection locations resulted in entirely different goaf gas distribution for the two cases.

Figure 9 shows that injection of inert gas through MG seal resulted in a reduction of oxygen concentration only near the point of injection, ie near maingate area.

The oxygen concentration level in this area reduced down to 8 to 10 percent.

However, oxygen level near the tailgate area was very high at 15 to 17 percent even after 24 hours of inert gas injection.

Results presented in Figure 10 shows that inert gas injection through 3c/t on the maingate side resulted in a reduction of oxygen concentration levels down to 10 to 12 percent over a wider area near the finish line.

Further simulations showed that when inert gas was injected through the MG seal, the oxygen concentration was above 14 percent over a wider area even after two days of inert gas injection.

In the second case with inert gas injection through 3 c/t, oxygen concentration was below 12 percent across the entire goaf.

Analysis of the figures indicate that the strategy of inert gas injection through the MG seal was not as effective as the alternative strategy of inert gas injection at 200m behind the face (ie through 3c/t).

Results also indicated that inert gas injection through the MG seal results in pushing the fresh air zone towards the goaf and consequently requires a longer time for goaf inertisation.

It is to be noted that open goaf simulation results also indicated that inert gas injection from the maingate side at 100 to 200m behind the face reduces the oxygen level in the high sponcom risk area of the goaf and helps in sponcom control during face retreat.

Analysis of the various simulation results also

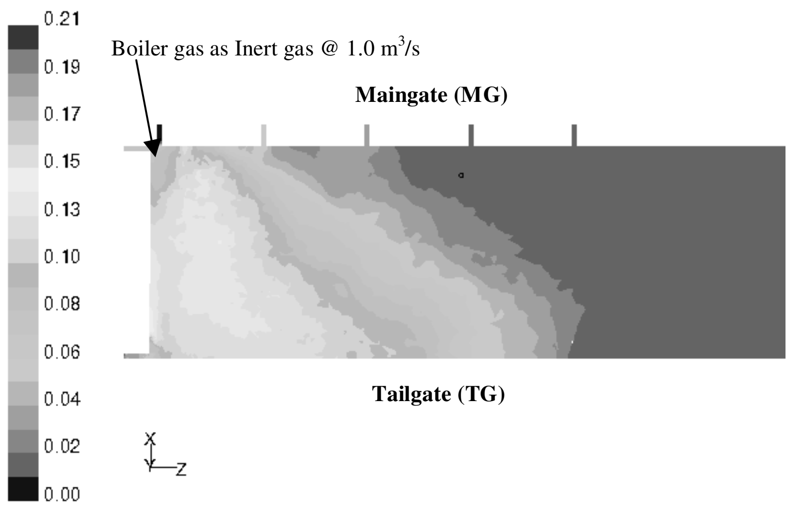

Figure 7 Oxygen distribution in the goaf – 1 day after sealing, with Boiler exhaust as inert gas

indicated that longwall panel geometry, goaf characteristics, gateroad conditions in the goaf, goaf gas emission rates and composition, ventilation during panel sealing off period, chock withdrawal and panel sealing sequence would also have a significant influence on goaf gas distribution and inertisation.

Optimisation studies

CFD modelling simulations with field site geometry and conditions showed that the strategy of inert gas injection through the TG seal only, would not be effective for goaf inertisation.

Simulations with inert gas injection through the MG showed that although this inertisation scheme resulted in better goaf inertisation compared with the previous scheme, it did not achieve the objective of goaf inertisation within a few hours of panel sealing.

Based on the results of various simulations, an optimum inertisation strategy was developed taking into consideration the positive effects of various inertisation schemes and the field site conditions.

The optimum strategy developed basically involved the following three steps:

(i) inert gas injection (@ 0.5 m^3/s) through the TG for two days before panel sealing

(ii) inert gas injection through 3 c/t for one day with door on chute road seal open

(iii) panel sealing and continuation of inert gas injection through 3 c/t.

This inertisation strategy was implemented in the transient CFD modelling simulations to study its effect on goaf gas distribution, particularly oxygen concentration levels in the goaf.

Inert gas was injected at the rate of 0.5 m³**/s** through the TG seal initially and then through 3 c/t seal on the maingate side, as outlined above. Modelling simulated the goaf gas conditions for three more days after panel sealing.

Results of the simulations showing oxygen distribution in the goaf just before final sealing (ie just after step (ii) in the above optimum inertisation

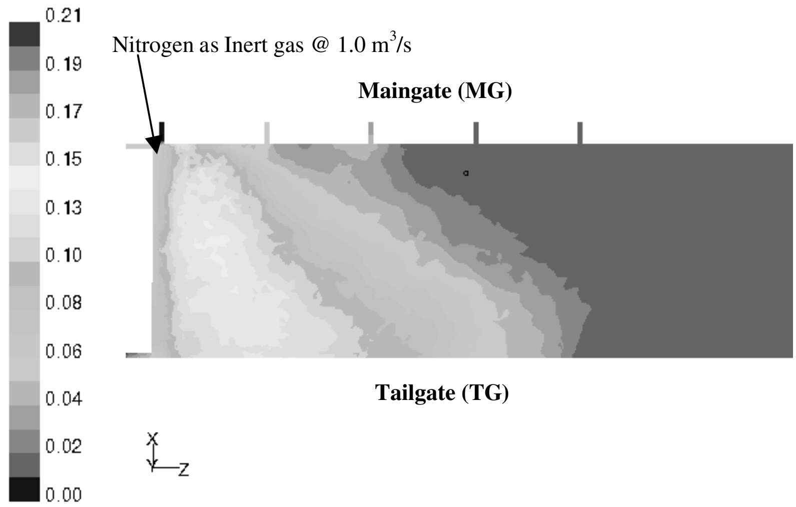

Figure 8 Oxygen distribution in the goaf – 1 day after sealing, with Nitrogen as inert gas

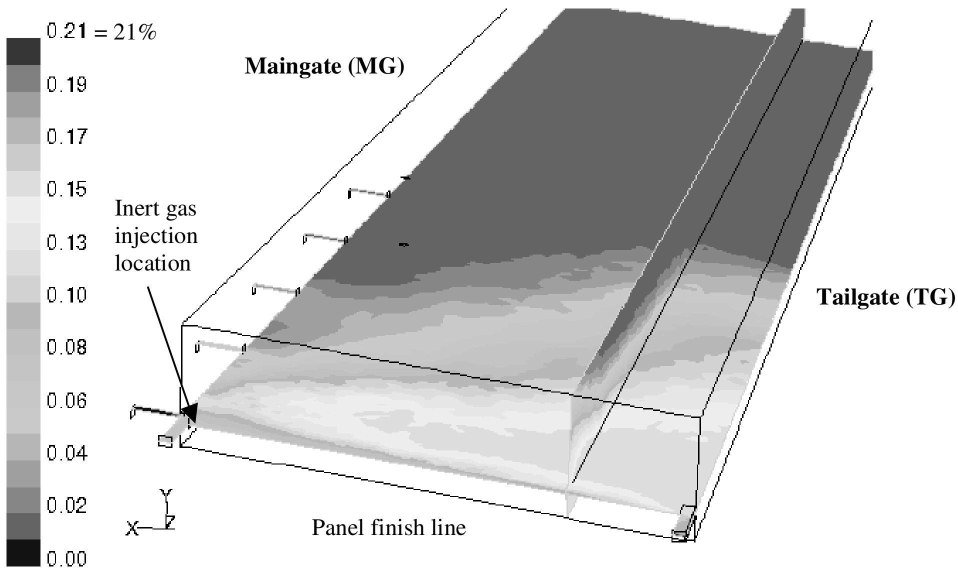

Figure 9 Oxygen distribution in the goaf – 1 day after sealing, with inert gas through MG seal

strategy) are shown in Figure 11.

Results show that the oxygen level was below 12 percent at all locations in the longwall goaf. Further simulations and analysis of the results showed that the optimum inertisation strategy developed during the course of investigations had achieved goaf inertisation within a few hours of panel sealing.

Simulation results showed that the optimum strategy effectively reduced the oxygen concentration at all locations in the goaf to below 12% levels even before panel sealing.

Field demonstration studies

The field demonstration studies were carried out at Newlands Colliery in the northern Bowen Basin of Queensland.

The mine is located near Glenden township, which is at about 180km west of Mackay. The mine operates a single longwall face employing two leg high reach 1000T capacity chocks and produced about 5.5Mt in 2000.

The mine extracts the upper Newlands seam, which averages 6m in thickness in that region. The longwall mining height is about 4.8m. The width of the longwall panels was about 250m and the length ranged from 1600m to 2500m.

Newlands Colliery is one of the less gassy mines in Australia, with goaf gas emissions in the range of 100l/s to 500l/s.

It is to be noted that effective inertisation of a sealed goaf may take a longer time in less gassy mines.

Therefore, Newlands Colliery presented one of the difficult conditions for goaf inertisation, which was ideal for field demonstration studies.

Over the years, Newlands has made significant

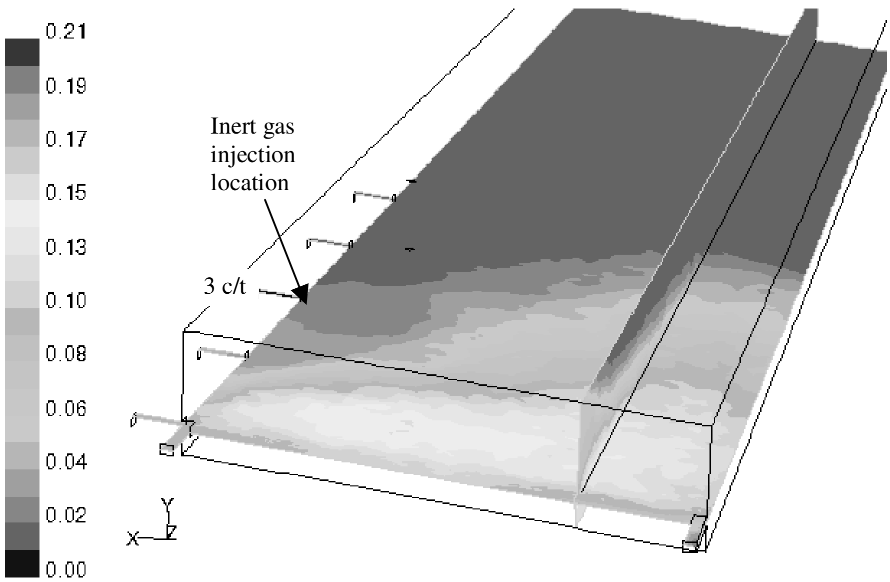

Figure 10 Oxygen distribution in the goaf – 1 day after sealing, with inert gas through 3 c/t seal

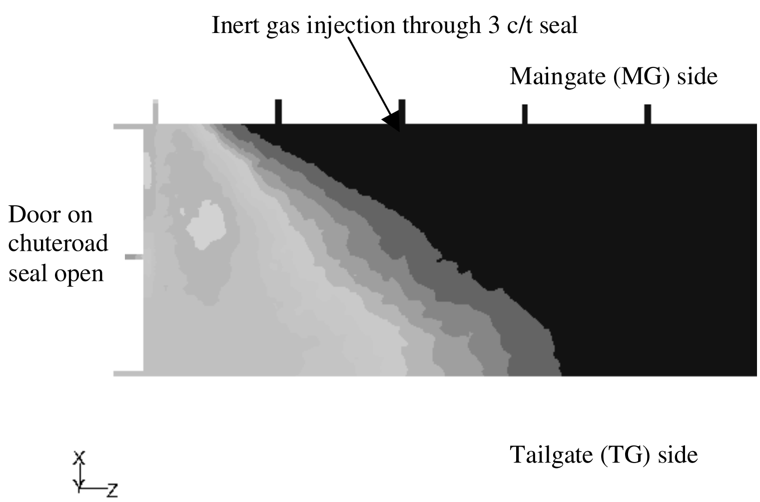

Figure 11 Oxygen distribution in the goaf – inert gas injection through 3 c/t with return doors open

improvement in the inertisation schemes and was able to reduce the goaf inertisation time down to two days, a good result compared with other mines. However, there was a need to optimise the inertisation operations to ensure complete inertisation of the goaf and to further reduce the inertisation period.

Field demonstration studies of the optimum inertisation strategy were conducted in N4B LW panel of the Newlands Colliery.

This panel was the first panel in the sequence of longwall extraction on the north side. The layout of the N4B panel and the ventilation system are presented in Figure 12.

The orientation of the panel was such that the outbye tailgate corner was the point of lowest elevation in the panel. In this panel a 'U' ventilation system was employed with the top maingate as intake and the bottom tailgate as return roadway.

Goaf gas emission flow rate in the panel was about 300 l/s ($0.3m^3/s$). Approximately $50m^3/s$ of airflow was supplied to the panel during panel extraction and the airflow was reduced to about $10m^3/s$ during the face recovery operations.

A chute-roadway was driven near the finish line of the panel to simplify the chock withdrawal process.

During face recovery operations this chute roadway was used as a return roadway after collapse of the face line near the TG. It is also to be noted that the face finish line was at two cut-through (c/t) in this panel.

Gas composition distribution at various locations around the goaf during the chock recovery in the panel is shown in Figure 13. Results show that oxygen ingress distance on the maingate intake side was about 300m and about 200m on tailgate side.

Readings indicate that gas distribution in the goaf during the chock recovery stage still depended largely on the panel ventilation system.

Conversely, the buoyancy effect of methane gas emissions in the goaf was not significant at the working seam level. The high oxygen concentration zone was spread over a wide area in the goaf.

Based on the results and analysis of the review studies and modelling investigations, an optimum inertisation strategy had been developed for Newlands Colliery to achieve the project objective of reducing oxygen concentration in the goaf to below 8 percent within a few hours of sealing the panel.

The new strategy developed during the course of the project has been implemented in the field studies.

Tracer gas studies were also carried out to map the inert gas dispersion patterns in the goaf. An extensive underground gas monitoring system was installed around the N4B panel involving 9 monitoring tubes installed on both sides of the goaf.

Three surface boreholes were also drilled into the goaf specifically for these demonstration studies to monitor the gas concentration levels deep inside the

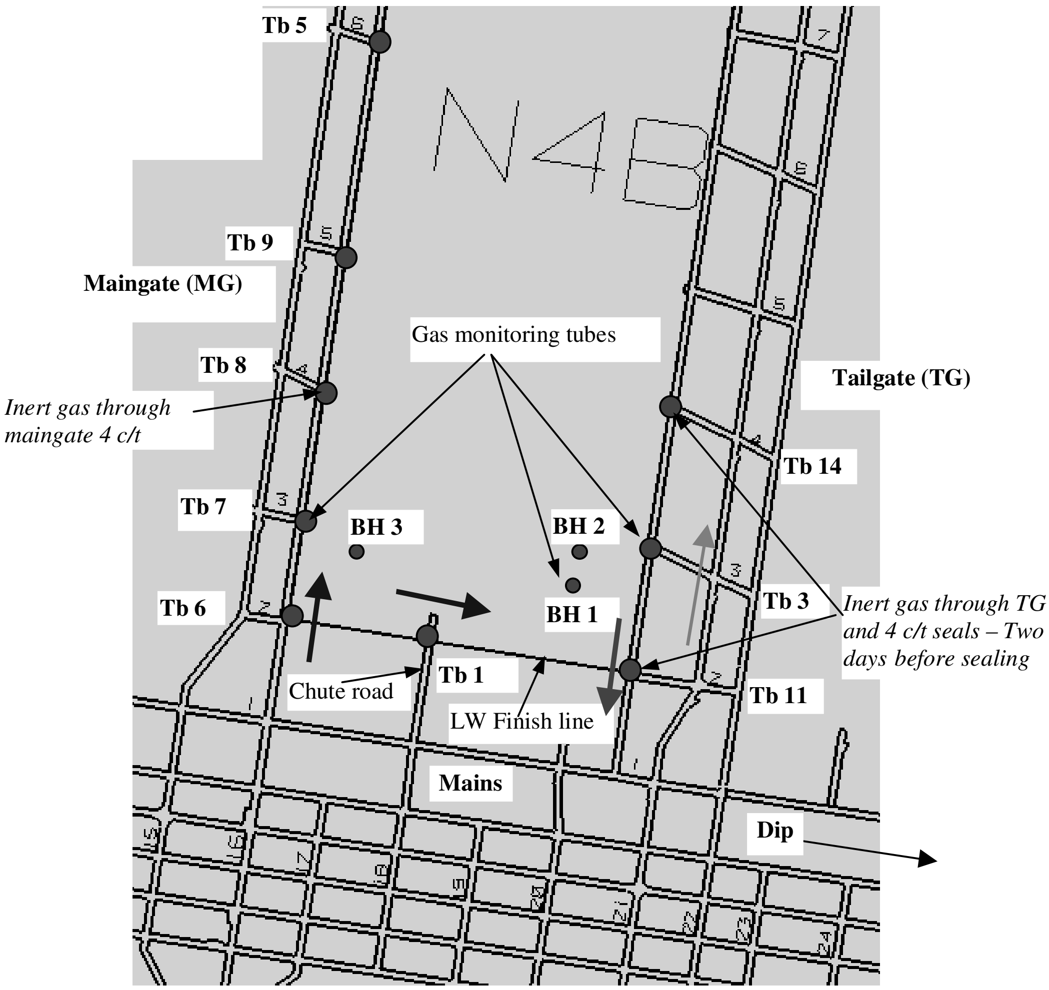

Figure 12 Longwall panel layout and location of gas monitoring tubes at the field site

goaf during sealing off and inertisation operations. Newlands Colliery and project collaborator SIMTARS have also been extensively involved in these field studies.

The optimum inertisation strategy developed during the course of the project for Newlands Colliery site conditions basically involved:

(i) inert gas injection through tailgate 4c/t and TG seals for two days before sealing

(ii) inert gas flow rate at $0.5m^3/s$ **(Boiler gas)**

(iii) inert gas injection through maingate 4c/t (ie at 200m behind the face finish line) for one day with door on chute road seal still open

(iv) panel sealing and continuation of inert gas injection through maingate 4c/t until oxygen levels in the goaf reduced below 8 percent.

Goaf gas conditions were monitored continuously at 30 minute intervals during the field demonstration studies to study the changes in goaf gas distribution during the inertisation process.

The results of the field demonstration studies illustrating the effect of the optimum inertisation strategy on N4B panel goaf inertisation are presented in this section.

The changes in gas concentration levels at chute road seal during inertisation and longwall sealing off periods are shown in Figure 14 It is to be noted that

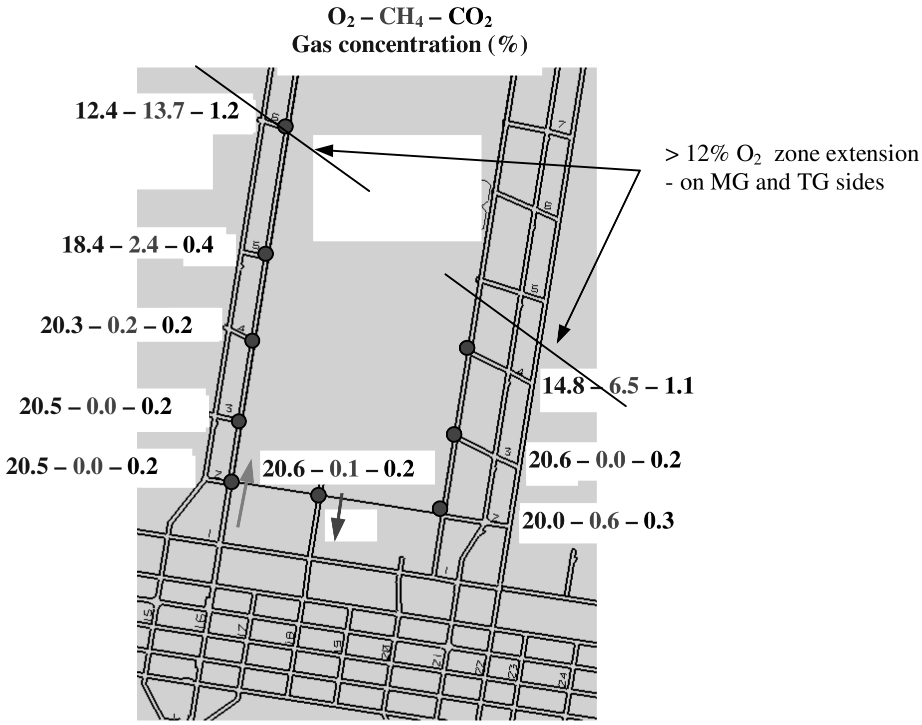

Figure 13 Gas distribution in the goaf – just after chocks recovery at the field site

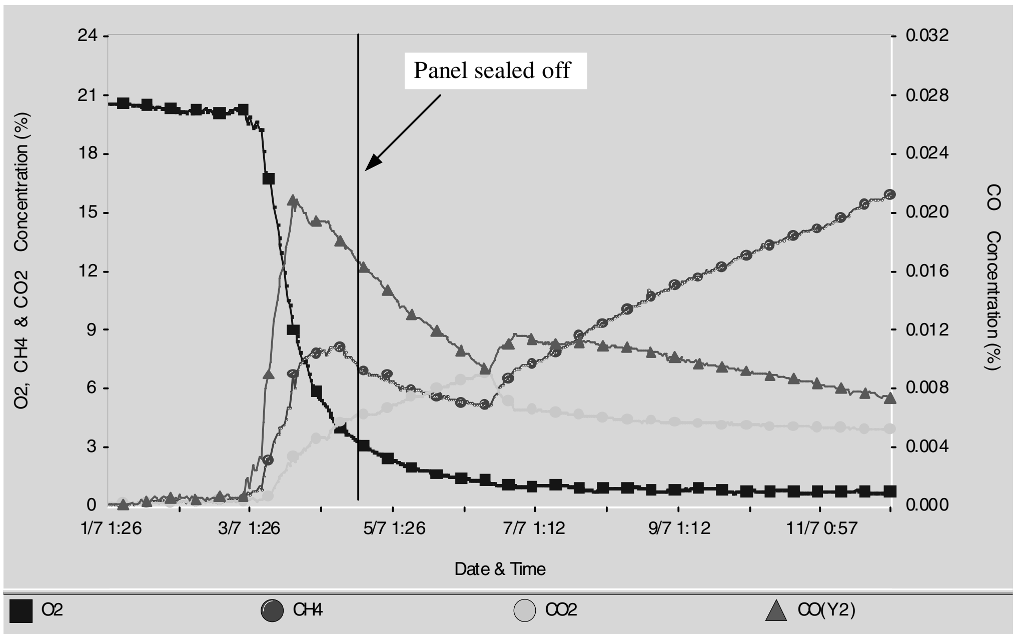

Figure 14 Gas concentration profiles at Chute road seal (Tube 1) during inertisation period

inert gas was not injected through this seal. Results show that the oxygen concentration level at this location reduced rapidly to below 8 ppercent levels within a few hours of inert gas introduction through 4c/t on the maingate side.

A similar trend was observed at the MG seal also. By the time the panel was sealed off at 10:20 hours on 4-7-01, the oxygen concentration level at both the MG and chute road seals was below 5 percent.

Gas distribution in the longwall goaf within one hour of panel sealing is shown in Figure 15.

Gas readings show that oxygen gas concentration was below 5 percent at all locations in the panel. In fact, the goaf atmosphere was completely inert and safe by the time of panel sealing.

Gas levels across the goaf were continuously monitored for another one week after stoppage of inertisation to check the effectiveness of goaf inertisation.

Monitoring results showed that oxygen concentration levels continued to fall and there were no signs of high oxygen concentration zones in the goaf. Results showed that oxygen gas levels remained low at around 2 to 3 percent and the goaf was completely inert.

Analysis of the results also indicate that boiler gas dispersion in the goaf was not just confined to a narrow zone in the collapsed maingate, but extended to a wider area in the goaf and resulted in faster and complete goaf inertisation. These results indicated that in the case of the optimum inertisation strategy, inert gas works in combination with goaf gas emissions and would achieve faster goaf inertisation. This is in contrast to the results presented in review case studies with the standard inertisation practice of inert gas injection through the MG seal. Traditional inertisation practice review studies indicated that in the case of the standard inertisation system, inert gas works against goaf gas emissions and hence take a longer time for inertising the goaf.

Field demonstration study results show that the

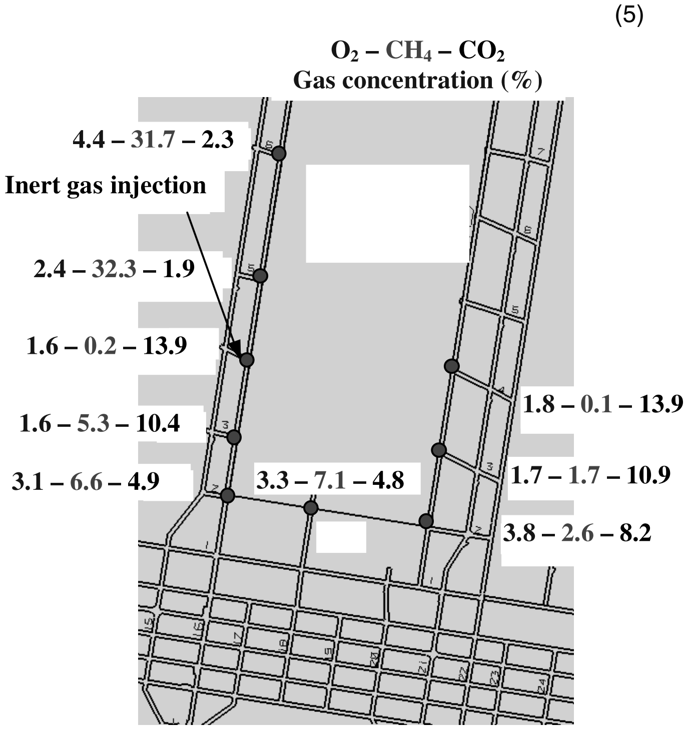

Figure 15 Gas distribution in the goaf – 1 hour after sealing, with optimum inertisation strategy

optimum inertisation strategy implemented at the field site was highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing.

During these demonstration studies, results show that the goaf atmosphere was completely inert with oxygen concentration below 5.0 percent at all locations in the goaf by the time of closing the doors on the final seals.

Results also showed that oxygen levels in the goaf did not rise after stopping the inert gas injection, confirming the success of goaf inertisation.

Conclusions and recommendations

The main conclusions and recommendations from the research are:

(1) During longwall retreat operations, the panel ventilation system and goaf gas emission flow rates would have a major influence on goaf gas distribution at working seam level when compared with the effects of goaf gas buoyancy pressures.

(2) During panel sealing off operations, when panel airflows are restricted, goaf gas composition and buoyancy pressure plays a major role on gas distribution in the goaf.

(3) Coal seam gradient, panel geometry, caving characteristics, chock withdrawal and panel sealing sequence also play a significant role in goaf gas distribution and needs to be considered during development of inertisation operations.

(4) Development of an inertisation strategy should take into consideration the effect of all the above site parameters on goaf gas distribution. The most important design parameters for goaf inertisation during longwall sealing operations are (in the order of influence):
   - a location of inert gas injection points
   - b inertisation strategy – leakage paths, timing, etc
   - c flow rate of inert gas injection
   - d inert gas composition.

(5) In many cases, the standard practice of inert gas injection through MG or TG seals immediately after panel sealing would not be effective for goaf inertisation. In addition, it may increase the inertisation time because it acts against the goaf gas emissions. The optimum inertisation strategy should work in combination with goaf gas emissions to achieve faster goaf inertisation.

(6) Inert gas injection through the 2nd or 3rd cut throughs behind the face, i.e. at 100 to 200 m behind the face finish line, would result in effective goaf inertisation at a faster rate, compared with inert gas injection through TG or MG seals.

(7) Inert gas flow rate of 1.0 m^3/s is recommended under less gassy conditions. Inert gas flow rate of 0.5m^3/s would be sufficient under moderately gassy conditions, if optimum inertisation strategies are implemented.

(8) The recommended guidelines for optimum inertisation strategy are:
   - a inert gas should be injected

into the goaf at around 200m behind the face finish line, ie, at an inbye location with respect to explosive fringe in the goaf.

b inert gas should be injected on the intake side of the goaf OR on both sides of the goaf.

c inert gas injection should start at least one or twodays before panel sealing, with minimum ventilation flow and doors on return seal still open.

d inert gas flow rate of 0.5 to 1.0m^3/s is recommended, subject to implementation of all these optimum strategies.

e inert gas injection to be continued after sealing until O_2 levels are below 8 percent.

In summary, the field demonstration study results showed that the optimum inertisation strategy implemented at the mine was highly successful in converting the goaf environment into an inert atmosphere within a few hours of panel sealing.

In fact, during the field demonstration studies, the goaf atmosphere was inert by the time of closing the doors on the final seals, with the oxygen concentration below 5 percent at all locations in the goaf.

This represents a major improvement to mine safety compared to typical inertisation practices that were able to achieve goaf inertisation within two to four days after sealing.

The project studies have greatly improved the fundamental understanding of the various site parameters and inertisation schemes on goaf inertisation.

This new understanding has been used to develop the optimum inertisation strategies for site conditions, which have proved to be highly successful in goaf inertisation.

This project demonstrated that it is feasible to completely inertise the longwall goafs within a few hours of sealing the panel by implementing optimum inertisation strategies.

The fundamental understanding of inert gas flow patterns and optimum inertisation guidelines developed during the course of the project greatly enhance the safety of coal mines.

Acknowledgments

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[1] CSIRO Exploration and Mining, Australia
[2] Newlands Coal Pty Ltd (NCA Coal Project), Australia

The challenge of measuring airflow through

MINE REGULATORS TO ALLOW REAL TIME VENTILATION MONITORING

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Abstract

The mathematical modeling of airflow through operating mine regulators is discussed. Results are used in the development of a computerised monitoring and simulation system to provide immediate or real time data on air behavior within each branch within an underground mine ventilation network through linking of sensors to the ventilation network simulation software.

Software has been developed to link real time information generated by mine ventilation monitoring sensors into the network program to undertake network simulations and allow interpretation of key system data and operational changes.

The outcome of the project is an online system which can report changes in the mine ventilation system, allow causes of changes to be isolated and rectified, improve balancing of available air throughout the mine and dispense with much of the labor used for underground ventilation measurement.

The main work activities involved in the research program have involved examination and modeling of regulators, software modification and considerable mine site testing and optimising activities.

1 Introduction

There is a move worldwide to remote or telemetric monitoring of mine atmosphere conditions. Robust, suitable and as required, intrinsically safe instruments are available for measurement of, for instance, gas concentrations, and air velocity and air pressure. These are often tied to extensive mine monitoring and communication systems.

One approach to establishing air quantity through a ventilation branch is through measurement of differential pressure across an opening or regulator. Mathematical relationships are available to relate (with some qualification) pressure drop and quantity through a regulator orifice placed symmetrically in a round flow conduit. However these can, at best, only be used to approximate mine regulator behavior due to:

- the irregularity of mine regulators in shape and symmetry and their positioning in normally roughly square or rectangular mine airways
- the construction of the mine regulator opening which may result from, for instance, the operation of louvers, a sliding door, window or curtain or placement of drop boards
- Uncontrolled air leakage through the regulator or adjacent bulkhead.

The study describes efforts to characterise or mathematically model regulators. It then describes how this information is used in the development of a computerised monitoring and simulation system to provide immediate or real time information on each branch within an underground mine ventilation network through linking of sensors to the ventilation network simulation software.

Software has been developed to link real time information generated by mine ventilation monitoring sensors into the network program to undertake network simulations and allow interpretation of key system data and operational changes.

The outcome of the project is an online system which can report changes in the mine ventilation system, allow causes of changes to be isolated and rectified and improve balancing of available air throughout the mine.

It is envisaged that in time the real time model will be an integral part of a real time mine wide planning, monitoring and control software platform and will be updated in real time along with the mine plan. The main steps involved in examination and modelling of regulators, software modification and considerable mine site testing and optimising activities are described.

2 Theory of regulators

A regulator is an artificial resistance (in the form of shock loss) introduced into an airway to control airflow.

2.1 Types of regulators

Regulators placed in mine air circuits may vary from well-engineered devices with a long life to temporary roughly constructed arrangements that achieve a practical purpose or 'the job in hand.'

Some of the more permanent devices take the following forms.

Drop board regulators

Drop board regulators are a popular form of variable resistance regulators. They can consist of two vertical steel rails placed on each side of the airway (usually against bulkhead pillars) into which large wooden boards are slotted from the ground up. Installation and alteration can be very labour intensive. More boards in place result in a smaller air opening and consequent generation of a higher shock loss. Personnel access through them is usually difficult.

Louvers

Louvers form a variable resistance regulator. Similar to domestic window louvers, they are usually made of steel. The shock loss is related to the degree to which the louvers are open.

Rubber flaps

Rubber flaps can be used where vehicle access is required through a regulator and a good seal is not required. The flaps are hung from the back or roof, usually from a beam, such that they overlap. Vehicles can pass through them without the driver stopping the vehicle or opening the flaps.

Canvas stoppings
These regulators consist of canvas stiffened by steel bars. The canvas is tied to the back and allowed to hang freely across the drift. Air pressure should ensure that the canvas forms a reasonable seal against adjacent bulkhead pillars. The height of the canvas is adjusted to vary the required shock loss.

Ventilation doors
Ventilation doors allow passage of personnel, vehicles and materials. They can completely seal off an airway (solid doors) or partially seal by incorporating an opening often covered by a sliding panel.

Ventilation bulkheads
In cases where a small amount of air is required a hole may be placed in a bulkhead. A sliding door may be used to control flow through the opening.

2.2 Derivation of regulator equation

A regulator can be described as a large thin plate installed in a fluid conduit with an orifice. When a difference in pressure exists between the two sides fluid flows in the pattern shown in Figure 1.

On the low pressure side the fluid issues as a converging jet in line with the centre of the orifice. The jet converges to its smallest area at a distance of about half the orifice diameter (Le Roux, 1979).

This area is called the 'vena contracta' (A_c at Fig. 1). The ratio between vena contracta and orifice area is the 'coefficient of contraction', C_c (A_c/A_r at Fig. 1).

McElroy (1935) found that the C_c value is a relation between the ratio of the orifice and airway cross sectional area, N (A_r/A at Fig. 1), and Z, which is an empirical factor designated as the contraction factor, which is expressed as:

$$C_c = \sqrt{\frac{1}{Z - ZN^2 + N^2}} \quad \textbf{(1)}$$

Values of Z vary according to the edge shape of the orifice. Since most regulators are square edged, a Z value of 2.5 is most commonly used in calculating C_c. Bernoulli's equation can be applied to both sides of the orifice as shown in Figure 1 in order to calculate the velocity and hence the airflow quantity.

A correction must be made for the contraction of the jet at the vena contracta. Since the orifice is larger than the vena contracta, orifice velocity is lower than in the vena contracta. The velocity equated based on Bernoulli's equations is the velocity at the vena contracta. Therefore, the velocity at the orifice can be obtained with the following equation:

$$V_2 = C_c \sqrt{\frac{2\Delta P_s}{\rho}} \frac{1}{\sqrt{1 - N^2}} \quad \textbf{(2)}$$

where C_c is the coefficient of contraction, as described before. Since airflow quantity through regulator $Q = V_2 A_r$, it follows that:

$$Q = C_c \sqrt{\frac{2\Delta P_s}{\rho}} \frac{1}{\sqrt{1 - N^2}} A_r \quad (3)$$

where A_r is orifice opening area in m^2.

3 Field tests of regulators

Field tests were conducted at the University of Queensland Experimental Mine (UQEM) to verify air behavior in flow through regulators. Parameters measured were airflow quantity and pressure drop across the regulator.

From pressure drop measurements, airflow quantity through the regulators can be calculated with Equation 3. Results of this calculation can be compared with measured values and the reasons for significant differences investigated.

3.1 UQEM tests

The UQEM regulator is the drop board type as shown in Figure 2. Results of this test are summarised in Table 1.

Based on DP_s measured, predicted airflow quantity through the regulator, Q, was then calculated with Equation 3. Values of Q were compared with the measured quantity, Q_m, as set down in Table 1 and Figure 3. It can be seen from both the table and figure that the measured quantity is consistently larger than predicted. There are several possible reasons as follows.

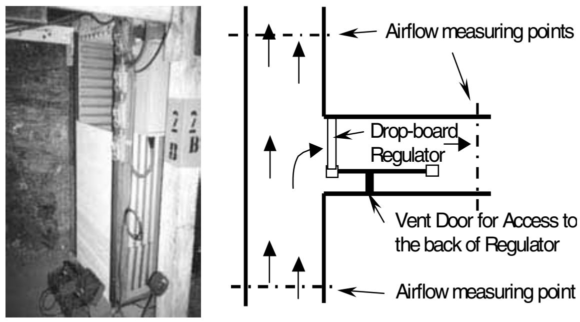


Figure 2 Drop board regulator tested at UQEM

Error during measurement
It is common for operator-induced errors to occur during mine drift measurement especially in small cross sectional airways. The authors experienced difficulty when measuring air velocity by continuous traversing because of limited space to move freely. Also, an author's body provided a significant obstacle to the airflow.

Non-symmetrical condition and shape
Equation 3 was derived based on a circular orifice in the middle of a regulator plate. The UQEM regulator opening is located on the upper side and opening is rectangular leading to distorted air patterns.

Leakage
Leakage occurs due to the presence of gaps between boards and between the regulator frame and the airway walls. The leakage quantity depends on

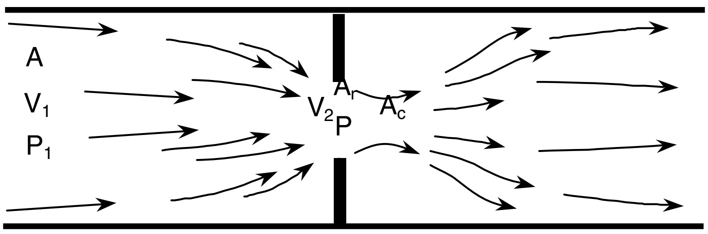


Figure 1 Airflow pattern through an orifice (after Burrows et al, 1989)

regulator construction and the differential pressure drop across the opening.

An approach is proposed to model the difference as air leakage since measurement error and the non-symmetrical condition were difficult to quantify. Therefore, the airflow quantity through the regulator can be expressed as:

$$Q = C_c \sqrt{\frac{2\Delta P_s}{\rho}} \frac{1}{\sqrt{1-N^2}} A_r + Q_l \qquad (4)$$

where Q_l is the leakage quantity. Thus Q_l needs to be quantified. An approach to this modelling is developed.

3.2 Relationship between airflow quantity and regulator resistance

The regulator can be treated as a set of two parallel airways namely:

- the regulator opening
- the leakage paths, that is passages through and around the regulator other than the regulator orifice itself.

This can be illustrated as in Figure 4.

Therefore, the total resistance of regulator (R_t) can be modeled to consist of the regulator opening resistance (R_o) and the leakage path resistance (R_l). When the regulator is in a fully closed condition, the air flows through the leakage path only. Airflow quantity through the regulator opening is calculated using the basic square law ($DP_s=RQ^2$). Based on this equation and Equation 3, the relationship between R_o and A_r can be established as follows (Gillies et al, 2002).

Figure 3. Comparison between measured and predicted quantity

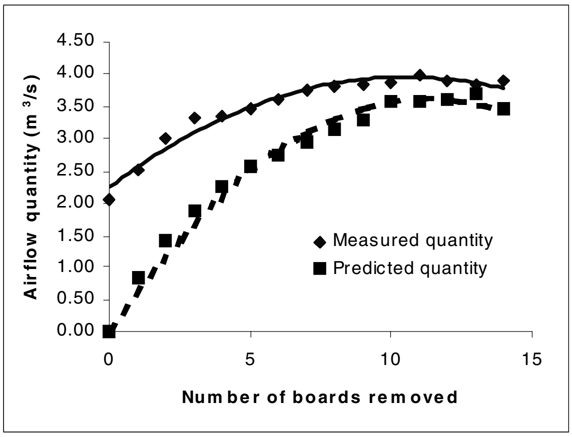
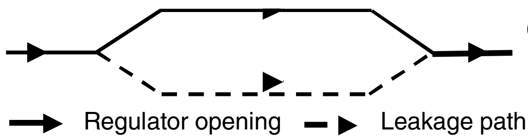


Table 1 Summarised results of UQEM test.

Condition	ΔP_s Pa	Q_m m³/s	Q m³/s	Difference %
Fully closed	163	2.05	0.00	n/a
1 board off	125	2.53	0.82	209.8
2 boards off	96	3.02	1.44	109.6
3 boards off	73	3.33	1.89	76.0
4 boards off	58	3.35	2.27	47.7
5 boards off	47	3.46	2.58	34.3
6 boards off	36	3.62	2.74	32.0
8 boards off	25	3.82	3.14	21.5
10 boards off	19	3.86	3.58	7.8
12 boards off	12	3.90	3.61	8.1
14 boards off	7	3.89	3.46	12.4

Figure 4 Airflow paths in regulator.



$$R_o = \frac{\rho}{2{C_c}^2}\left(\frac{1}{{A_r}^2} - \frac{1}{A^2}\right) \qquad (5)$$

where A is the airway cross sectional area. Since this equation does not take leakage into account, the actual regulator resistance will be different to the one calculated by Equation 5.

Thus actual resistance is R_t. R_t is made up of R_o and R_l in parallel configuration and so the relationship between them can be established. Since R_o has been quantified by Equation 5, R_l has to be quantified also to allow R_t to be calculated. Thus based on the measured pressure drop, the airflow quantity through the regulator can be determined.

To do this, R_o is first calculated using Equation 5, and then the total resistance is calculated using the square law based on the measured pressure drop and the measured airflow quantity. R_l then can be calculated using the parallel airways resistance relationship. Table 2 shows the calculated resistance of the regulator tested at the UQEM.

To quantify R_l a plot against regulator opening area was made, as shown in Figure 5. It was found that

$$R_l = 32.734 e^{1.1631 Ar}$$

Therefore, the total regulator resistance, R_t could be calculated using the parallel airways resistance relationship.

The airflow quantity was then re-calculated using the square law based on the new R_t. Results of this was then compared with measured values, Q_m, as summarized in Table 3 and Figure 6. It can be seen from both table and graph that the difference is at all times less than 10 percent which is well within practical underground measurement tolerance and therefore this new equation is sufficiently reliable to be employed for further analysis.

The relationship between the regulator opening area and total resistance can be derived as shown in Figure 7. Based on this, pressure and airflow quantity relationships can be calculated from mine regulator impedance characteristic curves. These can be drawn for different mine configurations as shown in Figure 8. The three curves shown illustrate relationships for one, three and five boards off from the regulator.

4 UQEM real time mine ventilation system

The aim of this mine ventilation research was to develop a computerised monitoring system to provide immediate or real time simulated information on each branch within an underground ventilation network. The system measures airflow or air pressure changes in selected ventilation branches and simulate flows through all other branches. This new approach to ventilation provides improved understanding of airflows through all mine sections.

The popular ventilation simulation modeling program Ventsim has been used as a simulation engine within the system. This software has been altered to accept real time information generated by underground mine ventilation monitoring sensors, undertake network simulations and interpret key system data and operational changes. Once the simulation program has updated readings it can remodel the whole mine system, report the flows in all branches and compare individual branch readings with expected values.

The UQEM was used to test the integration of a telemetry system into the Ventsim network analysis environment. An isometric plan of the UQEM is shown in Figure 9. The mine airflow monitoring system included consisted of one El-Equip 'Flosonic' and two vortex shedding Sieger BA5 air velocity sensors.

The FloSonic air velocity sensor is an ultrasonic anemometer measuring the average air velocity value across a drift with very good accuracy (Casten et al, 1995 & McDaniel et al, 1999). The initial aim of this testing was to use the system to monitor changing ventilation conditions, to establish airflow characteristics within the UQEM and to observe the resimulated network results.

Achievement of the main research aim was facilitated with the development of a real time solution requiring data communication links between the various system components. These components included the UQEM telemetry monitoring system, the telemetry control software, the developed data manipulation applications, a File Transfer Protocol (FTP) application and a modified real time version of Ventsim. Details of the integration of the UQEM real time ventilation monitoring system including Ventsim modification have been described by Gillies et al (2000).

5 Trials of the UQEM system

The performance of the modified airflow real time ventilation monitoring system at UQEM was evaluated. Parameters examined in this trial were:

- the ability of the system to detect changes in the mine ventilation system
- the accuracy of airflow quantity prediction in unmonitored branches within the mine ventilation network based on the number of sensors linked to the system
- constraints limiting performance of the system.

5.1 Test results

Four trial scenarios were implemented in the evaluation tests:

I. The inclined shaft door was open, and the regulator in 116' level set on fully open.

II. The inclined shaft door was open, and the regulator was set 1/5 open with 12 boards on.

III. The inclined shaft door was open, and the regulator set on fully closed.

IV. The inclined shaft door was closed, and the regulator was set on fully open.

For the purpose of the tests the main shaft and the double doors on the 140' level were closed and the door on the 154' level was removed to increase airflow through the 116' adit and inclined shaft.

During the tests field measurements using a calibrated vane anemometer and pressure transducer were conducted at the 116' adit, 116' regulator, inclined shaft and ventilation drive on the 140' level past the Dead Man's Pass as shown in Figure 10 and referenced as Station 26-11.

Results of these measurements were then compared with predicted values generated from the real time Ventsim models. The aim here was to evaluate the accuracy of airflow quantity prediction in unmonitored branches.

The real time Ventsim models were run with one to

Table 2 UQEM regulator resistances

Condition	R_t Ns^2/m^8	R_o Ns^2/m^8	R_l Ns^2/m^8	A_r m^2
Fully closed	38.65	∞	38.65	0
1 board off	19.46	186.77	42.43	0.09
2 boards off	10.56	46.39	38.61	0.18
3 boards off	6.58	20.39	35.31	0.27
4 boards off	5.17	11.29	49.52	0.36
5 boards off	3.93	7.08	60.21	0.45
6 boards off	2.75	4.80	46.76	0.54
8 boards off	1.71	2.53	54.71	0.72
10 boards off	1.28	1.48	246.09	0.90
12 boards off	0.79	0.92	140.23	1.07
14 boards off	0.46	0.59	37.87	1.25

Table 3 Comparison between measured and new predicted quantity

Condition	Q_m m^3/s	New R_t Ns^2/m^8	New Q m^3/s	Difference %
Fully closed	2.05	32.73	2.23	-8.0
1 board off	2.53	17.49	2.67	-5.2
2 boards off	3.02	10.80	2.98	1.1
3 boards off	3.33	7.27	3.17	5.1
4 boards off	3.35	5.18	3.35	0.0
5 boards off	3.46	3.84	3.50	-1.1
6 boards off	3.62	2.93	3.51	3.1
8 boards off	3.82	1.81	3.72	2.7
10 boards off	3.86	1.17	4.03	-4.3
12 boards off	3.90	0.78	3.93	-0.8
14 boards off	3.89	0.52	3.68	5.7

Figure 5 Quantification of resistance for leakage paths

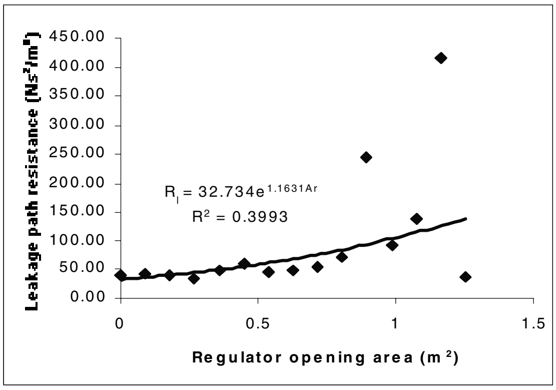
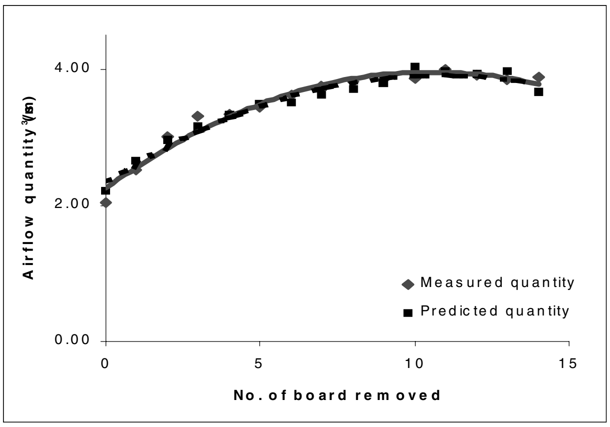


Figure 6 Comparison between measured and new predicted quantity



three real time airflow sensors link to the software and reporting to the Ventsim program as 'fixed quantity' branch quantity values. Theoretically more sensors linked to the system should give greater accuracy as real measurements from a greater mine geographic area and representing more realistic conditions of the mine are available.

Due to the electrical sensing problems encountered with the BA5 vortex-shedding sensor installed in 116 Adit, it was decided that the outputs from that sensor would not be included in the tests. A summary of the results is shown in Table 4.

It can be seen that the UQEM real time Ventsim monitoring system performs with reasonable accuracy, although some differences in quantities were larger than 10 percent as shown in the table. For example, the quantities through inclined shaft when the door connected to inclined shaft in 140' level was closed. However, this is acceptable, since the quantities predicted (ranging around 0.8-0.9m^3/s) and measured (around 0.6m^3/s) in these cases were low.

Results in Table 4 indicate that the system can predict changes within the mine ventilation system. The system predicted decrease in the regulator quantity as the regulator opening decreased. It also predicted decrease in quantity through the inclined shaft as the door was closed.

Within these tests no significant difference between the accuracy of one and two sensors linked to the system was observed. However, it cannot be concluded that this would be the case in a large operating mine since the location of the sensors will also have an important influence.

5.2 Constraints of the system

As described before, one aim of these tests was to identify constraints that might limit performance of the system. One major point of interest is the delay time or transient period between the instant of a change and when the system detects the change. The results of some changes are summarised in Table 5.

Figure 7 Relationship between new total resistance and regulator opening area

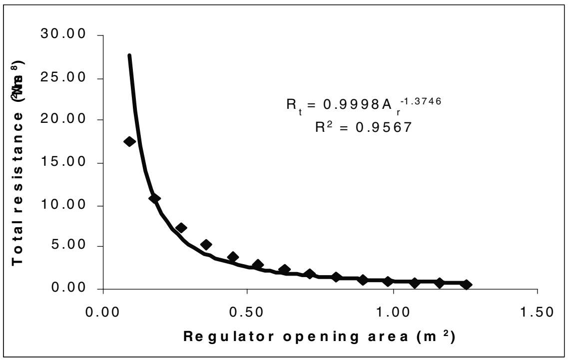


Figure 8 UQEM regulator characteristic curves

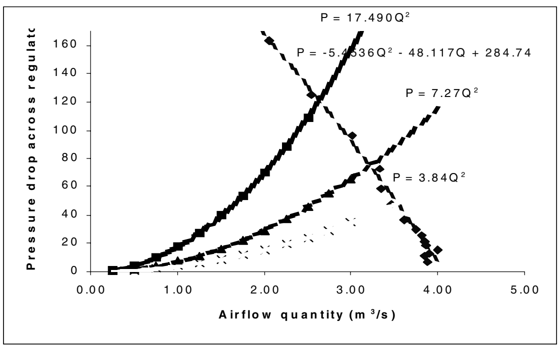


Table 5 Summary of the transition time observed

Changes	Time
Regulator fully open to 12 boards	70 seconds
Regulator 12 boards to fully closed	36 seconds
Regulator fully closed to fully open	84 seconds
Inclined shaft door open to closed	72 seconds
Inclined shaft door closed to open	75 seconds

The transient period in UQEM is short and therefore is not of great significance in interpreting the network system. However, in large-scale mines, the period can be up to 10 minutes. What this means is that reliance cannot be placed completely on 'real time' airflow readings being instantaneously correct as reported for all branches within a mine ventilation simulated network.

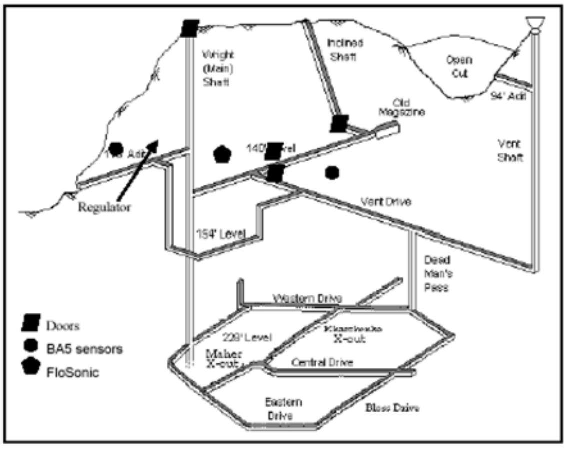
There is nothing that can be done to eliminate this characteristic as it is representative of the nature of airflow within underground mines. A change which leads to a hazardous condition may go unreported for time interval of this transient period. Of course changes in mine ventilation systems measured manually are rarely immediately picked up but the limitations of an automatically reporting real time system should be recognised.

6 Conclusions

Efforts to characterise or mathematically model a number of operating mine regulators have been described. Underground measurements have indicated that theoretical calculations to predict airflow quantity through practical mine regulators based on measured pressure drop are inadequate. The theoretical approaches are limited as they are based on prediction of fluid flow through a circular orifice in the middle of a plate whereas most mine regulators have a rectangular non-symmetrically positioned orifice. Also, most importantly, there is air leakage through the regulator bulkhead frame and gaps that increase actual quantity compared to that predicted.

The way to overcome this difference is to quantify the resistance of the leakage path based on regulator opening area and then recalculates the total resistance of the regulators. The relationship between leakage path resistance and regulator opening area varies, but the resistance should increase along with an increase in opening area. Based on measured pressure difference, the airflow quantity can be predicted accurately using the basic square law. It requires field

Figure 9 Plan of UQEM showing location of doors and sensors



measurement to quantify the leakage path resistance of each regulator, since each regulator has its own leakage characteristic (size and number of gaps, etc). This is a tedious work, since the regulators can be set with many opening areas. However, it was found that with limited measurement data, prediction results are still accurate within acceptable tolerance appropriate to understanding mine airflows.

The aim of the study was to gain greater understanding of a computerized monitoring system to provide immediate or real time simulated information in each branch of an underground ventilation network.

The system measures airflow in selected ventilation branches and simulates flows through all other branches. An investigation was undertaken as to whether the UQEM Real Time Airflow Monitoring system can detect changes within the mine ventilation system, examine accuracy of the system and identify constraints that will limit performance of the system.

As a result of trials, it was demonstrated that the system was able to detect changes occurring within the mine ventilation system and was also able to predict the changes accurately. Limitations caused by transient period delays have been examined.

Updating of simulation models from use of real time data has also been discussed. It is envisaged in the future that the ventilation model would be an integral part of a real time mine wide planning, monitoring and control software platform from which the model would be updated in real time.

Acknowledgement

The support of the University of Queensland and a number of operations within the Australian mining industry in funding this study are acknowledged.

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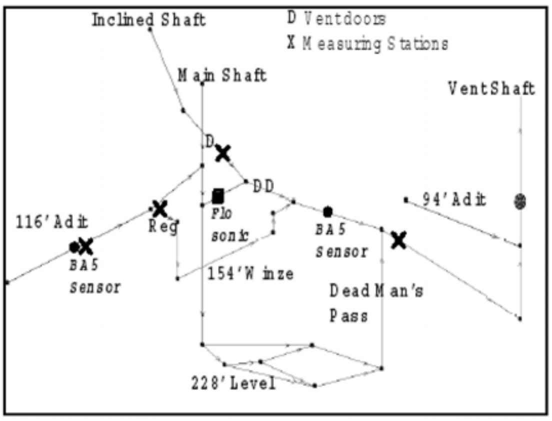
Table 4 Summary of trial results at UQEM

Scenario	Quantity (m^3/s)					
	Predicted	Measured	*Diff (%)*	Predicted	Measured	*Diff (%)*
One sensor linkage						
	Regulator			116' adit		
I	3.1	2.8	*-9.7*	3.9	4.1	*5.0*
II	2.2	2.1	*-2.9*	3.8	3.8	*-0.4*
III	1.7	1.3	*-22.0*	3.7	3.7	*0.2*
IV	3	2.8	*-6.7*	4.9	5.3	*8.4*
	Inclined shaft			Station 26-11		
I	2.8	2.8	*-0.4*	9.1	9.1	*-0.1*
II	2.7	2.8	*4.3*	8.9	9.0	*1.2*
III	2.7	2.8	*2.7*	8.8	8.7	*-0.9*
IV	0.9	0.6	*-38.7*	8.8	9.0	*1.9*
Two sensors linkage						
	Regulator			116' adit		
I	3.1	2.8	*-9.7*	3.9	4.1	*5.0*
II	2.2	2.1	*-2.9*	3.8	3.8	*-0.4*
III	1.7	1.3	*-22.0*	3.7	3.7	*0.2*
IV	2.8	2.8	*0.0*	4.9	5.3	*8.4*
	Inclined shaft			Station 26-11		
I	2.8	2.8	*-0.4*	9.1	9.1	*-0.1*
II	2.7	2.8	*4.3*	8.9	9.0	*1.2*
III	2.7	2.8	*2.7*	8.8	8.7	*-0.9*
IV	0.8	0.6	*-31.0*	8.8	9.0	*1.9*

Figure 10 Schematic diagram of UQEM ventilation system



Economic based optimisation of

AUSTRALIAN LONGWALL VENTILATION

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Abstract

Through the analysis of current longwall ventilation practice, economic considerations were established and used to construct a generic economic longwall ventilation model. The purpose of this modelling is to identify and outline a framework from which to evaluate the costs of a ventilation network and to provide the basis for design optimisation. The economic investigation of longwall ventilation draws on previously established longwall ventilation methods set in the context of ventilation practices from North America, Europe and Australia. While establishing a path to achieve the long-term goal of optimum longwall ventilation design many issues can be identified as having both fundamental design and economic implications. Some of these issues include gateroad development methods, sealing practices, labour utilisation, ventilation infrastructure, operational delay costing and consideration of alternate ventilation techniques such as booster fans and bleeder ventilation. These issues are considered in full as part of the established economic model. An equally important step in the modelling process is to evaluate and refine the established model particularly with respect to the identified issues. This provides a method to evaluate successful alternative ventilation techniques in an Australian context. The modelling process can then be further utilised to identify, test and evaluate fundamentally new longwall ventilation models outside of current practice.

1 Introduction

Planning processes for establishing ventilation network details are widely used in many different generic forms. The longwall ventilation planning and design process is a subset of these established procedures. Usually these processes are developed as a result of the personal experience of the mining engineer involved with ventilation planning of a number of projects over a period of time. The methodology utilised in this process strives to arrive at a ventilation design that satisfies all criteria set including those of minimum ventilation requirements and minimising cost.

The solution to a given longwall ventilation scenario may then meet the criteria set but may be sub-optimal dependant on the level of experience and expertise of the engineer involved in the design process. The knowledge-based development of design methodologies exists in various forms, an example of which can be seen in Basu & Wala (1993).It is proposed that the optimisation of these planning and design stages can be undertaken using an economic basis developed from considering existing practices in the context of economic fundamentals (Mayes & Gillies, 2001a). This economic basis would then be used to form a methodology utilised in the longwall ventilation planning process.

2 Economic considerations

In consideration of the development of an economic basis for a design methodology it is necessary to define a number of economic terms and their use in the derivation of economic considerations. The fundamentals listed below should not be considered as an exhaustive list of economic terms but a summary of already established concepts.

- capital and operating costs
- deferred and non-deferred costs.
- fixed and variable costs
- time value of money and interest
- internal rate of return and net present value
- depreciation and taxation implications

These economic terms are defined in any number of economic and ventilation texts including Stermole & Stermole (1990).

3 Longwall ventilation considerations

The consideration of fundamental design and economic issues involved in developing a robust ventilation design are discussed below.

3.1 Specifications

As a minimum sound engineering design and those legislative constraints imposed for the management of ventilation contaminants specify the minimum ventilation requirements. The management of ventilation contaminants has to consider respirable and explosible dust, toxic and explosible gases and heat. A comparison internationally of these features can enlighten the design process by highlighting different modes of thinking and tradition.

3.2 Infrastructure

Infrastructure used within the ventilation system forms the basic components or building blocks of the model. The major components of a ventilation network can be divided into the utilization of shafts and raisebores, roadway development, ventilation control devices or appliances and fans.

3.2.1 Shafts/raisebores

Recently with the advent of reliable and available raiseboring/drilling technologies the use of small diameter shafts/large diameter raisebores are used more widely to augment initially intake capacity and hence lower intake resistance. The extension of this application is considered in Section 7.2 where back return capabilities are considered and expanded on.

The economic consideration of these installations is traditionally focused on the basis of the operating costs of providing the necessary air power and the initial cost of shaft development. Mains roadways can be converted to reduce leakage and reduce the effective resistance. In practice there are a few Australian examples of the implementation of this concept in varying stages of completion.

3.2.2 Roadway development

The most fundamental use of roadways is that for ventilation. Typical Australian practice for gateroad development utilises two parallel headings. Fundamentally the cost of the second gateroad has to be attributed (certainly in full or maybe in part) to the ventilation system. With the recent use of three heading gateroads in one Australian colliery the additional costs over developing a two heading gateroad have to again be attributed to ventilation.

3.3.3 Ventilation appliances

This category of ventilation control devices includes stoppings, seals, overcasts and regulators. The cost elements of these devices are that of purchase, installation, labour and consumables. The selection of appliances is now even more difficult with a larger range of devices available with the advent of legislation providing for a minimum overpressure performance but not specifically dealing with leakage characteristics. Ongoing costs of labour and consumables can be considered in the maintenance of such devices and is discussed in Section 3.3.3.

3.2.4 Fans

The selection of main fans is an important function in the economic operation of a ventilation system and can contribute to minimized capital and operating expenditure if undertaken properly.

3.3 Operating costs

A number of different factors contribute to the expense of operating a longwall panel. When considering ventilation the categories of expense include most notably power, labour and maintenance and can be fixed or variable in nature.

3.3.1 Power

The costs associated with power consumption in the ventilation network are attributed to the operation of fans. It is usually easiest to consider the cost of electricity as the average cost per kWh. The cost of running ventilation fans is continuous and hence averaging is possible.

A large consideration in the operation of fans is the presence of leakage in the mine. This leakage can be seen to exist most predominantly in older ventilation appliances that are usually the devices closer to the bottom of the upcast shaft and pit bottom in an exhausting mine. There are gains to be had in rectifying this problem increasing the system resistance and adjusting the duty of the fans.

3.3.2 Labour

The cost of labour in Australian mines is increasingly the subject of contracts with the utilisation of specialist contract labour. As a process this makes the associated costs more visible and easier to incorporate into planning functions.

3.3.3 Maintenance

Maintenance of a longwall ventilation network is necessary for a number of reasons including roof falls, excessive rib spalls, water and silt build up and convergence and general operational wear and tear on ventilation appliances. These maintenance functions can be separated into leakage minimisation and resistance minimisation. It is possible to utilise a method of evaluating the selection of different maintenance projects based on that proposed by Peterson (1993). It is emphasised that the solution to each potential ventilation problem is considered as a separate economic opportunity in this methodology. In the evaluation of maintenance projects a series of goals is set and the network is assessed based on pressure and quantity survey data.

3.4 Operational delay costing

Robust design and planning procedures ensure in the ideal case that the ventilation system is capable of dealing with all elements of contaminant ingress and management. In the case of a poorly designed ventilation system it is possible to delay mining operations due to ventilation reasons, such as gassing out of faces and the existence of uncontrolled or poorly controlled hazardous environments.

To establish the delay cost there are several established methods. Commonly the value of the revenue lost from the absence of production is taken as the cost of delays. This takes into account the costs of the operation and the revenue generated from the sale of coal. For short delays the costs incurred are typical to those incurred for normal operating conditions. These include, for example, labour and electricity. For longer delays labour may be utilised elsewhere so the cost of the delay may decrease with time. Operational delay costing methods are extended further in Mayes & Gillies (2002).

3.5 Legislative cost implications

Further to sound engineering design legislative constraints are imposed for a multitude of reasons. Sometimes it can be seen that these legislative requirements are in fact constraining the productivity and/or profitability of the operation. An example exists in the USA where it is legislated that the belt air cannot normally be used to ventilate a face and hence is used as a neutral roadway. This is discussed later but can be seen as an additional development and operating cost to the ventilation system.

An example in Queensland existed under the recently replaced regulation where intake air could not be routed past

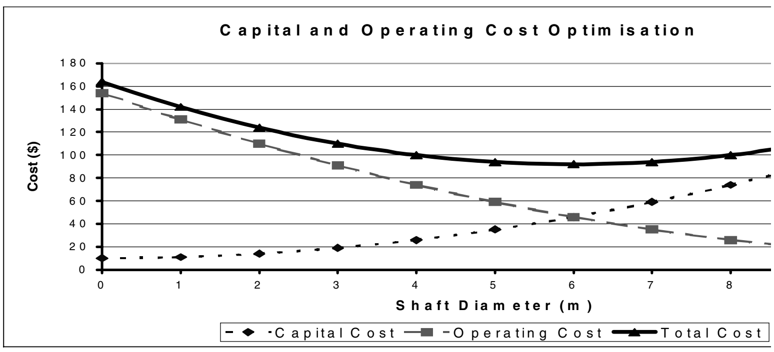

Figure 1 Theoretical example capital and operating cost function optimisation with minimum total cost indicating optimum selection of shaft diameter

old workings. In this case it meant that a return roadway was placed along side the main seals of previously exhausted longwall panels, now sealed goaf's. In the case where a mine was extracting longwall panels on both sides of the Mains roadways the use of flanking returns or a sacrificial roadway was necessitated. For some mines this may have been necessary to deal with large volume sealed goaf areas but with the necessary monitoring and ventilation design this did not need to be an issue.

4 Traditional economic evaluation methods

Traditional economic evaluation of ventilation systems has been confined to the stand-alone assessment of shaft installations and number of roadways selection.

Examples of these can be seen in most ventilation texts including Le Roux (1990), Lambrechts (1989), McPherson (1993) and Tien (1999). An applied example is provided by Krishna (1997). This analysis considers the air power operating cost in addition to the cost of developing that particular infrastructure item.

These costs functions are identified and then the optimum selection is based on, for example, a graphical solution, as can be seen in Figure 1. The solution of capital and operating cost functions for a shaft installation can be found where the summation is at a minimum total cost.

5 risk consideration

The probability and consequence or risk associated with the processes of longwall ventilation is considered in a number of different ways as it pertains to the development of an economic basis for longwall ventilation design methodologies.

5.1 Economic risk

In constructing the economic basis for future modelling it is important to consider the methods for dealing with economic risk. This is considered a part of the methodology of investing in the mining industry and for dealing with uncertainty with aspects of the developed economic model.

Uncertainty or risk and return form the basis for investment decision making processes. This can be dealt with in terms of setting higher hurdle rates for investments dealing with uncertainty. Economic risk is dealt with in detail in Runge (1998).

5.2 Ventilation environment risk

Risk also exists due to the hazardous nature of underground coal mine environments and the resulting interaction with induced ventilation. Ventilation systems are designed to fulfil a set of criteria to manage the inherent hazards present. This is to prevent the possibility existing where, for example, a spontaneous combustion event or explosible atmosphere exists.

In the longwall ventilation design methodology utilised it is proposed that the various designs being considered are evaluated according to the economic factors identified to produce a preferred ventilation design. The design is then assessed with respect to the ventilation environment risks present to identify whether the risk consideration of the hazards present are manageable in the ventilation design and management plan. If that particular design is not acceptable then the process is repeated in an iteration to consider the next most suitable design.

In the planning process limits are utilised to control the perceived hazards. These limits are based to a degree on sound engineering design and actual mining experience within that mine, set of conditions and/or particular seam and location.

The best example of this is the restriction of pressure differential that is induced across ventilation appliances and through the actual mine (ie coal pillars, overburden, sealed goafs) to prevent the possibility of a spontaneous combustion event occurring. When considering this hazard additional controls may be implemented such as rib injection to minimise leakage paths and hence oxygen transport.

These controls are however less effective and reliable compared to engineering design to prevent a situation occurring as utilised in the typical risk minimisation process and the implementation of controls. It should be acknowledged that excessive limits may be imposed as developed from a risk adverse methodology that may prematurely discount sound engineering solutions.

Another strategy that can be adopted for the operation of longwall ventilation systems is the consideration of real time monitoring of all ventilation parameters and the control of ventilation appliances. Work being undertaken by Gillies et al (2002) describes the use of monitoring technologies as part of the implementation of real time monitoring of the ventilation airflows within both metalliferous and coal mines. Previous work undertaken and international efforts in this area are referenced in this publication.

5.2.1 Risk evaluation and management

The fundamentals of risk evaluation and management are based on the closed loop process of hazard identification, risk assessment, development and implementation of procedures and monitoring the effectiveness of the developed procedures (Oberholzer, 1996). Various developed methods for dealing with risk evaluation and management exist and can be applied to the design iteration proposed after having selected the most attractive economic model developed and assessed.

6 Modelling

Based on the established economic considerations it is then possible to construct a model to include the different relationships present for each of the key elements present in the ventilation system. One of the most critical elements of such modelling is consideration for the life of each of the ventilation system components. That is, the scope of the ventilation model is important to the economic decision making process.

With the availability of software based ventilation simulations it is very easy to consider various variations within the ventilation system and compare the entire ventilation network solutions to establish the wider relationships. This augments the stand alone economic consideration already mentioned of shaft sizing and number of

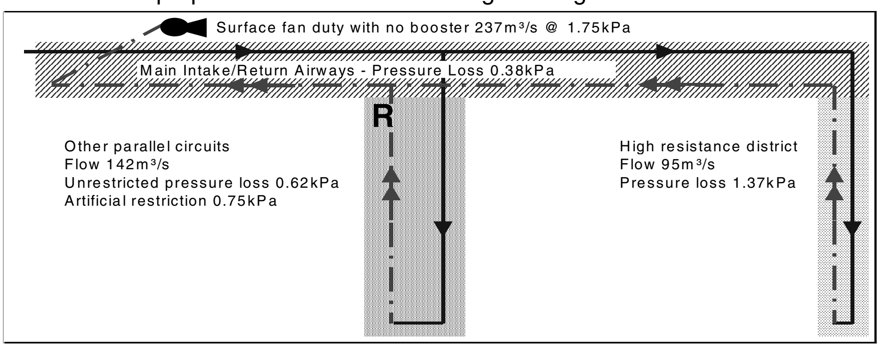

Figure 2 Longwall ventilation scheme with artificial restrictions

roadways selection by looking at a network based solution.

7 Alternative ventilation methods

With an economic basis outlined it is then possible to extend the analysis of longwall ventilation designs to include consideration for alternative ventilation techniques that are not utilised currently in Australia. The assessment and discussion of these techniques draws on observations and comparisons of international longwall ventilation practice primarily from Europe and North America.

7.1 Booster fans

Booster fans have historically had little application in Australian underground coal mines and no use in recent times.

The exception to this is the current installation at West Cliff Colliery located in the southern coalfields of the Sydney coal basin. In this case a booster fan has been installed in each of two headings in the Mains returns in parallel. This installation was justified on the basis of moving the longwall operations to a new district with set ventilation requirements over the life of the new district. The current ventilation system was unable to satisfy the future ventilation requirements and hence booster fans were considered and implemented (Benson, 2001). A similar installation is being developed in a Queensland colliery. Both of these installations utilise two booster fans in parallel to each other in the mains returns and are designed to handle the total air used in the mine.

The other possible method for booster fan utilisation is to use a booster fan as a negative regulator in panel/ district ventilation. This implementation removes the need for a regulator in that panel. An example of this is provided below in Figure 2 & 3.

At a point in the mines life where the main fans are operating close to their stall point or an unstable region of the operating curve several options must be considered to prolong the operation's life or provide the option to extend workings into new areas.

This includes consideration of the ability to increase the duty of the main fan installation with an associated increase in power consumption, whether new main fans are required or use of additional ventilation infrastructure such as a new shaft or an increased number of roadways underground. Each of these options can be assessed in terms of required capital and operating revenues. At this point booster fans can be considered and have in reality been used to extend the life of longwall operations, as can be seen in the English longwall mining industry.

An example of this is provided by Jobling et al (2001).

It should also be considered that the use of regulation in longwall operations represents significant additional cost to that required to actually satisfy ventilation requirements. Consider the following example adapted from Carruthers et al (1993). Figures 2 below describes a longwall ventilation scheme using artificial restriction.

For the longwall ventilation layout in Figure 2 can be seen to have a total power requirement with the presence of the artificial restrictions and a fan efficiency of 75 percent of 554kW.

In Figure 3 above the same ventilation scheme exists now with no artificial restrictions. If a booster fan was installed in the high resistance path and the regulators in the low resistance paths were removed then the new fan duties and power requirements would be:

- Main fan - 237m^3/s@1.0kPa = 313kW
- Booster fan - 95m^3/s@0.75kPa= 94kW

The total being 407kW or a power saving of 147kW. Assuming a power cost of $0.05/kWh this represents an annual power saving of approximately $64,000.

It can be seen that based on the operating costs that booster fan utilisation can result in power cost savings. At this point it is then necessary to consider the capital costs of the installation and the controls necessary to minimise induced risks such as local re-circulation.

Due to the more even pressure distribution within the ventilation system there may be a resultant increased level of overall safety through spontaneous combustion risk management.

The savings identified would actually be increased due to reduced pressure differentials applied to ventilation appliances in the network and hence less leakage would be experienced.

It should also be recognised that with booster fan installations monitoring and control of each installation must be maintained at the surface and that the necessary operating procedures must exist including interlocking of all the mine fans.

There also exists the need for considering pressure relationships and site preparation to minimise the potential for local re-circulation.

In the USA the use of booster fans is prohibited based on a fear that the operation of a booster fan installation could not be adequately controlled from outside the mine and could lead to abnormal re-circulation conditions or other potential hazardous situations (Kennedy, 1999).

It can be seen that with the use of available technologies booster fan installations have been operated in a controlled and safe manner, as can be seen in England, and that such legislative restrictions could force the closure of sub economic operations.

The use of booster fans has far greater savings than those demonstrated in the above example if their use facilitates the continued operation of the longwall operation. These factors should be considered as part of a complete economic assessment of existing or proposed ventilation designs.

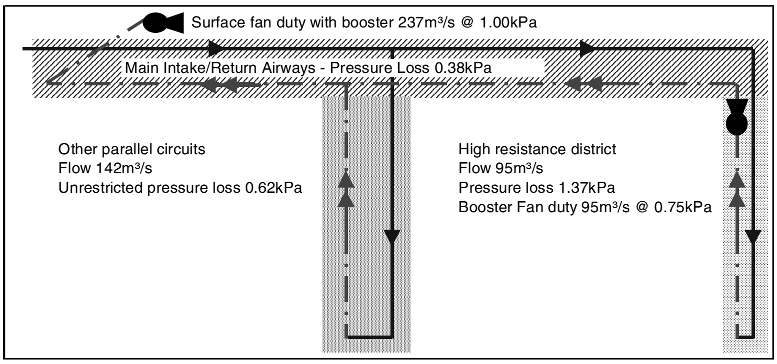

Figure 3 Longwall ventilation scheme with booster fan installed

7.2 Bleeder and Back Return Sub Mains roadways behind longwall

Historically there has been some use of bleeder roadways in longwall ventilation design in Australia but this practice was discontinued due to the need to manage the possibility of spontaneous combustion within most Australian coal seams.

The greatest potential for Sub Mains utilisation is when used in conjunction with a back return system. An example of a back return system with up-casting return shaft in the Sub Mains as utilised in a generic ventilation district model can be seen in Figure 4.

This generic model has been developed as a result of the studies undertaken on longwall ventilation method and layout as seen in Mayes & Gillies (2000) and further developed in Mayes & Gillies (2001b).

With increasing gas emissions from working faces at depth, the goaf and rib emissions are becoming more critical in the ventilation system design. To augment the return capabilities of the mains roadways it is possible to consider the use of a back return shaft/raisebore. This is then an exercise involving economic consideration of pressure distribution and loads on existing infrastructure and costs associated with development of sub mains roadways, shaft/raisebores and possible additional fan installations.

The advantages of such an inclusion can be seen to present an opportunity to more evenly distribute pressure differentials within the mine and in sealed areas. This solution can provide a more robust ventilation solution preventing possible downtime due to gassing out of working faces and general unsafe conditions.

The exception in bleeder ventilation in Australia is in two collieries in the southern coalfields of the Sydney coal basin in which a 'Z' layout longwall ventilation approach has been utilised. In this case there has been a demonstrated history of no spontaneous combustion events in the high insitu gas content coal formation. The sub mains roadways are used to intentionally ventilate the goaf to induce a pressure differential to draw gas away from the longwall face. Again with reference to the cost of operational delays the cost of developing, ventilating and operating these Sub Main roadways can be analysed in the system context.

7.3 Gateroad headings

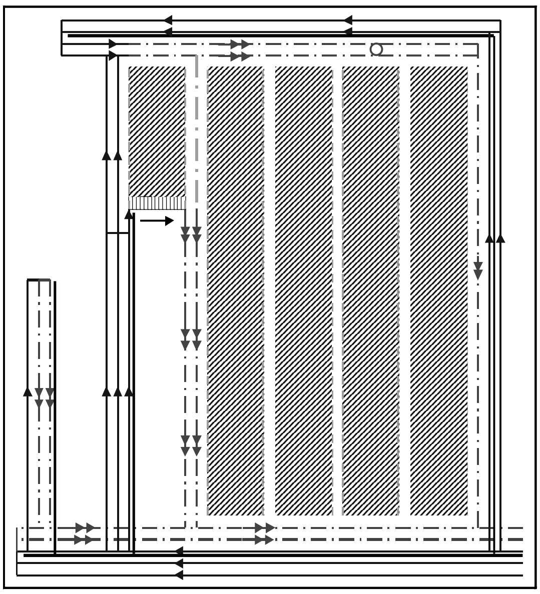

Figure 4 Generic longwall ventilation district model

As already discussed there are examples of 'number of roadways' selection derived from the summation of air power operating costs based on resistance calculations verses the cost of developing the roadways.

International practices have seen European mines justifying single entry multiuse gateroads and Australian mines justifying two entry gateroads with a recent move to three entry gateroads for ventilation resistance reduction over extended gateroad lengths. In North America there is a regulatory minimum of three headings with the frequent use of additional entries.

Factors considered in determining the economic number of entries in general include regulatory requirements for neutral roadways (present in the USA), expected or observed degradation of roadway quality and hence the establishment of a time dependant resistance relationship and probably most importantly the life of the ventilation infrastructure.

It can also be considered that using different development methods or equipment might allow some consideration for the dimensions of these roadways to be optimised. In this case there are certain fixed costs, such as the supply of services, semi-variable costs, such as required geotechnical support and variable costs, such as production related costs.

To be considered also is the gateroad rate of advance given a set number of entries of a certain cross sectional area and associated development requirement.

Part of this assessment should include the consideration that longwall production is the lowest cost per tonne and that with an increased number of roadways more coal is sterilised in pillars and hence overall recovery of the resource is reduced.

An issue contradicting this analysis is, for example, the potential for legislation to stipulate minimum ventilation quantities required for diesel equipment operating in a particular roadway. Regulatory bodies in the USA are considering this requirement that would force the optimisation process to consider fewer roadways to increase quantities and hence operating cost.

8 Evaluation

The evaluation of longwall ventilation networks can be separated into two distinct considerations. The first is of the actual ventilation network based on ventilation fundamentals. The second evaluation is of the economic assessment process and includes the criteria set and validation of the modelling process to provide a high level of confidence in the modelling results. These two aspects of evaluating the ventilation design process can be seen as complimentary as the goals are similar.

8.1 Ventilation system evaluation

When appraising a longwall ventilation system it has been proposed by Kennedy (1999) that the following aspects should be considered:

· Assessing the pressure distribution and load on the main fans. The reasons for high-pressure requirements of a mine is to overcome leakage or frictional resistance. If more air is required to overcome leakage then an increase in pressure will result in even more leakage.

• Assessing the ratio of mains to gateroad air course lengths. In this case the ventilation costs associated with the mains development is constant where as the costs associated with gateroad developments are constantly changing and are only ventilated in their fully developed state for a fraction of gateroad life.

- Assessing the load on the ventilation system as a result of barometric pressure changes. During a rapidly dropping barometric pressure change event the extent of sealed areas will 'breath' out contaminating the airflow against the sealed areas
- Assessing the ratio of air available at the last open-cut through to total air being moved by the fan. Ideally mines have achieved efficiencies of up to 80 percent.
- Assessing the quantity of ventilation required. This is a value arrived at from assessing the various functions of the ventilation system and the required ventilation and contaminant criteria set.
- Assessment of the location and quantity of leakage present. Identification of the location of leakage should be undertaken with consideration for the oldest ventilation appliances having the largest pressure differentials applied. Identifying the quantity of leakage on a section by section basis can establish normal and abnormal condition parameters and assist with the assessment of leakage characteristics.

It can be seen that practically these assessment criteria can be used to judge the condition of a ventilation system. More importantly these aspects can be considered in the planning and design stages with due consideration for the economic implications and relationships that exist.

8.2 Economic evaluation

Based on the proposed modelling basis it is then necessary during the iterative design process to evaluate the economic criteria set and review the performance of the modelling solutions.

This can be undertaken by modelling existing ventilation networks with varying levels of system complexity to compare predicted results with the observed real results. In this way a feedback loop can be closed to refine the economic modelling process.

This is important for the application of the developed economic model to hybrid ventilation systems incorporating alternatives not used currently in Australia. This is an important step despite these alternative practices being utilised internationally to evaluate these options in an Australian context. This may also lead to greater understanding of the application of these methods internationally.

The final step is the application of the developed economic model to ventilation systems that are not currently used. In this way consideration of ventilation systems is possible with a degree of confidence in the predicted results.

9 Conclusions

It can be seen that through the application of already established fundamental economic decision making tools that it is possible to establish the key aspects of all the components of a longwall ventilation system.

In this economic context it is then possible to augment the planning process and provide a basis from which to optimise the ventilation designs constructed.

The application of this work will directly benefit future endeavours to establish comprehensive ventilation system economic models that consider the many factors involved in ventilation design decisions.

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