SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

Final Project Report

Title: THE DEVELOPMENT OF A DISCUSSION DOCUMENT ON THE SAFETY RELATED RESEARCH NEEDS OF THE COAL INDUSTRY

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1. INTRODUCTION

The principal objective of this project has been to provide SIMCOL and its two sub-committees (COLEEAG and COLREAG) with a discussion document on research priorities.

Work on the project commenced at the end of March 1993 and an interim report was prepared analysing accident statistics for the South African coal mining industry for a ten year period to the end of 1992. This has recently been updated to include data to the end of 1993 and this analysis forms the first part of this report.

The second phase of the project has involved discussions with personnel from the mining industry, reviews of international coal mining research effort, consultation with researchers (both local and international) and an analysis of the current research programme approved by SIMCOL and SIMGEN.

This report concludes with suggested areas where research effort may have a significant impact on the safety of workers in South African coal mines.

TABLE 1

COLLIERY ACCIDENT STATISTICS 1984 - 1993

YEAR	1984			1985			1986			1987			1988		
CATEGORY	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured
Fall of Ground															
Rockbursts										1		1			
Other Falls	178	22	100	164	22	152	149	24	141	115	34	105	96	23	85
Machinery	58	5	53	54	4	50	74	6	68	50	2	47	34	4	30
Trucks and Tramways	239	18	221	245	16	230	204	22	184	178	17	158	158	19	142
Fall of material															
On Surface	34	1	33	38	4	38	27	1	27	14	2	13	9		9
Below Surface	87	2	85	58	2	57	57		57	47	5	42	34		34
Falling Shafts, Excavations															
On Surface	5	2	3	4	2	2	1	1					6	2	4
Below Surface	1	1		1		1	1	1	1				4		4
Struck by Cage/Skip	2	2	2	2	2		2		2				1		1
Travelling by Cage/Skip							1		1						
Breaking of Haulage Ropes															
Travelling by Ladder															
Overwind and Runaways															
Directly caused by electricity	26	2	29	15		20	12		12	8	2	7	9	2	7
Boilers and Steam Pipes															
Due to Underground Fires				1		1									
Inundation by Water/Mud							2	2	2	1	12	4	3	3	
Miscellaneous															
Explosion of Gas	2	7	1	1	33		2		10	2	37	11	2		6
Subsidence															
Burning and Scalding	12	1	15	18		18	11		11	9		12	4		4
Falling and Slipping	72	2	72	48	4	44	49	4	45	31	2	45	18		18
Splinters	6		6	6		6	1		1	16		2	1		1
Elevators				1		1				1			3		3
Heat Stroke															
Heat Exhaustion															
Sundry	107	8	101	126	1	125	106	6	104	95	7	89	18	2	16
Explosives															
Drilling into misfired holes	2		2							2		2			
Due to Fumes							1		1						
During Blasting Operations	9		10	16	3	18	12		16	9	2	14	6		8
Handling Detonation	1		1	3		3	1		1	2		2			
Whilst Charging															
Withdrawing Charges															
Sundry	2		2	1		1	1		5	1	1				
TOTAL	840	73	705	802	83	775	714	67	600	502	121	550	408	55	372

YEAR	1989			1990			1991			1992			1993		
CATEGORY	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured	Accidents (no)	Killed	Injured
Fall of Ground															
Rockbursts										1	1				
Other Falls	111	28	103	90	16	86	102	23	83	87	18	73	74	21	60
Machinery	33	4	29	49	4	45	35	2	33	33	2	31	16	1	14
Trucks and Tramways	123	13	110	127	17	112	122	10	116	119	10	111	105	11	95
Fall of material															
On Surface	26	2	24	17		17	17		17	32		32	27		27
Below Surface	30	1	29	26	3	23	21		21	28		28	22	1	23
Falling Shafts, Excavations															
On Surface	12	2	10	8	3	5	8		8	13	2	11	6		6
Below Surface	2		2	3		3	2		2	3		3	6	1	5
Struck by Cage/Skip	2		2	1		1				2		2			
Travelling by Cage/Skip															
Breaking of Haulage Ropes															
Travelling by Ladder															
Overwind and Runaways															
Directly caused by electricity	11	1	12	8	1	9	7	2	6	5	1	4	7		7
Boilers and Steam Pipes															
Due to Underground Fires				4		15	4	1	14	2	6	3			
Inundation by Water/Mud				3	3					1	1				
Miscellaneous															
Explosion of Gas	1	1	4				2		2	1		1	2	53	1
Subsidence							1		1						
Burning and Scalding				3		3	3		3	3	1	2	2		2
Falling and Slipping	27		27	29	1	28	19		19	25		25	19		19
Splinters	7		7	3		3	3		3	3		3	9		10
Elevators	3		3	10		10	4		4	15	2	14			
Heat Stroke															
Heat Exhaustion															
Sundry	9		9	22	3	19	27	3	26	13	3	10	4	1	3
Explosives															
Drilling into misfired holes							1		1						
Due to Fumes							1		1						
During Blasting Operations	7	1	8	10		19	5	2	4	3		3	9	1	11
Handling Detonation				1		1	1		1	1		1			
Whilst Charging															
Withdrawing Charges															
Sundry				1		1	2		5	1	1	2			
TOTAL	407	54	377	415	51	400	387	43	369	391	45	358	307	90	281

2. COLLIERY ACCIDENT STATISTICS 1984 - 1993

As specified in the project proposal coal mining accident statistics for the past ten years have been obtained and subjected to analysis. Such data has been collected by the Government since early this century and for many years was reported annually by the Department of Mines in the Mining Statistics publication. The relevant table each year was Table 13 - Accidents and Resulting Casualties, which classified accidents into 33 categories.

During 1988 the Office of the Government Mining Engineer computerised its accident recording system, thereby accommodating much greater detail in the system. Although the number of major categories decreased by one to 32, nearly 200 sub-categories were introduced. Since the last 10 year period spans this change in reporting method and the latter years afforded the greater detail, it was decided to standardise on the old format (the so called Table 13) and to re-constitute the modern data in the old format. Since this meant reducing the degree of detail, it was possible to do this without undue loss of accuracy, while redefining the old data into the modern categories would have introduced a large degree of guesswork in many cases. Nevertheless there may be some small errors in the re-classification of the recent data but these will be unlikely to significantly affect the conclusions.

2.1 Data for the Past Ten Years

The coal mine data for the period 1984 to 1993 are presented in Table 1. In this table and throughout the report accidents are defined, according to Regulation 25.1 of the Minerals Act, 1991 as an event which results in

(a) the death of any person, or
(b) an injury to any person likely to be fatal, or
(c) unconsciousness from heatstroke, heat exhaustion, electric

TABLE 2

CONSOLIDATED ACCIDENT STATISTICS 1984 - 1993

CATEGORY	ACCIDEN		KILLED		INJURED	
	TOTAL	%	TOTAL	%	TOTAL	%
Fall of Ground:						
Rockbursts	2	0.0	1	0.1	1	0.0
Other Falls	1164	22.2	228	32.9	1048	21.1
Machinery	435	8.3	34	4.9	400	8.1
Trucks and Tramways	1619	30.8	153	22.0	1376	27.7
Fall of Material:						
On Surface	241	4.6	10	1.4	235	4.7
Below Suface	410	7.8	14	2.0	399	8.0
Falling Shafts, Excavations:						
On Surface	63	1.2	14	2.0	149	3.0
Below Surface	23	0.4	3	0.4	21	0.4
Struck by Cage/Skip	12	0.2	4	0.6	10	0.2
Travelling by Cage/Skip	1	0.0	0	0.0	1	0.0
Breaking of Haulage Ropes	0	0.0	0	0.0	0	0.0
Travelling by Ladder	0	0.0	0	0.0	0	0.0
Overwind and Runaways	0	0.0	0	0.0	0	0.0
Directly caused by electricity	110	2.1	11	1.6	113	2.3
Due to Underground Fires	11	0.2	7	1.0	33	0.7
Inundation by Water/Mud	10	0.2	21	3.0	6	0.1
Miscellaneous:						
Explosion of Gas	15	0.3	131	18.9	36	0.7
Subsidence	1	0.0	0	0.0	1	0.0
Burning and Scalding	65	1.2	2	0.3	70	1.4
Falling and Slipping	337	6.4	13	1.9	342	6.9
Splinters	55	1.0	0	0.0	42	0.8
Elevators	37	0.7	2	0.3	35	0.7
Heat Stroke	0	0.0	0	0.0	0	0.0
Heat Exhaustion	0	0.0	0	0.0	0	0.0
Sundry	526	10.0	34	4.9	502	10.1
Explosives:						
Drilling into misfired holes	5	0.1	0	0.0	5	0.1
Due to Fumes	2	0.0	0	0.0	2	0.0
During Blasting Operations	88	1.7	15	2.2	109	2.2
Handling Detonation	10	0.2	0	0.0	10	0.2
Whilst Charging	0	0.0	0	0.0	0	0.0
Withdrawing Charges	0	0.0	0	0.0	0	0.0
Sundry	9	0.2	2	0.3	16	0.3
TOTAL	5251	100.0	694	100.0	4962	100.0

shock or the inhalation of fumes or poisonous gas, or any incapacitation normally requiring treatment in a decompression chamber, or

(d) incapacitation from heatstroke, heat exhaustion, electric shock or the inhalation of fumes or poisonous gas which will prevent the affected person from resuming his normal or similar occupation within 48 hours, or

(e) an injury which either incapacitates the injured person from performing his normal or similar occupation for a period totalling 14 days or more, or which causes the injured person to suffer the loss of a limb, or part of a limb, or sustain a permanent disability.

From definition (e) above it follows that injuries are defined as an event leading to an amputation or which result in 14 days or more of lost time.

It may appear pedantic to spell out these definitions but it is important to appreciate that in other countries the definitions differ widely and that any comparison of international data must be treated with caution.

Although the year by year totals fluctuate, it can be seen from Figure 1 that during this 10 year period the number of reportable accidents and injuries have all been substantially reduced and now stand at less than half their 1984 values. Fatality rate fluctuations are much greater, nethertheless a downward trend from 1987 to 1992 is still discernable, with another peak occurring in 1993. Similar graphs for each of the major categories of accidents have been included in Appendix I as Figures 2 to 9.

It can also be seen from Table 1 that although there are 33 categories, the majority of accidents and casualties come from a handful of causes. Since major incidents (particularly explosions) cause distortions in individual years, it was decided to total the statistics for the 10 year period before analysing the prevalence of individual categories. These figures, which are given in Table 2 show very clearly that accidents caused by

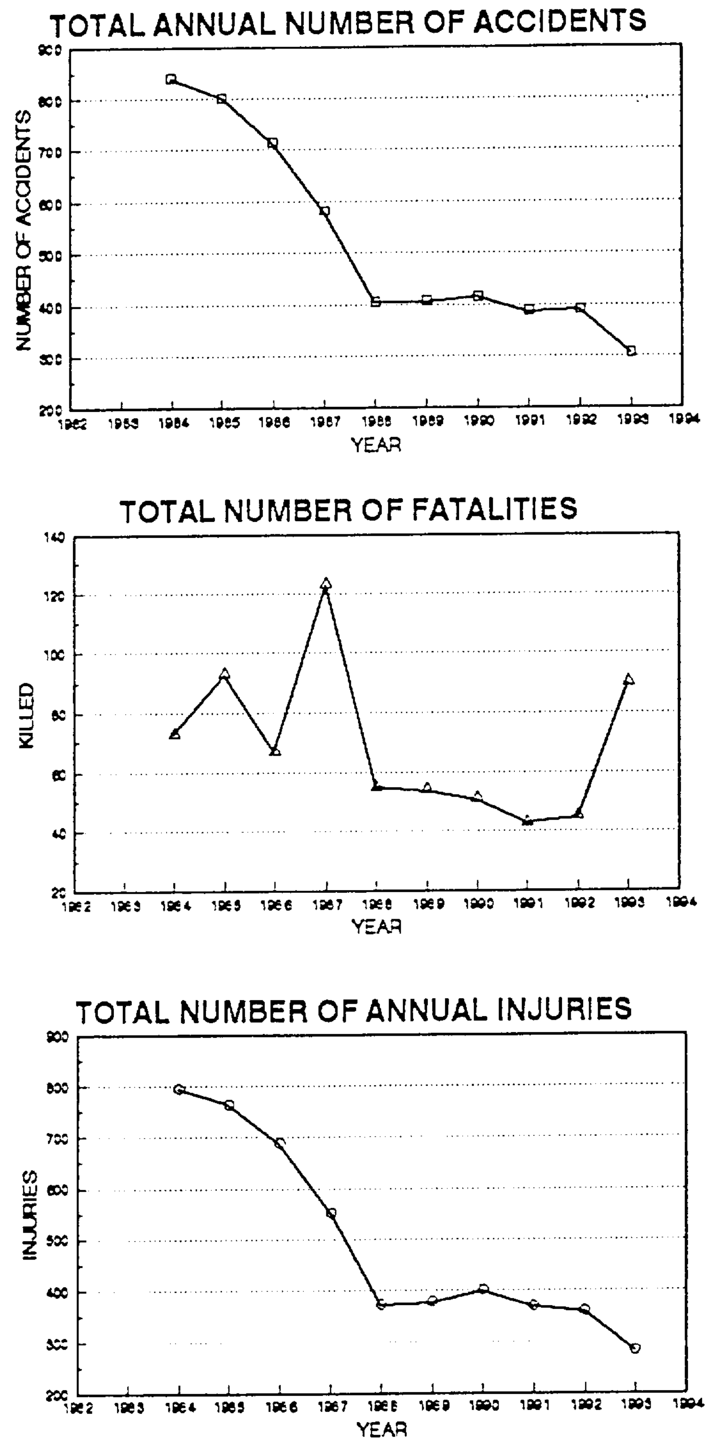

FIGURE 1 Trends in Accident, Fatality and Injury Statistics Over a 10 Year Period

TABLE 3

CONSOLIDATED DATA BY MAJOR CATEGORY

CATEGORY	NO OF ACCIDENTS		KILLED		INJURED	
	TOTAL	%	TOTAL	%	TOTAL	%
HAULAGE,TRANSPORT,MACHINERY						
Machinery	435	8.3	34	4.9	400	8.1
Trucks and Tramways	1619	30.8	153	22.0	1376	27.7
Fall of Material (Surface)	241	4.6	10	1.4	235	4.7
Fall of Material (U/G)	410	7.8	14	2.0	399	8.0
Sub Total:	2705	51.5	211	30.4	2410	48.6
STRATA CONTROL ACCIDENTS						
Rockbursts	2	0.0	1	0.1	1	0.0
Other Falls	1164	22.2	228	32.9	1048	21.1
Sub Total:	1166	22.2	229	33.0	1049	21.1
FIRES AND EXPLOSIONS						
Explosion of Gas	15	0.3	131	18.9	36	0.7
Due to Underground Fires	11	0.2	7	1.0	33	0.7
Sub Total:	26	0.5	138	19.9	69	1.4
FALLING AND SLIPPING						
Shafts,Excavasions (Surface)	63	1.2	14	2.0	149	3.0
Shafts,Excavations (U/G)	23	0.4	3	0.4	21	0.4
Falling and Slipping	337	6.4	13	1.9	342	6.9
Sub Total:	423	8.1	30	4.3	512	10.3
SHAFT TRAVELLING						
Struck by Cage/Skip	12	0.2	4	0.6	10	0.2
Travelling by Cage/Skip	1	0.0	0	0.0	1	0.0
Breaking of Haulage Ropes	0	0.0	0	0.0	0	0.0
Travelling by Ladder	0	0.0	0	0.0	0	0.0
Overwind and Runaways	0	0.0	0	0.0	0	0.0
Elevators	37	0.7	2	0.3	35	0.7
Sub Total:	50	1.0	6	0.9	46	0.9
INUNDATION BY WATER/MUD						
Inundation by Water/Mud	10	0.2	21	3.0	6	0.1
Sub Total:	10	0.2	21	3.0	6	0.1
EXPLOSIVES & BLASTING						
Drilling into misfired holes	5	0.1	0	0.0	5	0.1
Due to Fumes	2	0.0	0	0.0	2	0.0
During Blasting Operations	88	1.7	15	2.2	109	2.2
Handling Detonation	10	0.2	0	0.0	10	0.2
Whilst Charging	0	0.0	0	0.0	0	0.0
Withdrawing Charges	0	0.0	0	0.0	0	0.0
Sundry	9	0.2	2	0.3	16	0.3
Sub Total:	114	2.2	17	2.4	142	2.9
MISCELLANEOUS						
Directly caused by electricity	110	2.1	11	1.6	113	2.3
Subsidence	1	0.0	0	0.0	1	0.0
Burning and Scalding	65	1.2	2	0.3	70	1.4
Splinters	55	1.0	0	0.0	42	0.8
Heat Stroke	0	0.0	0	0.0	0	0.0
Heat Exhaustion	0	0.0	0	0.0	0	0.0
Sundry	526	10.0	34	4.9	502	10.1
Sub Total:	757	14.4	47	6.8	728	14.6
TOTAL	5251	100.0	694	100.0	4962	100.0

TABLE 4

SIGNIFICANCE OF MAJOR CATEGORIES

Descending - Number of Accidents

CATEGORY	NO OF ACCIDENTS		ORDER OF SIGNIFICANCE
	TOTAL	%	
HAULAGE,TRANSPORT,MACHINERY	2705	51.5	1
STRATA CONTROL ACCIDENTS	1166	22.2	2
MISCELLANEOUS	757	14.4	3
FALLING AND SLIPPING	423	8.1	4
EXPLOSIVES & BLASTING	114	2.2	5
SHAFT TRAVELLING	50	1.0	6
FIRES AND EXPLOSIONS	26	0.5	7
INUNDATION BY WATER/MUD	10	0.2	8
TOTAL	5251	100.0	-

Descending - Number of Fatalities

CATEGORY	KILLED		ORDER OF SIGNIFICANCE
	TOTAL	%	
STRATA CONTROL ACCIDENTS	229	33.0	1
HAULAGE,TRANSPORT,MACHINERY	211	30.4	2
FIRES AND EXPLOSIONS	138	19.9	3
MISCELLANEOUS	47	6.8	4
FALLING AND SLIPPING	30	4.3	5
INUNDATION BY WATER/MUD	21	3.0	6
EXPLOSIVES & BLASTING	17	2.4	7
SHAFT TRAVELLING	6	0.9	8
TOTAL	694	100.0	-

Descending - Number of Injuries

CATEGORY	INJURED		ORDER OF SIGNIFICANCE
	TOTAL	%	
HAULAGE,TRANSPORT,MACHINERY	2410	48.6	1
STRATA CONTROL ACCIDENTS	1049	21.1	2
MISCELLANEOUS	728	14.6	3
FALLING AND SLIPPING	512	10.3	4
EXPLOSIVES & BLASTING	142	2.9	5
FIRES AND EXPLOSIONS	69	1.4	6
SHAFT TRAVELLING	46	0.9	7
INUNDATION BY WATER/MUD	6	0.1	8
TOTAL	4962	100.0	-

falls of ground, transport, haulage, use of machinery and explosions dominate the statistics. This becomes even more evident if the categories are re-grouped according to the type of research which should reduce the number of accidents e.g. rockbursts and other falls require strata control research, explosions and fires require research into combustion mechanisms, sources of ignition, methods of making inert, etc, while it can be imagined that machinery, trucks and tramways and handling of materials could all benefit from research into illumination, ergonomics, communications and noise control. The revised categories are shown in Tables 3 and 4. It would seem logical that priority in research funding should also be given to these areas in the first instance.

From these two tables it can be seen that three major categories (Haulage, Transport and Machines, Strata Control and Fires and Explosions) account for 74% of all accidents, 83% of all fatalities and 71% of all injuries. No other single cause accounts for more than 8,1% of accidents, 4,3% of fatalities or 10,3% of injuries. It would seem, therefore, that priority in research funding should be given to these areas in the first instance.

2.2 **Accidents at Surface and Underground Mines**

Since the major portion of the research levy is based on lost shifts, both surface and underground mines pay in proportion to the number and severity of the accidents they experience. However, since the research funded by SIMRAC is predominantly related to underground conditions, the accident statistics for the past five years (1989-1993) have been divided into surface mines, surface of underground mines and underground mining. These are presented in Table 5 for each of the five years, while the totals for the 5 years period are given in Table 6. This data shows that more than 90% of all accidents, fatalities and injuries occur on underground mines, with at least 70% of the total taking place underground.

TABLE 5

ACCIDENT CLASSIFICATION - SURFACE vs UNDERGROUND

YEAR: 1989

LOCATION CATEGORY	STRIP/OPENCAST			SURFACE OF U/G			UNDERGROUND		
	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured
HAULAGE,TRANSPORT,MACHINERY	15	2	13	63	9	54	134	9	125
STRATA CONTROL ACCIDENTS	0	0	0	0	0	0	111	28	103
FALLING AND SLIPPING	2	0	2	23	2	21	16	0	16
SHAFT TRAVELLING	1	0	1	3	0	3	1	0	1
INUNDATION BY WATER/MUD	0	0	0	0	0	0	0	0	0
FIRES AND EXPLOSIONS	0	0	0	1	1	0	1	1	4
EXPLOSIVES AND BLASTING	0	0	0	0	0	0	7	1	6
MISCELLANEOUS	2	0	2	10	0	10	17	1	16
TOTAL:	20	2	16	100	12	88	287	40	271

YEAR: 1990

LOCATION CATEGORY	STRIP/OPENCAST			SURFACE OF U/G			UNDERGROUND		
	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured
HAULAGE,TRANSPORT,MACHINERY	21	3	18	49	6	43	149	15	136
STRATA CONTROL ACCIDENTS	0	0	0	0	0	0	90	18	86
FALLING AND SLIPPING	7	2	5	15	2	13	18	0	18
SHAFT TRAVELLING	0	0	0	7	0	7	4	0	4
INUNDATION BY WATER/MUD	0	0	0	3	3	0	0	0	0
FIRES AND EXPLOSIONS	0	0	0	2	1	1	5	1	15
EXPLOSIVES AND BLASTING	0	0	0	2	0	2	10	0	19
MISCELLANEOUS	2	0	2	13	0	13	18	2	18
TOTAL:	30	5	25	91	12	79	294	34	296

YEAR: 1991

LOCATION CATEGORY	STRIP/OPENCAST			SURFACE OF U/G			UNDERGROUND		
	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured
HAULAGE,TRANSPORT,MACHINERY	19	4	15	53	4	50	123	4	121
STRATA CONTROL ACCIDENTS	2	1	1	0	0	0	100	22	82
FALLING AND SLIPPING	2	0	2	19	0	19	8	0	8
SHAFT TRAVELLING	0	0	0	2	0	2	2	0	2
INUNDATION BY WATER/MUD	0	0	0	0	0	0	0	0	0
FIRES AND EXPLOSIONS	0	0	0	1	0	1	5	1	15
EXPLOSIVES AND BLASTING	1	0	1	2	0	5	6	2	5
MISCELLANEOUS	3	0	3	15	4	11	24	1	26
TOTAL:	27	5	22	92	8	88	266	30	259

YEAR: 1992

LOCATION CATEGORY	STRIP/OPENCAST			SURFACE OF U/G			UNDERGROUND		
	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured
HAULAGE,TRANSPORT,MACHINERY	21	3	19	66	4	63	125	5	120
STRATA CONTROL ACCIDENTS	0	0	0	0	0	0	88	16	73
FALLING AND SLIPPING	4	0	4	20	2	18	17	0	17
SHAFT TRAVELLING	3	0	3	8	1	8	6	1	5
INUNDATION BY WATER/MUD	0	0	0	0	0	0	1	1	0
FIRES AND EXPLOSIONS	0	0	0	1	0	1	1	6	2
EXPLOSIVES AND BLASTING	0	0	0	1	1	2	4	0	4
MISCELLANEOUS	5	0	5	9	2	7	11	3	8
TOTAL:	33	3	31	105	10	99	253	32	229

YEAR: 1993

LOCATION CATEGORY	STRIP/OPENCAST			SURFACE OF U/G			UNDERGROUND		
	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured
HAULAGE,TRANSPORT,MACHINERY	13	1	12	49	2	47	107	10	100
STRATA CONTROL ACCIDENTS	0	0	0	0	0	0	74	21	60
FALLING AND SLIPPING	1	0	1	15	0	15	15	0	14
SHAFT TRAVELLING	0	0	0	0	0	0	0	0	0
INUNDATION BY WATER/MUD	0	0	0	0	0	0	0	0	0
FIRES AND EXPLOSIONS	0	0	0	0	0	0	2	53	1
EXPLOSIVES AND BLASTING	2	1	2	0	0	0	7	0	9
MISCELLANEOUS	2	0	2	10	1	10	10	0	10
TOTAL:	18	2	17	74	3	72	215	85	194

TABLE 6

ACCIDENT CLASSIFICATION - SURFACE vs UNDERGROUND CONSOLIDATED DATA

LOCATION CATEGORY	STRIP/OPENCAST			SURFACE OF U/G			UNDERGROUND		
	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured	Accident (no)	Killed	Injured
HAULAGE,TRANSPORT,MACHINERY	89	13	77	280	25	257	638	43	602
STRATA CONTROL ACCIDENTS	2	1	1	0	0	0	463	103	404
FALLING AND SLIPPING	16	2	14	92	6	86	74	0	73
SHAFT TRAVELLING	4	0	4	20	1	20	13	1	12
INUNDATION BY WATER/MUD	0	0	0	3	3	0	1	1	0
FIRES AND EXPLOSIONS	0	0	0	5	2	3	14	62	37
EXPLOSIVES AND BLASTING	3	1	3	5	1	9	34	3	43
MISCELLANEOUS	14	0	14	57	7	51	80	7	78
TOTAL:	128	17	113	462	45	426	1317	220	1249

	STRIP/OPENCAST (%)	SURFACE OF U/G (%)	UNDERGROUND (%)	TOTA
ACCIDENTS	6.7	24.2	69.1	100
FATALITIES	6.0	16.0	78.0	100
INJURIES	6.3	23.8	69.9	100

3. FUNDING OF THE SIMRAC LEVY

The Safety in Mines Research Advisory Committee raises funds for research through a levy on the mining industry. The levy consists of two components, a sector dependent component (i.e. coal, gold and platinum and other mines) and a generic levy to cover research of general interest. In the case of sector dependent levies a rate is imposed for each day lost due to fatalities and reportable injuries during the past three years. The generic levy is based on a set rate per worker employed and the levy rates for 1993 and 1994 are given below.

	ORIGINAL LEVY RATES			
	Rand Per Day Lost			R/Worker
	Coal Mines	GAP Mines	Other Mines	Generic
1993	4,85	1,7962	0,448	3,59
1994	4,7088	1,8854	0,310	5,415

In 1994 these levies have raised a total of R6 043 038 for coal mining research and R301 708 from the coal industry for generic research. The levies for 1993 were R5 585 764 and R276 915 respectively, showing an 8 to 9% growth this year in research budgets. The coal industry generic levy contributes about 11% of the total funds (R2 718 991) raised for generic research.

Details of the funding raised from each Group (and in this context a company operating more than one mine is considered a Group) are provided in Table 7. In order to calculate the coal and generic levies, it is first necessary to calculate the allocated days lost per Group and the workforce per Group. This allowed Table 8 to be constructed and it is presented here purely for information and is not intended to be judgemental in any way. Mining and safety standards are only two of many factors contributing to accident rates and other aspects such as ratio of surface to underground activities, geological conditions, degree of mechanisation, age of mines, etc all have a significant influence. Nevertheless, it is interesting to note that, in general, the larger mining operations are two to four times safer than the small, single mine operations grouped together under the heading "Private". It is also interesting to see the effect a major disaster can have even on figures based on the previous three years. For example, if the Middelbult explosion was excluded from the Sasol data, their days lost/worker/year figure would have been 7,62 instead of 20,87 (the 1993 figure was 7,40).

TABLE 7

COAL INDUSTRY RESEARCH LEVY - 1994

GROUP	COAL RESEARCH LEVY (R)	GENERIC RESEARCH LEVY (R)	TOTAL RANDS
Sasol	2 359 198	43 325	2 402 523
Trans Natal	923 062	48 600	971 661
Iscor	785 286	49 120	834 406
Rand Mines	518 241	56 940	575 179
Amcoal	437 325	52 879	490 202
Private	307 151	7 759	314 910
JCI	181 524	13 132	194 656
Duiker	156 247	10 830	167 077
Kangra	156 200	4 949	161 149
Gold Fields	125 923	10 705	136 628
Tselentis	64 628	2 263	66 892
Aquipcoal	28 253	1 208	29 460
TOTAL	6 043 038	301 708	6 344 746

TABLE 8

DAYS LOST/WORKER/YEAR BY GROUP

GROUP	DAYS LOST 1990 TO 1993*	WORKFORCE	DAYS LOST WORKER/ YEAR	COMPARABLE FIGURE LAST YEAR
Sasol	501 019	8 001	20,87	7,40
Private	65 229	1 433	15,17	13,04
Kangra	33 172	914	12,10	10,83
Tselentis	13 725	418	10,94	12,14
Aguipcoal	6 000	223	8,97	0,44
Trans Natal	196 029	8 975	7,28	4,99
Iscor	166 770	9 071	6,13	4,56
Duiker	33 182	2 000	5,53	1,54
JCI	38 550	2 425	5,30	5,32
Gold Fields	26 742	1 977	4,51	4,43
Rand Mines	110 058	10 515	3,49	2,94
Amcoal	92 874	9 765	3,17	3,37
Total	1 283 350	55 717	-	-
Average	-	-	7,68	4,98

* Data taken 01-07-1990 to 30-06-1993.

TABLE 9

SIMCOL PROGRAMME TO DATE

PROJECT NO	TITLE OF PROJECT	1993		1994	
		FUNDING R000's	% OF TOTAL	FUNDING R000's	% OF TOTAL
001	Handbook on Strata Control	70	1,2	--	--
005	The Effect of Structural Discontinuities On The Strength of Coal Pillars	132	2,4	99,1	1,6
014	Behaviour of Brittle Rock Under Plane Strain Load	39	0,7	--	--
019	Evaluate Various Types of High Extraction Mining Methods to Increase Extraction of Coal Safely	559	10,0	575,5	9,6
021	A Reassessment of Coal Pillar Design Procedures	896	16,0	902,7	15,1
026	Develop Multi Seam Extraction Criteria	280	5,0	--	--
	TOTAL FOR STRATA CONTROL	1976	35,3	1577,3	26,3
010	Explosion Hazards	1473	26,3	1877,2	31,4
029	Improved Underground Ventilation Conditions in Coal Mines	100	1,8	--	--
030	Reduce The Methane Hazard in Collieries	1000	17,8	1050,9	17,6
031	Control Measures For Coal Mine Fires	150	2,7	--	--
104	Simulation of Coal Dust Explosions	--	--	100	1,7
108	Development of Active Guidance Systems For Use Following Severe Explosions	--	--	85	1,4
115	Reassess Survival Strategy For Post Coal Mine Explosions and Fires	--	--	283,9	4,7
	TOTAL FOR EXPLOSIONS AND FIRES	2723	48,6	3397	56,8
027	Reduction of Worker Exposure to Dust	650	11,6	909,2	15,2
033	Illumination of Collieries	209	3,7	--	--
034	The Development of a Discussion Document On The Safety Related Research Needs of The Coal Mining Industry	45,4	0,8	--	--
	Provision For Initiation of Project Work On An Adhoc Basis	--	--	100	1,7
	TOTAL	5603,4	100	5983,5	100

4. THE SIMCOL FUNDED RESEARCH PROGRAMME

During its first year of operation (1993) the research programme supported by SIMCOL was largely determined by existing research activities, the proposals received and the research objectives of the Chamber of Mines and the Government Mining Engineer. Table 9 shows the contracts awarded in January 1993 and that the total commitment for that year was R5 603 400. Funding for 1994 increased by 6,8% to R5 983 500 but when continuation of existing contracts is taken into account only R568 900 or 9,5% of the total amount was available for new projects. If individual research projects are to be limited to three years duration then a rolling programme should be instituted in which approximately a third of the annual budget becomes available each year for new projects.

Table 9 also shows the division of research funds between the major areas. Over the past two years 31% of the budget has been devoted to research in the general area of strata control, 53% for work on explosions and fires and 1,8% for work on illumination in collieries. While 13,5% of the budget has been devoted to a project on the Reduction of Worker Exposure to Dust, the potential for this work to directly influence and reduce the risk of explosions (through reduced levels of explosible dust) or the risk of machinery, haulage and transport accidents through improvements in visibility, is extremely limited.

The SIMCOL controlled budget over the past two years has been divided between only three research contractors, shown in Table 10. This has resulted in a virtual monopoly by the CSIR of the SIMCOL, SIMGAP and SIMGEN budgets.

TABLE 11

GENERIC PROGRAMME - 1994

PROJECT NO	TITLE OF PROJECT	FUNDING R000's	% OF TOTAL
109	Develop Remote Control Systems For Mining Equipment	50,5	1,9
	TOTAL FOR STRATA CONTROL	50,5	1,9
006	Self-Rescuer Monitoring	452,7	17,0
101	Practices and Procedures To Overcome The Problems Associated With Disorientation and Low Visibility In The Aftermath of Mine Explosions Or Fires	253,0	9,5
102	Analysis of Incidents Involving SCSR Activation	155,5	5,8
	TOTAL FOR EXPLOSIONS AND FIRES	861,2	32,3
004	Radiation Protection	239,6	9,0
010	Control of Diesel Exhaust Emissions In Underground Working	484,0	18,2
011	Develop Means To Enhance The Effectiveness of Existing Hearing Conservation Programmes	177,3	6,7
103	Improved Footwear For Use In The South African Mining Industry	100	3,7
105	Evaluate The Severity And Develop Appropriate Means Of Assessing Mine Employees Risk To Lost Time Accidents	232,4	8,7
107	Physiological Effects That Shift Workers Are Exposed To	119,3	4,5
108	Develop and Evaluate A Prototype Procedure For Use By Mine Management To Objectively Assess Risk Inherent In Mining Situations As A Basis For Improved Safety	400,6	15,0
	TOTAL FOR GENERAL	1753,2	65,8
TOTAL GENERIC PROGRAMME		2664,9	100

TABLE 10

DISTRIBUTION OF RESEARCH FUNDS

CONTRACTOR	1993		1994	
	TOTAL VALUE	%	TOTAL VALUE	%
CSIR	5387	96,1	5799,4	96,9
University of Pretoria	132	2,4	99,1	1,7
Wits	84,4	1,5	85,0	1,4
TOTAL	5603,4	100	5983,5	100

5. GENERIC RESEARCH PROGRAMME

In addition to the funds raised by the Coal Mining Levy and discussed in the preceding section, the Generic Levy, based on the number of employees per mine, is used for research that will be of benefit to the entire mining industry. The list of research contracts, all of which were awarded to the Division of Mining Technology, CSIR is given in Table 11. Again a significant proportion of this budget (32,3% or R861 200) is devoted to research in the general field of explosions, fires or rescue following one of these incidents.

6. COAL MINE SAFETY RESEARCH WORLDWIDE

Part of this project involved a review of funding of coal mine safety research elsewhere in the world and the 25th International Conference of Safety in Mines Research Institutes held in Pretoria (13 - 17 September 1993) provided an ideal opportunity to gather information.

Data from the former Eastern Bloc countries was difficult to obtain, disjointed and almost impossible to compare with the South African situation, in terms of funding, numbers of personnel involved or type of research. Because of exchange rates budgets appeared to be extremely low, while the numbers of personnel involved in mine safety programmes is extremely high by our standards. In addition the research units are fragmented and very specialised, with only the basic, fundamental research likely to be of direct relevance to our local mining industry. From discussions held it would appear that the programmes in the United States, Germany, the United Kingdom and Australia come closest to paralleling the research needs of South Africa.

In the United States coal research budgets are currently being cut back in favour of environmental projects. For example, the Department of Energy's coal research programme (including such aspects as coal utilization and combustion processes) has been progressively cut back from $226 million in 1992 to $190 million in 1993 with provision for $141,3 million in 1994. Within the mine safety area the Department of Labour's $40,4 billion budget for 1994 includes $192 million for the Mine Safety and Health Administration, an increase of $400 000 over 1993 and this additional money will all be spent on enforcing coal mine safety and health laws, with no extra provision for research.

It is interesting to note that in the U.S.A. the Office of Surface Mining which currently has a budget of over $300 million, spends $191,6 million on its abandoned mine lands programme, an identical sum to that spent on the MSHA programme to protect the safety and health of mine workers.

The best known of the American mine safety institutions is the United States Bureau of Mines, which for nearly 80 years has conducted research into all aspects of mine safety. Its budget for 1994 is $155 million, a drop of $20 million from 1993. Although no announcement has been made of where cutbacks will take place, it is understood that its core programme of coal mine safety, involving explosions, illumination, ergonomics, dust and noise will continue.

The most recent reliable financial data on coal research in Germany (Hardman, 1993) suggests that the total budget in 1991/92 for the hard coal sector was DM305 million, with about DM61,5 million or 20% devoted to occupational safety and health. These funds were raised from various State and Federal subsidies (39%), European Community research grants (10%) and the coal industry's own funds (51%). Although no details are available it is believed that the decline in the hard coal industry has reduced the funds available for research and that many of the European Community grants are not being renewed. It is likely therefore that the larger research institutions such as DMT will devote more of their efforts to non-mining research and abandon their more expensive programmes in areas such as explosions.

In Australia coal related research has, for more than a decade, been mainly funded by the Federal Government using funds raised by a 5c/tonne levy on the industry. Since 1978 approximately A$167 million has been spent in this way through the National Energy Research Development and Programme (NERDDP). The Australian Coal Association also maintained its own research capability in the Australian Coal Industry Research Laboratory (ACIRL), while the New South Wales and Queensland Governments maintained safety research laboratories.

In 1992 NERDDP was taken over by the Australian Coal Association Research Programme and inherited A$47 worth of research contracts (Hardman, 1993) broken down as follows:

Underground Mining	Opencut Mining	Coal Preparation	Coal Utilization	Total A $ Million
23,5	5,3	4,6	13,4	46,8

The main purpose of transferring the research to ACARP was to "stimulate a co-operative strategic approach to coal related R and D with the programme being needs driven rather than curiosity driven with more productive and effective co-operation between research organisations and industry".

The amount of funds expected to be available for research over the first five years is as follows:

TABLE 12

PROPOSED BUDGET FOR COAL RESEARCH IN AUSTRALIA

Five Year ACARP Expenditure Pattern A$ million						
Year	Admin	U/G	Open Cut	Prep/ Util	Special Project	Total
92/93	1.1	1.6	1.0	1.1	0.5	5.3
93/94	1.2	2.1	1.5	1.5	0.7	7.0
94/95	1.3	2.6	1.7	1.6	0.8	8.0
95/96	1.4	2.8	2.0	2.1	0.7	9.0
96/97	1.5	2.8	2.0	2.0	0.7	9.0
TOTAL	6.5	11.9	8.2	8.3	3.4	38.3
%	17.0	31.1	21.4	21.6	8.9	100.0

The research priorities for underground mining have been set as follows:

<u>High Priority</u>

* Roadway Development Productivity
* Improved Availability of Equipment
* Strata Control
* Exploration Techniques

<u>Moderate Priority</u>

* Longwall Mining Systems
* Thick Seam Mining
* Gas Control and Outbursts
* Ventilation and Dust Control
* Management and Safety Issues

Because the research programme is now controlled by the Australian Coal Association (the mine owners), it is perceived by many researchers that the emphasis has shifted from safety research to productivity, mining methods and improved extraction and that, of the A$11,9 million to be spent on underground mining research over the first five years, very little will be spent solely on safety research. Indeed, several commentators have reported that fundamental and applied research is giving way to projects providing a consultancy service to the mines.

In the United Kingdom coal mine safety research is undertaken and funded both by the Health and Safety Executive and British Coal. However, both organisations report their programme and any results to the Safety in Mines Research Advisory Board which presents Annual Reports. Funding is reported in terms of intramural effort (expressed in man-years) and an extramural budget. Over the past four years the reported effort, purely in the area of health and safety, is shown below in Table 13.

TABLE 13
U.K. COAL MINING SAFETY RESEARCH
1989 TO 1993

CATEGORY	YEAR			
	89/90	90/91	91/90	92/93
HSE Internal	19 m-y	14,9 m-y	16,1 m-y	16,2 m-y
HSE External	£159 k	£114 k	£240 k	£277 k
BCC Internal	82 m-y	49 m-y	£2,2 m	£2,3 m
BCC External	£1143 k	£811 k		
BCC Medical	£950 k	£875 k	£350 k	£350 k

The latest report of the Safety in Mines Research Advisory Board, which is for 1992, lists the research activities under six categories. These, together with research topics are listed below:

1) **Fires and Explosions**
   * Flame Safety Lamps
   * Flammability Testing of Hydraulic Fluids
   * Barrier Systems For Protection Against Coal Dust Explosions
   * Frictional Ignitions
   * Explosion Proof Stoppings
   * Certified Mine Lighting Systems
   * Permitted Explosives

2) **Haulage and Transport**

* Free Steered Vehicles
* Long-term Study of Haulage and Transport Accidents
* Automatic Detection of Men on Conveyors
* Stability of Man Riding Trains

3) **Mining Environment**

* Detection, Control and Monitoring of Gases and Vapours
* Underground Fires and Smoke
* Diesel Particulates
* Respirable Dust
* Radon and Radon Daughters
* Noise

4) **Human Factors and Ergonomics**

* Locomotive Driver Training
* Ergonomics of Driver Cabs
* Electrical Failure to Isolate

5) **Occupational Medicine**

* Exposure to Quartz Dust
* Monitoring Strategy For Respirable Dust

6) **Other Research**

* Fatigue Studies
* Communication Through Falls of Ground
* Rockbolting - Instrumentation and Monitoring

Although the 1992 programme was comprehensive and probably cost in the region of £4 million (R20 million) the subsequent rapid decline in the British coal mining industry, together with the sale of its research facilities ahead of the main privatisation programme means that research effort has decreased markedly. Under private enterprise and with production limited to about 30 million t.p.a. it is unlikely that a significant mine safety research programme can be sustained in the United Kingdom.

7. SAFETY RELATED RESEARCH NEEDS

From the data presented in Section 2 of this report, it is possible to reach some basic conclusions. Three major categories of accidents account for more than 70% of all accidents, fatalities and injuries. A crude comparison of accident statistics and SIMCOL research funding is provided in Table 13.

TABLE 14
PREVALENCE OF ACCIDENT CATEGORIES VERSUS RESEARCH FUNDING

ACCIDENT CATEGORY	PERCENTAGE OF			
	Accidents	Fatalities	Injuries	Research Funding
Machinery, Transport etc.	51,5	30,4	48,6	1,8
Strata Control	22,2	33,0	21,1	30,7
Fires and Explosions	0,5	19,9	1,4	52,8

Accident Statistics 1984 - 1993
Funding Data 1993 and 1994

These figures indicate that while strata control research is marginally overfunded, fires and explosions research receives over 50% of the budget while only accounting for 0,5% of the accidents, 1,4% of injuries and 19,9% of fatalities. At the same time machinery, transport and haulage accident research is grossly underfunded. Two reasons for this historic imbalance can be suggested, both of which are concerned with the severity of explosions.

In most cases explosions lead to multiple fatalities and this gives rise to emotive statements in the media and bad publicity for the industry. Secondly, the severity of explosions is such that the risk of being killed is much higher in explosions than in any other type of accident. For example, taking the data for the past ten years as given in Table 3, each haulage, transport and machinery accident led to 0,078 fatalities, each strata control accident led to 0,20 of a fatality, while each explosion caused 8,7 fatalities. This means that the risk of being killed <u>if</u> involved in an explosion is 112 times that of being killed <u>if</u> involved in an machinery accident. This obviously contributes greatly to the average mineworkers fear of explosions.

7.1 **Research Into Machinery, Transport, Haulage Accidents**

The statistics presented in Table 3 indicate that on average there are 270 accidents in this category each year leading to 240 injuries and 21 fatalities. Discussion with a wide variety of people from industry leads one to the conclusion that although poor illumination and a noisy environment contribute to many accidents, each incident in this category tends to be unique and human error is the dominant underlying cause.

It is suggested, therefore, that four engineering areas of research and two approaches involving human factors should be considered for future funding. These are

a) <u>Illumination</u>. Although a start was made in 1993 with a research project in this area (COL 033) much still needs to be done both in designing lighting schemes for mobile equipment and in providing adequate lighting at locations where work is done outbye of the working places. In particular, lighting on mobile equipment must not only assist the driver but must be designed to allow pedestrians to judge the distance to a vehicle, the speed at which it is travelling and the clearance between the vehicle and sidewalls.

b) <u>Noise</u>. In a typical noisy environment not only are pedestrians at risk from moving equipment but even with static equipment fatigue due to noise may well be an important cause of loss of judgement. Research into noise levels, awareness, time of exposure and loss of concentration could well be rewarding.

c) Vibration. Mining industries oversees have for a long time been aware of the effects of vibration on the long term health of drivers. However, work is still needed on the effects of vibration on driver comfort and concentration.

d) Ergonomics. Recent work by the US Bureau of Mines and British Coal has highlighted the poor layout of many driver positions, in terms of comfort, access to controls and ability to see the task and computer programme have been developed and used to redesign equipment. Even tasks such as cleaning spillage from conveyors, moving materials, coupling vehicles, etc. could well be made safer by applying the principles of ergonomics to the task and to the design of any equipment used in the operation.

e) Since very little hard data on the causes of machinery, transport and haulage accidents has been analysed, a one year project devoted to this aspect would undoubtedly yield valuable information. A single researcher could, with the co-operation of the Inspectorate, analyse all accidents leading to injuries (on average 5 per week), as well as visit and properly document the cause and underlying factors in each of the fatal accidents (one every two weeks).

f) While the above project would, in many cases, involve a post accident human error audit, there is much merit in developing a system of potential human error audits to identify and deal with behaviorally related accidents before they happen. Having identified the individual potential errors, this technique enables the examination of the error pool for common predisposing factors and this in turn enables identification of the best course for improvement.

7.2 Research in the Field of Strata Control

Over the past 10 years 229 people have been killed by falls of ground, which is now the single largest cause of fatalities in our coal mines (see Table 14). A recent review (Akermann, 1994) of the period 1988 - 1993 showed that 77% of all reportable fall of ground (FOG) incidents occurred at the working face of bord and pillar operations. Of these cases, roof falls accounted for 68%, sidewall collapses 22% and face collapses 10%. It is also interesting to note that 81% of these falls had a thickness of 0,5 m or less. Many of these FOG accidents could be attributed to human error resulting in inadequate examination, standards not applied and lack of caution.

At present virtually all of the SIMCOL funding for strata control research is directed towards pillar stability (regional support) with the exception of COL 019, which deals in part with local support of workings. Although further work on some aspects of pillar design is still necessary, particularly with regard to long-term stability and its effect on the environment and urbanisation, coal pillar design in South Africa has reached an advance stage and further work may be of academic interest only. The only work of direct relevance to the problem area identified by the statistics i.e. the working face, is covered under the Generic Research Programme and deals with remote operation of continuous miners, thereby keeping personnel out of unsupported splits. The time may now well be right to initiate research projects in the following areas:

a) Investigation of Roof Bolting Practices. It may well be possible that shorter bolts, closer spaced would provide more effective support.

b) Mechanisation. Mechanised finger line support installation may prevent production delays and enhance safety.

c) Sounding Equipment. Sounding of the roof by conventional means is always subjective and development of electronic sounding equipment for use in coal mines should be encouraged.

d) Guidelines on FOG Reporting. All FOG accidents should be investigated by rock mechanics personnel and a detailed data base established to assist with future research. A short research project could provide useful guidelines on FOG reporting.

e) Sidewall Support in Thick Seams. Some form of cuttable sidewall support is required when thick seams are mined. Even when remote operation of machines is being utilized safety precautions such as sidewall support and fabric should be available if local conditions indicate the need for such precuations.

7.3 Research Into Fires And Explosions

At present there is no research being undertaken in the area of flammability of materials and fire prevention and the only work of any relevance at all to fires involves COL 115, the Reassessment of Survival Strategies For Post Coal Mine Explosions and Fires. During a visit to South Africa last September, Dr Alan Roberts, a leading expert on research into fires and explosions, commented on the need for research into the flammability of materials and combinations of materials permitted in South African coal mines and the standards for storage of materials, electrical sub-stations and conveyor roads.

Since this year (1994) 57% of the nearly R6 million SIMCOL research budget is spent on explosion research, it is appropriate to review the reported incidents and not just the accidents involving injury or death. The statistics presented here may vary slightly from those presented in Tables 1, 2 and 3 because this analysis involves more detail for the pre-1988 data than that recorded in the old format by the G.M.E.'s office.

For the period 1984 to 1993, 51 incidents were reported, providing an average of 5,1 occurrences per year. Of the 51 incidents, 40 were classified as ignitions and 11 as explosions, as shown in Table 15.

TABLE 15

IGNITION AND EXPLOSION FREQUENCY FOR THE PERIOD 1984 TO 1993

YEAR	IGNITIONS		EXPLOSIONS		
	NO	INJURED	NO	INJURED	KILLED
1984	5	0	2	0	6
1985	6	1	1	7	34
1986	2	-	0	-	-
1987	1	-	1	11	35
1988	1	1	1	5	0
1989	4	0	1	4	1
1990	7	0	2	13	0
1991	5	1	1	17	1
1992	5	1	1	2	6
1993	4	0	1	0	53
TOTAL	40	4	11	59	136

Causes of Explosions

Sources of ignition can be divided into three major categories, namely frictional, flame and electric ignitions. Frictional ignitions include ignitions due to the cutting picks of continuous miners or road headers contacting stone, cutting picks of coal cutters, cutting picks of shearers and ignitions due to stone on stone friction. Flame ignitions include those due to blasting, spontaneous combustion or heated surfaces. Electric ignitions include ignitions due to electric sparks and lightning forming stray currents. Table 16 provides a list of the sources of ignition and the frequency at which they were involved during the past decade.

TABLE 16

SOURCES OF IGNITION IN SOUTH AFRICAN COLLIERIES FOR THE PERIOD 1984 - 1993

SOURCE OF IGNITION	IGNITIONS	EXPLOSIONS	TOTAL	% TOTAL
FRICTIONAL:				
CM Picks	8	3	11	21
CC Picks	2	0	2	4
Shearer Picks	1	0	1	2
Stone on Stone	3	0	3	5,5
FLAME/HEATED SURFACE:				
Blasting	0	2	2	4
Spontaneous Combustion	0	1	1	2
Heated Surfaces	1	0	1	2
ELECTRIC:				
Electric Sparks	1	2	3	5,5
Lightning Stray Currents	0	1	1	2
UNKNOWN	26	2	28	52

Frictional ignitions obviously play a dominant role as ignition sources, being the cause of 32,5% of all incidents. Since many of the ignitions and explosions where the cause was never determined may have been due to friction, it is perhaps important to comment that of those incidents for which the cause was determined, frictional ignitions accounted for 68%. On the other hand blasting and electric sparks form only 8% and 12% respectively of the known sources of ignition.

Changing Pattern of Ignition Sources With Time

While the above analysis has given a clear indication of the current ignition sources and their relative significance, it is also important to study trends to determine where research effort and preventative measures can have the greatest impact in reducing the explosion risk. Data for the past three decades has been anlysed and is compared with that for the first three years of the 1990s.

TABLE 17

THE CHANGING PATTERN OF IGNITION SOURCES

IGNITION SOURCES	PERIOD							
	1960s		1970s		1980s		1990 to 1992	
	I	%	I	%	I	%	I	%
CM Picks	0	0	1	5,5	14	29,5	6	25,5
CC Picks	1	4,5	3	17	11	22,5	0	0
Shearer Picks	0	0	0	0	1	2	0	0
Stone on Stone	0	0	0	0	4	8	1	4
Blasting	14	64	6	33,5	5	10	1	4
Spon Comb	0	0	0	0	0	0	2	8
Heated Surface	1	4,5	1	5,5	1	2	0	0
Naked Flame	2	9	1	5,5	0	0	0	0
Electricity	2	9	2	11	5	10	0	0
Lightning	2	9	4	22	3	6	0	0
UNKNOWN	0	0	0	0	5	10	14	58,5
TOTAL	22	100	18	100	49	100	24	100

I = number of incidents of ignitions/explosions

Two very obvious changes are the steady increase in frictional ignitions following the introduction of continuous miners in the early 1970s and an equally noticeable decrease in the percentage of incidents caused by blasting. A more difficult phenomenon to explain is the increase in ignitions caused by coal cutter (CC) picks. While the number of coal cutters in use and the tonnage mined by conventional mechanised mining increased during this period, the quite remarkable increase in ignitions from this source may well have arisen from a perception that coal cutters only excavate a narrow kerf and so are inherently less dangerous than continuous miners.

Electricity, lightning, naked flames, etc have all remained small and almost constant components of the total scene throughout the period under review.

Location of Explosions and Ignitions

In order to assess the influence of mining method on the occurrence of explosions and ignitions, the data for the period 1982 to 1993 has been classified according to the location of the incident and the mining method involved. This analysis is presented in Table 18.

TABLE 18

LOCATION OF INCIDENT EPICENTRES IN SOUTH AFRICAN UNDERGROUND COLLIERIES FOR THE PERIOD 1982 TO 1993

LOCATION	IGNITIONS	EXPLOSIONS	TOTAL	% TOTAL
FACE AREA:				
Bord and Pillar	25	10	35	55
Longwall Development	4	0	4	6
Longwall (Face)	3	0	3	5
ABANDONED AREAS:				
Pillar Extraction Goaf	2	3	5	8
Longwall Goaf	1	0	1	1,5
NON-FACE AREAS:				
Intake Airways	0	2	2	3
Return Airways	0	2	2	3
Shaft Areas	0	1	1	2
UNKNOWN	11	0	0	16,5

It is clear from Table 18 that 66% of all incidents occurred in the face area.

Explosions and Fires Research

From the above analysis and discussions with researchers and industry personnel the following research areas would appear to need attention:-

a) Immediate Suppression of Explosions. Since frictional ignitions by continuous miners are the dominant source of ignition and 66% of all incidents occur in the face area, work on machine mounted suppression systems should be given the highest priority.

b) Ventilation of Headings. Again for the above reasons, the occurrence of accumulations of explosive concentrations of methane and dust at the working face should be prevented by proper ventilation and work on ventilation of headings and particularly the area around the drum should continue. This work could include basic studies of novel ideas such as air and water curtains for ventilation control, making the atmosphere at the drum inert and chemical removal of methane either at the face or by seam infusion.

c) Ventilation, Monitoring and/or Sealing of Goafs. Since nearly 10% of incidents are associated with goafs, research into the ventilation and monitoring of goafs in working sections (pillar extraction or longwall) should be undertaken. The other problem of sealing abandoned goafs has been partially addressed during 1993 (COL 031) but the whole question of explosion proof stoppings for all abandoned areas, whether goafs or not, should be investigated.

d) Stone Dust Quality, Waterproofing and Dust Layering. A great deal of scientific evidence has been produced worldwide on the efficiency of stone dust in preventing coal dust explosions. This, together with recent work at the G.P. Badenhorst Test Gallery, should be put into the context of South African mining conditions in a practical way. For example, when stooping takes place some splits may well have been stone-dusted several months before pillar extraction at that location. What then would be the effect of a thin layer of coal dust on top of the stonedust and would waterproof stonedust be preferable under typical operating conditions?

e) Effect of Airborne Dust on Explosibility of Methane. Recent research has shown, for two South African coals, that explosible concentrations of methane and dust can occur at methane levels well below 5%. These limits should be established for other coals and field work undertaken to determine the likely risks in practice.

f) Review of Frictional Ignition Research. A review was conducted by COMRO some years ago with the conclusion that no further work was necessary. However, the continuing problem with frictional ignitions indicates that another review should be undertaken with particular reference to continuous miner picks and drums. This should conclude with a comparison of international scientific recommendations against current practice in South African Collieries.

g) Continuous Monitoring Schemes For Gas and Airflow. It is undoubtedly true that many ignitions and explosions are the result of local decisions to "temporarily" ignore mine standards. Continuous monitoring schemes connected to a control room, with the data recorded, could lead to remedial action by supervisors before an incident can occur. At present many of the commercial systems are inappropriate for bord and pillar mining and instruments are unreliable under South African conditions. Adaptation of existing schemes and development of new instruments could improve the viability of continuous monitoring, including on-board gas warning devices. These schemes should include provision for monitoring and recording methane, carbon monoxide and airflow.

h) Development of a Fire Testing Gallery. As the recent event at Koornfontein Mines has shown, fires, although rare in South African collieries, can be devastating. As new products and materials become available their flammability under different ventilation conditions should be checked and a basic fire testing gallery would complement the other facilities available at Kloppersbos. A review project to study the need for and possible design of, such a facility should be conducted.

7.4 **Other Research**

Sections 7.1, 7.2 and 7.3 have dealt with research into the three areas of greatest concern in terms of accidents, fatalities and injuries. The other research that requires continued support is into dust control as, with increased mechanisation, the health of workers in face areas could well become an issue. The present project (COL 027) is making good progress in determining effective control measures, but monitoring equipment and procedures are also in need of investigation. In particular, a project to evaluate technical aspects of the gravimetric programme and the consistency of the instruments used could now be appropriate.

Another area of research not addressed by the current programme is the use of modern teaching and training techniques such as computer aided learning and simulation games. Certainly some of the trainers within the industry believe that safety campaigns, slogans, induction and re-induction programmes have reached the limit of their effectiveness and there is a need to modernise our approach to the transfer of safety knowledge. Consequently the use of computer based simulation games should be examined since they are known to stimulate the learner and effectively transfer knowledge.

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* The dozens of industry personnel with whom discussions have been held on accidents and safety and who have given their opinions on research needs so freely.

Without the help of these people this project could not have been completed.

APPENDIX I

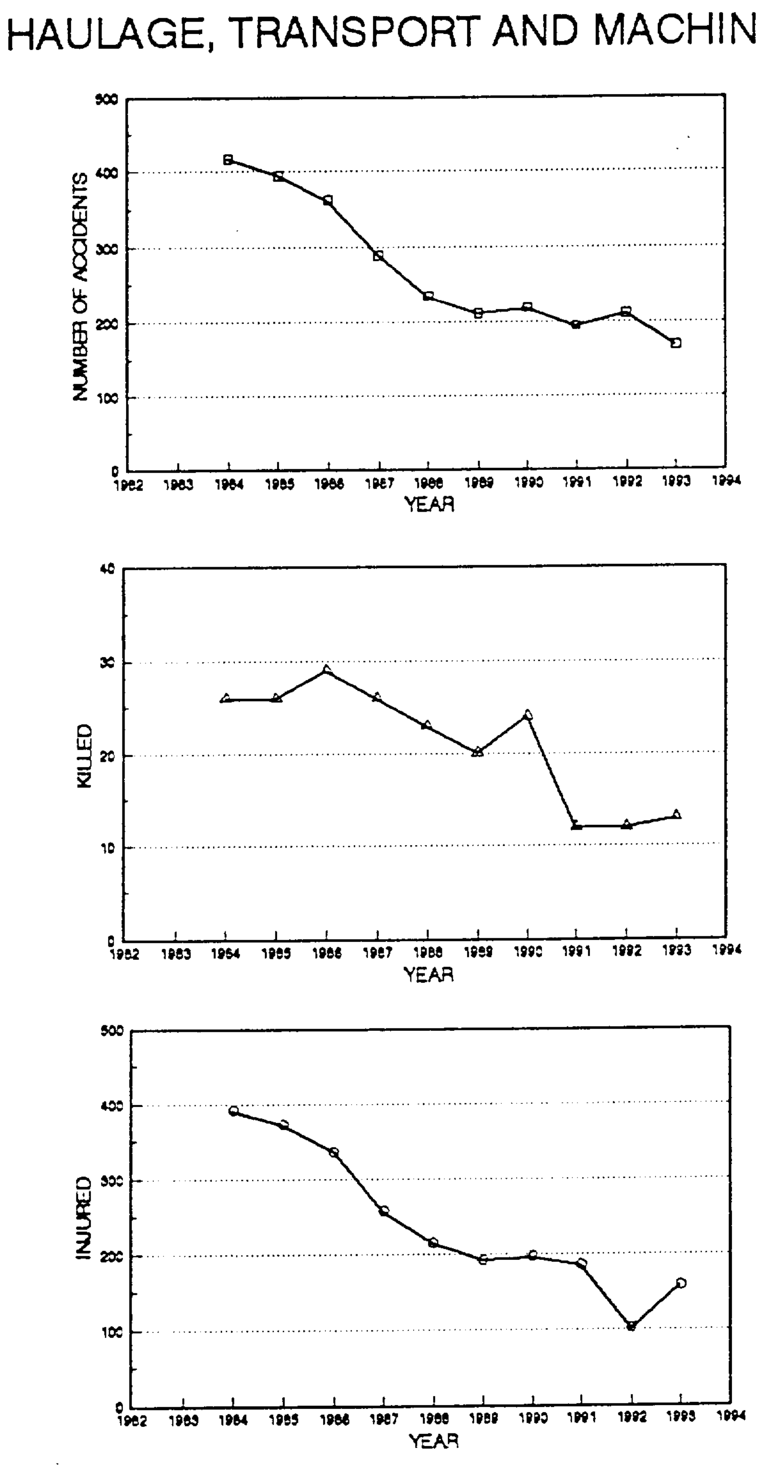

FIGURE 2 **Trends in Haulage, Transport and Machinery Accidents Over a 10 Year Period**

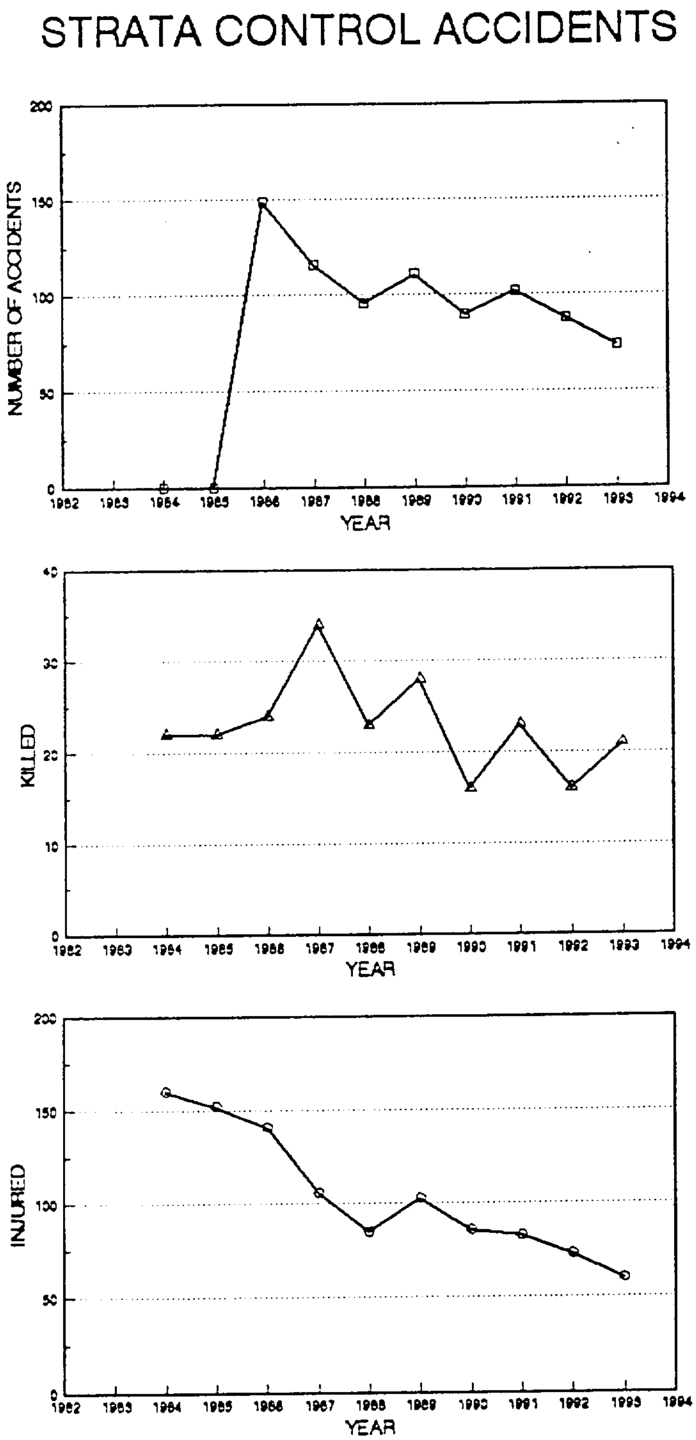

FIGURE 3 Trends in Strata Control Accidents Over a 10 Year Period

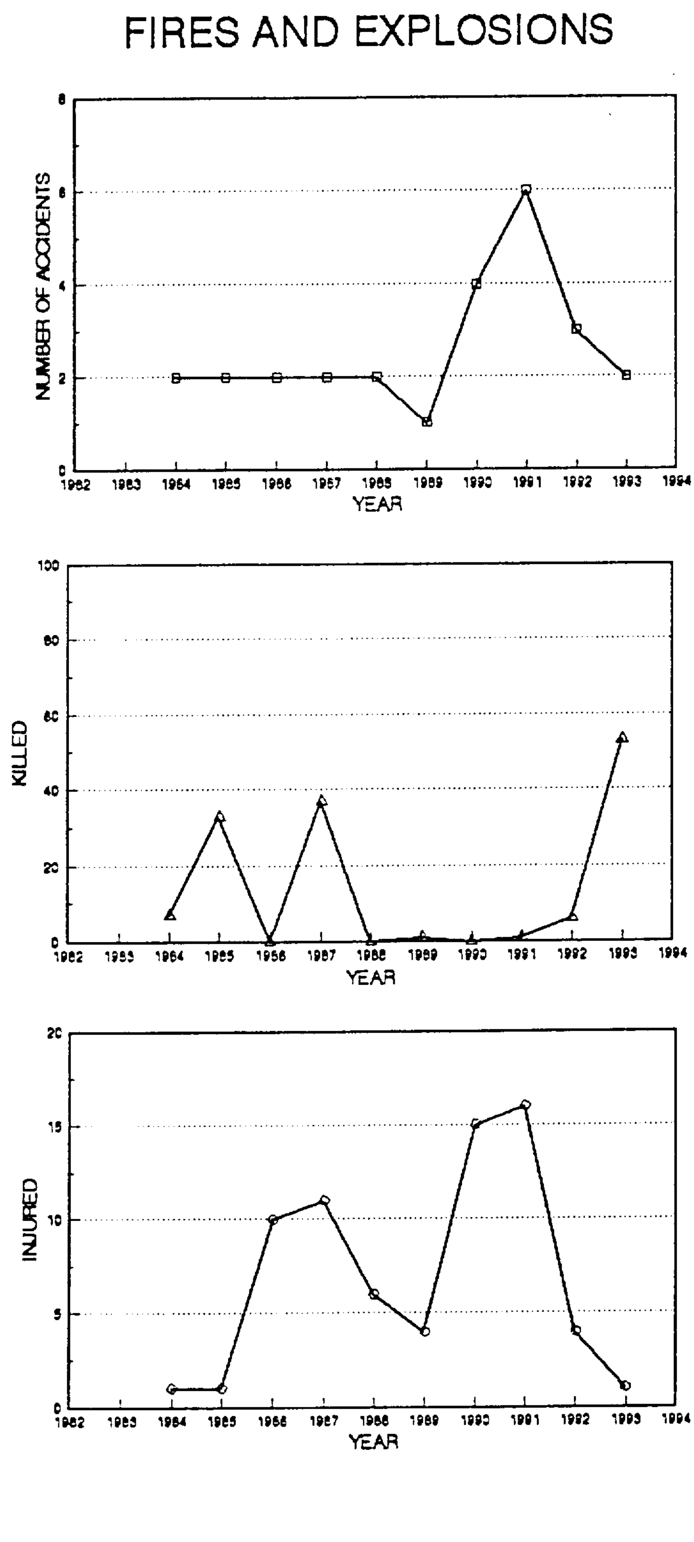

FIGURE 4 **Trends in Accidents Due To Fires and Explosions Over a 10 Year Period**

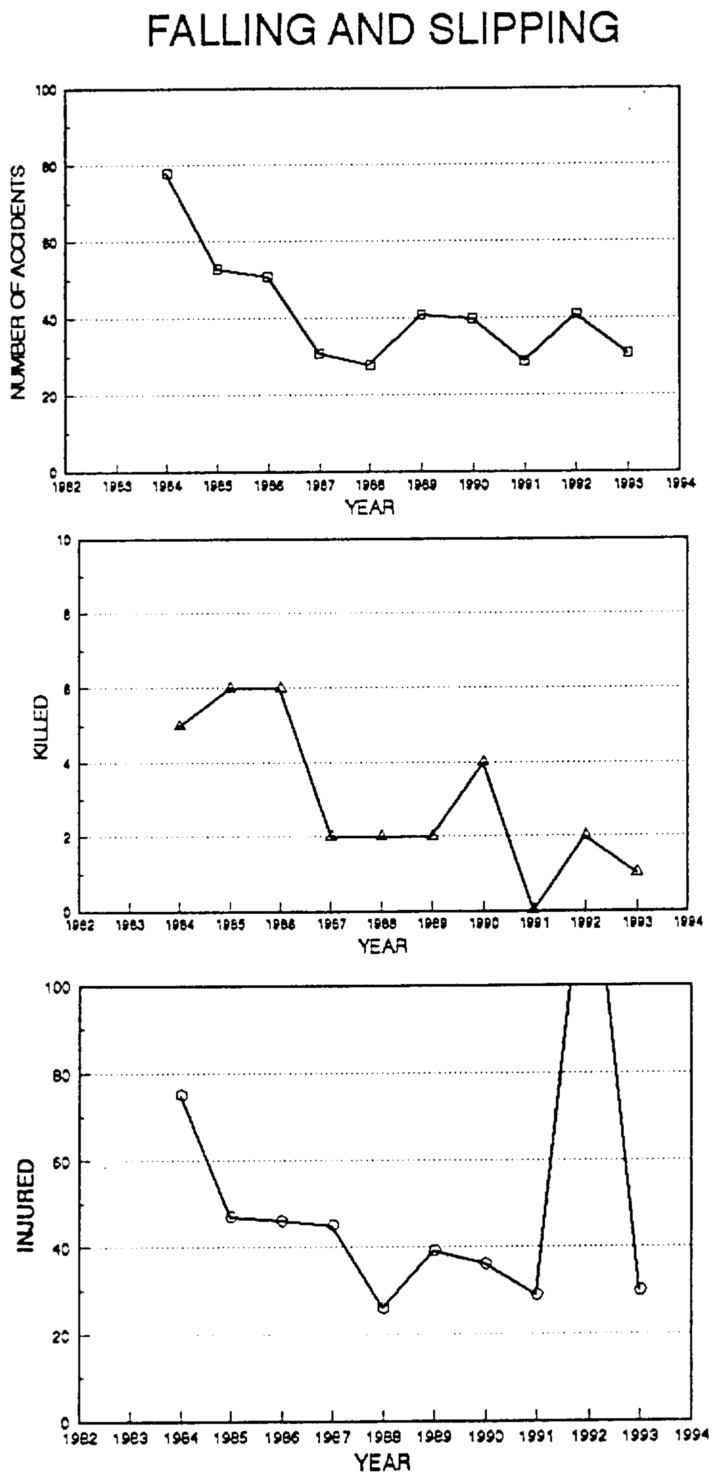

FIGURE 5 **Trends in Falling and Slipping Accidents Over a 10 Year Period**

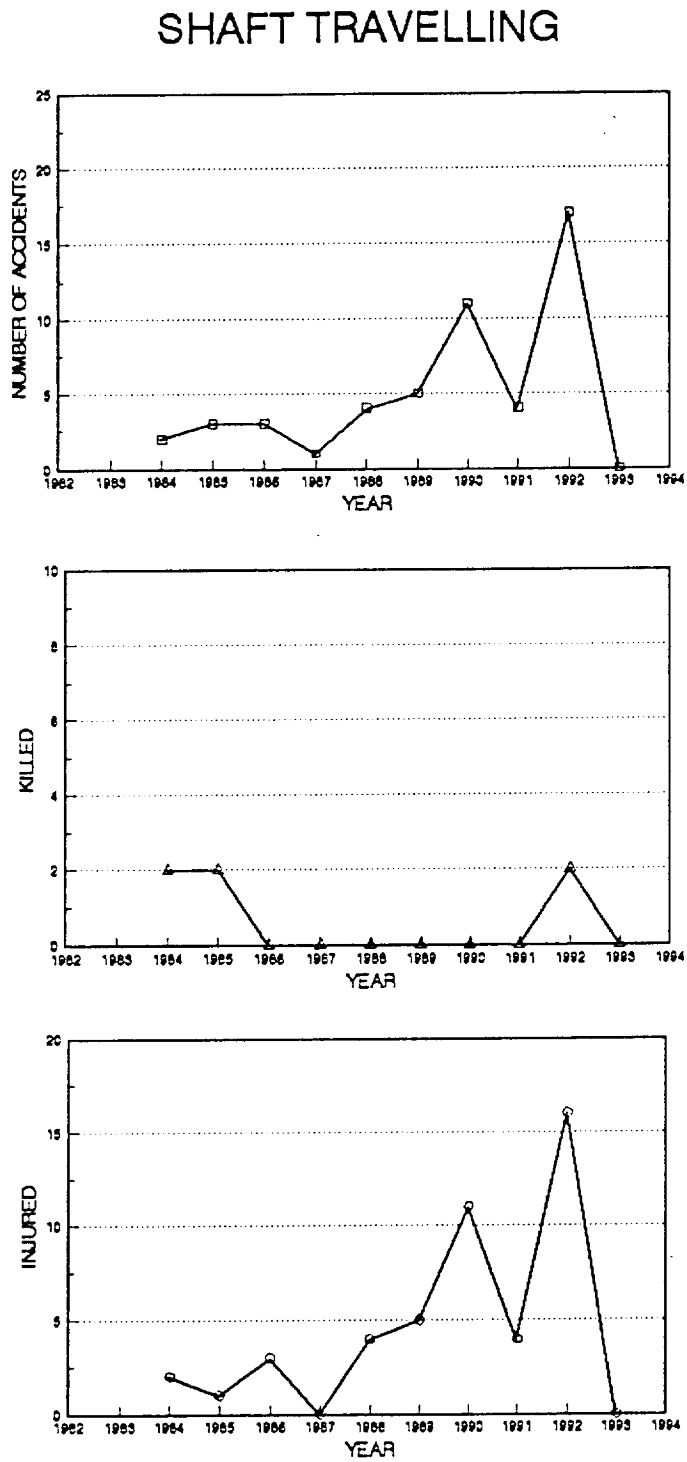

FIGURE 6 **Trends in Shaft Travelling Accidents Over a 10 Year Period**

INUNDATION BY WATER/MUD

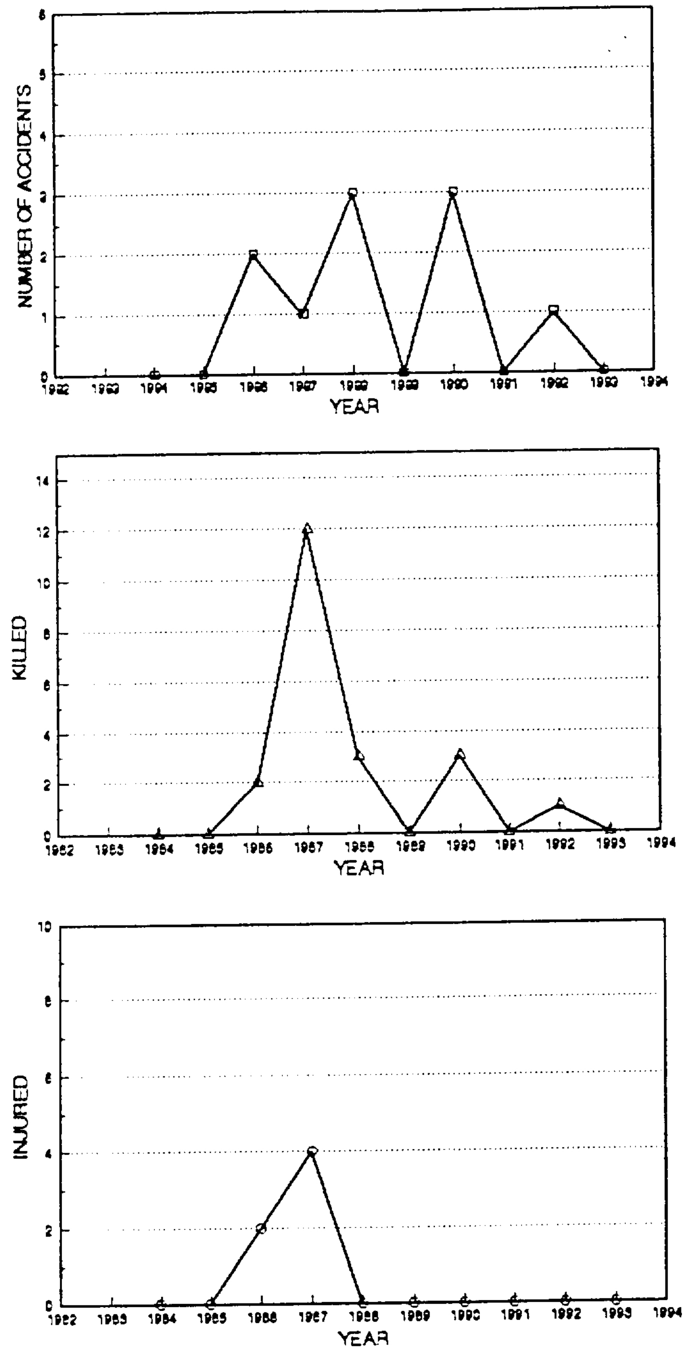

FIGURE 7 **Trends in Accidents Due To Inundations By Water/Mud**

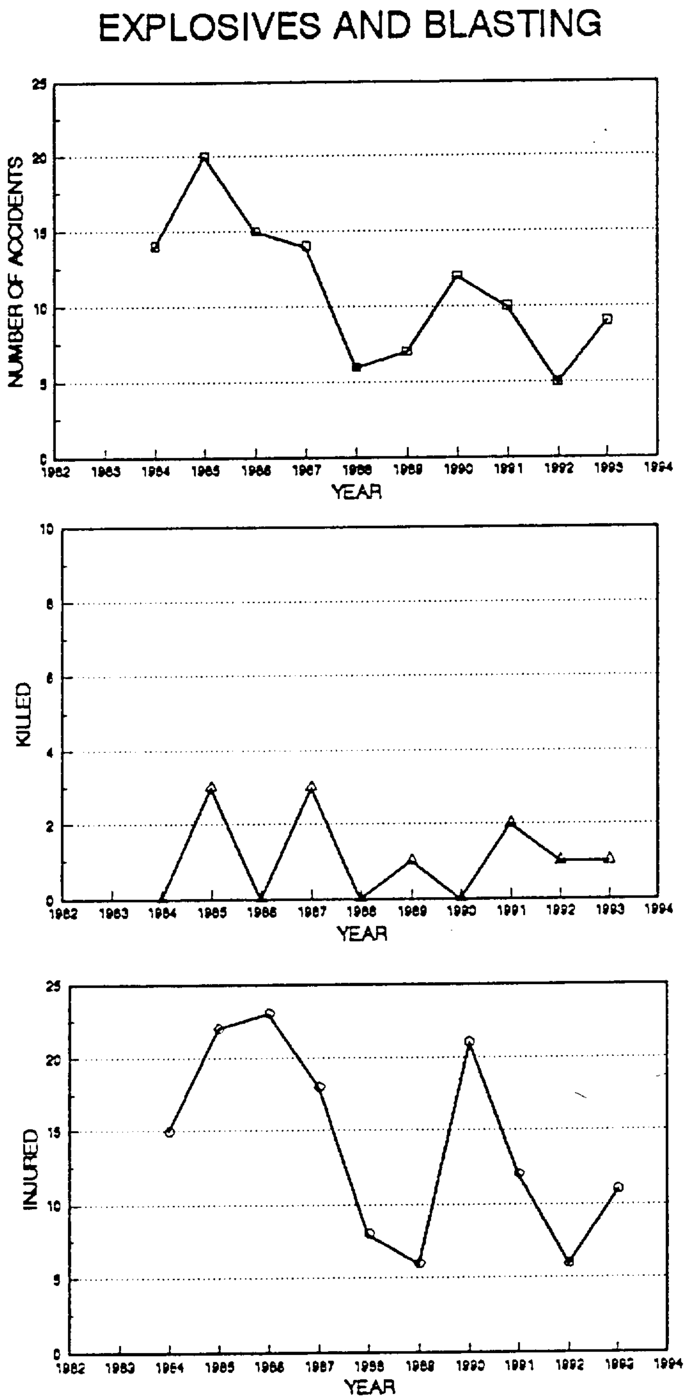

FIGURE 8 **Trends in Accidents Due To Explosives and Blasting Over a 10 Year Period**

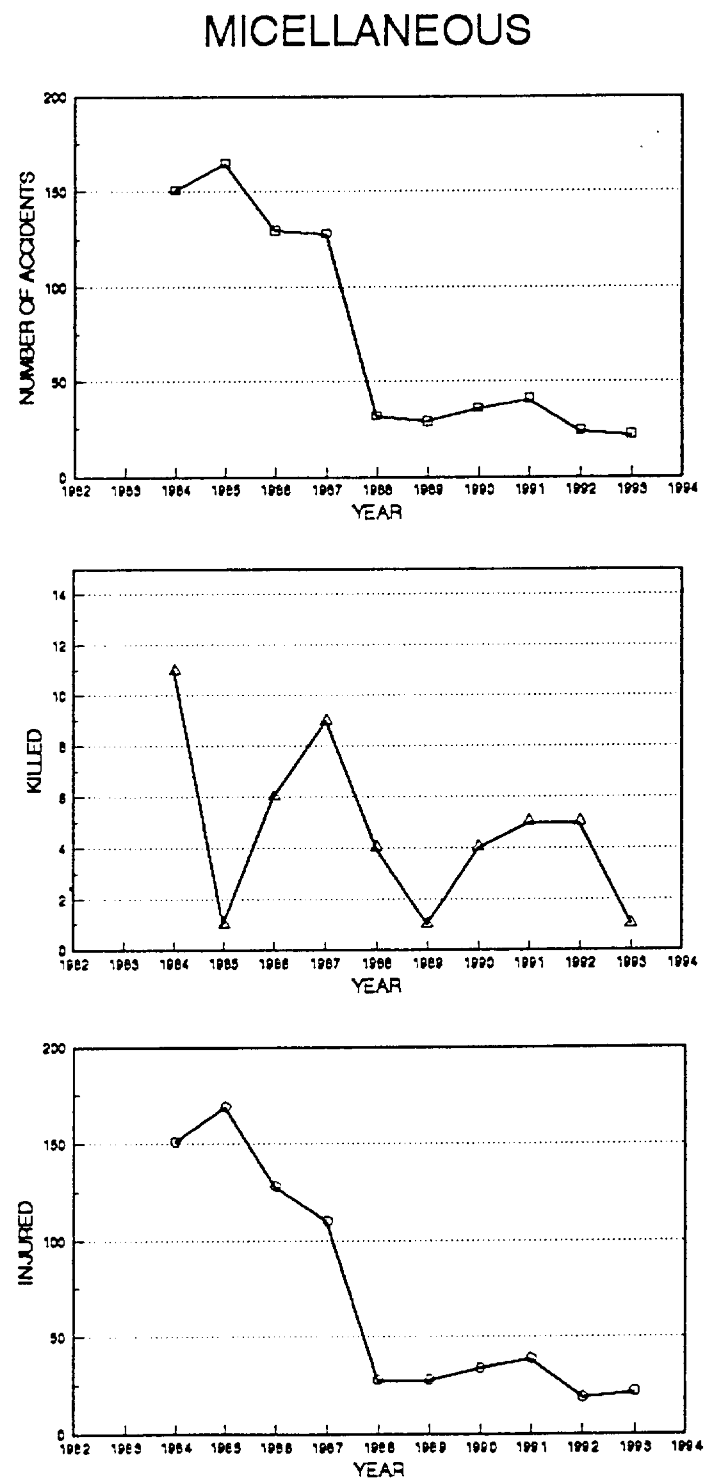

FIGURE 9 **Trends in Miscellaneous Accidents Over a 10 Year Period**