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Editor's Comment

The Science and Practice of Mine Ventilation

Marco Biffi
Honorary Editor

Please send your comments and opinions to info@mvssa.co.za

The Constitution of the MVSSA wants to "... promote and advance the science and practice of [mine]ventilation engineering...". This phrase, that has survived several constitutional amendments over the years, was written in the infancy of this profession at a time when it was well understood, wisely so, that mine ventilation is a specialised branch of engineering.

This technical expertise is essential to enable underground mining in conditions that would be otherwise prohibitively unbearable to workers. It was written at a time when extensive manual labour was literally the back-bone of mining, particularly in this part of the world, displaying uncanny understanding of mining realities on the part of the MVSSA's founding members.

At the same time, the Chamber of Mines of South Arica instituted several specialised qualifications amongst which were the suite of Certificates in Mine Environmental [ventilation] Control which, to this day, has been globally acknowledged as pioneering in defining specialised education and training material for this discipline.

Over the years, the status of these qualifications has been surpassed and ignored by the academic world which failed to recognise the need to formalise the role of mine ventilation beyond that of an adjunct suite of extra-curricular courses leading to a postgraduate certificate or a master degree.

The news that the University of the Witwatersrand will be partnering the MVSSA in providing a Level 6 qualification registered with the Higher Education Qualifications Council in South Africa signifies a huge step in the right direction. It recognises and pegs the old Certificate in Mine Environmental Control and professional roles associated therewith at a validated level within the national education and training qualification frame-works. However, this qualification is still not an engineering degree: close, but no cigar!

The issue is not necessarily a question of status. Motivation for this discussion are the underlying principle and implications of this situation.

Incidentally, during recent weeks, correspondence within the North American Society for Mining Metallurgy and Exploration's Underground Ventilation (SME UVC) digest featuring some prominent North American and Australian colleagues,has been critical of the way in which mine ventilation is being relegated to the back seat when it comes to academic recognition and research funding.

In opinions raised in that forum, this robs the profession of its rightful place, and undermines relevance in the eyes of young, up-and-coming undergraduate students. In other mining countries outside Africa, mine ventilation is deemed to be a sub-set of mining engineering. Technically, this is correct. However, despite this being an increasingly sophisticated and specialised discipline complementing modern underground mining in a world where worker health and safety is championed by industry leaders as being paramount, mine ventilation as a career prospect seems to be relegated to a mere "stepping-stone" for young mining engineers on their way to "bigger things".

There is very little opportunity and glamour supporting Mine Ventilation as a career of choice. Given various safety imperatives and production pressures in the every-day life of young mining engineers, the advanced professional and technical development of talented young engineers in this discipline is therefore stumped.

This seems to be the reality in countries where, traditionally, universities have taken pride in the development of specialist ventilation engineers who, over the years, have become doyens recognised in their countries and internationally.

Fingers are being pointed to the same institutions for not supporting mine ventilation research and development and for the apparent lack of academic drive and innovation in this discipline.

Further criticism is that, young mining engineers are not stimulated and are not helped in developing advanced mine ventilation knowledge and skills while operating in their mine ventilation roles in an industry that demands increasingly more time to be dedicated to "production excellence" and profitability This contradicts the fact that mining profitability is to a significant extent the product of healthy and safe mining practices in turn rooted in good underground environmental conditions. The concern is that the long-term viability of the mine ventilation discipline in the modern mining world may be compromised.

In South Africa, developments in the last eighteen months or so have seen again some significant cuts in staff complements, affecting the discipline, driven by the same monotonic drive to cut "costs" - quite literally at all costs. The irony is that the value of good ventilation practice is realised only once it is no longer available and particularly in the aftermath of tragic incidents - that are sadly starting to be on the increase.

It is noted that initiatives from the recently established Wits Mining Institute have a small ventilation component as part of the institute's mission to promote innovation and sustainability through the development of skills and technology. Furthermore, the recent launching of the CSIR's Mining Precinct, aimed at developing new people-centred technologies to empower mines and prepare them for new mining methods, holds equally interesting promises for modern mining in this part of the world. The question remains as to what role mine ventilation can play, if any, in this "brave new world". The promotional material from both institutions speaks to mechanised mining, innovating techniques such as non-explosive rock breaking, rock mass behaviour, real-time information management, digital mining, communications systems, positioning, mapping and navigation, visual, environmental and rock monitoring. Ventilation possibly finds a home in the digital environmental monitoring chapter and the ubiquitous health and safety topics but is not mentioned much beyond that. Being provocative, ventilation does not seem to have (yet again?) a seat at this party and if there is one it is not obvious at this stage. The silver lining is that even machinery in a highly mechanised or even automated mine, is not likely to enjoy high (or low) temperatures, high humidity (or ice), dusty or even gassy environments. Therefore, a degree of environmental control will be required for those new technologies as well.

Irrespective of these wishful considerations, until this new world becomes a reality, humans will be employed in hostile underground environments. Until the advent of automation, mining leadership must realise that a strong and competent mine ventilation discipline is still needed. It is a fact that a good ventilation officer may not add one ounce of mineral product to the bottom line directly. However, to produce safely and efficiently, while realising that aspiration for zero harm, someone must provide and competently drive the thinking, the planning, and implementation of environmental control systems so fundamental in achieving those goals.

ERRATA: BARENBRUG CHARTS, 4th EDITION

Following notification last year relating to printing errors and quality issues of some psychrometric charts published in the 4th Edition of "Psychrometry and Psychrometric Charts" By A. W. T. Barenbrug produced by the MVSSA, the Society is in a position to replace the following:

Chart 3; 82.5kPa

Chart 4; 85.0kPa

Chart 5; 87.5 kPa

Chart 14; 110.0kPa

Chart 17; 117.5kPa

Chart 18; 120.0kPa

Chart 19; 122.5kPa

Chart 20; 125.0kPa

Chart 21; 127.0kPa

The above list includes all charts identified to be inaccurate.

Kindly contact the Secretary of the Society by email at secretary@mvssa.co.za or telephonically at 011 482 7957 with your contact details so that arrangements may be made to get replacement charts posted to you.

We apologise sincerely to affected students, members and clients who may have been inconvenienced by this error.

Marco Biffi Hon. Editor

SECRETARIAL

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The approach followed to conduct an "Exposure allocation methodology comparison study" *on Respirable Quartz Concentration for quarterly leading indicator reporting purposes*

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ABSTRACT

This paper discusses the approach that was followed to evaluate and compare the results from 5 different dose calculation methodologies to calculate and allocate employees' Respirable Quartz Concentration (RQC) exposure, when reporting "Quarterly Leading Indicators" to the Department of Mineral Resources (DMR).

The need for this project originated as it seemed that there is currently more than one method to calculate (and subsequently allocate) employees' RQC exposure when reporting "Quarterly Leading Indicators" to the DMR.

1. INTRODUCTION

1.1. Purpose

The purpose of the study is to conduct an "Exposure allocation/calculation methodology comparison study" for Respirable Quartz Concentration (RQC).

The need for this project originates as it seems that there is currently more than one method to calculate (and subsequently allocate) employees' RQC exposure when reporting "Quarterly Leading Indicators" to the Department of Mineral Resources (DMR).

The aim of this project will be to compare the results obtained from different exposure calculation and allocation methods.

2. PROJECT METHODOLOGY

2.1. Project Site

One of the deep underground gold mines situated in the Witwatersrand (South Africa) area was selected as the project mine.

The personal exposure to RQC data collected during 2014 was utilised for this study.

Exactly the same personal dust exposure data was utilised in each of the methods discussed in this report.

2.2. Method 1 (Method Currently Utilised by the Mine)

2.2.1. Exposure data

The exposure data of the current quarter was utilised to calculate the exposure category (as per the method specified in the South African Mines Occupational Hygiene Programme (SAMOHP) Code Book) for each Homogeneous Exposure Group (HEG) for the specific quarter.

Original paper presented at the 2016 MVSSA Conference

2.2.2. Statistical indicator

The exposure category for the HEG calculated by means of the 90th percentile value of all samples collected during the quarter within the HEG.

2.2.3. Quartz analysis utilised

Allocate the average silica content, of all samples analysed during the previous year, as the only average silica content for the current quarter.

2.2.4. RQC exposure allocation

All employees within the HEG are allocated the same exposure category as an indication of the exposure dose received for the specific quarter.

2.3. Method 2

2.3.1. Exposure data

The exposure data of the current quarter was utilised to calculate the exposure category (as per the method specified in the South African Mines Occupational Hygiene Programme (SAMOHP) Code Book) for each Homogeneous Exposure Group (HEG) for the specific quarter.

2.3.2. Statistical indicator

The exposure category for the HEG calculated by means of the 90th percentile value of all samples collected during the quarter within the HEG.

2.3.3. Quartz analysis utilised

Allocate the actual analysis results for each sample submitted for analysis during the quarter.

Samples analysed and found to be "Below Detection Limit" (BDL) are allocated a silica content equal to the average of all other samples analysed during the quarter for the specific HEG, as indicated in the table below:

HEG	Average Silica Content (%) of all Samples Analysed during the Quarter				
	Q1	Q2	Q3	Q4	2014
Stoping	28.8	26.9	23.4	33.9	28.7
Development	24.7	20.3	23.3	23.7	23.2
Tramming	19.3	25.8	21.1	24.2	22.3
Shaft & Services	19.8	26.0	21.5	24.4	22.7
Roving UG	23.0	20.8	22.9	26.3	23.0
Roving Surface	16.3	25.9	28.7	14.3	20.3

2.3.4. RQC exposure allocation

All employees within the HEG are allocated the same exposure category as an indication of the RQC exposure received for the specific quarter.

2.4. Method 3

2.4.1. Exposure data

The exposure data of the current quarter was utilised to calculate the exposure category (as per the method specified in the South African Mines Occupational Hygiene Programme (SAMOHP) Code Book) for each Homogeneous Exposure Group (HEG) for the specific quarter.

2.4.2. Statistical indicator

The exposure category for the HEG calculated by means of the average/mean value of all samples collected during the quarter within the HEG.

2.4.3. Quartz analysis utilised

Allocate the average silica content, of all samples analysed during the previous year, as the only average silica content for the current quarter.

2.4.4. RQC exposure allocation

All employees within the HEG are allocated the same exposure category as an indication of the exposure received for the specific quarter.

2.5. Method 4

2.5.1. Exposure data

The exposure data of the current quarter was utilised to calculate the exposure category (as per the method specified in the South African Mines Occupational Hygiene Programme (SAMOHP) Code Book) for each Homogeneous Exposure Group (HEG) for the specific quarter.

2.5.2. Statistical indicator

The exposure category for the HEG calculated by means of the average/mean value of all samples collected during the quarter within the HEG.

2.5.3. Quartz analysis utilised

Allocate the actual analysis results for each sample submitted for analysis during the quarter.

Samples analysed and found to be "Below Detection Limit" (BDL) are allocated a silica content equal to the average of all other samples analysed during the quarter for the specific HEG, as indicated in the previous table.

2.5.4. RQC exposure allocation

All employees within the HEG are allocated the same exposure category as an indication of the exposure received for the specific quarter.

2.6. Method 5

2.6.1. Exposure data

The exposure data of the current quarter was utilised to calculate the exposure category (as per the method specified in the South African Mines Occupational Hygiene Programme (SAMOHP) Code Book) for each Occupation for the specific quarter.

2.6.2. Statistical indicator

The exposure category for the occupation calculated by means of the average/mean value of all samples collected during the quarter within the occupation group.

2.6.3. Quartz analysis utilised

Allocate the actual analysis results for each sample submitted for analysis during the quarter.

2.6.4. RQC exposure allocation

All employees subjected to personal sampling, within the occupation and within the quarter, are allocated the precise sampled RQC for that quarter.

All employees NOT subjected to personal sampling, within the occupation and within the quarter, are allocated the average/mean RQC of all employees sampled within that occupation group during the quarter.

Please note that due to the manual calculation process required to test this method, this method was only tested for the Stoping HEG.

3. RESULTS

3.1. Method 1 (Method currently utilised by the mine)

The calculated statistical indicators which resulted from employing the calculation methodology described in Section 2.2 of this paper, are summarised as Table 1.

3.2. Method 2

The calculated statistical indicators, which resulted from employing the calculation methodology described in Section 2.3 of this paper, are summarised as Table 2.

Table 1. Calculated Statistical Indicators per HEG for Method 1

STOPING		RQC for 2014			
		Q1	Q2	Q3	Q4
90th Percentile	Value	0.1061	0.1331	0.1007	0.0925
	Category	A	A	A	B
	No. of Employees	832	832	832	832
DEV		RQC for 2014			
		Q1	Q2	Q3	Q4
90th Percentile	Value	0.1509	0.0811	0.0589	0.0523
	Category	A	B	B	B
	No. of Employees	267	267	267	267
TRAMMING		RQC for 2014			
		Q1	Q2	Q3	Q4
90th Percentile	Value	0.0737	0.0538	0.0426	0.0635
	Category	B	B	C	B
	No. of Employees	197	197	197	197
SHAFT & SERV		RQC for 2014			
		Q1	Q2	Q3	Q4
90th Percentile	Value	0.0456	0.0481	0.0445	0.0567
	Category	C	C	C	B
	No. of Employees	279	279	279	279
ROVING UG		RQC for 2014			
		Q1	Q2	Q3	Q4
90th Percentile	Value	0.0680	0.0570	0.0489	0.0726
	Category	B	B	C	B
	No. of Employees	590	590	590	590
ROVING SURFACE		RQC for 2014			
		Q1	Q2	Q3	Q4
90th Percentile	Value	0.0292	0.0468	0.0292	0.0321
	Category	C	C	C	C
	No. of Employees	56	56	56	56
Total Employees	2221				

Table 2. Calculated statistical indicators per HEG for Method 3.3. Method 3

STOPING		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
90th Percentile	Value	0.0820	0.1123	0.0851	0.1278	0.1085
	Category	B	A	B	A	A
	No. of Employees	832	832	832	832	832
DEV		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
90th Percentile	Value	0.1356	0.0878	0.0310	0.0494	0.0938
	Category	BA	B	C	C	B
	No. of Employees	267	267	267	267	267
TRAMMING		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
90th Percentile	Value	0.0595	0.0655	0.0312	0.0302	0.0556
	Category	B	B	C	C	B
	No. of Employees	197	197	197	197	197
SHAFT & SERV		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
90th Percentile	Value	0.0337	0.0481	0.0331	0.0426	0.0411
	Category	C	C	C	C	C
	No. of Employees	279	279	279	279	279
ROVING UG		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
90th Percentile	Value	0.0530	0.0385	0.0418	0.0586	0.0476
	Category	B	C	C	B	C
	No. of Employees	590	590	590	590	590
ROVING SURFACE		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
90th Percentile	Value	0.0170	0.0357	0.0300	0.0121	0.0258
	Category	C	C	C	C	C
	No. of Employees	56	56	56	56	56
Total Employees		2221				

Table 3: Calculated Statistical Indicators per HEG for Method 3

STOPING		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0538	0.0645	0.0445	0.0511	0.0545
	Category	B	B	C	B	B
	No. of Employees	832	832	832	832	832
DEV		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0640	0.0594	0.0276	0.0347	0.0504
	Category	B	B	C	C	B
	No. of Employees	267	267	267	267	267
TRAMMING		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0473	0.0304	0.0217	0.0263	0.0332
	Category	C	C	C	C	C
	No. of Employees	197	197	197	197	197
SHAFT & SERV		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0268	0.0271	0.0213	0.0263	0.0256
	Category	C	C	C	C	C
	No. of Employees	279	279	279	279	279
ROVING UG		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0300	0.0283	0.0250	0.0282	0.0277
	Category	C	C	C	C	C
	No. of Employees	590	590	590	590	590
ROVING SURFACE		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0201	0.0204	0.0156	0.0164	0.0182
	Category	C	C	C	C	C
	No. of Employees	56	56	56	56	56
Total Employees		2221				

3.3. Method 3

The calculated statistical indicators, which resulted from employing the calculation methodology described in Section 2.4 of this paper, is summarised as Table 3.

3.4. Method 4

The calculated statistical indicators, which resulted from employing the calculation methodology described in Section 2.5 of this paper, is summarised as Table 4.

3.5. Method 5

The calculated statistical indicators, which resulted from employing the calculation methodology described in Section 2.6 of this paper, are summarised as Tables 5 and 6.

4. FINDINGS

4.1. Interpretation of results for methods 1, 2, 3 and 4 for all HEGs combined.

The summary of the results for methods 1 to 4 for all HEGs combined is presented as Figure 1.

From the data it is clear that:

- Use of the 90th percentile value as an indicator of exposure dose of the HEG should not be considered, as it over-estimates the percentage of employees exposed to the "high exposure" exposure groups and potentially under-estimates the percentage of employees exposed to the "low exposure" groups, e.g.:
  - Methods 1 and 2 employ the practice of utilising the 90th percentile value to assign exposure dose;
  - Method 1 reports that 49.5% of employees are exposed to concentrations above the Occupational Exposure Limit (OEL) while only 4.5% of the samples collected were greater than the OEL;
  - Method 2 reports that 37.5% of employees are exposed to concentrations above the Occupational Exposure Limit (OEL) while only 4.6% of the samples collected were greater than the OEL;
- However, it is suggested that Method 2 will be more accurate than Method 1, as Method 2 utilises the specific silica content analysis for each specific sample collected and not an assigned historical value, as is the case when employing Method 1.
- Use of the average/mean value as an indicator of exposure dose of the HEG should not be considered, as it potentially under-estimates the percentage of employees exposed to the "high exposure" exposure groups and potentially over-estimates the percentage of employees exposed to the "low exposure" groups, e.g.:
  - Methods 3 and 4 employ the practice of utilising the average/mean value to assign exposure dose;

Table 4: Calculated Statistical Indicators per HEG for Method 43.5. Method 5

STOPING		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0449	0.0551	0.0349	0.0568	0.0493
	Category	C	B	C	B	C
	No. of Employees	832	832	832	832	832
DEV		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0513	0.0514	0.0190	0.0299	0.0411
	Category	B	B	C	C	C
	No. of Employees	267	267	267	267	267
TRAMMING		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0276	0.0305	0.0166	0.0234	0.0247
	Category	C	C	C	C	C
	No. of Employees	197	197	197	197	197
SHAFT & SERV		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0210	0.0251	0.0167	0.0221	0.0214
	Category	C	C	C	C	C
	No. of Employees	279	279	279	279	279
ROVING UG		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0239	0.0186	0.0216	0.0245	0.0221
	Category	C	C	C	C	C
	No. of Employees	590	590	590	590	590
ROVING SURFACE		RQC for 2014				
		Q1	Q2	Q3	Q4	2014
AVG	Value	0.0118	0.0186	0.0160	0.0082	0.0133
	Category	C	C	C	C	C
	No. of Employees	56	56	56	56	56
Total Employees		2221				

- Method 3 reports that the highest exposed employees (49.5% of employees) are exposed to concentrations between 50% and 100% of the OEL. However, 4.5% of the samples collected were greater than the OEL, resulting in "over-exposures" being "masked" from the reported data;
- Method 4 reports that 100% of the employees are exposed to concentrations between 50% and 100% of the OEL. However, 4.6% of the samples collected were greater than the OEL, resulting in "over-exposures" being "masked" from the reported data;
- However, it is suggested that Method 4 will be more accurate than Method 3, as Method 4 utilises the specific silica content analysis for each specific sample collected and not an assigned historical value, as is the case when employing Method 3.

4.2. Interpretation of results for methods 1 to 5 for the STOPING HEG only.

The summary of the results for Methods 1to 5 for the Stoping HEG only, is presented as Figure 2. From the data above it is clear that:

- Use of the 90th percentile value as an indicator of exposure dose of the HEG should not be considered, as it over-estimates the percentage of employees exposed to the "high exposure" exposure groups and potentially under-estimates the percentage of employees exposed to the "low exposure" groups, e.g.:
- Methods 1 and 2 employ the practice of utilising the 90th percentile value to assign exposure dose;
- Method 1 reports that 100% of employees are exposed to concentrations above the Occupational Exposure Limit (OEL) while only 11.9% of the samples collected were greater than the OEL;
- Method 2 also reports that 100% of employees are exposed to concentrations above the Occupational Exposure Limit (OEL) while only 11.3% of the samples collected were greater than the OEL;
- However, it is suggested that Method 2 will be more accurate than Method 1, as Method 2 utilises the specific silica content analysis for each specific sample collected and not an assigned historical value, as is the case when employing Method 1.
- Use of the average/mean value as an indicator of exposure dose of the HEG should not be considered, as it potentially under-estimates the percentage of employees exposed to the "high exposure" exposure groups and potentially over-estimates the percentage of employees exposed to the "low exposure" groups, e.g.:
- Methods 3 and 4 employ the practice of utilising the average / mean value to assign exposure dose;
- Method 3 reports that 100% of the employees are exposed to concentrations between 50% and 100% of the OEL. However, 11.9% of the samples collected were greater than the OEL, resulting in "over-exposures" being "masked" from the reported data;

Table 5: Calculated number of employees per exposure category per occupation for Method 5

STOPING HEG	Total Employees	Number of Employees allocated per category														
		Quarter 1			Quarter 2			Quarter 3			Quarter 4			2014		
Occupation		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
20304	13		12	1			13			13			13		9	4
20305	18			18		17	1			18		18			15	3
20311	77	1	75	1	76		1		77			1	76	2		75
20312	8			8	1		7			8			8	1		7
20402	288		2	286	3	2	283	1	286	1	2	279	7	6	265	17
20499	6			6			6		5	1		6			2	4
20702	171	1	5	165	1	2	168		1	170		170	1	2	156	13
21002	17		17			17			17			17			17	
21004	13			13		13			1	12		13			2	11
29901	6			6			6			6			6			6
40526	215	2	207	6	1	210	4	1	213	1	211		4	8	191	16
TOTAL	**832**	**4**	**318**	**510**	**82**	**261**	**489**	**2**	**600**	**230**	**213**	**504**	**115**	**19**	**657**	**156**

Table 6: *Calculated percentage of employees per exposure category per occupation for Method 5*

STOPING HEG	% of Employees allocated per category														
	Quarter 1			Quarter 2			Quarter 3			Quarter 4			2014		
Occupation	A %	B%	C%	A%	B%	C%	A%	B%	C%	A%	B%	C%	A%	B%	C%
20304	0.0	92.3	7.7	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	69.2	30.8
20305	0.0	0.0	100.0	0.0	94.4	5.6	0.0	0.0	100.0	0.0	100.0	0.0	0.0	83.3	16.7
20311	1.3	97.4	1.3	98.7	0.0	1.3	0.0	100.0	0.0	0.0	1.3	98.7	2.6	0.0	97.4
20312	0.0	0.0	100.0	12.5	0.0	87.5	0.0	0.0	100.0	0.0	0.0	100.0	12.5	0.0	87.5
20402	0.0	0.7	99.3	1.0	0.7	98.3	0.3	99.3	0.3	0.7	96.9	2.4	2.1	92.0	5.9
20499	0.0	0.0	100.0	0.0	0.0	100.0	0.0	83.3	16.7	0.0	100.0	0.0	0.0	33.3	66.7
20702	0.6	2.9	96.5	0.6	1.2	98.2	0.0	0.6	99.4	0.0	99.4	0.6	1.2	91.2	7.6
21002	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0
21004	0.0	0.0	100.0	0.0	100.0	0.0	0.0	7.7	92.3	0.0	100.0	0.0	0.0	15.4	84.6
29901	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	100.0
40526	0.9	96.3	2.8	0.5	97.7	1.9	0.5	99.1	0.5	98.1	0.0	1.9	3.7	88.8	7.4
TOTAL	**0.5**	**38.2**	**61.3**	**9.9**	**31.4**	**58.8**	**0.2**	**72.1**	**27.6**	**25.6**	**60.6**	**13.8**	**2.3**	**79.0**	**18.8**

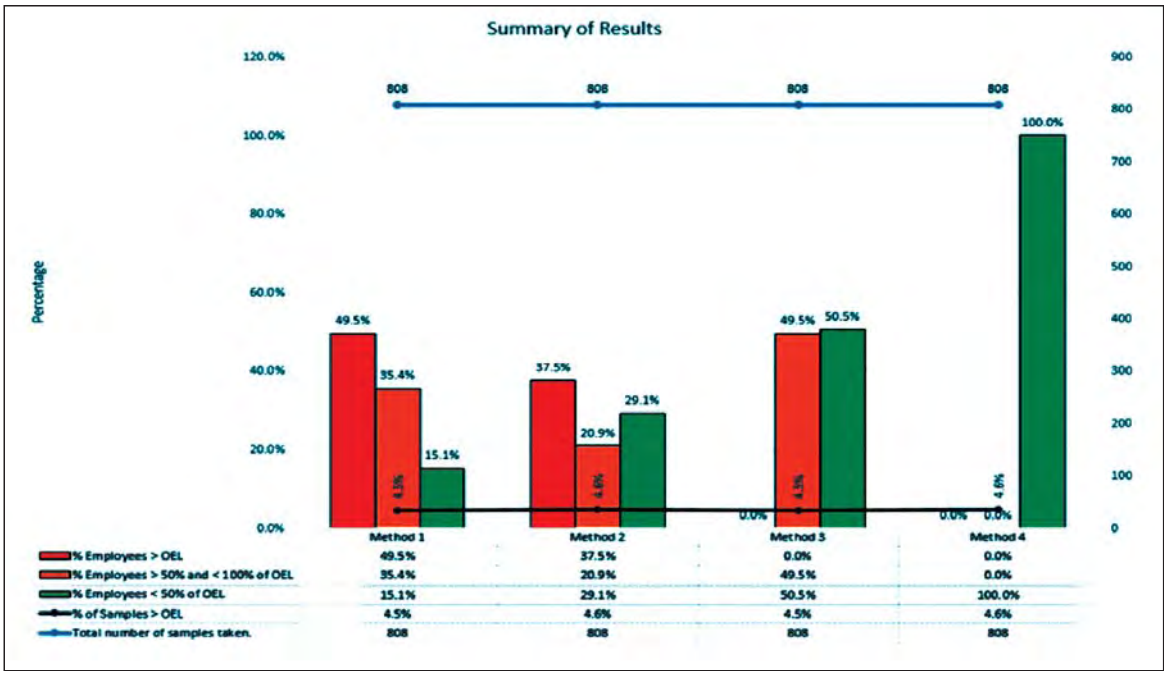

Figure 1: Summary of results for methods 1, 2, 3 and 4 for all HEGs combined

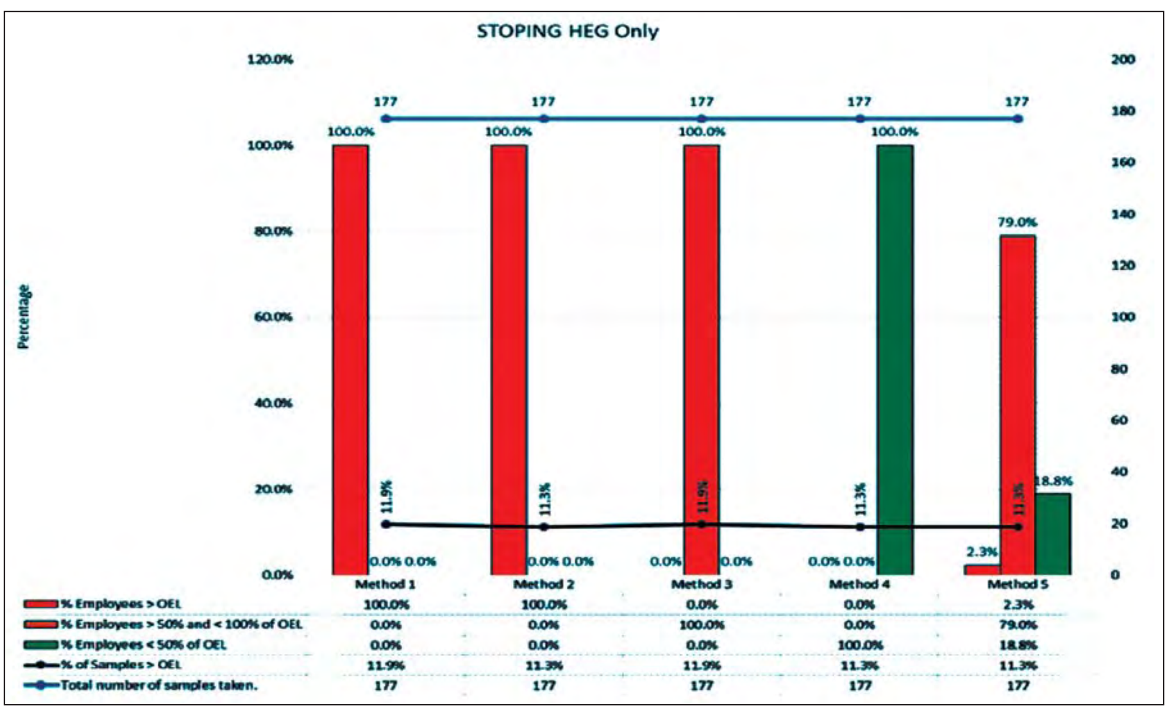

Figure 2: Summary of results for methods 1 to 5 for the STOPING HEG only

- Method 4 reports that 100% of the employees are exposed to concentrations between 10% and 50% of the OEL. However, 11.3% of the samples collected were greater than the OEL, resulting in "over-exposures" being "masked" from the reported data;
- However, it is suggested that Method 4 will be more accurate than Method 3, as Method 4 utilises the specific silica content analysis for each specific sample collected and not an assigned historical value, as is the case when employing Method 3.

• Use of the average/mean value as an indicator of exposure dose of the occupation could potentially be considered as an indicator of exposure dose, e.g.:

- Method 5 employs the practice of utilising the average/mean value to assign exposure dose per occupation to those employees that were not subjected to sampling during the quarter;
- Method 5 reports that:

  * 2.3% of the employees are exposed to concentrations greater than the OEL;

  * 79.0% of the employees are exposed to concentrations between 50% and 100% of the OEL; and

  * 18.8% of the employees are exposed to concentrations between 10% and 50% of the OEL
- However, 11.3% of the samples collected were greater than the OEL. This can occur when a specific occupation are exposed to high concentrations, but the total number of employees in the occupation represent a small number of employees when compared to the total number of employees in the HEG.

5. RECOMMENDATIONS

It is suspected that a number of different calculation methods (different from those discussed in this report) can still be explored.

It is the opinion of the authors of this paper that:

- The current method employed by the mine for "Milestone Reporting" purposes (Method 1) over-estimates employees exposure and therefore the exposure categories of such employees;
- The current practice of utilising historical silica quartz analysis results for dose allocation purposes (e.g. utilising 2013 silica analysis results for 2014 dose allocation purposes) should be discontinued with;
- The method, described as Method 5 in this re-port, would represent a more accurate method for "Milestone Reporting" purposes.

It is recommended that the content and finding of this report should be discussed on a national level to assist all stakeholders in developing a uniform method of results calculation for Leading Indicator reporting purposes.

6. ACKNOWLEDGEMENT

The authors would like to thank the Management of Sibanye Gold for permission to present this paper

Block cave mine ventilation optimisation techniques

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ABSTRACT

Block cave mining operations are widely used for the extraction of steep to vertical orebodies typically found in diamond and base metal deposits. Block caving permits large volumes of ore to be extracted relatively cheaply, increasing production and making lower grade ore bodies economical to mine. These mines are constructed in two main phases, i.e. capital development phase and full production phase.

When considering ventilation engineering planning, it is essential that the mine layout and plan are correctly understood for both phases. Depending on mining schedule and design, ventilation engineering challenges include airflow profiles that typically have peaks during capital development when the apex and/or undercut, extraction, haulage and ore transport levels require many development ends to be ventilated simultaneously.

Various mines were investigated for similarities and differences in mining layout, ore handling and ventilation engineering. The paper summarises ventilation and cooling techniques that were identified that can be employed to optimise block cave mines to ensure fit-for-purpose mine ventilation designs.

1. INTRODUCTION

Block caving is generally considered when open pit mines become exhausted and extension of the mining operations is required. Block caving is a well-established underground hard rock mining method that can be utilised for near-vertical orebodies.

A block cave is established a few hundred meters below the open pit operation and progressively collapses under its own weight and gravity (Figure 1).

Block caving ensures extraction of large volumes of ore at a reasonable cost and with the increased production rates; low-grade orebodies can now be more economical to mine.

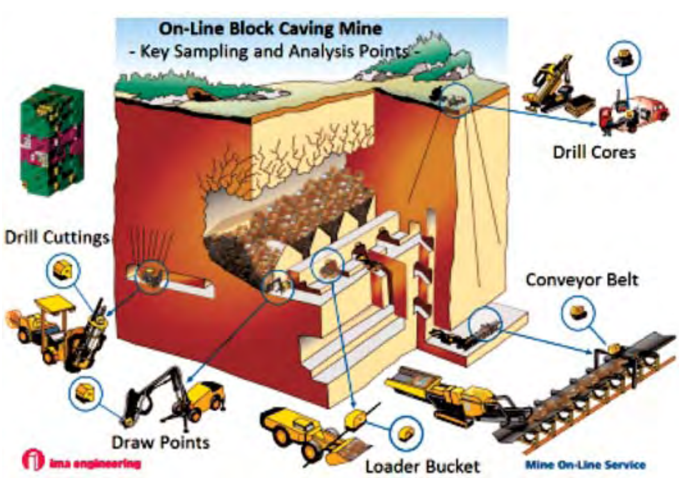

Figure 1. Block cave mining method

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Figure 2. Planned and operating block cave mines

This mining method is more efficient than any other underground mining method and is being considered more frequently worldwide.

Figure 2 shows major operating and planned block cave mines across the globe (some information from Hem and Caldwell (2012)).

The objective of this paper is to demonstrate the role that the ventilation fraternity plays in mine planning when employing optimisation techniques that will lead to a LEAN, fit-for-purpose mine design. The LEAN business principle relates to practices that aim to create more value with fewer resources just-in-time.

2. BLOCK CAVING INFRASTRUCTURE

Block caving initially involves a significant amount of capital development as the selected production footprint needs to be accessed from shafts and/or declines from surface.

Thereafter horizontal development starts on a number of levels that generally include an apex level, undercut level, production/extraction level, ore handling/haulage level and ventilation levels (Calizaya and Mutama 2004).

3. BLOCK CAVING PROCESS

During the capital development phase, the apex level is mainly utilised for inspection to ensure the 'w' shaped funnels between the undercut and apex level are connected (Figure 3).

On the undercut level parallel drifts/crosscuts are developed where drilling and blasting takes place to destress the cave. On the extraction level parallel crosscuts are developed from which draw-points and draw-bells are drilled and blasted. Another level is typically developed below the extraction level for ore transport, water pumping and return-ventilation (Duckworth et al. 2005). Haulage level and ventilation level airways are initially utilised to ensure that through-ventilation between the levels is achieved during the capital development phase.

During the capital development phase first production tons will be mined and a slow production ramp-up rate will be achieved. It is however only after the above horizontal infrastructure is

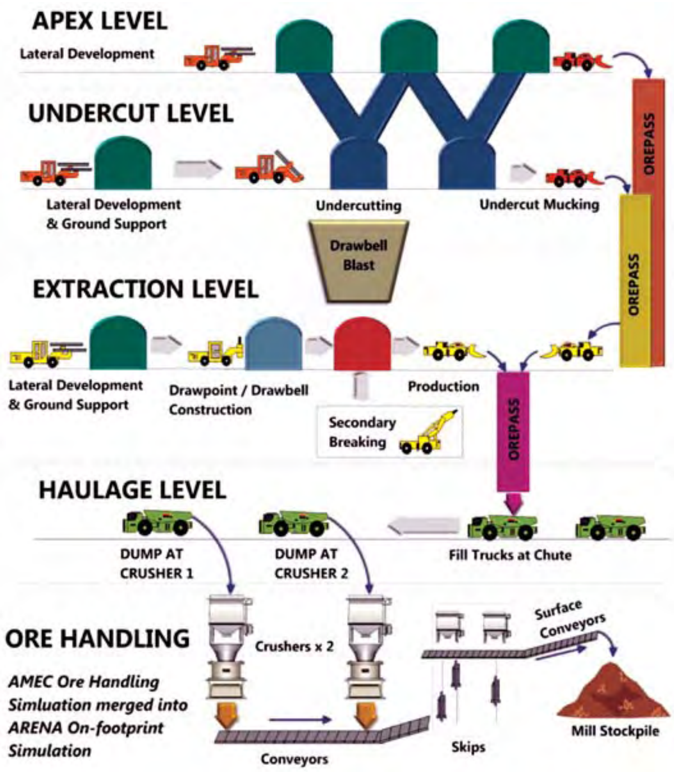

Figure 3. Block caving levels

established that production rates can ramp-up to steady state operations. The orebody will then be ready for blasting to start a continuous caving process. The cave will progressively collapse upward through the orebody and may in the long term cause areas on the surface to subside.

Figure 4 shows a typical block caving operation process where horizontal levels are developed and long-holes between the undercut and extraction levels are blasted which in turn enables the orebody to cave naturally (Mattox et al. 2014). Ore handling is by loaders at the extraction level that tip large rocks into crushers. Crushed rock is then tipped onto conveyor belts and is then either conveyed to surface or conveyed to production skips that hoist rock to surface. Some operations do not make use of crushers or conveyors but utilise trucks to transport rock to surface.

Secondary blasting at the drawpoints is intermittently required to blast large rocks that interfere with the caving process. The frequency of secondary blasting depends on the orebody fracturing capabilities and rock strength to ensure the cave keeps on fracturing naturally.

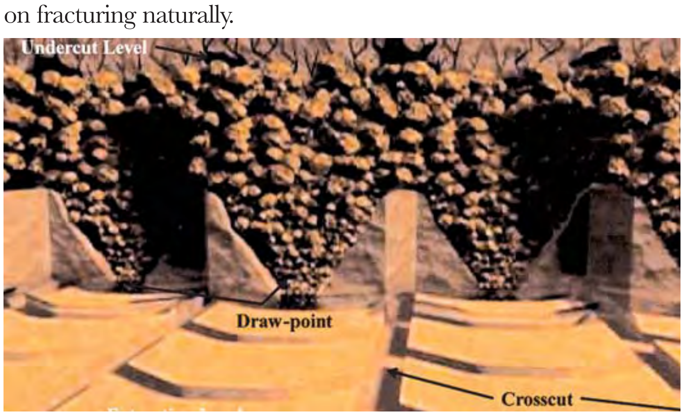

Figure 4. Block caving process

4. VENTILATION OPTIMISATION TECHNIQUES DURING CAPITAL DEVELOPMENT PHASE

During ventilation engineering planning, it is essential that the mine layout and plan are correctly understood for both the capital development and steady state production phases. Depending on the mining schedule and design, ventilation engineering challenges include high temperatures and airflow profiles that typically have peaks during capital development when the apex and/or undercut, production, ventilation and ore transport levels require many development ends to be ventilated simultaneously. There are a number of aspects that need to be included in the planning and these are discussed below.

4.1. Develop critical path to achieve through-ventilation

The critical path is the shortest path that can be mined to ensure that through-ventilation is achieved on the extraction level. Through-ventilation will enable the mine to achieve multi-end development and even multi-blast or fixed-time multi-blasting opportunities.

During this phase, the mine planning team, development schedule team and ventilation planning team need to be perfectly aligned to ensure that each department's key milestones are met. It is only when through-ventilation is established that adequate development can commence.

4.2. Capital development ventilation-on-demand

Ventilation-on-demand is an engineering control system that stops or reduces air supply to an inactive end and redirects this air to another active mining location. This reduces the overall air flow that needs to be delivered from surface. Ventilation-on-demand during the development phase can only be achieved when the mining and ventilation operations teams plan mining activities together.

In practice, this is typically achieved using force-ventilation tubing in development ends that will be tied with ropes to control the air distribution.

Alternatively, the system can be automated with open/close ventilation valves by either activating a local on/off switch or with the use of Programmable Logic Controllers (PLCs) via a Supervisory Control and Data Acquisition (SCADA) system. In some cases automated valves are used when multiple crosscuts on the undercut and extraction levels are in development and production to ensure loading crosscuts are ventilated appropriately.

4.3. Capital development cooling

Development ends are typically hot environments. The heat load is mainly caused by fresh hot broken rock, diesel loaders and/or trucks, ground water and fan heat. The overall mine cooling system needs to be carefully planned to ensure that cooling is available during all critical phases of the life-of-mine.

During the capital development phase an opportunity exists to cool the ends using localised cooling coil cars served by small temporary refrigeration machines providing chilled water. Spot cooling is an ideal solution for short-term use while larger permanent refrigeration machines with long lead-times are procured. However, spot cooling systems are inefficient and difficult to maintain over prolonged periods, and if the temporary refrigeration machines are located underground, they require access to return airways to enable heat from the refrigeration machine to be rejected.

Figure 5. Bank of cooling coils

4.4. Thermal design criteria

Thermal design criteria are specified to ensure acceptable working conditions and efficient operation during the life-of-mine. Capital development is the worst period in a block cave mine's life in terms of pressures on the thermal environment. During this period extensive development and production ramp-up take place but the required infrastructure (such as refrigeration equipment and main fans) has not yet been fully established.

To assist with the setting up of the mine's infrastructure and to enable steady state production to be established sooner, owners/operators can consider a temporary relaxation of underground reject temperature criteria. Application and risk management procedures have to be drafted and presented to the regulatory authorities for approval. The risks associated with any temporary relaxation need to be acknowledged and can include heat stress and heat stroke incidents. These risks need to be included in a heat stress management plan.

4.5. Heat stress management

HSM involves heat tolerance screening, work-rest cycles, nutrition and hydration regimes, medical surveillance, acclimatisation, etc. Heat stress management (HSM) is generally a feature in hot deep mines where auto-compression, high rock geothermal properties, high production rates, etc. are encountered.

HSM enables the mining operation to operate in high reject temperatures (typically above 27.5°Cwb) and needs to be carefully monitored, measured and recorded. As part of a HSM plan, shift cycles should also be assessed to ensure that safe and healthy practices are employed for both short and long-term operations (Kielblock 1992). Functional work assessment could be implemented in addition to the above to ensure overall physical work fitness.

4.6. Economic airway and vertical hole design

Capital development includes the development of vertical fresh air and return air passes between surface and the mining footprint. These vertical holes are then connected to the block cave by means of horizontal airways.

Economic velocities of the vertical holes and the horizontal airways need be determined to ensure that capital/development costs and operating cost provide a positive net present value.

5. VENTILATION OPTIMISATION TECHNIQUES DURING STEADY STATE PRODUCTION

During steady state production all capital development activities are completed and the cave naturally yields under gravity.

In some instances secondary breaking is required to blast large rocks to enhance the natural caving process.

This section investigates various approaches that can be followed in ventilation engineering, ore handling and mining layout.

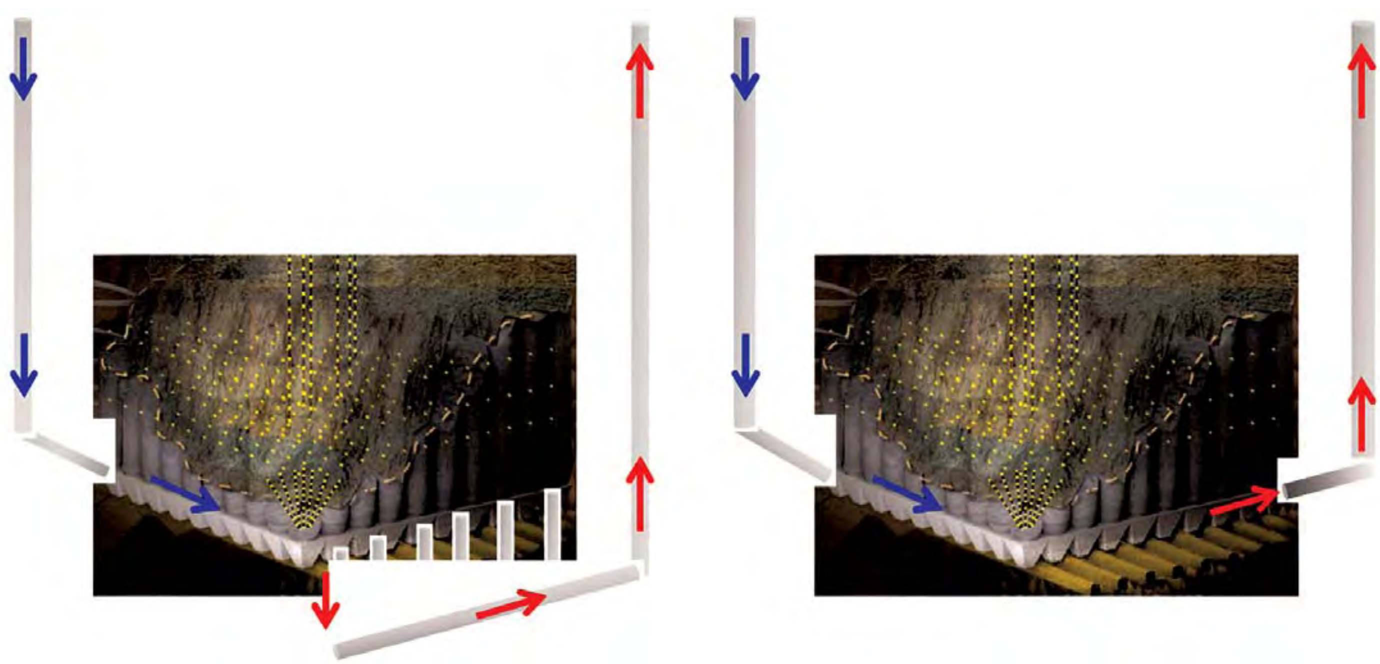

Figure 6. Ventilation level vent layout

5.1. Vent distribution

Figure indicated that a block cave mine typically consists of five levels; apex, undercut, extraction, haulage and ore handling levels. Apex and undercut levels are caved during steady state production and thus three main levels remain that need to be ventilated continuously. In some instances the apex and undercut levels will be ventilated for longer with some air to ensure that mining personnel can inspect holings from the extraction level.

The main ventilated levels are complimented with a ventilation level that is dedicated to warm dusty exhaust air. The haulage level is sometimes constructed adjacent to the extraction level and both these levels are generally in fresh air.

Ventilation of the cave is generally from one side of the mining footprint to the other side of the mine through parallel crosscut airways. Air can either be directed to a ventilation level below the extraction level (Figure 6A) or the ventilation level can be situated on the same level if the mining footprint allows (Figure 6B). The latter will result in reduced development and no vertical return air passes will be constructed.

Another ventilation distribution concept that needs to be considered is whether the mine will be ventilated towards the crushers (i.e. in series with the crosscuts, Figure 7) or away from the crushers (i.e. in parallel with the crosscuts, Figure 8).

Ventilation of the crushers in series with the crosscuts will result in reduced total required air quantity and lower power consumption at the main fans.

The main disadvantage of this system is that personnel will work in warm dusty exhaust air and crusher equipment life is reduced.

Ventilation of the crushers in parallel with the crosscuts will result in increased air quantity and power consumption at the main fans as the crushers will be ventilated as a separate ventilation district that is directly connected to the return airway.

5.2. Regulators

When directing fresh air through parallel crosscuts, air control and balancing may be more difficult than anticipated as the fresh air want to take the shortest route through the first few crosscuts.

To balance air-flow quantities to each loading crosscut, regulators need to be carefully planned and placed. These can be managed by positioning and regulating crosscut airflow at Return Air Passes (RAPs). This can be achieved by using see-through strip brattices at the return ends of crosscuts.

Some mine designs include one RAP per crosscut and other mines have one RAP for a number of crosscuts which reduces capital cost but results in more challenging control systems. Strategic placement of RAPs can reduce worker exposure to pollutants and improve ventilation control. This reduces health and safety risks and ensures maximum productivity.

5.3. Re-use ventilation system

Re-use air systems underground facilitates constant air quantity drawn from surface. When air is reused it is generally recooled and reconditioned in horizontal bulk air cooling spray chambers.

Adequate filtering of dusty reused air is vital in the control of dust concentrations in these schemes (Booth-Jones et al. 1984).

Block cave mine layouts have the opportunity for reconditioning and reuse of ventilation air (Marx et al. 2010). A reuse system is fairly easily possible with the reuse of air from the conveyor belt and crushers. Filtering of the dust can be achieved in water spray chamber scrubber that reconditions air for reuse on the extraction level.

Installing reuse systems not only reduces the overall air quantity but also provides an opportunity for cooling at the reuse scrubbers. Lastly, the over-all power consumption will be reduced at the main fans.

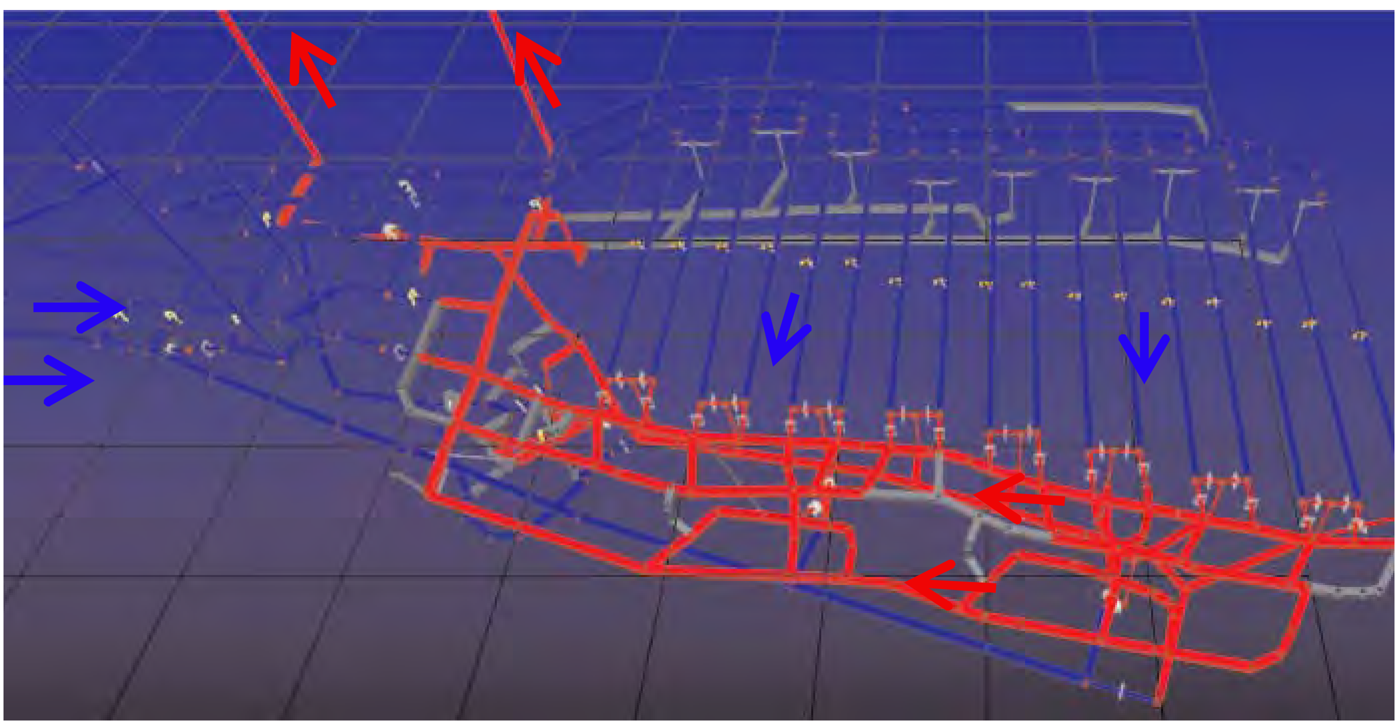

Figure 7. Crushers and crosscuts ventilated in series

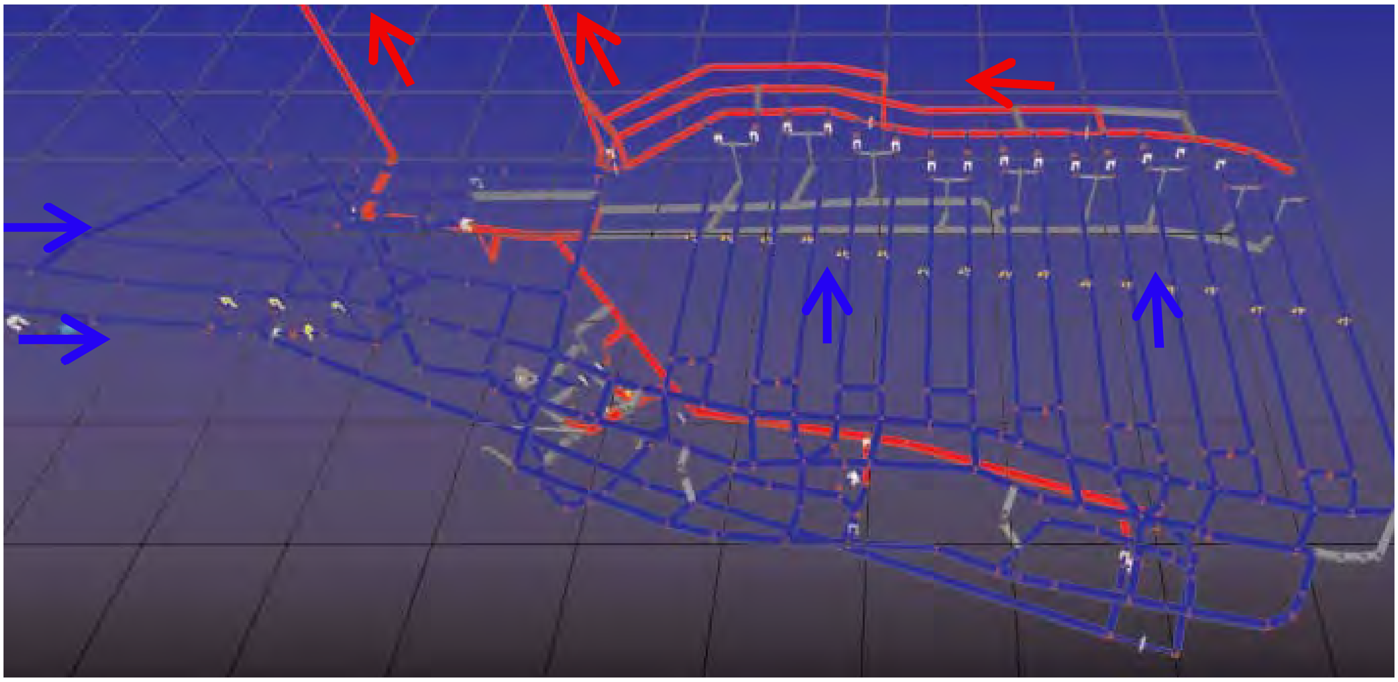

Figure 8. Crushers and crosscuts ventilated in parallel

5.4. Crusher ventilation system

Crushers are used to break large rocks from the cave into smaller manageable sizes that are conveyed or hoisted from underground to surface. Crusher layout and designs need to ensure uninterrupted tipping and minimal pollutant exposure to personnel and equipment reducing health risk and maintenance requirements (Wallace et al. 2014). As discussed above, in many mines crushers are ventilated with fresh air that in turn is ventilated directly to return.

More recently mines are considering LEAN approaches for the overall mine designs and crushers are ventilated with used air from the extraction level. In these cases air at the main fans and operating costs are reduced. Visibility may however be a concern but filtering engineering controls can be considered in these cases.

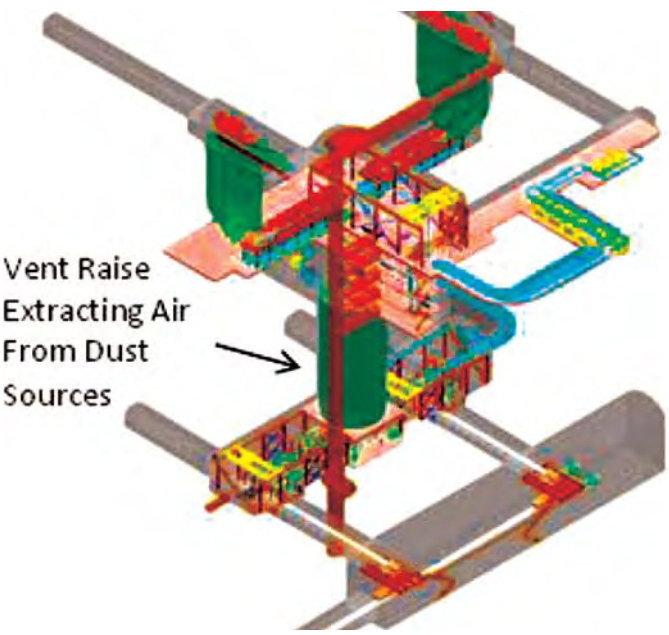

Figure 9. Crusher dust extraction system (Wallace et al. 2012)

Crusher ventilation systems are further improved by engineering control systems. Control systems typically include bratticing, air curtains, auxiliary fans and ducts, etc. A properly designed crusher ventilation system ensures effective capturing of dust generated by tipping and crushing operations and removes pollutants, including heat, directly to a return airway. Figure 9 shows a crusher dust extraction system.

5.5. Steady state cooling

Refrigeration systems are generally required for block cave operations due to their depth below surface, heat load contributed by mechanised vehicles and large volumes of broken rock. Correct positioning of cooling equipment is essential to ensure efficient, practical cooling with minimal capital and operating cost.

Block cave layouts generally create the opportunity for underground refrigeration systems to be positioned such that short pumping distances are required for both evaporator and condenser circuits. This is achieved due to the unique layout of block caves where the main intake and return airways are located near to each other. Air cooler locations need to be carefully considered to avoid over-cooling of intakes and to deliver the desired air quality near the intake to the extraction level (Marx et al. 2012).

5.6. Services ventilation

Due to the layout typical of block cave mines, crushers, workshops, pump stations and other services can be ventilated direct to return. This opportunity reduces the risk of exposure to pollutants, including smoke in the case of a fire. It does, however, increase the overall air requirement of the mine.

5.7. Ventilation-on-demand

Ventilation-on-demand (VOD) strategies are possible in block cave mines due to the parallel layout of loading crosscuts and that not all crosscuts are operational all the time. VOD systems consist of crosscut regulators (typically doors), variable speed fans, vehicle tracking, etc. coupled with monitoring and control equipment. The equipment ensures that the minimum required airflow for heat and pollutant dilution is achieved in 'closed' cross-cuts and the required high flow is achieved for diesel and heat pollution in 'open' cross-cuts. VOD can reduce the overall air requirement of the mine and with well-managed systems could be of great value.

Some mines install VOD regulators on the fresh air side of the cave and others on the return air side or both. The location of these regulators depends on which side loaders access the cave and then tip into crushers.

When VOD regulators are installed on the return airway side, frequent maintenance of the control system will be required due to pollutants such as dust, diesel exhaust, heat and blast fumes from secondary blasting.

Well-managed VOD systems are beneficial in that they reduce the total air quantity required from surface since only the loading and serviced crosscuts are ventilated and the rest remain closed. The consequence of less air is reduced power consumption at the main fans.

However, these systems can only work when underground daily planning and cave draw control is effective and the work force applies the operational procedures to VOD regulators (i.e. open for loaders and closed for other work).

5.8. Loader equipment selection

Diesel LHDs not only generate exhaust gas but produce up to three times the amount of heat generated by electrical LHDs for the same work output. Although electrical LHDs have the challenge of trailing cables to be considered, there is a saving in overall air quantity and cooling required. Battery operated LHDs could also be considered.

6. CONCLUSION

The ventilation department can be very valuable during mine planning when the mining method, sequence of mining and mining process is understood. The ventilation planners need to identify critical phases over the life-of-mine to ensure that short and long-term ventilation requirements are met.

Optimisation techniques that can be employed at block cave mines include optimal appropriate selection of design criteria and accurate application of ventilation-on-demand and heat stress management plans. The ventilation distribution and ventilation layout are key in determining the direction in which air will flow and to determine the total air quantity. The best optimised selection can have a major impact on the business case.

Reuse ventilation is an important ventilation technique that reduces the total air requirement at the main fans. Reuse systems are often combined with horizontal bulk air spray chambers that provide scrubbing and cooling capabilities.

When refrigeration is mandatory to achieve thermal design conditions, careful consideration is required when deciding on a surface and/or underground refrigeration system. Constructing air coolers near the localised source of heat i.e. the block cave will ensure best positional efficiency.

The paper has summarised ventilation techniques that were identified to optimise block cave mines for fit-for-purpose LEAN designs when an already economical mining method is selected.

The ventilation techniques are safe, use state-of-the-art technologies and result in favourable economies of scale. It can therefore be concluded that the ventilation fraternity is and will continue to play a relevant part in mine design planning.

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Operational advantages of mobile refrigeration

using a closed loop heat rejection configuration

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ABSTRACT

The operational advantages of localised cooling, in particular moving the cooling source as close as possible to the area where cooling is required, has been investigated by different authors over a number of years. A notable advantage is the energy efficiency potential associated with cooling locally, mainly due to the savings obtained from a reduction in cooling water and the reduced dewatering pumping power of water back to surface. The challenges with supplying water from the cooling source to the remote areas where the cooling is required led to the development of mobile refrigeration units capable of providing localised cooling. The developed mobile refrigeration air cooling unit (ACU) alleviates some of these problems by increasing the amount of cooling that can be done per litre of water available. These result in more effective and energy efficient cooling, but these units do however still require cooling water to operate. This paper looks into the possible operational advantages, including energy efficiency and reliability, when the condenser circuit of the ACU is not connected to the main cooling water supply, but rather connected in a closed loop heat rejection configuration with the return airway (RAW).

1. INTRODUCTION

Engineers working in the mining industry in South Africa are continuously looking for ways to improve the mining operations with regards to energy usage, reliability, safety and cost. In labour intensive mining operations it is impossible to improve the overall mine performance without looking at the performance of the ventilation and cooling systems. Special emphasis is placed on the energy efficiency of the ventilation and cooling systems as the margins of profitability of mines are under pressure as the mining distance increases both vertically and horizontally.

Ramsden et al. (2001) states that several South African gold mines are examining the feasibility of extending workings to below 4000m. "Since 2010, the AngloGold Ashanti Technology & Innovation Consortium (ATIC), established by AngloGold Ashanti, has been looking for ways to leverage established technology in new ways, in an effort to not only extract additional gold from current depths of around 4000m, but also to realise its long-term vision to reach depths of 5000m and beyond." (AngloGold Ashanti, 2013). The increased travel distance for air to get from the shaft inlet to the working areas means larger heat gains and therefore more cooling required. This in turn means that the cost to mine in remote areas increases due to the increase in cooling demand and the increase in energy usage to supply cooling water to the areas and return it back to surface. The costs associated with the installation of infrastructure to enable mining in remote areas also make it less attractive to mine in these areas.

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2. COOLING METHODS

Infrastructure for the cooling of remote underground working areas usually consists of a cooling source (usually a fridge plant or ice plant), a chilled water reticulation system (consisting of storage dams, pipes, pumps, etc.), bulk air coolers (BACs) and localised cooling units.

2.1. Localised cooling units

Localised cooling units, as the name indicates, are used to cool air near the working areas. These units usually have a lower cooling capacity than larger BACs and can be moved when cooling is required elsewhere as the mining progresses.

2.1.1. Conventional cooling cars

Cooling cars (CC) are air-to-water heat exchangers mounted in a chassis on rolling stock, which enables them to be moved and installed in different areas of the mine. These units are installed near the working areas and are small in size to ensure that the units can be moved with relative ease. CCs have an inlet and outlet water connection to which the chilled water supply and return piping can be connected. A fan is mounted onto the CC to force air over the finned tube cooling coil (see Figure 2-1).

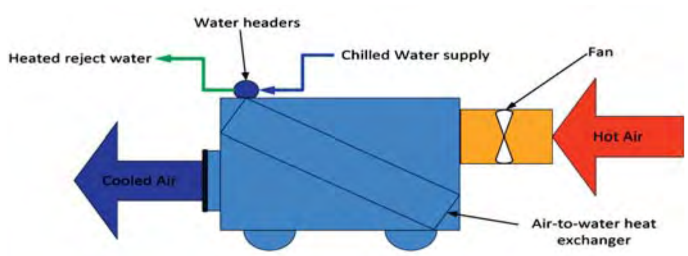

Figure 2-1. Illustration of a cooling car layout indicating water and air flow paths

The cooling capacity of these units are directly dependent on four inputs namely the air mass flow rate, the water mass flow rate, air temperature (dry-bulb and wet-bulb) and the water temperature.

2.1.2. Mobile refrigeration units

The Air Cooling Unit (ACU) is a mobile refrigeration unit, which consists of a vapour compression system in a chassis mounted on rolling stock, which means that the cooling source can be moved closer to the working areas. The feasibility and energy efficiency of these cooling units was first investigated by van Eldik (2007).

The ACU MKI was developed capable of producing approximately 100 kW of cooling.

The unit was deemed a more energy efficient alternative to using CCs because the unit could utilise less water, which greatly reduces the total electrical power consumption to cool deep level mines.

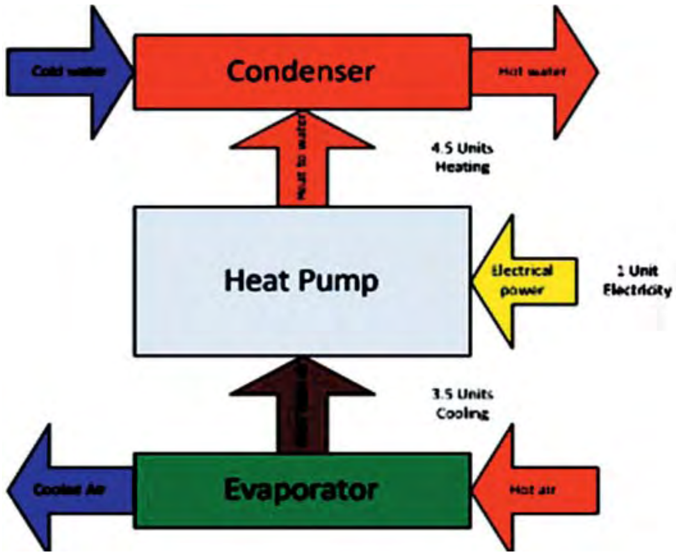

Figure 2-2. Typical vapour compression cycle energy balance

This saving is obtained because the ACU can utilise water as heat sink with a supply temperature of up to 40°C and still deliver effective cooling. Because of the vapour compression cycle used the ACU can heat water to much higher temperatures than with a conventional cooling car.

The larger temperature difference (ΔT) obtained by the unit reduces the amount of water required and therefore reduces the pumping costs. The ACU MKI was followed by the development of the ACU MKII capable of producing 250 kW of cooling.

Greyling (2008) investigated the energy efficiency potential of the ACU MKII for the use in the planned deepening of AngloGold Ashanti's Mponeng gold mine in the Carbon Leader and Below 120L VCR projects.

3. CLOSED LOOP ACU CONCEPT

The energy efficiency potential of the ACU has been investigated on a number of occasions and it has been found that the ACU can reduce the energy consumption of localised cooling applications when compared to conventional cooling cars. The unit does however still require the same infrastructure as the cooling cars to deliver water to it and then the infrastructure to pump water back to surface. The potential therefore exists to reduce the energy consumption by eliminating the need for a constant supply of cooling water for air cooling purposes altogether.

The closed loop ACU concept consists of the following:

- One ACU MKII cooling unit.
- Three 500 kW nominal cooling cars.
- Three 22 kW axial flow auxiliary mine fans mounted on the cooling cars.
- A circulation water pump.
- Piping for closed loop circulation of the water.

The philosophy is to transfer the heat in the water from the ACU condenser to the reject air in the mine 37 return airway (RAW). For this, the condenser circuit of the ACU is connected in a closed loop configuration with three conventional 500 kW cooling cars which is used to reject the heat to the air in the RAW. The water is then circulated back to the ACU condenser circuit using the water pump to complete the cycle (Figure 3-1). The system is dependent on an accessible return airway to be feasible, where the rejected

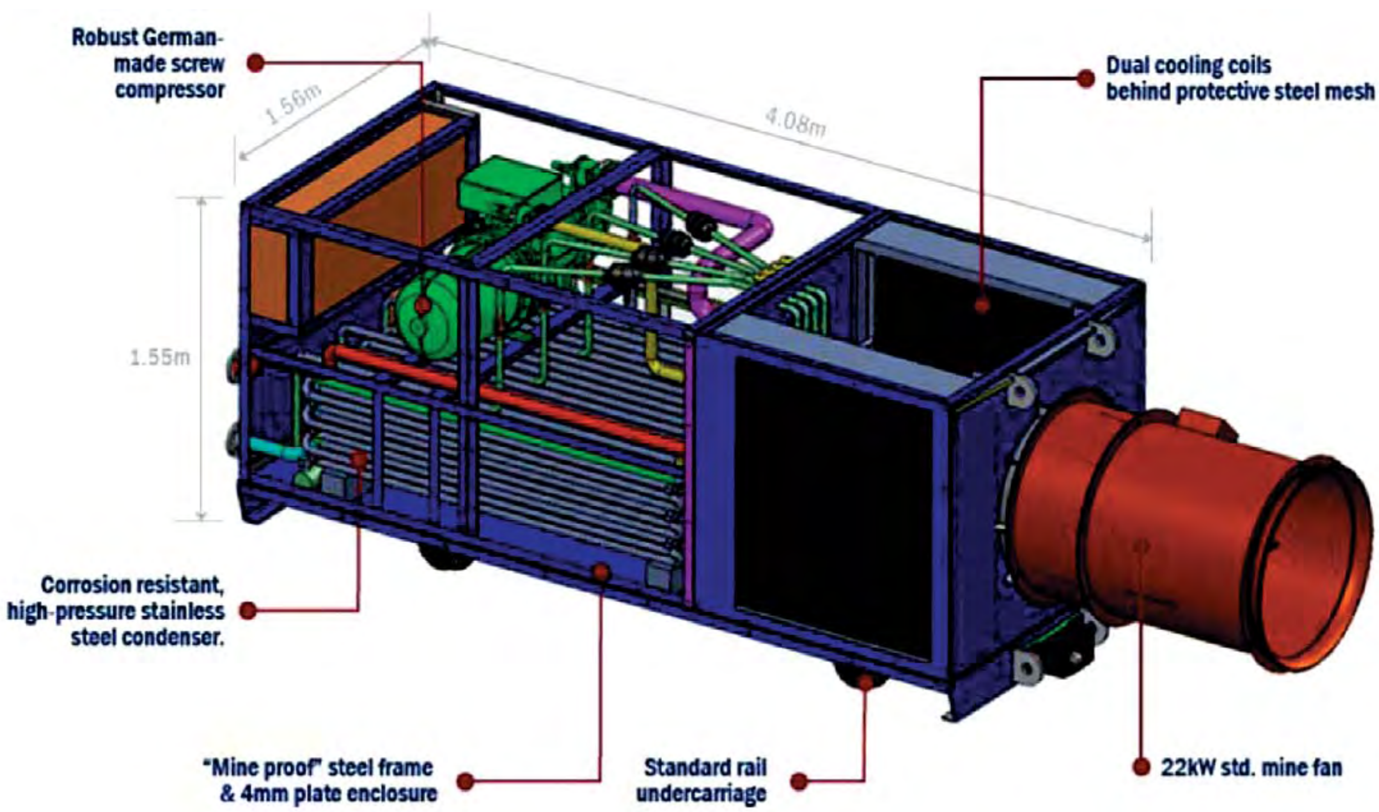

Figure 2-3. Illustration of the ACU MKII component layout

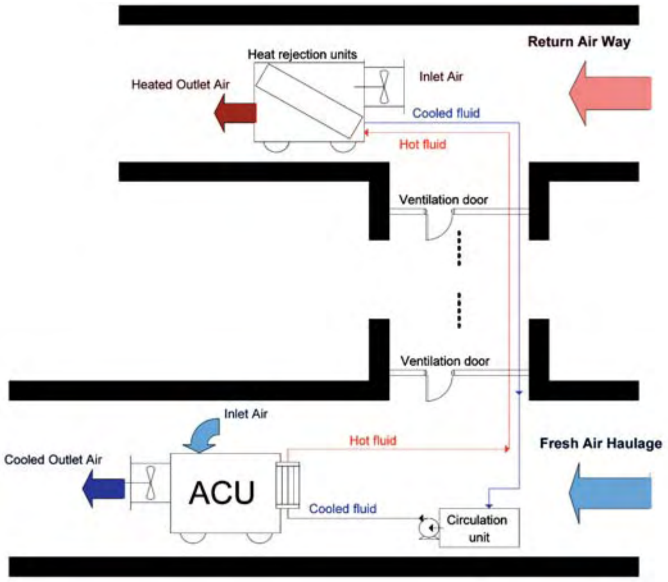

Figure 3-1. Closed loop ACU configuration

heat will not negatively affect any workings, or increase temperatures above legal limits for persons in the areas.

4. ENERGY EFFICIENCY INVESTIGATION

To investigate the energy efficiency potential of the closed loop ACU configuration, a simulation model was created to simulate the following:

- Cooling at different vertical depths using a conventional 500 kW cooling car.
- Cooling at different vertical depths using a conventional ACU MKII cooling configuration.
- Cooling at different vertical depths using an ACU MKII connected in a closed loop heat rejection configuration as described above.

Flownex SE® was used to create the models for the individual components (cooling equipment, water reticulation, airflow paths, etc.) as well as the total integrate mine model.

The energy efficiency of the three cooling strategies was evaluated based on the total cooling per kW electrical power required to do the cooling.

4.1. Simulation model

A model mine was simulated using real mine data, but a hypothetical level was added to simulate at a depth of 4000m. The three different cooling applications were then plugged into the mine model at different depths to evaluate the different cooling performances.

The first cooling application simulation was the localised cooling at different depths using CCs connected to the chilled water reticulation network as illustrated in Figure 4-1. The conventional ACU configuration is modeled similar to the CC with the ACU being connected to the chilled water network.

The water is heated in the ACU condenser circuit and rejected through the mine water reticulation system back to surface where it is recooled first by a precooling tower and then the surface fridge plants.

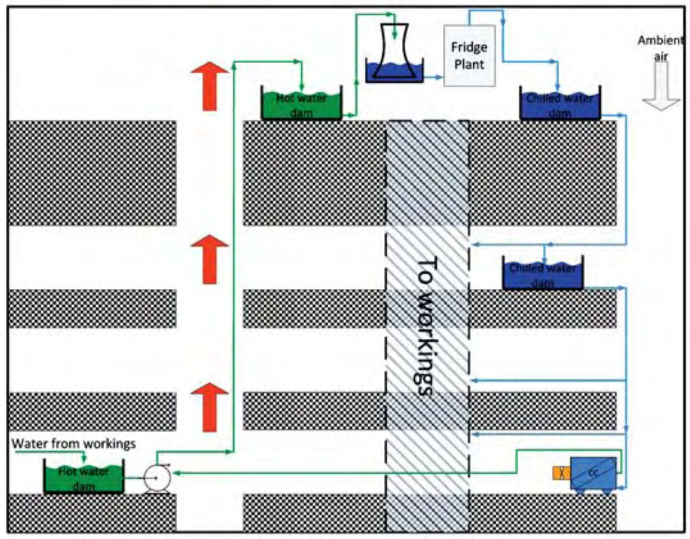

Figure 4-1. Cooling car connected to chilled water diagram

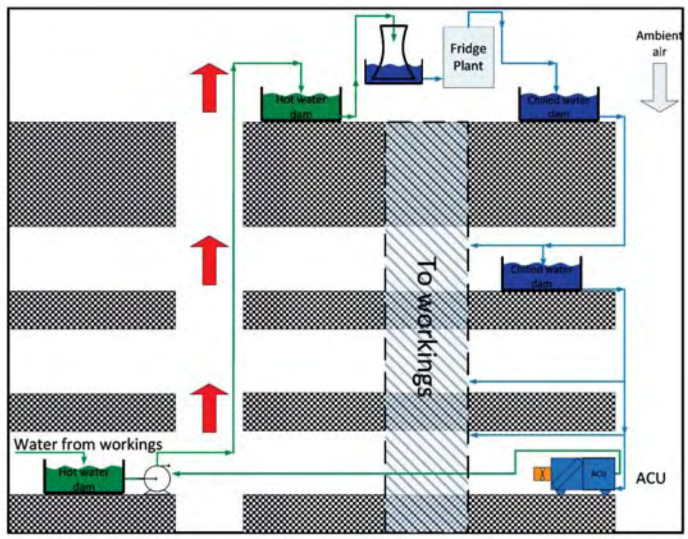

Figure 4-2. ACU connected to chilled water diagram

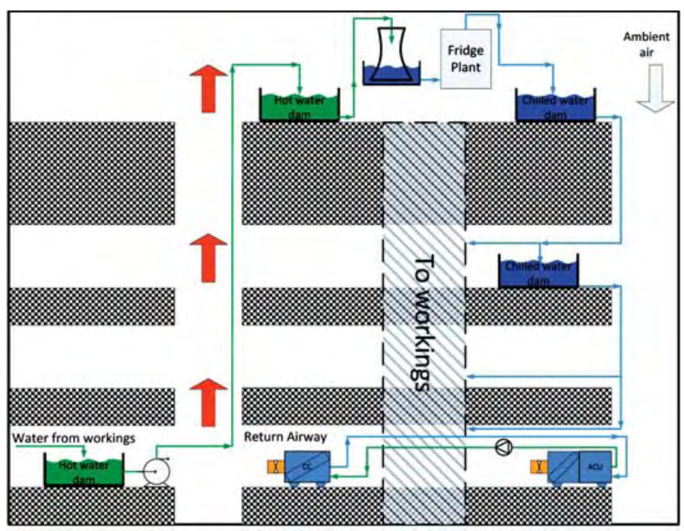

Figure 4-3. ACU with closed loop condenser heat rejection diagram

Table 4-1. Simulation results summary

	Units	CCs	ACU	ACU CL	CCs	ACU	ACU CL	CCs	ACU	ACU CL	CCs	ACU	ACU CL
Depth (model)	m		2472.00			3018.00			3312.00			4000.00	
Air inlet DB	°C		29.32			31.29			32.35			35.13	
Air inlet WB	°C		23.74			25.90			27.04			29.64	
RAW inlet DB	°C		36.00			36.00			36.00			36.00	
RAW inlet WB	°C		32.70			32.77			32.76			32.85	
ACU/CC air flow rate	m³/s	14.11	9.52	9.52	14.12	9.52	9.52	14.13	9.52	9.52	14.14	9.52	9.52
Heat rejection CC air flow rate (per coil)	m³/s	-	-	9.87	-	-	9.88	-	-	9.88	-	-	9.89
Cooling	kW	233.81	306.54	44.65	254.46	306.54	43.92	265.56	306.54	43.56	294.33	306.54	42.83
Pump electrical power	kW	388.38	99.46	2.34	474.22	127.39	1.92	520.38	143.70	1.75	628.51	185.90	1.45
Fridge plant electrical power	kW	120.58	30.88	0.00	120.59	32.40	0.00	120.59	33.30	0.00	120.59	35.67	0.00
Total fan electrical power	kW	37.27	20.75	80.01	39.30	21.89	84.90	40.43	22.53	87.65	43.15	24.07	94.35
Compressor power	kW	0.00	66.75	79.72	0.00	66.75	79.72	0.00	66.75	79.72	0.00	66.75	79.72
Total electrical power	kW	546.23	217.84	162.08	634.11	248.43	166.54	681.40	266.27	169.12	792.25	312.38	175.53
Electrical power per cooling	kWe/kWc	2.47	0.74	0.68	2.61	0.84	0.69	2.68	0.90	0.71	2.79	1.05	0.73
Energy saving per kW cooling	%	0.00%	70.15%	72.58%	0.00%	67.94%	73.39%	0.00%	66.57%	73.67%	0.00%	62.49%	73.80%

The closed loop ACU configuration is modeled with the ACU in the supply air stream and the three CCs in the RAW to reject the heat from the ACU condenser coil with a water pump for circulation.

The closed loop ACU system component configuration is designed taking into account possible fouling on the air side when sizing the capacity of the heat rejection coils.

Flownex® heat exchanger components were used to model the performance of a Manos Zeus cooling coil based on the manufacturer's performance charts.

The total electrical power consumption of each cooling strategy was calculated based on the following:

- Fridge plant power input required to chill water for use in the cooling equipment.
- Fans mounted on the cooling cars and ACUs.
- Pumps used to return water to surface or to circulate the closed loop water.
- Compressor power of the ACU.

4.2. Energy efficiency investigation results

Results were generated from the simulations at different depths including the expected temperatures of the air, water temperatures, cooling duties, etc.

To ensure that the different cooling strategies can be compared with one another special focus is placed on the electrical power consumption of the strategies per unit cooling delivered.

This was done for different depths below surface and a summary of the results can be seen in Table 4-1.

From the simulation results, it can be seen that there are large energy savings potential when using either the ACU or the ACU closed loop (ACU CL) configuration compared to the conventional CC application.

The results show a savings potential of 68.5% for the conventional ACU configuration and 71% for the ACU CL configuration at a depth of 2472m below surface.

The energy saving potential of the ACU CL configuration increases to 73.8% at a depth of 4000m, while the conventional ACU decreases to 62.5%. From the results it can also be seen that the closed loop ACU configuration has the potential to save an additional 2.5% at 2472m and 11.3% at a depth of 4000m more than the stand alone ACU.

5. ECONOMIC EVALUATION

Based on the simulation results obtained above, an economic analysis was done to investigate the economic feasibility of the closed loop ACU configuration.

The capital costs of one installation of each of these cooling strategies were calculated as well as the operational cost based on the active energy charge (based on 2016 Megaflex tariffs) to deliver cooling with the different strategies. A five year cost forecast was done to compare the cost of the cooling over a five year period taking into account an 8% yearly electricity increase. The time value of money is not taken into account in this evaluation.

Sibisi (2014) estimated the cost of installing one kilowatt of cooling infrastructure (fridge plants and all required infrastructure) to be between R8,000 and R10,000 in 2014. Du Plessis et al. (2014) proposed the installation of underground fridge plants at Sibanye's Beatrix 4#. The capital costs calculated in their study showed a cost of R10,222 per kilowatt cooling for underground fridge plants. The largest influencing factor on the cost of surface fridge plants and infrastructure in the past 2 years was the decreased value of the South African rand compared to the United States (US) dollar. The exchange rate was R10.49 to $1.00 on 1 January 2014 compared to the rate in October 2016 of R13.86 to $1.00, which means a total increase of 32.16% from 1 January 2014 to 27 October 2016. Using R8000/kWc from Sibisi (2014) as the base rate in 2014 and incorporating the 32.16% increase, the cost of cooling infrastructure per installed kilowatt was then calculated as R10,572.

The capital cost of the cooling cars and the conventional ACU strategies increased with an increase of depth due to the need for more chilled water and therefore larger surface fridge plant capacity. This was taken into account in the capital expenditure calculations.

From Figures 5-1 and 5-2, it can be seen that the ACU CL becomes an especially attractive option if central cooling infrastructure still needs to be installed, even more so with an increase in vertical depth of mining. This also makes the closed loop ACU configuration more attractive for new mines that do not yet have the cooling infrastructure installed and would like to postpone large capital expenditure.

It can also be a solution for marginal profit mines that need the cooling to open up working areas, but do not have the capital available to install large cooling plants.

6. OPERATIONAL ADVANTAGES

There are a number of operational advantages of having small localised cooling units with a closed loop configuration which can be moved with relative ease without requiring additional cooling from surface.

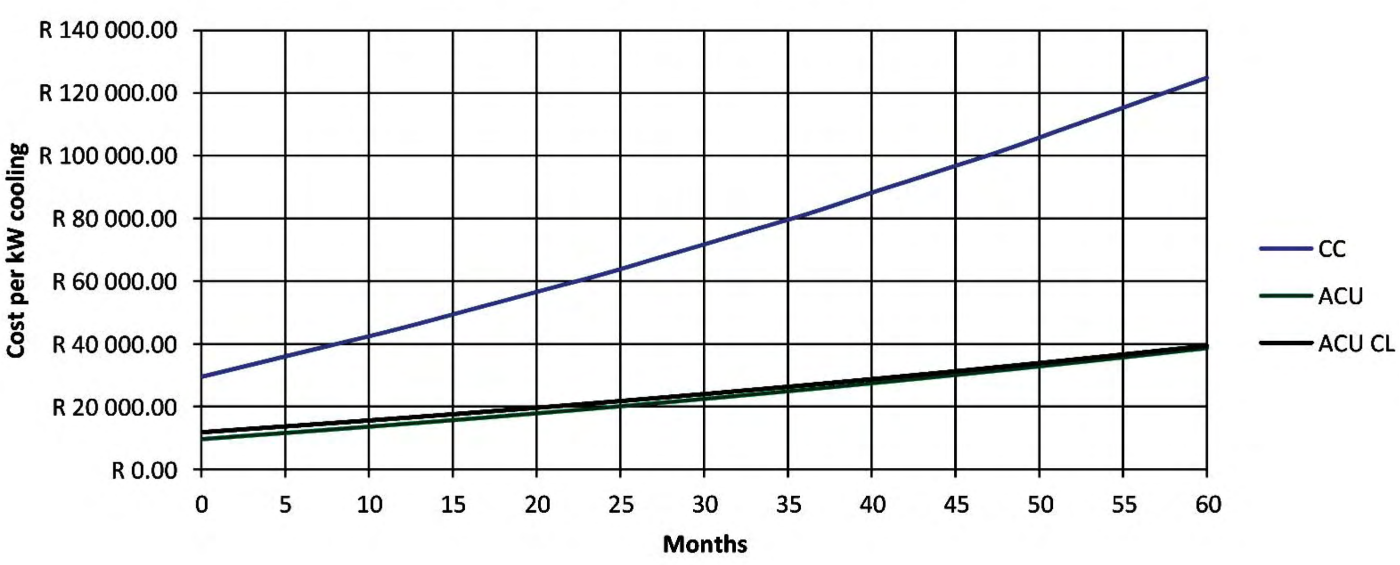

Figure 5-1. 5 Year total cost to mine prediction per kW cooling at 2472m depth below surface

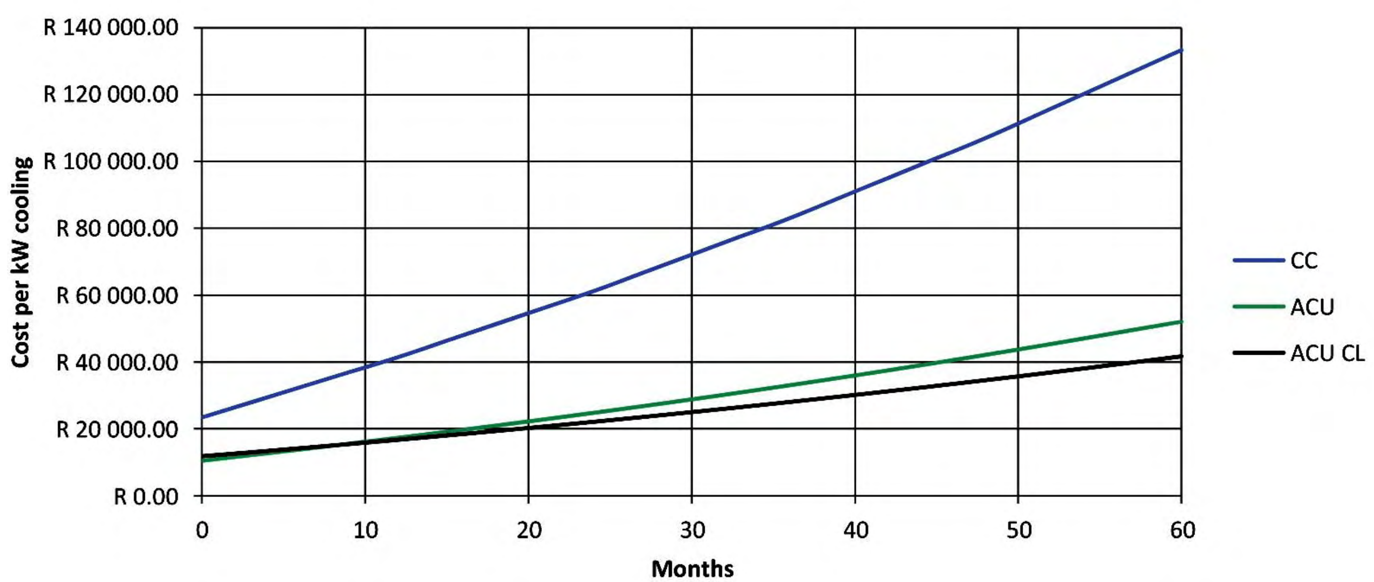

Figure 5-2. 5 Year total cost to mine prediction per kW cooling at 4000m depth below surface

6.1. Relatively small and easy to install

The closed loop ACU configuration installation consists of the following equipment:

- ACU MKII.
- 3 x CCs for heat rejection.
- Piping and fittings between the ACU and the RAW CCs.
- Circulation water pump.
- Fans mounted on heat rejection CCs and the ACU.

It can therefore be installed with relative ease and much quicker than the required infrastructure of larger cooling plants.

These units can be installed as a mine develops, postponing the installation of large cooling plants and infrastructure and the installation time and capital expenditure associated with it.

6.2. Cooling on demand

The closed loop ACU configuration allows for immediate cooling on demand of specific areas without the need for cooling from another source such as surface or underground fridge plants. This means that the areas served by closed loop ACUs are independent of the larger mine cooling infrastructure and therefore not affected by the maintenance schedules of the fridge plants and chilled water reticulation network.

6.3. Maintenance and reliability

The ACU CL configuration consists of off-the-shelf items and can be maintained by qualified personnel.

It is however necessary to monitor the condition of the ACU as a major repair requires the extraction of the unit from underground. The largest component of the ACU is the condenser coil. Replacing this coil requires that the ACU be extracted from the mine to be replaced on surface.

The effects of the return air in the RAW on the heat rejection installation, including the heat rejection coils and fans, must be considered. These components may be subject to increased corrosion and fouling due to the impurities in the return air and also the humidity of the air. These components must be inspected frequently and cleaned, as required, to increase the life expectancy of these components.

For mines with poor RAW air quality this may result in the heat rejection coils being replaced more frequently, thus negatively impacting the total operational cost of the ACU CL concept. There is however a benefit of the closed loop configuration with regards to corrosion. This due the fact that by keeping the water in the ACU condenser circuit in a closed loop, one enables better management of the water quality and therefore a reduction in the effects of corrosion and erosion on the water side of both the ACU and the RAW cooling coils.

Another advantage of using a closed loop water circuit rather than water from the chilled or service water network is that the water pressure in the closed loop can be controlled for optimum operation.

7. CONCLUSION

There are a number of operational advantages of installing mobile refrigeration units for localised cooling using a closed loop heat rejection configuration, as discussed in this paper.

These advantages are even greater for new mines, which do not yet have the larger cooling infrastructure or marginal profit mines with limited capital to install large fridge plants.

The energy efficiency potential of the closed loop ACU configuration could also greatly reduce the operational cost for localised cooling in especially outlying areas of deep mine expansion.

The closed loop ACU shows even greater energy savings potential than the stand alone ACUs and this energy benefit increases with an increase in mining depth.

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Ventilation of underground coal mines - *A Computational Fluid Dynamics study*

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ABSTRACT

The auxiliary ventilation systems used to ventilate the development headings has conventionally been studied by conducting experiments. Since the efficiency of any auxiliary ventilation system is dependent on a number of system variables, conducting such experiments on a large scale become a challenging exercise. With the advancement in computer systems and numerical codes, an alternate solution becoming popular in the mining industry is the use of Computational Fluid Dynamics (CFD). Although a number of researchers are using such software in the mining industry, the accuracy of the results is still questioned by the conservatives. This paper outlines not only the steps to be followed for conducting a CFD study in general, but also provides the results of three validation studies relating to auxiliary ventilation. This was done to emphasise how CFD can be used with confidence to study ventilation in underground mines. The work presented in this paper is part of a Ph.D. research study in the School of Mining Engineering at the University of the Witwatersrand.

1. INTRODUCTION

Mine ventilation systems have been designed and installed almost since the beginning of mining, and ventilation is a well-studied subject. A number of computerised mine ventilation network analysis software packages are available to design the main ventilation circuit. However, the ventilation of the blind headings, which is carried out using auxiliary ventilation equipment is studied and planned using experiments/experience and CFD analysis.

The efficiency of an auxiliary ventilation system is largely affected by the associated system variables (Suglo and Frimpong, 2002). The study of these system variables such as the dimensions of the headings, orientation and capacity of the auxiliary equipment, and velocity of air in the last through road (LTR) requires a large number of experiments. However, to carry out a large number of experiments in a mine has always been an expensive exercise. With the advancement in the field of computer science and numerical modelling, powerful computers and numerical software are available which can be used to study auxiliary ventilation and achieve extensive solutions. Due to these reasons, the need to use CFD is an important step forward.

The relationship between the experimental studies and numerical models has always been dependent on the validation of the numerical results with experiments. Therefore, a primary requirement/limitation of a CFD study is the validation of the numerical model. Once validated these CFD models can be used to examine the different auxiliary ventilation configurations and enable the practitioner to predict, visualise and optimise the ventilation in headings.

This paper aims to highlight the key steps involved to solve a ventilation problem in an empty heading using the ANSYS Fluent CFD package. Furthermore, the suitability of ANSYS Fluent k-e realisable CFD model for studying ventilation of an empty heading has been shown by conducting a comparison of three experimental and numerical studies.

2. KEY STEPS OF CFD

CFD is one of the branches of fluid mechanics. It started in the early 1970s and employed physics, numerical mathematics and computer sciences to simulate fluid flows. It has become a powerful tool in almost every branch of fluid dynamics and engineering (Ren and Balusu, 2010). CFD has been described (Anderson, 1995) as "the art of replacing the partial derivatives in the fluid motion equations with discretised algebraic form". The CFD solvers are designed to solve a set of Partial Differential Equations (PDEs) defining the flow fields of the problem. These PDEs (governing equations) as shown in Figure 1 are derived from the following three fundamental principles of physics which rule all the aspects of fluid flows (Anderson, 1995).

- Conservation of Mass
- Newton's Second Law of Motion
- Conservation of Energy

The governing equations are coupled equations, which are non-linear and are therefore, very difficult to solve analytically, necessitating the use of numerical methods. The system of equations is converted into algebraic equations which are subsequently solved numerically at discrete points in the time and or space, using different explicit and implicit numerical techniques. CFD can be used to solve fluid dynamics problems in both two and three dimensions, producing illustrative results, which helps the user to have an increased understanding of the problem.

The three steps to solve any fluid dynamics problem are (Anderson, 1995):

- Visualising the problem and defining the quantities that are required to be measured.
- Designing a mathematical model includes the selection of the governing equation/equations, and the initial and boundary conditions.
- Use numerical techniques to solve the fluid problems, which involve discretisation of the governing equations into algebraic forms to be solved at discrete locations.

3. CONCEPTUAL FRAMEWORK OF CFD STUDY

3.1 Pre-processing

It involves the creation and discretisation of the solution domain,

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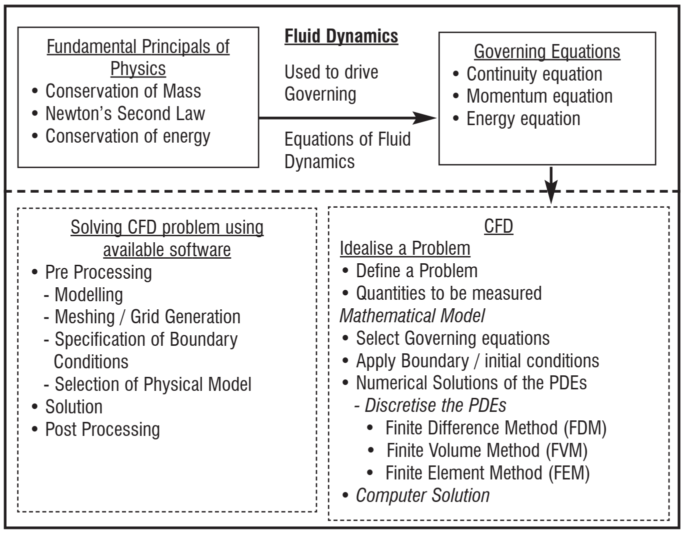


Figure 1. Important aspects of CFD and numerical modelling

the description of the properties of the domain being studied and, finally, the specification of the boundary conditions.

3.1. Modelling

The problem domain and every component of it are required to be modelled. For this study ANSYS Fluent workbench was used but there are many other CAD software applications such as AMD, Pro Engineer, CATIA, Solid works etc. (ANSYS Design Modeler User's Guide and ANSYS Fluent Meshing User's Guide, 2015).

3.1.1. Meshing / Grid generation

The mesh defines the locations, at which the governing equations are solved for the given flow domain. The mesh resolution controls these locations, the accuracy of the calculation, and the solution time required by the computer. Software programmes (Point-wise, GAMBIT etc.) have been specially developed for the purpose of mesh and grid generation. The common types of mesh elements used in CFD solvers are hexahedral, tetrahedral Prism and Wedge in 3D and quadrilaterals and triangles in 2D (GAMBIT User Manual, 2007). Both structured and non-structured meshes can be generated in ANSYS Fluent as well. The mesh types that are supported by ANSYS Fluent include triangular, quadrilateral, tetrahedral, hexahedral, pyramid, prism (wedge) and polyhedral (ANSYS Fluent Meshing User's Guide, 2015).

3.1.2. Specification of boundary conditions

The boundary conditions are specified after grid generation. These boundary conditions are applied at different locations of the problem domain i.e. for mine ventilation problems the inlet, walls, outlets etc., depending on the problem.

3.1.3. Selection of solution model

A number of solution models (Turbulence models, radiation models, Large Eddy Simulation model etc.) generally called the physical models are available within the CFD software (Diego et al., 2011). These models are chosen depending on the nature of the problem, for example, a turbulence model is generally used to simulate turbulent flow in the study of underground mine ventilation. Where the Reynolds numbers are high, the viscosity effects are too low to restrict / stop the amplification of disturbances and they grow and interact with the neighbouring disturbances. The flow become disordered and non-repeating and is called the turbulent flow (Launder, 1991). Turbulent flow shows rapid fluctuations of flow variables about a mean value which are very difficult to resolve and is computationally very expensive. The solution to this problem is that the exact governing equations be time averaged or ensemble averaged, resulting into a less computationally expensive set of equations. These equations though bring additional unknown variables with them, but are determined using turbulence models.

The selection of a particular turbulence model is one of the difficult parts of using ANSYS Fluent, because it is not possible in general to classify turbulence models and flow problems. It depends on the type of the physical problem, the memory limitations/accuracy required and the normal practice that is followed. ANSYS Fluent provides a number of choices of turbulence models (ANSYS Fluent Theory Guide, 2015) including:

- K-ε models
- Standard k-ε model
- Renormalisation-group (RNG) K-ε model
- Realisable K-ε model

3.2. Solution

Once the problem has been completely defined, it is ready for the computation of a solution. Iterative strategy is used to solve the non-linear system of governing equations in order to calculate the solutions.

3.3. Post-processing

The solution stage is followed by the results; the results are in the form of a huge number of flow field variables depending upon the size of the problem. These variables are represented in illustrative and meaningful ways using plots of contours and vectors, streamlines, data curve etc. which help the user, to have an increased understanding. Comparison of these results is done with the available physical experimentation results for verification, since incorrect input data, poor choice of simulation methods or incorrect interpretations of the outputs can mislead the researcher and result in incorrect conclusions.

4. VALIDATION OF NUMERICAL MODEL

Validation of a numerical model is required to demonstrate its accuracy so that it may be used with confidence, and that the results be considered reliable. The numerical model is optimised for the validation case until the results are comparable with the actual physical process results (analytical results) or experimental results. The validated model can then be used for studies involving a large number of situations in similar environments without doing further validations. This becomes an even bigger advantage when it comes to ventilation in the mining industry, where it is extremely difficult and at times even dangerous to perform experiments and take accurate measurements.

The validation of a numerical model is generally carried out using one of the three approaches:

- Comparison of simulated results with the laboratory results

- Comparison of simulated results with the experimental results taken from literature, and
- Comparison of simulated results with insitu experimental results.

Laboratory studies usually involve the use of a scaled down model, and similarity parameters. In this paper the results of three validation studies have been presented. One of the studies used experimental results from literature and for the remaining two studies insitu experiments were conducted. The results showed that k-ε realisable model available in ANSYS Fluent is well suited for the studies related to the ventilation of the development heading. The validation studies presented in this paper include the ventilation of an empty heading for the following scenarios:

1) Without the use of any auxiliary equipment,

2) With the use of a line brattice (LB) and

3) With the use of a ducted fan.

A brief account of the validation studies carried out for this research is given in the ensuing paragraphs.

4.1. Numerical considerations

The models for all the studies were developed, meshed and simulated in ANSYS Fluent Workbench. A fine hexahedral mesh of size equal to 0.04m was used for all the cases. K-ε realisable model with enhanced wall treatment was used for all the cases. The boundary conditions used for these studies are given in Table 1.

Table 1. Boundary conditions used for the validation studies

Validation Case Study	Boundary condition	Location
Validation Study One	Velocity Inlet	Inlet of the LTR
	Outflow	Outlet of the LTR
	Wall	All the boundaries of the domain except for inlet and outlet
Validation Study Two	Velocity Inlet	Inlet of LTR
	Outflow	Outlet of the LTR
	Wall	Brattice and all the boundaries of the domain except for inlet and outlet of the LTR
Validation Study Three	Velocity Inlet	Fan inlet
	Outflow	Outlet of the tunnel
	Wall	Duct and all the boundaries of the domain except for fan inlet and outlet of the tunnel

4.2. Validation Study One

The effect of the LTR velocity on the penetration of air into a heading connected to the LTR and ventilated using no auxiliary device was investigated in this study (Feroze and Phillips, 2015). The dimensions of the heading and LTR used for this study are given in Figure 2. LTR velocities of 0.78m/s, 1m/s, 1.35m/s and 1.9m/s were used. Determination of the penetration of air was based on the maximum axial velocity calculated using absolute axial velocity at different depth planes. The results were compared with experimental results from previous work undertaken by the Chamber of Mines Research Organisation (COMRO), Meyer (1989). A comparison of the results is given in Table 2.

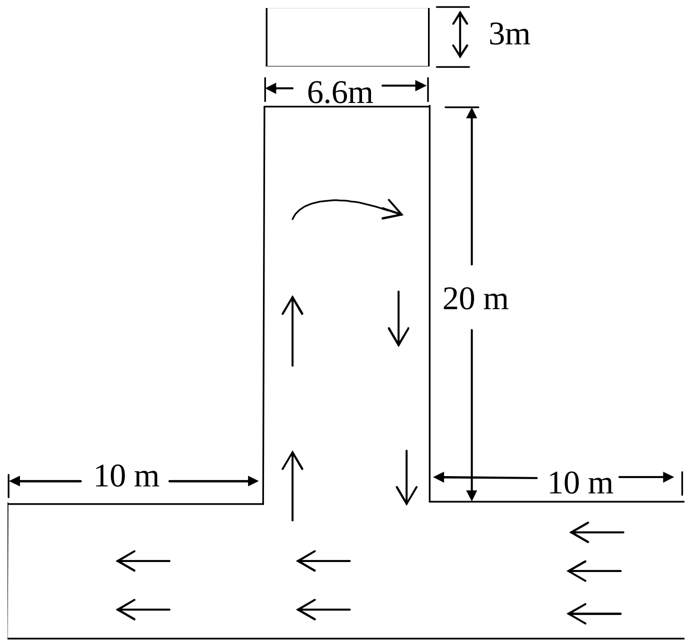


Figure 2. Model Dimensions for case study 1

Table 2. Results of validation study 1

LTR velocity (m/s)	Experimental results	Numerical results
	Penetration depth (m)	Penetration depth (m)
0.78	12.2	12.3
1	15.8	15.2
1.35	16.8	15.9
1.9	12.4	12.7

4.3. Validation Study Two

This study was carried out to validate the results of a LB ventilation system simulated in ANSYS fluent. The insitu measurements were taken in an empty heading ventilated using LB in Kriel Colliery. The dimensions of the heading and LB are given in Figure 3. The velocity of air at several locations inside the heading was measured. The air velocities and direction of the air inside the heading were recorded using the hot wire and rotating vane digital anemometers and smoke tube respectively.

A comparison of the velocities of air measured inside the heading is given in Table 3 along with the coordinates of these points. The coordinates of the bottom right corner of the LTR was considered as (0,0,0) and the other coordinates were based on this reference point. Positive and negative signs are indicating the direction of air movement (positive sign indicated movement of air into the heading, and negative for the opposite movement).

4.4. Validation Study Three

The third study was carried out to validate the results of a ducted fan simulated in ANSYS fluent. The experiment work was performed in a 66.2m long mock tunnel in the School of Mining Engineering, University of the Witwatersrand. The tunnel is dome shaped at the entrance, but becomes rectangular near the face as shown in Figure 4a, the dimensions of the duct in the tunnel are shown in Figure 4b and Figure 5.

The velocity of air delivered by the fan close to the face (0.5m) of the tunnel at five points shown in Figure 4b was measured both

Table 3. Comparison of experimental and numerical results

Coordinate point (m)	Experimental Results	Numerical Results
	Velocity (m/s)	
At the inlet of LB		
(7, 0.5, 5.75)	0.96	1.0304
(7, 2, 5.75)	0.96	1.0338
Inside the heading		
12.64, 0.5, 9.92	-0.11	-0.1207
12.64, 2, 9.92	-0.13	-0.14171
15.28, 0.5, 9.92	-0.51	-0.4818
15.28, 2, 9.92	-0.48	-0.504
15.28, 0.5, 14.92	-0.55	-0.5847
15.28, 2, 14.92	-0.60	-0.6278

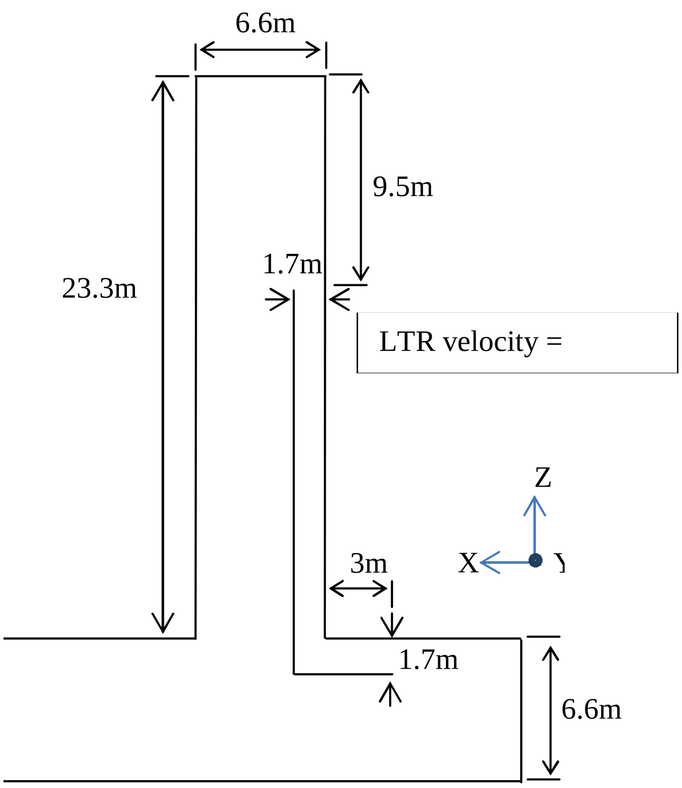
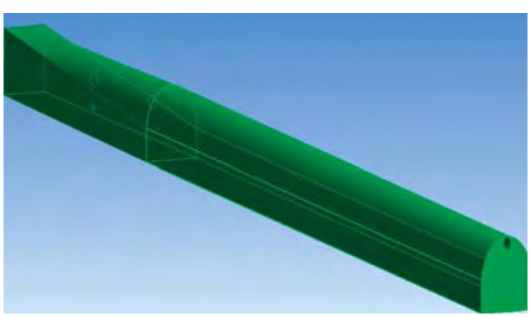
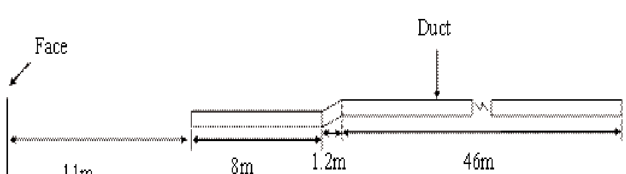


Figure 3. Important dimensions of the heading and LTR

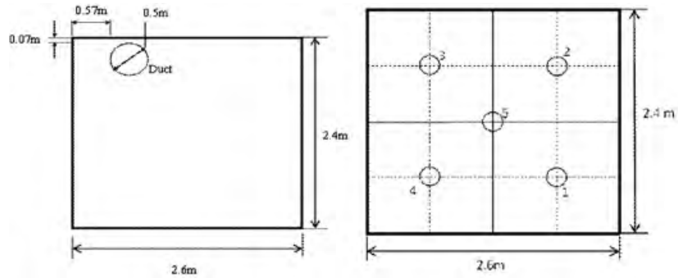


a) Tunnel and fan duct



b) Schematic diagram of the duct

Figure 4. School of Mining Engineering, University of the Witwatersrand, tunnel and duct fan system



a) Tunnel face dimension and duct distances b) Measurement points

Figure 5. Dimensions of tunnel face/duct and measurement points

Table 4. Comparison of experimental and numerical results

Point	Experimental Results	Numerical Results
	Velocity (m/s)	
1	-0.84	-0.871
2	-0.11	-0.104
3	2.35	2.437
4	0.30	0.311
5	0.75	0.784

experimentally and numerically for the settings of the fan when it was delivering a quantity of 1.98m^3/s. A comparison of the experimental and numerical results is given in Table 4.

4.5. Absolute Percentage Difference

The absolute percentage difference between the experimental and numerical results for the three studies is given in Figure 6. The approximate maximum and minimum differences were found equal to 10% and 1% respectively. The average difference was found to be equal to 5.21%. Hence, the results indicate that numerical modelling can be used with confidence to study the various aspects of ventilation in underground mines.

5. CONCLUSION

The various aspects of CFD modelling, and the requirement of validation along with the results of the three validation studies were presented. The validation studies demonstrated the usability of CFD and showed that the ANSYS Fluent k-ε realisable model is suitable to study the ventilation of headings using auxiliary devices with confidence. This outcome will hopefully encourage the mining industry to use CFD during the interactive design process to modify/improve ventilation systems, and improve health conditions and productivity.

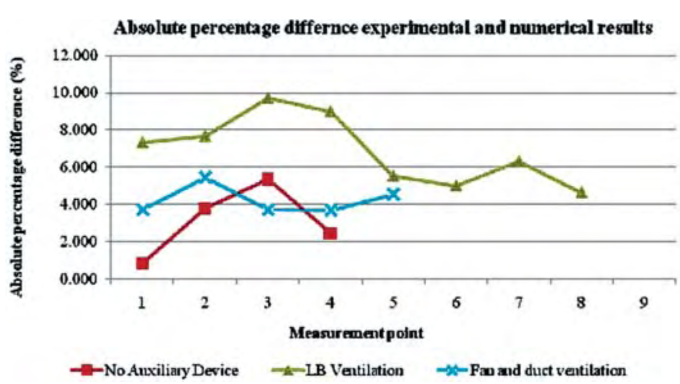


Figure 6. Absolute percentage difference between experimental and numerical results

6. ACKNOWLEDGEMENT

The work presented in this paper is part of a Ph.D. research study in the School of Mining Engineering at the University of the Witwatersrand. The authors would like to acknowledge the Wits Mining Institute (WMI), University of the Witwatersrand, for making the Digital Mine facility available for the research, and the financial assistance required to purchase the high performance PC and the CFD software.

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Obituary

Jim Guthrie

22 September 1946 to 4 September 2017

The Executive and Council of the Mine Ventilation Society of South Africa are saddened at the passing of Mr Jim Guthrie, a colleague, dedicated and enthusiastic Past President and Fellow of the MVSSA.

Jim was raised in Zambia, and was married to Tombie. Together they raised four children.

Jim began his ventilation career in 1965 at the Nchanga Consolidated Copper Mines in Zambia. After moving to South Africa in 1968 he obtained the Advanced Certificate in Mine Environmental Control.

He gained hands-on experience in base metal, gold and diamond mines until 1986 when he transferred to the Anglo American head office.

There he assumed the role of head of ventilation for the DeBeers Group. He later headed the Anglo American Group Technical Ventilation and Occupational Hygiene Engineering Services. During this period Jim headed and contributed to the science of the development of numerous Anglo American development projects in all of the major commodities and in several countries.

He retired in 2008 to settle in White River.

Jim was admitted as a Fellow of the Society on 12 August 1971 and was elected to the Council of the MVSSA in 1985 when he assumed control of the, then, "Visits and Meetings" portfolio. His level-headedness and organisational abilities were amply demonstrated by the many successful symposia, conferences and meetings he organised on behalf of the Society.

On 28 June 1991 Jim was elected President of the Society for the 1991-1992 session and continued to serve on Council as Past President until 1999. Jim served 46 years as a Fellow of the Society and 18 years as a member of the MVSSA Council.

1990 MVS Conference, Kimberley. Jim was Master of Ceremonies

Jim was a versatile ventilation practitioner with a broad experience in both South African and international mining industry spanning several commodities that included diamond, gold, platinum, coal and base metals. There are not many who can claim to have worked extensively in so many mining commodities. His expertise and technical contributions to the ventilation fraternity are recorded in an impressive curriculum of journals, conferences, company literature and representation of the industry on many forums.

A truly remarkable man who will be remembered in the annals of the Society!

Jim Guthrie and G Ritson (Mobil) at the 1989 MVS Symposium. Jim was the organiser

Jim was elected President of the Society for the 1991-1992

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WORKING CONDITIONS
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VENUE: Emperors Palace, Ekurhuleni
CONTACT: The Mine Ventilation Society of South Africa
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Future challenges for the Ventilation Professional

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		Non-Members	√	Members	√
Full registration	31 - May - 01 June	R 6 750.00		R 5 150.00	
Single day registration	31 May Includes cocktail party	R 3 700.00		R 2 900.00	
	01 June	R 3 700.00		R 2 900.00	
Cocktail party	31 May				

All the above prices are exclusive of VAT

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The MVSSA AGM will be held on 31 May 2018

PERSONAL DETAILS OF DELEGATE (*Please complete in block letters*)		
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Terms & Conditions:

1. Payment is required 30 days from date of invoice. All payments must be made to the Mine Ventilation Society of South Africa.
2. No seat will be reserved unless the Mine Ventilation Society of South Africa has received a signed registration form.
3. The Mine Ventilation Society of South Africa reserves the right, due to circumstances beyond our control, to change the speakers.
4. Payment is required 30 days.
5. The signed registration form is legal and binding.
6. Delegates must inform The Mine Ventilation Society of South Africa in writing of any substitutions. There is no charge for substitutions.
7. The Mine Ventilation Society of South Africa is not liable for travel & accommodation of delegates. The cost only includes material, lunches and refreshments.
8. There is a 10% cancellation fee.

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Future challenges for the Ventilation Professional

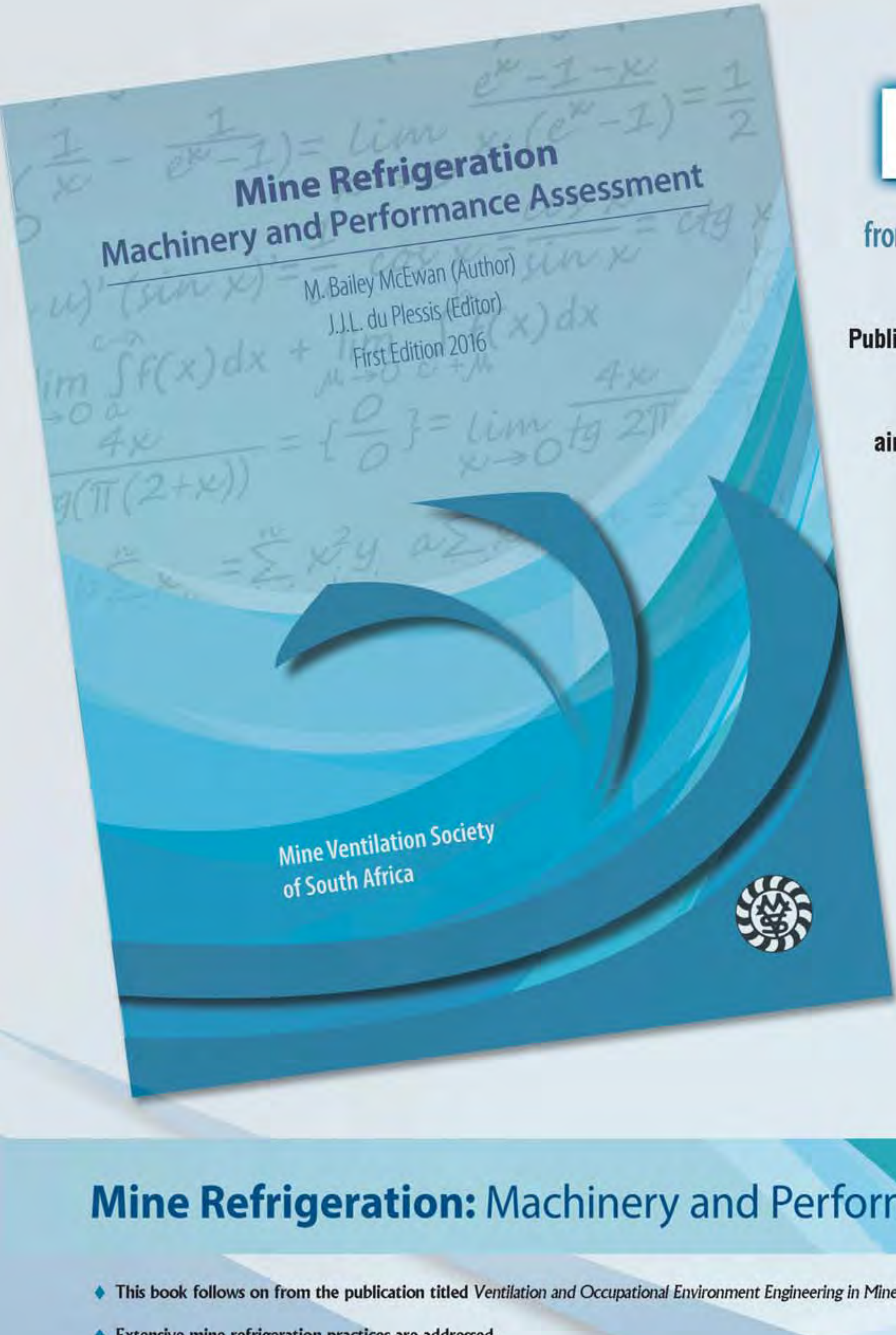
Preliminary Programme

Thursday 31 May

	Session theme: Fire And Emergency Preparedness	
07:00 - 08:00	Registration	
08:00 - 08:15	Welcome by MVSSA Senior Vice President	M. van der Bank
08:15 - 08:45	Key Note Speaker: Manager Mining & Mineral Resources Natural Resources and Environment Director Mining Hub Mining Precinct @ Carlow Rd	N. Singh
08:45 - 09:10	Fire engineering fit for the mining industry	W.M. Marx
09:10 - 09:35	Self-contained self-rescuer training for new challenges	M. Biffi
09:35 - 10:00	Education and training: The current status	M. Beukes
10:00 - 10:25	"Junior presentation:"	
10:25 - 11:00	Tea	
	Session theme: Energy and Occupational Hygiene	
11:00 - 11:25	Energy recovery from a fluidized-bed ventilation air methane abatement unit: A thermodynamic assessment	B. Moghtsderi
11:25 - 11:50	Challenges around reporting and taxation for coal mining fugitive greenhouse gas emissions	A. Cook
11:50 - 12:15	Good practice guidance on occupational health risk assessment	C. Badenhorst
12:15 - 12:40	Considerations in the development of the "new" ventilation professional	H. Moorcroft
12:40 - 13:05	"Junior presentation:"	
13:05 - 14:00	Lunch	
14:00 - 17:15	AGM	
18:00	Cocktail party	

Friday 1 June

	Session theme: Ventilation & Refrigeration	
07:00 - 08:00	Registration	
08:00 - 08:25	Review of mine ventilation and cooling strategies in different countries	R. Wilson
08:25 - 08:50	Advantages of monitoring the infield operational conditions of localised cooling in remote underground areas	M.N. Ras
08:50 - 09:15	The importance of accurate rock property and virgin rock temperature data in ventilation and cooling planning requirements	K. van Zyl
09:15 - 09:40	A comparative study of different cooling strategies for underground mining	R. Potgieter
09:40 - 10:05	"Junior presentation:"	
10:05 - 10:35	Tea	
10:35 - 11:00	Remote maintenance management as part of a ventilation control system	C. Visagie
11:00 - 11:25	Two Rivers Platinum Mine: Doing more with less	C. Bisschoff
11:25 - 11:50	Underground velocity lights: Principle of operation and an effective method to test their functionality	F.S. Bergh
11:50 - 12:15	Development of a virgin rock temperature measurement instrument	A. Labuschagne
12:15 - 12:40	"Junior presentation:"	
12:40 - 13:00	Closure MVSSA President	M. van der Bank
13:00 - 14:00	Lunch	



NEW

from the Mine Ventilation Society of South Africa

Publication covering refrigeration theory, refrigerating machinery and air-water heat-exchangers on mines

Mine Refrigeration: Machinery and Performance Assessment

- This book follows on from the publication titled *Ventilation and Occupational Environment Engineering in Mines 3rd edition in 2014.*
- Extensive mine refrigeration practices are addressed.
- Mine refrigerating machinery is generally large and complex and this publication offers a full treatment of many different types and configurations of machinery as well as using the theory to allow for performance evaluation supported with actual industry examples.
- Technical knowledge developed and accumulated over many decades in a variety of mine cooling and refrigeration systems is embodied.
- The book is aimed at assisting students, subject matter experts and engineering professionals of today and the future in the field of large refrigeration installations, their operation and evaluation.
- All aspects of mine refrigeration systems are covered, seeking to improve levels of knowledge in this challenging and specialised field of engineering.

To order a copy of this book contact the Mine Ventilation Society of South Africa:
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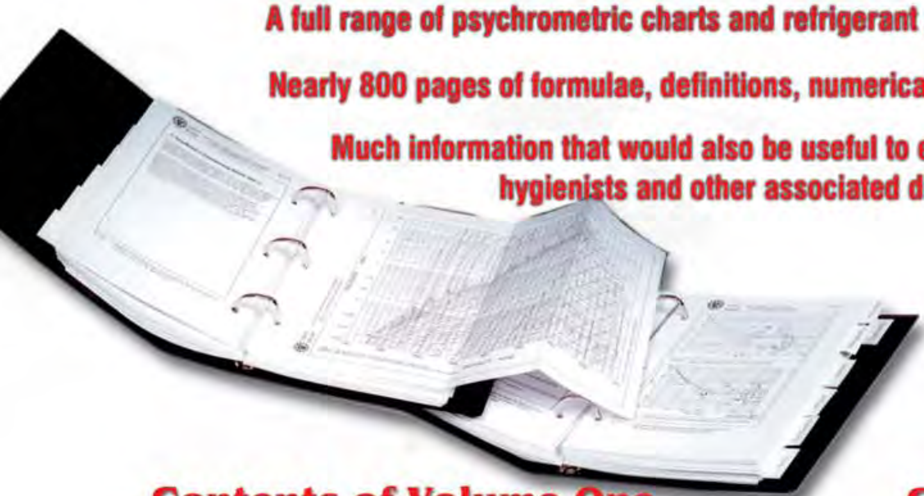

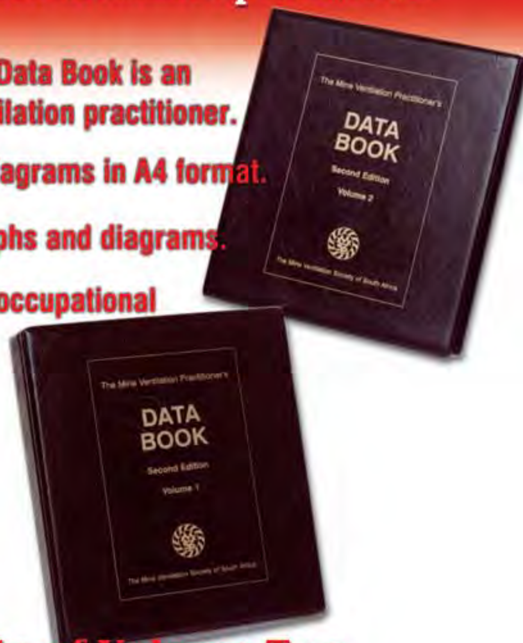

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This release marks one more step in our development plan to help our clients achieve more with less effort. During tough economic times, the workload doesn't necessarily decrease. Faced with the need to do more, with fewer resources, ventilation engineers must work smarter and faster.
New tools and streamlined menu options in VUMA3D-network 2018 mean you can do exactly that.

Enhancements to the user interface have been delivered in the form of ribbon tabs. These tabs have been grouped to make VUMA3D even more intuitive and easier to use. The need for multiple drop downs has been eliminated through this change.

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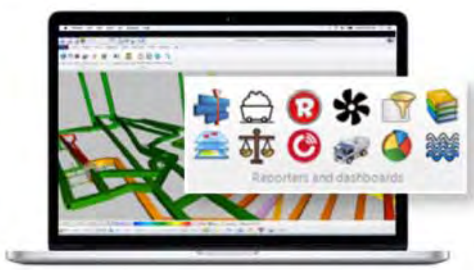
The overall impact of VUMA3D-network 2018 is ease-of-use and improved connectivity. Accuracy and quality standards have been maintained while increasing efficiency and productivity.



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