

# **THE CONTROL OF DIESEL PARTICULATES IN UNDERGROUND COAL MINES**

**By**

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requirements for the degree of Doctor of  
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## **DECLARATION OF ORIGINALITY OF WORK**

This thesis contains no material that has previously been submitted for an award or degree at any university. To my knowledge, the work reported in this thesis is original and contains no material published by other investigations, except where appropriate reference has been given to the source of the material.

Brian Davies

## ABSTRACT

The aims of the research for this thesis were fourfold, all of which focused at reducing employee exposure to diesel particulate in underground coal mines.

The four aims were to:

- a) Develop a method to test disposable diesel exhaust filters and if possible improve their performance
- b) Investigate the relationship between maintenance and diesel particulate generation
- c) Highlight the benefits of newer design engines in emission reduction
- d) Review the research of the Tower Colliery Research group as their findings have been the basis for the development of control technologies for diesel particulate in NSW underground coal mines.

Methods used to achieve these aims involved:

- a) The construction of a test rig to measure the efficiency and backpressure of new and used disposable filters
- b) The testing of the in-service fleet at four of BHP Billiton Illawarra Coal mines using an R&P Series 5100 diesel analysis system mounted in a trailer
- c) Comparison of a newer design engine with three current vehicles under mining conditions
- d) A detailed statistical review of all available data from the Tower Colliery Research group.

Key outcomes from research conducted for this thesis are:

- a) The filtration efficiency and backpressure of disposable diesel exhaust filters used by BHP Billiton Illawarra Coal have been improved.

These improvements, together with changes to work practices, generate potential cost savings of \$395,000 per annum while affording increased protection to equipment operators.

- b) Seven engines with unacceptable raw exhaust elemental carbon emissions were identified in a fleet of 66 tested. Some faults identified as causing these elevated emission levels were – blocked exhaust flame traps (scrubber tanks), incorrectly set tappets and worn injectors.
- c) Testing of a prototype 4WD fire protected vehicle powered by an “over-the-road” engine as against three current vehicles, highlighted reductions in atmospheric elemental carbon concentrations of 67-90%. Significant reductions in raw exhaust elemental carbon levels were also observed.
- d) A statistical review of data produced by the Tower Colliery Diesel Research group identified elevated exposures within mine transportation roadways. This outcome is significant as much research within the mining industry has focused on other areas in the belief that high air quantities in transportation roadways would limit exposures. This does not appear to be the case.

The project has had a number of positive outcomes, all of which have assisted in the reduction of equipment operators to excessive levels of diesel particulate.

## ACKNOWLEDGEMENTS

When first encouraged to undertake this thesis I was of the opinion that going back to university after 30 years was all just a bit too hard. After several attempts, Professor John Stearne convinced me that working in industry for 40 years brought with it benefits that many other (and younger) PhD students didn't have. Due to his persistence I relented and after an initial period of adjustment, I have thoroughly enjoyed the experience. I am very grateful for his faith in me to successfully return to university life.

Many other people seemed to think that my project had merit, and contributed in many and varied ways. Without doubt this project would not have progressed without the support and commitment of Steve Pratt, Manager Technology and External Relations, BHP Billiton Illawarra Coal. Steve is truly committed to reducing the exposure of his employees to diesel particulate and I thank him for his support.

Steve decided to accept early retirement in September 2003 and he leaves behind a legacy of world's best practice at BHP Billiton Illawarra Coal in regard to the control of diesel particulate.

It goes without saying that projects involving coal mines also involve people and this project was no exception. Many operators, engineers and management personnel have assisted in progressing this project and I would like to thank the management and workforce of Tower, Elouera, Appin, West Cliff and Dendrobium Collieries for their assistance. Microfresh Filters Pty Ltd and 3M Australia Pty Ltd also provided support in producing filters for testing at no cost to the project.

Similarly, my return to the university structure would not have been so smooth without the assistance and guidance of the staff of the Victoria University of Technology Centre for Environmental Safety and Risk Engineering. In particular I would like to thank Professor Ian Thomas (my principal supervisor), Ms Helen Demczuk and Mr David Nance.

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Two people deserve special mention for their support throughout the project. The first is Les Eager, an old colleague from previous employment days, who has organised the testing of machines and assisted with the day-to-day testing programme. Without his help it is doubtful that the extensive testing programme undertaken in this project would have occurred.

The last person who I would like to thank is my wife Sue. She has supported me from day one, when John Stearne suggested the idea, and actively became involved in this project by typing this thesis. During those days where it would have been easy to watch Super 12 rugby rather than work on my project Sue reminded me of the final objective and I am truly grateful. Sue's contribution is something I cannot underestimate and I hope she sees this thesis as hers as well as mine.

During the course of my project Sue and I had the unfortunate experience of both our mothers passing away. I hope, in the rest of my life, I can be as good a person as they were.

In their memory I would like to dedicate this project jointly to Beryl Margaret Davies and Olive Eva Louise Hopkins.

I am sure there are others who have helped along the way. I trust they will not be offended if I have neglected to mention them by name but I'm sure they know how grateful I was for their assistance.

Brian Davies

## ABBREVIATIONS

ACARP	Australian Coal Association Research Programme
ACGIH	American Conference of Governmental Industrial Hygienists
AIOH	Australian Institute of Occupational Hygienists
ANOVA	Analysis of Variance
BOM	Bureau of Mines (USA)
CANMET	Canadian Centre for Mineral and Energy Technology
Cat	Caterpillar Inc
CDF	Cumulative Distribution Frequency Plot
CMTS	Coal Mines Technical Services Pty Ltd
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
DDC	Detroit Diesel Corporation
DDEF	Disposable Diesel Exhaust Filter
DEEP	Diesel Emissions Evaluation Programme ( <a href="http://www.deep.org">www.deep.org</a> )
DMC	Diesel Man Car
DMR	New South Wales Department of Mineral Resources
DP	Diesel Particulate
EC	Elemental Carbon
EPA	United States Environmental Protection Agency

g/bhp-hr	Grams per brake horsepower hour
g/hr	Grams per hour
g/kWhr	Grams per kilowatt hour
g/MJ	Grams per Mega Joule
H <sub>A</sub>	Alternate Hypothesis
HEG	Homogeneous Exposure Group
HEI	Health Effects Institute
Hg	Mercury
H <sub>0</sub>	Null Hypothesis
ISO	International Standards Organisation
JCB	Joint Coal Board (Coal Services Pty Ltd)
km	kilometre
kPa	kilopascal
kW	Kilowatt
LCL	Lower Confidence Limit
m <sup>2</sup>	square metre
mg/m <sup>3</sup>	milligram per cubic metre
mm	millimetre
MPV	Multi Purpose Vehicle
MSHA	Mine Safety and Health Administration

MVUE	Minimum Variance Unbiased Estimate
MWM	Motorenwerke Mannheim AG
NATA	National Association of Testing Authorities
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
NSW	New South Wales
NO	Nitric Oxide
NO <sub>2</sub>	Nitrogen Dioxide
NO <sub>x</sub>	Oxides of Nitrogen
OEM	Original Equipment Manufacturer
OC	Organic Carbon
PAH	Polycyclic Aromatic Hydrocarbons
PET	Personnel and Equipment Transporter
PJB	P J Berriman Pty Ltd
PNA	Polynuclear Aromatic Hydrocarbons
ppm	parts per million
PT	Peak Torque
RCD	Respirable Combustible Dust
RP	Rated Power
R&P	Rupprecht & Patashnick Inc

RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers Inc
SMV	Specialised Mining Vehicles Pty Ltd
TC	Total Carbon
TEOM	Tapered Element Oscillating Microbalance
TSI	TSI Inc
UCL	Upper Confidence Limit
UGAS	Undiluted Gas Analysis System
VERT	Verminderung der Emissioner von Realmaschinen in Tunnelban
WA	Western Australia
$\mu\text{m}$	Micrometre
$\Delta p$	Pressure Differential
4WD	Four Wheel Drive

## CONTENTS

Declaration of Originality of Work .....	i
Abstract .....	ii
Acknowledgements .....	iv
Abbreviations.....	vi
Contents .....	x
1. INTRODUCTION .....	1
2. REVIEW OF LITERATURE RELEVANT TO DIESEL PARTICULATE.....	3
2.1 Introduction.....	3
2.2 Diesel Particulate Composition.....	3
2.3 Health Effects of Diesel Particulate .....	5
2.4 Methods of Analysis .....	13
2.5 Workplace Exposure Standards .....	18
2.6 Control Technologies.....	21
2.6.1 Fuel Quality.....	22
2.6.2 Ventilation .....	23
2.6.3 Exhaust Treatment Devices .....	25
2.6.4 Engine Decoking.....	28
2.7 Engine Design and Maintenance.....	28
2.8 Summary.....	32
3. RAW EXHAUST DIESEL PARTICULATE MEASUREMENT SYSTEM.....	34
3.1 Introduction.....	34
3.2 Rupprecht & Patashnick Co Inc Series 5100 Diesel Particulate Measurement System.....	35
3.2.1 Principle of Operation .....	35
3.2.2 Application to the Coal Industry .....	37
3.2.3 Design of the Mobile Laboratory .....	39
3.2.4 Factors Influencing Sample Collection and Analysis.....	41
3.3 Calibration and Validation of Measurement System.....	42
3.3.1 Calibration Procedures .....	42
3.3.1.1 Rupprecht & Patashnick Co Inc Series 5100 Diesel Particulate Analyser .....	42

## CONTENTS (Cont'd)

3.3.1.2	Temperature Sensor .....	42
3.3.1.3	Flow Meter .....	43
3.3.2	Validation Procedures .....	43
3.3.2.1	Manufacturer .....	43
3.3.2.2	Other Researchers .....	44
3.3.3	Australian Validation Trials .....	45
3.3.3.1	Introduction .....	45
3.3.3.2	Test Procedure .....	46
3.3.3.3	Test Results .....	49
3.4	Conclusions .....	53
4.	DISPOSABLE EXHAUST FILTERS .....	54
4.1	Introduction .....	54
4.2	Aim of Project .....	56
4.3	Filter Media .....	56
4.4	Filter Life .....	59
4.5	Methodology and Techniques .....	61
4.5.1	Historical Test Methods .....	61
4.5.2	Historical Filter Test Rig Designs .....	65
4.5.3	Project Test Rig Design .....	71
4.5.4	Filter Backpressure Testing .....	77
4.5.5	Number of Samples .....	78
4.5.6	Test Rig Blank Analysis .....	79
4.6	Experimental Results .....	80
4.6.1	Filtration Efficiency Versus Pleat Numbers .....	80
4.6.2	Backpressure Versus Pleat Numbers .....	86
4.7	Discussion of Results .....	87
4.7.1	Filtration Efficiency Versus Pleat Numbers .....	87
4.7.2	Backpressure Versus Pleat Numbers .....	92
4.7.3	Examination of Used Filters .....	94
4.7.4	Recommendation for Mine Trial .....	95
4.8	Mine Trial of 160 Pleat Filters .....	96
4.8.1	Trial Protocol .....	96

## CONTENTS (Cont'd)

4.8.2	Trial Difficulties.....	97
4.8.3	Results.....	98
4.8.4	Estimated Cost Savings.....	101
4.9	Conclusions.....	102
5.	THE INFLUENCE OF MAINTENANCE PROCEDURES ON RAW EXHAUST DIESEL PARTICULATE CONCENTRATIONS.....	103
5.1	Introduction.....	103
5.2	Aim of Project.....	104
5.3	Historical Overview.....	104
5.4	Methodology.....	112
5.4.1	Introduction.....	112
5.4.2	Sampling Equipment and Procedures.....	113
5.5	Standards.....	115
5.6	Results.....	116
5.6.1	Number of Engines Tested.....	116
5.6.2	Raw Exhaust Elemental Carbon Results.....	118
5.6.3	Raw Exhaust Gas Analysis.....	120
5.6.4	Calculation of Acceptance Criteria.....	122
5.6.5	Abnormal Engines in Fleet.....	123
5.7	Discussion of Results.....	124
5.7.1	Introduction.....	124
5.7.2	Investigation of Abnormal Engines.....	125
5.7.3	Comparison to MSHA Certification Data.....	129
5.7.4	Comparison to Previous Australian Data.....	130
5.7.5	Inter-Mine Comparison of Data.....	133
5.7.6	Influence of Eromanga Fuel.....	134
5.7.7	Relationship Between Raw Exhaust Elemental Carbon Generation Rates and Current Statutory Ventilation Requirements.....	136
5.7.8	Relationship Between Raw Exhaust Gas and Elemental Carbon Concentrations.....	137
5.8	Conclusions.....	138

## CONTENTS (Cont'd)

6.	EFFECT OF ENGINE DESIGN ON DIESEL PARTICULATE CONCENTRATION.....	140
6.1	Introduction.....	140
6.2	Aim of Project.....	142
6.3	Historical Overview.....	142
6.4	Engine Design Research.....	143
6.4.1	Over-The-Road Diesel Engines.....	143
6.4.2	Underground Mining Diesel Engines.....	145
6.5	Methodology and Techniques.....	148
6.5.1	Introduction.....	148
6.5.2	Test Methods.....	148
6.5.3	Sample Collection Protocol.....	149
6.6	Experimental Results.....	151
6.7	Discussion of Results.....	153
6.8	Conclusions.....	154
7.	TOWER COLLIERY RESEARCH GROUP EXPOSURE DATA.....	156
7.1	Introduction.....	156
7.2	Aim of Project.....	157
7.3	Tower Colliery Diesel Research Group.....	158
7.3.1	Background.....	158
7.3.2	Overview of Available Data.....	162
7.3.3	Conclusions of Tower Colliery Diesel Research Group.....	163
7.4	Exposure Assessment.....	166
7.4.1	Brief History of Exposure Assessment.....	166
7.4.2	Selection of an Exposure Standard.....	168
7.4.2.1	Germany.....	168
7.4.2.2	Canada.....	169
7.4.2.3	United States of America (USA).....	169
7.4.2.4	Australia.....	170
7.4.2.5	Summary.....	171
7.4.3	Overview of Data Treatment.....	172

## CONTENTS (Cont'd)

7.5	Workplace Exposure Data .....	177
7.5.1	Assignment of Homogeneous Exposure Groups .....	177
7.5.2	Exposure Assessment Results .....	186
7.5.3	Equality of Equipment .....	194
7.6	Proposed Control Technologies .....	196
7.7	Conclusions.....	199
8.	SUMMARY OF CONCLUSIONS .....	202
9.	PUBLICATIONS AND PRESENTATIONS .....	207
10.	REFERENCES .....	208

## APPENDICES

- 1 Tower Colliery Research Group – Exposure Data
- 2 Tower Colliery Research Group – Test Tunnel Data
- 3 Guideline on Diesel Particulate for The Australian Institute of Occupational Hygienists