SOUTH AFRICAN COAL MINE EXPLOSIONS

Martin du Plessis
Chief Regional Mining Engineer
South African Department of Mineral and Energy Affairs

SUMMARY

Explosions have been occurring regularly during the past in South African coal mines. There have been disturbing increases in the frequency and the occurrence rates of explosions. The main source of ignition has shifted from the use of explosives to frictional ignitions resulting from the use of mechanical miners.

The unsatisfactory safety record of the South African mining industry led to the establishment of the Leon Commission of Inquiry into mine health and safety. Following recommendations of the Commission, a new Mine Health and Safety Bill was drafted and a task group was appointed to advise on measures to be taken to decrease the risk of coal mine explosions.

The Mine Health and Safety Act now provides for proper hazard identification, risk control, training and participation of employees and their representatives in health and safety matters.

New measures have been proposed to reduce the risk of coal mine explosions.

It is believed that the explosion hazard will best be addressed by improved training and the promotion of a culture of safety amongst all mining personnel.

1. INTRODUCTION

Coal mining is probably nearly as old as mankind itself and many deaths due to explosions in collieries have resulted through out the centuries. The earliest reference to such a fatality is contained in the register of St. Mary's Church, Gateshead, in the United Kingdom, which list the burial on October 14, 1621, of Richard Backas - "burnt in a pit".[1]

The dangers of flammable or noxious gases were well known in Roman times. Pliny (23-79AD) wrote "In deep wells the occurrence of sulphurate or aluminosa vapours is fatal to the diggers. The presence of this peril is shown if a lighted lamp let down into the well is extinguished. If so, other wells are sunk to the right and to the left, which carry off these noxious fumes. Apart from these, the air itself becomes noxious with depth, which can be remedied by constantly shaking linen cloths, thus setting the air in motion." Remedial measures taken were not always appropriate as demonstrated in the writing of Georgius Agricola in his book on mining and metallurgy, *De Re Metallica* in 1556. He wrote "in some of our mines there are other pernicious pests. These are demons of ferocious aspects. Demons of this kind are expelled and put to flight by prayer and fasting."

All coal mining countries have had their share of explosion disasters. South Africa is, sadly, no exception.

2. BACKGROUND

The South African coal mining industry dates back more than 130 years when coal was first mined, on a small scale for local consumption only, near Molteno in the Eastern Cape. Soon afterwards the Natal coal fields were discovered which rapidly expanded at the turn of the century with the onset of the industrial age.

While not the main mining commodity, the coal mining industry, employing approximately 58 000 workers, is continually growing. The current annual run of mine production is approximately 250 Mt of which approximately 50% is from underground sources.

The South African coal deposits occur in the Ecca Series of the Karoo system. Currently the main coal fields being exploited, by more than 80 mines, are the Witbank, Eastern Transvaal, Highveld and Vryheid deposits.

South African coal is generally hard, of relative high volatile content, shallow lying and occurring in thick flat seams over large areas largely free from faulting.

Mining is mainly highly mechanised, ranging from conventional drilling and blasting sections to continuous miners and longwalls. In 1994, about 10% of the underground production came from longwalls, while the rest were obtained from the bord and pillar method, including stooping operations. [2]

3. SOUTH AFRICAN COAL MINE EXPLOSIONS

Coal mine explosions vary from a flash at the face to an explosion involving the whole mine.[3] Records indicate that since the first fatality due to a coal mine explosion, which occurred at the Elandslaagte colliery in 1891, a further 333 explosions have resulted in 1034 deaths at the end of 1995. Most explosions were contained to a flash at the face with no casualties but many resulted in major death tolls.

Table 1 shows the 10 worst South African coal mine explosions.

Table 1

DATE	COLLIERY	KILLED	INJURED
1925	Durnacol No. 2 Colliery	125	0
1935	Marsfield Colliery	78	0
1935	Nothfield Colliery	78	4
1935	Glencoe Colliery	77	0
1983	Hlobane Colliery	68	8
1944	Hlobane Colliery	56	13
1993	Middelbult Colliery	53	0
1930	Burnside Colliery	38	0
1987	Ermelo Mines Services	35	11
1985	Middelbult Colliery	34	7

Only in the case of the Durnacol disaster did a coal dust explosion propagate through the entire mine. Analysis of explosion records done recently by Flint [4], indicates that coal dust played a significant part in at least 7 other explosions.

3.1 EXPLOSION FREQUENCY

Table 2 shows the number of occurrences, injuries and deaths due to explosions in South African coal mines, during periods of 5 years, since 1950. The last period covers the 6 years from 1990 to 1995.

Table 2

PERIOD	EXPLOSIONS	INJURED	KILLED
1950-54	7	11	36
1955-59	4	14	23
1960-64	9	12	25
1965-69	18	9	7
1970-74	8	61	29
1975-79	13	28	1
1980-84	35	66	108
1985-89	16	28	71
1990-95	30	26	60
TOTALS	**140**	**255**	**360**

The average annual explosion frequency during the period 1950 to 1979 was 2. This figure increased alarmingly to more than 5 during the period 1980 to 1995. The increase in the occurrence of explosions must be seen against the increase in production, mainly due to the increasing use of mechanical miners.

Table 3 shows the progressive number of continuous miners provided by the major supplier and the annual run of mine production since 1980.

Table 3

YEAR	NO. OF CM'S	PROD Mt/a	YEAR	NO. OF CM'S	PROD Mt/a
1980	25	115	1988	154	182
1981	37	130	1989	134	178
1982	61	142	1990	145	175
1983	72	146	1991	145	178
1984	83	163	1992	149	190
1985	100	176	1993	151	220
1986	107	178	1994	171	242
1987	116	176	1995	186	252

3.2 Explosion Severity

Even more disturbing than the increase in the frequency rate of explosions, is the rise in the severity of explosions. Explosions with multiple fatalities started occurring more frequently. Since 1980 there have been 8 explosions with 5 or more fatalities with a death toll of 239. One hundred and twenty one fatalities had occurred in the 30 years which preceded 1980.

3.3 Sources of Ignition

Sources of ignition are grouped in 5 categories by Landman.[3]

Table 4 shows the number of ignition sources during the period 1950 to 1995. The percentages are shown in brackets.

Table 4

SOURCE OF IGNITION	1950-59	1960-69	1970-79	1980-89	1990-95
FRICTIONAL	0	1 (4)	7 (33)	31 (61)	29 (97)
LIGHTNING	0	2 (7)	4 (19)	3 (6)	0
ELECTRICITY	3 (27)	3 (11)	3 (14)	5 (10)	0
EXPLOSIVES	5 (46)	16 (57)	6 (29)	6 (12)	1 (3)
NAKED FLAME	3 (27)	4 (15)	1 (5)	1 (2)	0
UNCLASSIFIED	0	2 (6)	0	5 (9)	0
TOTAL	**11 (100)**	**28 (100)**	**21 (100)**	**51 (100)**	**30 (100)**

Clearly, the main source of ignition has shifted from the use of explosives to frictional during the last 25 years. A small number of these ignitions was associated with goafing while the majority originated at the face where mechanical miners were used.

3.4 Explosions Compared to Other Accidents.

Accidents are normally classified in 38 categories. For the purpose of this comparison, the fatalities which resulted from accidents are grouped as shown in Table 5.

Table 5

YEAR	MACHINERY	ROCK FALLS	EXPLOSIONS	MISC	TOTAL	FATALITY RATE PER 1000 PER ANNUM
1984	32	22	7	11	73	0,67
1985	30	22	33	8	93	0,83
1986	33	24	0	10	67	0,61
1987	40	34	37	12	123	1,17
1988	23	23	0	9	55	0,55
1989	17	28	1	7	53	0,56
1990	21	16	0	14	51	0,53
1991	12	23	1	7	43	0,48
1992	15	17	6	8	46	0.65
1993	12	21	53	4	90	1.57
1994	22	9	0	24	55	1,02
TOTALS	**257**	**239**	**138**	**114**	**749**	

4. THE LEON COMMISSION OF ENQUIRY

The Leon Commission was appointed by the State President to enquire into safety and health matters in the mining industry and to make recommendations on improvements. The Commission was chaired by the Honourable Mr. Justice Ramon Leon. The other commissioners were Professors Miklos Salaman, John Davies and Albert Davies, all recognised experts in their fields. The Commission commenced hearing evidence on July 18, 1994 and continued until August 24, 1994. The oral evidence transcribed into about 2 600 printed pages. The Commission produced a comprehensive report at the beginning of 1995, making numerous recommendations to improve safety and health in the South African mining industry. For the purpose of this presentation, two of these recommendations will be commented on further.

4.1 NEW MINE HEALTH AND SAFETY ACT

It was recommended that a new Mine Health and Safety Bill, devoted to regulating health and safety in the mining industry, be drafted by a tripartite body representing the State, the employers and the employees. The drafting of the new Bill was concluded at the end of 1995. After protracted negotiations and revisions by various committees, the Bill was finally signed by the State President during June 1996. The Mine Health and Safety Act is being phased into operation with effect from August 1, 1996.

The objectives of the Mine Health and Safety Act are stated in Section 1 of the Act. They are;-

- to protect the health and safety of person at mines
- to require employers and employees to identify hazards and eliminate, control and minimise the risks relating to health and safety at mines
- to give effect to the public international law obligations of the Republic that concern health and safety at mines
- to provide for effective monitoring of health and safety conditions on mines
- to provide for enforcement of health and safety measures on mines
- to provide for investigations and inquiries to promote health and safety on mines
- to promote -

  (i) a culture of health and safety in the mining industry
  (ii) training and health in the mining industry
  (iii) co-operation and consultation on health and safety between the State, employers, employees and their representatives.

4.2 *TASK GROUP FOR THE PREVENTION OF COAL MINE EXPLOSIONS*

Following recommendations by the Leon Commission, the newly formed Mining Regulation Advisory Committee (MRAC), appointed a tripartite task group to advise on measures to be taken to minimise the risk of coal mine explosions. The task group commenced its work on July 1 1995 and soon thereafter they reported to the MRAC that they deemed the regulatory requirements relating to coal dust explosions to be inadequate. Consequently the task group was instructed to compile guidelines for a code of practice for the prevention of coal dust explosions.

The following precautionary measures are provided for in the guidelines;-

- limiting the formation and dispersion of coal dust

  Some basic acceptable controls of dust generation are given and the mine's proposed dust control measures are called for.

- the removal of coal dust

  A programme for the regular clean up and removal of coal dust, from specific areas, must be laid down.

- inertisation of coal dust

  A degree of inertisation of 80% has been called for in the face area (within 180m from the face) of all coal mines, other than anthracite mines, irrespective of the volatile matter content of the coal.

- limiting the extent of a coal dust explosion

  The employment of barriers, either stone dust barriers constructed to Polish standards, or water barriers provided to British standards, has been called for. Barriers are required to be installed in belt roads and, unless an incombustible rate of 80% is maintained in the face area, in roads carrying return air.

- dealing with abandoned areas

  Stoppings placed to seal off abandoned areas must -

  - control gas-air exchanges between the sealed and open areas
  - be capable of preventing an explosion initiated on one side from propagating to the other
  - remain intact during the containment period of a fire within the sealed zone

  Provision has been made for the placement of containment walls (designed to withstand a static pressure of 140kPa) and "explosion proof seals".

- compliance monitoring

  More frequent sampling of mine dust in the face areas has been called for. Provision has been made for underground colorimetric analysis of samples.

- risk assessment and training

  Mine -specific report on measures required to overcome the explosion risk and training programme for explosion prevention to be incorporated in the code of practice.

Measures to be taken to prevent the ignition of a primary dust cloud were not covered in the guidelines as these were dealt with in operational ventilation codes of practice.

4.2.2 OTHER RECOMMENDATIONS

The task group submitted a final report to the Mining Regulation Advisory Committee, making several recommendations to decrease the risk of coal mine explosion. Some aspects covered are: -

(a) Frictional ignitions by mechanical miners

Having identified this as the major source of ignition, possible preventative measures were investigated. The effectiveness of pick-path water spraying as a guard to frictional ignition prevention was acknowledged. Continuous miners currently available in South Africa are not equipped for this as water is generally applied in a spray form around the cutting drum. It also appeared that the likelihood of an ignition is not significantly reduced with a slower cutting speed in the range considered to be of practical value. Improved pick design, to the extent that a frictional ignition cannot occur, is unlikely in the foreseeable future.

A machine mounted ignition suppression system, developed in Germany, was recently tested at the Kloppersbos research facility in a specially constructed tunnel. The system relies on an ignition being detected by electronic sensors and extinguished by the discharge of a surpressing agent. Two tests have been done and the system successfully stopped both explosions.

An ignition prevention system was recently developed, also in Germany. The system utilises water and air being applied through nozzles in a spray form, in and around the cutting area at the face. A compressed air quantity of $8m^3$/min is used which immediately dilutes any methane produced at the face to a safe concentration. The system can be provided on all types of mechanical miners. It is trusted that the system will soon be in operation where there is a risk of frictional ignitions.

(b) Human factors

It seems that explosion experts from all over the world are unanimous that nearly all explosions are caused by human failure, not restricted to the worker at the coal face. It is believed that the explosion hazard will best be addressed by improving awareness and training amongst all levels of mining personnel. Recommendations in this regard include:

(i) research to be done as how to best improve training and awareness

(ii) handbooks and appropriate audio-visual material to be compiled and made available to mining personnel

(iii) the explosion hazard must be more comprehensively covered in the curricula of training programmes of key personnel such as mechanical miner operators, supervisory and managerial staff.

(c) Further research/investigation required to:

(i) determine the rates of deposition of float coal

(ii) improve ventilation of total extraction operations

(iii) control dust generation at mechanical miners

(d) Ignition investigation and review

Any ignition/explosion must be fully investigated by trained personnel to determine its causes in order that preventative measures can be assessed. All incidents to be reviewed regularly by a task group to determine whether further precautionary measures are required.

5. FURTHER DEVELOPMENTS

In spite of the regulatory requirements of refuge chambers and self contained self rescuers, recent experience show that persons who survived the initial explosion forces were unable to reach a place of safety within the time afforded to them by their self rescuers. In this regard, the following have been done:-

(a) Air supply by means other than via boreholes.

The provision of boreholes at 400m intervals is not easily achievable. As an alternative, oxygen generating candles, similar to those employed in submarines, are now in use in some refuge chambers which are relocated when the face has advanced 300m. Work has also been done proving respirable air can be supplied by means of compressed air contained in cylinders.

(b) Guidance system

An electronic system, using audible and visual signals, is employed to guide people to the refuge chamber.

(c) Life support vessel

A life support vessel, capable of sustaining 20 persons for up to 5 days, is currently under construction. The first unit is scheduled for delivery to a mine during October 1996.

6. CONCLUSIONS

The continuing occurrence of coal mine explosions world-wide, albeit it at a rate less frequent than in the past, is proof that the risk of a coal mine explosion has not been eliminated. Fuel is mined with methane very often present. Conditions in the underground environment can very rapidly change from a condition where an explosion cannot occur, to a situation which requires but one ingredient in the "recipe for a disaster" which has the potential to destroy a mine.

Further research world-wide, may in the future lead to the elimination of the explosion hazard. Until such time, the slightest relaxation of proven precautionary measures cannot be afforded.

It is believed that the best way currently to address the problem in South Africa, is to promote a culture of safety at the work place by improving training and awareness. The new Mine Health and Safety Act has laid the foundation necessary to improve safety, not only in the explosion hazard, but also in the mining industry in general. It is trusted that great improvements in mine health and safety will soon become evident.

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