

# SIMRAC

**DRAFT**

## Final Project Report

**Title:** OPTIMIZE AWARENESS OF HAZARDS IN UNDERGROUND COAL MINES CAUSED BY ELECTRICAL IGNITIONS AND FIRES THROUGH APPROPRIATE TRAINING GUIDELINES

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# EXECUTIVE SUMMARY

The primary objective of the work reported in this document was to compile training guidelines to address the hazards arising from electrical ignitions and fires in underground coal mines. The resulting training guidelines, which contain recommended technical requirements and suggestions for appropriate training methodologies, for each category of staff that could influence the likelihood of electrical ignitions and fires occurring, are contained in Appendix 1.

A number of secondary objectives were also addressed. These included suggestions for changes to legislation, improvements in maintenance and repair procedures, suggestions for technical guidelines, and various other issues that could influence the likelihood of electrical ignitions and fires occurring in coal mines.

A conclusion of particular importance is that it is clear that engineers who hold Certificates of Competency for Engineers (whether in the Mechanical or Electrical disciplines), are often not sufficiently trained or knowledgeable to enable them to recognise all electrical fire and ignition hazards underground, and to control them adequately. Various alternative strategies for addressing this shortcoming are made in the report.

The Mine Health and Safety Act and Regulations are unclear as to whether an electrical engineer must be appointed in overall charge of electrical equipment underground, although current local practice is that any holder of a Certificate of Competency may be so appointed. All other major coal producing countries require that electrical installations be under the control of electrical engineers, and it is recommended that local practice be changed to comply with this approach.

Electrical Foremen on mines exercise significant influence over electrical safety issues, and it is recommended that legal recognition be given to their role in this regard. Their educational and training requirements should also be formalised.

A number of recommendations are made for methods of improving training in the coal industry in general (particularly as regards the Colliery Training College), and suggestions are made for practical techniques for assessing the competence of new electrical staff by mines, and ensuring that they receive appropriate training.

## **Acknowledgements**

The work reported in this document was undertaken in collaboration with the South African Flameproof Association, and Health, Safety and Engineering Consultants Limited (HSEC). Their substantial contributions to the project are appreciated and acknowledged.

We express our gratitude to the management of the mines that were visited during the project. The anonymity guaranteed to these mines unfortunately precluded them from being named. The technical staff at the various mining group head offices, and the Colliery Training College, were extremely forthcoming in providing relevant information, and gave freely of their time to assist in the work. Special thanks are due to staff at the central and regional offices of the National Union of Mineworkers, for their enthusiastic and constructive support of our investigations.

Finally, thanks are also due to the various equipment manufacturers and repairers who were visited and interviewed, the staff of the South African Bureau of Standards, and the Witbank Branch of the Department of Minerals and Energy.

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# 1 Executive Report

## 1.1 Background and Objective of the Work

The work reported in this document arose from general concern in industry regarding the hazards that could arise from fires and ignitions caused by electrical faults.

Some relevant work had been undertaken, by the South African Flameproof Association (SAFA), immediately prior to the onset of the project reported here. This work indicated that a lack of knowledge is a primary reason for potentially dangerous conditions arising underground with regard to electrical reticulation systems in general, and explosion protected equipment in particular. The nature of mining requires that engineering personnel, other than the responsible engineer, often have to make on-the-spot decisions. These decisions typically require the application of fundamental engineering principles. Unless these principles are clearly understood, incorrect or inappropriate decisions that can lead to dangerous conditions arising, can be made. A proper understanding of the engineering principles would also allow staff to identify technical decisions that should be referred to others for consideration. Furthermore, many of the responsible engineers have a mechanical engineering background and are consequently less conversant with the technology of electrical and explosion protected equipment. The work also indicated that non-engineering personnel, particularly those in supervisory capacities, can unwittingly have a detrimental effect on safety, by issuing instructions that are at odds with good engineering practices. A proper understanding of the motivation behind engineering procedures would contribute greatly to avoiding inappropriate instructions being issued.

The SAFA project also indicated a lack of consistency in the technical standards applied in the industry. Problems were identified in the manner in which systems and equipment is designed, installed and maintained, as well as in how explosion protected equipment is tested, approved and repaired. A variety of reasons for this situation were suggested. Some of the more important are the often inappropriate application of practices in other countries to our mines, and a lack of appreciation of interactions between various parts of an overall mine electrical reticulation and distribution system. This situation can best be addressed by a comprehensive review of all technical aspects related to electrical systems in underground collieries.

In addition, the SAFA project identified ease of entry into the explosion protected equipment market, together with inadequate approval procedures and "mineworthiness" evaluations, to be a major source of concern with reference to potentially dangerous equipment being used in coal mines. There was also a marked lack of appreciation,

among maine staff in particular, of the technical limitations in approval process with regard to enduring the safety of electrical equipment.

It was therefore clear that a great need exists to not only train personnel appropriately (providing the required knowledge and skills to all those who can influence the probability of fires and electrical ignitions occurring underground), but also to ensure that they are taught the most suitable technical standards and practices.

The project reported here was accordingly structured to provide, as the primary output, training guidelines for the safer use of electricity by mine engineers, supervisors and artisans in underground coal mines with specific regard to electrical ignitions and fires.

It was also envisaged that the work, if appropriate, and depending on the results of the investigations undertaken, could result in the following outputs, in addition to the primary output described above:

- Suggestions for improvements to established approaches to the design, manufacture, installation, operation, maintenance and repair of electrical systems and equipment in coal mines, so as to minimise the electrical ignition hazard.
- Proposals for changes to legislation.
- Suggestions for technical guidelines and relevant mine Codes of Practice.
- Suggestions for improvements to the equipment approval process.
- Training methods appropriate to local conditions.

## **1.2 Summarised Conclusions**

The following major conclusions arise from the work reported in this document:

- The current method of evaluating candidates for award of the engineering Government Certificate of Competency is not adequate to ensure that holders of such certificates are technically competent to manage the hazards arising from electrical ignitions and fires in coal mines.
- The requirements of the mine Health and Safety act and the regulations are unclear as to whether or not mechanical engineers may be appointed in general charge of electrical equipment.
- All other major coal mining countries require that suitably trained electrical engineers be appointed in overall charge of electrical systems in mines.
- Electrical protection engineering is not necessarily adequately covered in undergraduate curricula for electrical engineers at either technicons or universities.
- The equipment available for training electrical staff at the Colliery Training College is outdated, and insufficient use is therefore made of experimental training.

- Engineers on mines rely very heavily on foremen, in carrying out their legal duties with regard to safety matters
- Turnover of electrical staff on coal mines is high, and this situation exacerbates the training problem

### 1.3 Summarised Recommendations

The main recommendation arising from this work is that the training guidelines contained in Appendix 1 be implemented. In addition, the following recommendations, which relate mainly to the "other outputs" described in the contract documentation, are made:

- 1) It is recommended that consideration be given to clarifying the current Mine Health and Safety Act and the regulations so as to clearly state whether an engineer holding an electrical Certificate of Competency is required to be appointed in general charge of electrical equipment on a mine. In the event that engineers with an electrical certificate are required to be appointed for responsibility on electrical matters:
- 2) Ensure that electrical material is included as compulsory questions in the Government Certificate of Competency examinations for electrical engineers. In the event that engineers appointments are not required to be discipline specific, refer the relevant matters to the Mine Regulations advisory Committee (MRAC) and the Mine Qualifications Authority (MQA), as discussed with the relevant SIMRAC committee.
- 3) The matter of the competence of mechanical engineers to deal with electrical responsibilities be considered and a means be found to overcome any shortcomings in this regard.
- 4) Consider whether the distinction between electrical and mechanical certificates is still valid. If not, consider the differences in the curricula for Technicons and Technical Colleges for mechanical and electrical students. Whatever course of action is decided on with respect to 2) and 3):
- 5) Require all engineers responsible for electrical equipment to undergo a course in the practical application of electrical protection at either under-graduate or post-graduate level.
- 6) Pursuant to item 4), ensure that a question dealing with electrical protection is included as a compulsory question in the Government Certificate of Competency examination.
- 7) Consider whether the generalised form of the examination for a Government Certificate of Competency for engineers is adequate.
- 8) Notwithstanding item 6), consider the introduction of a Government Certificate of Competency specifically for coal mines.
- 9) In addition to items 5) to 7), review the format of the current examinations for the Government Certificate of Competency in order to test the engineer's competence to take responsibility for matters concerning health and safety.

- 10) Give serious consideration to changing the process concerned with the evaluation of the competency of engineers. In this regard consider identifying the hazardous operations involved in each type of mining and require candidates to pass examinations based on these hazards with a high pass mark being required.
- 11) Take cognisance of the fact that foremen play a vital role in health and safety related issues and as such require legal recognition and additional training for them to carry out their functions.
- 12) Pursuant to item 12), formulate the experimental and competence requirements for foremen.
- 13) Introduce a coal industry training course for foremen.
- 14) Require a full safety evaluation of explosion protected equipment, which includes matters other than purely the explosion protection technology.
- 15) Pursuant to item 14), consider the appointment of Accredited Assessing Authorities, or alternatively, the compilation of "mineworthiness" standards for use by the certification authorities in order to facilitate evaluation by accredited testing authorities viz SABS.
- 16) In the event that items 14) and 15) are rejected, consider the necessity for an "Assessment Certificate" for mine personnel appointed for such a purpose.
- 17) Pursuant to item 16), formulate the qualifications, experiential requirements and examinations necessary for such a certificate.
- 18) In the light of criticism of the Colliery Training College training by electricians and foremen, establish an industry advisory committee to review the training courses with the inclusion of representation by role players such as foremen and electricians.
- 19) Notwithstanding item 18), the Colliery Training College should approach the manufacturers and suppliers to provide modern equipment, circuit diagrams and typical user manuals to the College for training purposes.
- 20) The College to provide more demonstration based equipment for certain training modules, viz pilot wire systems.
- 21) Address the impact that management perceptions has on safe working practice with electrical equipment.
- 22) Introduce an industry standard training programme, including certification, for post-apprenticeship electricians in the industry to facilitate evaluation of past training and additional training needs for new employees on a coal mine.
- 23) Consider the implementation of an industry pre-screening test for electrical staff who are to be employed on a coal mine. The implementation of a interactive software based system should be considered for testing.
- 24) Investigate the reasons for the high turnover of skilled staff and means to address the situation.
- 25) Consider the means to overcome the prevalence of incorrect settings of overload relays on gate end boxes.
- 26) Investigate the major reasons for, and means to overcome, the problem of non-compliance with regulations, codes of practice and safe engineering practice on coal mines.



## 1.4 Layout of the Report

This report is laid out as follows:

- A summary of the conclusions and recommendations is presented in the rest of this section.
- The training guidelines (the primary output), are contained in Appendix 1. Appendix 1 is presented in such a way that it can stand alone from the rest of the document, and can be considered by training staff in isolation from the rest of the work.
- The methodology used, and conclusions drawn from the work, are reported in the main body of the report in accordance with the enabling outputs described in the original contract documentation.
- Liberal use is made of appendices to present detail on topics that are referred to in the main body of the report. A full listing of the appendices is contained in the Table of Contents.

## 2 Research Methodology

The method that has been adopted in reporting the research methodology followed, is to review the action taken to address each of the enabling outputs described in the contract to carry out the work. This is done as follows:

### **Enabling Output 1 (a) - Detailed review of the report on Project Col 031**

A requirement of the call for tenders contained in the relevant Government Gazette was that the SIMRAC Report on Project COL 031 should be read. This was duly done.

### **Enabling Output 1 (b) -Literature survey**

A list of the mining regulations, technical literature and publications that was reviewed is contained in the Section 4 of this report. This work is summarised in the rest of this section.

The Mine Health and Safety Act 1996 was studied in addition to the current mining regulations.

The regulations of a number of overseas countries were obtained and studied. These included the relevant regulations of :

- The United States of America
- The United Kingdom
- Australia - both New South Wales and Queensland
- People's Republic of China

Discussions were also held with coal mining people in Poland and Germany on the regulations in those countries.

In addition a variety of codes of practice, standard specifications and compendia from the above countries were obtained and studied.

Existing training programmes such as the Colliery Training College courses for electrical personnel, operational personnel and for gas testing were evaluated. The South African Flameproof Association course on explosion protected equipment was reviewed and the project team co-operated in editing the course compiled to replace the original course. This work was undertaken as part of the project, although it was not part of the contracted scope of work for COL316.

A number of training manuals for gold mining and industries other than mines were studied. The project team were involved in compiling electrical training courses for underground coal mines on behalf of a mining house, and experience gained during this project was fed into the work reported here.

The curricula of a number of tertiary training institutions, including universities, technicians and technical colleges were evaluated with particular reference to the training of electrical engineers. Discussions were held with members of staff of some of the institutions as well as with representatives of the Engineering Council of South Africa and other representative engineering bodies within the mining industry and in other industries.

The past examinations for the Government Certificate of Competency were studied for content.

Accident reports pertaining to electrical accidents and ignitions were studied to gain insight into the mechanisms of electrical ignitions and the reasons for other electrical accidents.

Copies of manufacturers training manuals were read to determine the suitability of these for mine personnel. Schematic and wiring diagrams of equipment were evaluated for ease of use and understanding.

Pertinent issues that were identified in the literature survey are reported elsewhere in appropriate sections of the report.

### **Enabling Output 1 (c) - Interview selected people at the Department of Minerals and Energy (DME), mines, mine head offices, and among equipment manufacturers, suppliers and repairers**

Discussions were held with various head office employed engineers who had the responsibility to determine relevant group philosophies and procedures. The views of the individuals were obtained on:

- levels of expertise of mine staff;
- training needs;
- potential safety risks;
- legislation;
- approval procedures;
- manufacturers quality management systems, and
- codes of practice.

A number of industry training courses and manuals were obtained from individuals involved in the interviews.

Interviews with DME staff were held at various times during the project, in order to gain insight into the State's views regarding relevant issues related to the project.

Discussions were held with the Health and Safety Representative of the National Union of Mineworkers, who provided letters of introduction to the various union regional offices in which regions coal mining was practised. Representatives of the union in Newcastle and Witbank were visited and telephonic discussions were held with the Pietersburg office of the union. During the visits and discussions the objectives of the project, the methodology and dates of mine visits were discussed. The union representatives were asked whether the union wished to be represented during the mine visits and information on mine contact persons was given to the union, where available at the time. The union indicated that they were keen to participate in the visits, and they were requested to liaise directly with the relevant mine management regarding detailed visit arrangements.

The past General Secretary and current Consultant to the S A Electrical Workers Association was contacted and the objectives of the project, proposed visits and proposed methodology were discussed with him.

The objectives of the underground visits and the process that would be used was discussed at a meeting with the Council of the South African Colliery Engineers Association. A separate meeting was held with the President of the South African Colliery Managers Association to discuss the project.

Discussions were held with the South African Bureau of Standards on approval procedures and methods of improving the auditing of SABS mark holders for quality control and the introduction of mine worthiness standards. Project team members were representatives on the South African Flameproof Association "Ex Steering Committee" which deals with issues related to the SABS involvement in explosion prevention technology and certification.

Some of the major manufacturers were visited to determine:

- their procedures and the competence of their staff;
- their attention to design detail and quality control;
- their comments on current approval procedures, quality management systems and quality auditing by SABS;
- what abuses had been observed by them during underground visits and on equipment sent for repair, and
- to obtain their views on areas which required attention from a training perspective.

The Colliery Training College in Witbank was visited and discussions were held with staff members on the current training courses and their views on training in general.

### **Enabling Output 1 (d) - Visit and observe at selected underground mining operations as required**

Underground visits to a number of collieries were arranged. The collieries were selected to include as wide a range of conditions as possible, including size of group, technical back-up from head offices, mining methodology, age of mine and size of mine. Thus the collieries visited included large, new coal mines utilising state of the art equipment, old collieries with small engineering teams and no head office technical back-up, collieries with a substantial head office support team and collieries where more than one type of mining was being practised.

The mine visits were carefully planned to enable the project team to determine the levels of knowledge of the mine staff and to canvass the staff's views on:

- their training.
- their ability to carry out their responsibilities;
- their views on where problems lay with existing systems of training, responsibilities and
- work content

Additional objectives of the mine visits were:

- to inspect work practices, working conditions and methods;
- to determine the influence of other issues on the performance of their work, and
- to identify, where applicable, health and safety risks associated with present practice at the mine.

This aspect of the work required a sensitive approach to avoid arousing animosity from any of the role players, to allay any suspicion of the project team's objectives and to encourage open discussion of matters of concern.

In order to determine the work content of the various staff members, questionnaires were compiled for artisans, foremen and engineers. The questionnaires included some basic questions to ascertain the extent of knowledge of the various interviewees.

Initially, the intention was to conduct interviews using the questionnaires as prompts for the project team. This approach was rejected on the realisation that particular interviewees were adversely affected by the presence of the team members. Subsequently, the interviewees were left to complete the questionnaires on their own. This led to a more frank response from the interviewees.

At all stages of the process absolute anonymity was guaranteed to those interviewed.

The colliery visits resulted in unavoidable (although limited) disruption to normal mine production activities. Although every effort was made to minimise disruption, an offer was made to the management of each mine visited to, at no charge, document a risk assessment on any electrical hazard that was identified during the visit. This offer was accepted in all cases, and the project team was able to provide assistance to the mines in addressing a number of unacceptable electrical hazards. The mine visits and staff interviews were accordingly well supported.

**Enabling Output 2 (a) - Review Technical Approaches Adopted in Other Countries (Principally U K, USA and Australia), by accessing the knowledge and experience of the Project team and, if Necessary, by Personal Visits.**

The project team identified the need for personal visits to ensure that their knowledge of the conditions in the various countries, where applicable, was still valid, that any changes in legislation or procedures could be investigated, and to more fully explore certain issues which the project team members were not fully conversant with.

The visits were intended to examine all the issues in the selected countries that are listed in Enabling Output 3.

The following countries were visited:

- United Kingdom.
- Germany.
- Poland.
- United States of America.
- Australia.
- People's Republic of China.

The reasons for targeting the specific countries are more fully detailed in Appendix 2 - Countries selected for overseas visits.

## **Enabling Output 2 (b) - Review training approaches adopted in other countries**

The training requirements and legally stipulated competence levels were primarily discussed with the legislators. In some cases other parties were involved in this aspect of the investigation.

A major objective of the visits to each country were to, wherever possible, assess training facilities and training methods at first hand. This was achieved in most of the countries visited, even though some of the visits were of very short duration.

Sets of examination papers used in the USA for assessing electricians for employment on underground mines were obtained.

## **Enabling Output 2 (c) - Review current legislation**

The Mine Health and Safety Act was studied and the current regulations were examined.

## **Enabling Output 2 (d) - Review current practices in the evaluation of equipment**

The methodology used for this output consisted of discussions with the SABS, participation in the South African Flameproof Association SABS Ex Forum, participation in the SABS working group on explosion protection technology and perusal of current specifications and codes of practice.

## **Enabling Output 2 (e) - Review current practices adopted by mines and their technical consultants to ensure safe design, installation and operation of safety critical equipment**

This enabling output was achieved by analysing the results of the various visits described above.

## **Enabling Output 3 (a) - Research each issue that could result in electrical ignition or fire and, for each, determine the practices that should be applied**

Cognisance was taken of all the information gained during the investigative stages listed above, which included:

- analysing the current levels of expertise and how this expertise is applied in practice;
- determining the systems that are available, canvassing views on the success of these systems and views on improvements to existing systems and the need for additional systems;
- determining the levels of skills and technical knowledge through discussions with role players and, where necessary, by simple tests;
- identifying the issues that needed to be addressed;
- analysing the information gained in discussions with industry and government representatives locally and in the various foreign countries;
- assessing the suitability of foreign methods for application in the South African paradigm;
- considering the role of legislation with particular reference to the practical limitations on responsible persons to carry out their tasks as expected in terms of health and safety objectives;
- analysing the ability of appointed engineers to effectively take responsibility for the electrical health and safety requirements in terms of the law;
- investigating the legislative requirements with reference to the design, manufacture, repair and certification or approval of explosion protected equipment;

- taking cognisance of the factors that determine the working practices of electrical personnel and others, which could have a bearing on health and safety from an electrical viewpoint;
- considering the issues that influence the attitudes of electrical and other personnel on the working practices of electrical personnel;
- determining the reasons for malpractice, disregard for safe working practices and codes of practice or legislation and regulations;
- determining the degree to which the new intake of electricians consists of electricians previously employed on coal mines and those new to the industry;
- considering the application of an industry standard competence test for electricians in the coal mining industry.
- considering the desirability of periodic re-testing electricians after their initial qualification;
- considering the issuing of a certificate for those electricians who have successfully passed the above mentioned examination;
- considering the cost and practical implications of training, taking cognisance of the high turnover of skilled staff on most local coal mines, and
- considering means to achieve improvements in training while reducing the cost of training.

### **Enabling Output 4 (a) - Review past published works that covers the issue of training in the South African mining industry**

A comprehensive literature search into all training related work was undertaken. Permission was also given to the project team by the Chamber of Mines of South Africa, to review all confidential documents of relevance in its possession.

### **Enabling Output 4 (b) - Research and develop appropriate training methodologies to support training programmes that require the transfer of knowledge (as opposed to skills) to mine staff**

This work was undertaken reviewing past published work, interviewing selected people in the mining industry (particularly those acknowledged as expert and professional trainers), and applying the expertise of the project team.

### **Enabling Output 5 (a) - Identify the skills that need to be taught to each category of staff**

Based on the results of the work carried out on the above enabling outputs, the required skills were identified.



### **Enabling Output 5 (b) - Identify the knowledge and understanding that needs to be taught to each category of staff**

As for Enabling Output 5 (a), the requisite knowledge and understanding was identified.

### **Enabling Output 6 (a) - For each training requirement noted in 5 (a) and 5 ( b) above, propose suitable training methods that trainers could incorporate in training courses to increase the chance of success, and present the information in an appropriate and user-friendly manner**

The most appropriate training methods that should be applied to mining industry staff became clear, following the literature review and the interviews with industry staff.

## **3 Discussion of Results**

The results of the work are summarised in this section, while, in the interests of clarity, many of the details in support of the discussions are included in appropriately referenced appendices to the report. In interpreting the discussions, it should be noted that the emphasis of the work varied slightly from that initially envisaged. Any such variances were discussed with, and approved by, the relevant SIMRAC sub-committee.

The results of each enabling output are presented as follows:

### **Enabling Output 1 - Identification of all factors that can lead to electrical ignitions and fires**

The major causes of ignitions, defined for the sake of this report as the ignition of explosive gases or combustible dust, differ substantially from the primary factors that could cause fires, defined as the ignition and burning of a substance that will not result in an explosion but is likely to present conditions which are injurious to health and safety.

It is, however, not always possible to differentiate between factors that can lead to a fire or ignition and those that can result in other types of electrical accidents. Although the main focus of the investigations was on fire and ignition related factors, all other electrical malpractices that were identified, or for which evidence was noted, were recorded.

## **Enabling Output 1 (a) - Detailed review of the report on Project COL 031**

The review of the COL 031 report did not assist substantially in identifying the root causes of electrical accidents. Personal visits were therefore paid to the offices of the Inspectorate, where a sample of actual accident report forms were extracted and studied.

## **Enabling Output 1 (b) - Literature survey**

The literature survey identified the following issues:

- the report by the Leon Commission of Enquiry recommended changes which would allow mining supervisors to carry out the supporting supervisory duties for which these positions were legislated. Legislation provides no similar requirement for engineering supervisors, other than engineers. This matter is more fully discussed in Appendix 9 - Engineering Supervisors;
- the examination for the Government Certificate of Competency attempts to cover too much material for the examination to provide an adequate evaluation of an engineer's competency to take responsibility for underground coal mining matters. This conclusion is more fully discussed in Appendix 3 - The Government Certificate of Competency ;
- candidates writing the examination for Government Certificates of Competency tend to avoid questions on electrical protection technology, even if the question is compulsory;
- the current system of accident reporting and/or the classification of accidents does not facilitate investigation into the primary causes of the accidents. This is particularly evident when attempting to identify fires caused by electrical events. This matter is more fully discussed in Appendix 8 - Accident Statistics;
- most university graduates have not studied electrical protection theory; and
- the Study Guide on Electrical Protection for B Tech students, which was the only curriculum on the subject that could be acquired, indicated that the level of theory handled in the course was higher than the project team considered necessary for mine engineers. However, some of the more practical issues that are important to ensure the safety of mine electrical systems, did not get sufficient attention.

The most successful training approach to adopt for mining industry staff is one that relies heavily on hands-on experimentation.

## **Enabling Output 1 (c) - Interview selected people at the DME, mines, mine Head Offices, and among equipment manufacturers, suppliers and repairers**

The following issues were identified:

- electrical reticulation schemes are designed by head office specialists in most cases. In certain cases the reticulation design is entrusted to consultants who specialise in the technology;
- protection systems are the responsibility of head office specialists who either design the protection in detail or in principle;
- in those cases where the protection design is done in principle, the switchgear manufacturers will invariably do the detailed design. In certain cases the detailed design is done by consultants;
- the calculation of protection settings is mainly done by consultants, although in some cases this is carried out by head office specialists;
- periodic or scheduled auditing of protection settings is mainly left to consultants;9  
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- in a number of cases, protection relays are not intended for overload protection but are set to purely protect against fault conditions. In certain cases this practice has dangerous implications;
- manufacturers and repairers report a relatively high degree of tampering with safety related equipment and equipment which has deteriorated to highly unsafe conditions being returned to them;
- some manufacturers reported gross overloading or abuse of equipment detected by them during calls to mines;
- minor electrical events which could have resulted in a fire are often not identified as warranting the submission of an accident report. Numerous near misses are apparently not reported as incidents. This is particularly the case with uncleared short circuits that result in major thermal damage to equipment and which had a high potential for causing a fire; and
- the flameproof equipment in the Colliery Training College is to a large extent outdated. The training at the College is discussed in more detail in Appendix 5 - The Colliery Training College.

## **Enabling Output 1 (d) - Visit and Observe at Selected Underground Mining Operations as Required**

The findings were as follows:

- the general state of equipment on the mines was reasonably good;
- foremen and electricians had a reasonable knowledge of the maintenance requirements for flameproof equipment. However, only 48 per cent of the foremen could correctly identify the main safety feature of flameproof equipment (enclosure that can safely withstand internal ignition of methane) and 43 per cent could identify the main safety feature of intrinsically safe equipment (low energy levels or cool spark). It is cautioned that it is possible that language problems might account in part for the apparent poor level of knowledge observed;
- a surprising outcome of the investigation was that, on average, electricians demonstrated a higher level of knowledge of technical issues than did the foremen. The size of the sample might account for this aberration. However, the fact that the foremen, within the sample, were not as conversant with these matters is cause for concern;
- in general electricians and foremen who had been trained at the Collieries Training College were not satisfied with the level of training received, 50 per cent and 26 per cent of foremen and electricians respectively were satisfied with the training. 70 Per cent of the engineers were generally satisfied with the training;
- knowledge of the extent of the certification process for explosion protected equipment, and the responsibility of mine personnel for design and safety aspects not covered by the certification process, was unknown by virtually every interviewee. This matter is more fully discussed in Appendix 7;
- engineers were generally of the opinion that the training they received prior to writing the Government Certificate of Competency examination, and the examination itself, were inadequate to prepare them to discharge their legal responsibilities with regard to explosion protected equipment. This matter is more fully examined in Appendix 3 - the Government Certificate of Competency ;
- only 40 per cent of the engineers stated that they were capable of carrying out their legal responsibilities to their satisfaction;
- engineers were almost unanimous in stating that they are dependent on their foremen for carrying out their legal responsibilities;
- none of the engineers interviewed were capable of completing a simple fault level calculation;
- mine personnel generally have no adequate knowledge of protection technology;
- the concept of fault levels in an electrical system, and the implications of fault level and switchgear rupturing capacity under fault conditions, is largely misunderstood or ignored in practice;
- many cases exist where protection settings and switchgear tripping action is not checked regularly or at all;
- at least one intensive investigation has determined that many medium voltage switches are incapable of tripping. It is not known how widespread this state of

affairs is, although it is speculated that it may be common enough to present a major safety hazard:

- in general, protection relays on medium voltage switchgear are set too high for the equipment they are intended to protect;
- in certain cases, protection relays had been allowed to deteriorate to the extent that the relays could not possibly operate;
- existing training schemes vary greatly;
- training is often done on an ad hoc basis. While training facilities are available, it is often production pressures that inhibit mines from releasing electrical staff for formal training;
- turnover of electrical staff varies greatly, with a few mines having very stable work forces, while others experience very substantial turnover. This matter is more fully discussed in Appendix 11 - Staff Turnover;
- staff turnover and shortages of skilled staff impact negatively on training;
- in many cases staff are aware that they are not working in accordance with the Minerals Act regulations or the mine codes of practice. Some reasons and discussions on the subject of disregard for rules and regulations is presented in Appendix 6 - Attitudes;
- electrical staff in general are not aware of how explosion protected equipment is evaluated for the purpose of certification, and consequently do not appreciate the limitations of the certification process for ensuring electrical safety underground;
- surveillance of equipment is generally not carried out or is inadequate to detect design or quality shortcomings;
- the liability of suppliers according to the newly promulgated Mine Health and Safety Act is perceived by mine staff to reduce the need for surveillance of equipment;
- many electrical staff perceive that they receive greater reward for unsafe working practices, particularly when working safely would lead to production interruptions. This matter is more fully discussed in Appendix 6, Attitudes; and
- electrical staff are often ignorant of the potential for a coal dust explosion in areas remote from the working faces. In particular, heavy layers of dust on and in medium voltage switchgear with a high potential for a short circuit followed by a possible dust explosion, was not recognised as being particularly hazardous.

**Enabling Output 2 (a) - Review technical approaches adopted in other countries (principally U K, USA and Australia), by accessing the knowledge and experience of the project team and, if necessary, by personal visits.**

The full details of overseas visits to the UK, the USA, Australia, Poland and the People's Republic of China, are included in Appendix 12 - Report on Overseas Visits. The following are the major areas of importance that were identified:

- with some exceptions in Australia and the USA coal mines are deeper and more gassy than South African coal mines;
- with the exception of the USA, electrical engineers are required to be appointed to be in general charge of electrical equipment in collieries. In one case, namely Queensland, the terminology in the regulations could be taken to mean that an electrician or foreman electrician can perform this task. However, scrutiny of the educational and academic requirements for this person indicate that the education and training requirements of these staff are virtually identical to those for engineers in New South Wales;
- staff on the coal mines is stable to very stable. Only Australia reports a tendency towards higher labour turnovers for reasons similar to those listed in Appendix 11 - Staff Turnover;
- with the exception of the USA most of the staff in coal mines have been employed in the industry for their entire careers, and
- Britain, New South Wales, Queensland and the Peoples Republic of China require very thorough testing of explosion protected equipment including issues other than the protection technology itself. This is more fully discussed in Appendix 7 - Certification/Approval of Explosion Protected Equipment.

## **Enabling Output 2 (b) - Review Training Approaches in Other Countries**

Formal training methods employed in other countries are not dissimilar to those applied locally, and comprise a mix of theoretical, experimental and on-the-job training. It is however immediately apparent that, in most other countries, training of electrical staff enjoys significantly higher priority than it does locally. The training establishments in most other countries are well equipped with working examples of the machinery that the electrical staff will work on underground. In some cases, notably Poland, the machines and the lecturing facilities are in the same "classroom" and trainees move readily between the more formal lecturing and the experimental environments.

On-the-job training is the norm in the USA, and the academic requirements for electrical staff are loose, although electricians must be Certificated by the Mining Authority. In the USA, the threat of litigation appears to be the dominant motivator to mine owners to ensure that their staff are competent.

Refresher training is an important component of the training approach in other countries, as is differentiation between electricians allowed to work on low, medium and high voltage equipment.

In none of the countries visited, was language proficiency or literacy of trainees an issue.

## **Enabling Output 2 (c) - Review current legislation**

From a review of current South African legislation, the legislation in other countries, and the observations made during the project, it is clear that the main aspect of legislation that requires further consideration is that related to the training and certification of mine and other staff, and the legislative control of off-mine facilities and services that could influence electrical safety underground. Consideration of the following issues is required:

- It is unclear whether or not South African regulations require that engineers who hold an electrical certificate of competency must be appointed in general charge of electrical equipment. At issue is whether Clause 7(2) of the Mine Health and Safety Act overrides the requirement of the definition (6B) in the regulations that requires that an engineer be appointed who holds an *appropriate* mechanical or electrical engineer's certificate of competency. This matter is more fully discussed in Appendix 4 - Appointment of Engineers.
- Unlike the situation in other countries which require specific coal mine certificates, similar to the South African situation with the mine manager's certificate, the Government Certificate of Competency for engineers is not mine type specific. Since the current examinations for the certificate are unable to cover the subject matter adequately, the introduction of an engineering certificate with particular emphasis on the application of technology to potential hazards on coal mines is proposed. This matter is more fully discussed in Appendix 4 -Appointment of Engineers.
- From discussions held with mine engineers, the geographical spread of their sections and other matters were reported to be such that the engineer could not possibly carry out all his/her legal functions properly. Heavy reliance is consequently placed on foremen to assist the engineer in the discharge of his legal duties. For the same reasons that mining supervisors are required by the regulations to be appointed, the legal requirement to appoint foremen to assist engineers in the control, management and direction of artisans and other engineering team employees should be considered. The appointment should be subject to a foreman demonstrating his ability to carry out tasks required of him. This matter is further discussed in Appendix 9 -The Engineering Competence of Engineering Supervisors.
- The regulations only require explosion protected equipment to be tested for its explosion prevention properties. Most other countries require a more complete assessment of the equipment to determine that it is well designed, constructed and

suitable for the application in mining. Therefore in the South African context explosion protected equipment should be assessed for suitability and, as far as is reasonably practicable, for safety aspects. This matter is more fully discussed in Enabling Output 2 (d) - Review Current Practices in the Evaluation and approval of Equipment.

- Regulation 21.17.5 requires that "If any repair or modification which may affect its explosive-protected apparatus characteristics is carried out on explosion protected apparatus by an organisation not licensed by the approved inspection authority, the apparatus shall not be put into service in a hazardous area unless a new test report has been issued by the inspection authority." This regulation, together with the training and testing initiatives introduced by SABS, has had the effect of improving the knowledge, standards and service of repairers. However, an unlicensed repairer may, in ignorance of the technology, introduce modifications or repairs that are dangerous. It would be preferable to require that *all* repairs to explosion protected equipment be carried out by licensed repairers.
- Mine workshops are not required to be licensed. The reason given for this anomaly is that Certificated engineers have the necessary knowledge and time to control such a workshop. Experience has shown that very few Certificated engineers have the knowledge which SABS requires of licensed repairers. In many cases the persons controlling mine workshops are foremen or other non-Certificated engineering supervisors. Mine workshops that repair explosion protected equipment should also follow the procedure that applies to licensed workshops.

## **Enabling Output 2 (d) - Review current practices in the evaluation and approval of equipment**

This matter is fully discussed in Appendix 7 - Certification/Approval of Explosion Protected Equipment.

The important points are as follows:

- The current certification system requires that equipment must be evaluated for its explosion protection properties only. Other potentially dangerous conditions are not evaluated.
- The Department of Minerals and Energy representatives have indicated that the identification of such conditions is the responsibility of the mine.
- Users believe that the certification process is all embracing and do not identify the need for further surveillance.
- Very specific skills and experience are required to carry out the evaluation and these skills are almost certainly not available on the mines.
- The process of evaluation on each and every mine is unproductive.



The certification and approval of equipment requires attention both in terms of the legislative requirements and in practice.

## **Enabling Output 2 (e) - Review current practices adopted by mines and their technical consultants to ensure safe design, installation and operation of safety critical equipment**

In general, the initial design of electrical reticulation systems is undertaken by specialists, either at head offices or by specialist consultants. The same procedure applies to most major system expansions. No reason for concern in this regard was apparent from the investigations.

However, design work related to minor expansions, increases in the power transmission capability of sections of a system and periodic adjustments to the system to compensate for changes to mining plans are usually performed by mine staff. With inadequate knowledge of protection technology the possibility of dangerous conditions arising is high. Investigations indicated that a number of such situations had arisen on mines without the responsible engineers and managers being aware of the situation.

These problems arose largely through ignorance and can be addressed by proper education and training and the appointment of appropriate people.

In addition it was apparent that little attention is paid to protection equipment since it does not contribute to productivity and if inoperative, does not interfere with or interrupt operations and is only required for very infrequent operation. As reported in Appendix 6 - Attitudes and Appendix 10 - Perceptions, the failure of protective equipment to operate correctly can in some cases be beneficial to production.

In order to exercise control over this matter, most mines make use of periodic audits. These audits are carried out by head office personnel, independent consultants or by senior mine personnel. In view of the widespread lack of maintenance and incorrect settings observed during mine visits, the audits are obviously failing in their purpose.

As reported in Enabling Output 1 (d), intensive tests at one mine indicated that an alarming number of circuit breakers were incapable of tripping. This situation can only be identified by carrying out trip tests on circuit breakers. Since these tests interrupt the supply of power to operating sections they can only be carried out during production downtime and when power is not required for routine maintenance. In practice it is difficult to arrange for such tests and consequently they are rarely carried out.

In certain cases audits are carried out by safety personnel who are not conversant with electrical technology. These audits usually serve no other purpose than being a good-housekeeping exercise. In other words, a clean and neat substation might receive a good report, despite all protection equipment being out of order.

### **Enabling Output 3 (a) - Research each issue that could result in electrical ignition or fire and, for each, determine the practices that should be applied.**

Electrical accidents may be broadly classified as accidents which:

- are highly likely to occur but with the probability of a limited number of deaths or injuries; or
- have a low likelihood of occurrence but the probability that multiple deaths or injuries could occur.

In terms of the project focus, the latter type of accidents are usually those involving fires or ignitions. However, although the project focused specifically on ignitions or fires caused by electrical equipment, all electrical malpractice are cause for concern and cannot, for the purpose of training, be separated from those likely to cause ignitions or fires. Refer to Appendix 8 - Accident Statistics for a fuller account of the matter.

The categorisation in the Accident Statistics from the Department of Minerals and Energy is based on the direct cause of death or injury, and not on the causative agent which gives rise to the accident which results in the death or injury. As an example, an electrical incident in 1994 resulted in an oil fire which ignited coal in the vicinity. 16 People died of asphyxiation and their deaths are listed under the category "Fire". Similarly a gas ignition by electrical equipment is likely to be listed under the category "Dust/gas/fumes".

Recognising then that electricity may have resulted in more deaths and injuries than the statistics indicate, the number of accidents, fatalities and injuries is still likely to account for approximately 2 per cent of all the accidents, deaths and injuries that occur in underground coal mines.

An essential focus of the enabling output is to attempt to arrive at reasons why accidents occur. This matter was investigated in some depth and is reported as follows:

## Possible Reasons for Electrical Accidents

Considering that the project team were not known to most of the staff working on the mines that were visited as a preparatory phase of the project, it was rather alarming to find that a fair number of malpractices were observed to be taking place in the presence of the team.

In addition, manufacturers and repairers stated that a disturbing amount of the equipment that had been returned from mines for repair, had had the safety features tampered with. Department of Minerals and Energy inspectors also reported that many malpractices were identified during mine visits or as a result of incidents.

Discussions with electrical personnel where regulations or codes of practice were not being adhered to, yielded some insight into the reasons for the actions. In other cases the reasons have been deduced from past experience or from insight gained during other projects of a similar nature. Discussions with the staff of manufacturers who were involved with commissioning or trouble shooting on equipment, and had regular contact with mine personnel, also yielded potential reasons for the actions of mine electrical staff.

It is therefore necessary to consider whether the malpractices occurred purely as a result of ignorance and lack of training, or whether other factors had a bearing and would need to be addressed to achieve a good safety culture in the industry. On the basis of work carried out by S Mason and reported in the Mining Technology Journal - June 1995, with reference to the "Queensland Coal Mines Analysis of Lost Time Accidents", from discussions with personnel and based on previous experience of the project members. Anecdotal evidence for most of the reasons for failure to comply with safe practice is provided in Appendix 6 - Attitudes. Based on the investigations, the following main reasons for failure to observe safety requirements are proposed:

- absence of codes of practice;
- ignorance of codes of practice, regulations and good engineering practice;
- failure to understand the reasons for the codes of practice and regulations;
- absence of training, inadequate or inappropriate training;
- failure to provide follow-up training;
- advice or training given irregularly or spontaneously by other personnel who frequently disregard the codes of practice and regulations;
- inadequate provision of aids such as circuit diagrams, testers etc.;
- perceived rewards following malpractices;
- malpractices that work with no apparent safety implications;
- the belief that following rules is more difficult than is warranted by the perceived risk;
- the belief that the risks resulting from disobeying the codes of practice and regulations are manageable;

- lack of dissemination of information in connection with serious accidents. (This matter is more fully dealt with in Appendix 8 - Accident Statistics);
- peer pressure and pressure from other personnel; and
- motivation.

In general, perceptions of various roles players can have a major bearing on attitudes. These are more fully dealt with in Appendix 10 - Perceptions.

## **Methods of Addressing the Above Causative Factors**

In most cases, the steps that should be taken to address the causes of electrical accidents, as listed above, are obvious. The following specific comments are however made:

- Mines should make greater use of the opportunity to compile voluntary codes of practice related to electrical equipment and systems. The codes should be carefully written taking cognisance of the best available expertise and good engineering practice. In this regard, the project team reviewed a number of existing codes of practice where the requirements of the code were ambiguous or, in some cases, incorrect to the extent that dangerous conditions could arise if their requirements were implemented. Properly compiled codes could however provide core documents that direct all requirements for specifications, procedures, training material and the like.
- Improved training is a requirement. Training must be improved with regard to both its content (see Appendix 1 - Training Guidelines) and its frequency. A particularly important aspect that is lacking in current training approaches is the fostering of knowledge rather than purely skills. It is essential that the trainees understand, as far as their cognitive abilities allow, the reasons for the requirements dictated by codes of practice and the Regulations.
- Greater use must be made of experimental or "hands-on" training, and up-to-date equipment must be designed and provided for this purpose.
- Managers and supervisors must be made aware of the potential implications of ignoring electrical system safety. Allied to this requirement is that the attitude to safety needs to be improved in many cases.
- A system needs to be established that allows the Inspectorate to disseminate safety critical information to mines following an accident, without contravening the "sub-judice" principle. Alternatively, accident investigations need to be concluded as speedily as possible so that relevant safety information may be released to the industry.

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# Appendix 1

## TRAINING GUIDELINES FOR THE ELIMINATION OF ELECTRICAL IGNITIONS AND FIRES IN UNDERGROUND COAL MINES

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# 1 TECHNICAL TRAINING

In this appendix, training guidelines for each category of staff that should be trained in order to address the hazards arising from electrical ignitions and fires, are presented. For each category of staff, the content of a suitable training course is given, as well as comment, where necessary, on training methodologies that may be applied.

## 1.1 Engineers Responsible for Electrical Plant

### 1.1.1 Introduction

Each mine should have at least one engineer (or senior foreman), who shall have overall responsibility for electrical plant. In the event that a person other than an engineer is appointed to this position, that person should be given the authority commensurate with the responsibility. Since such authority given to a person other than an engineer could result in conflict with engineers, the appointment of an engineer to this position is recommended.

Engineers responsible for electrical plant should be trained to a higher level of appreciation of electrical matters than that required for other engineers.

### 1.1.2 Technical Requirements

Training, and preferably testing, on the following subject matter is considered essential:

- Regulations
  - 1) Electrical regulations
  - 2) Difference in definition and use of terms low, medium and high voltage or pressure or tension in regulations, common usage and universal definition
- General principles of electrical reticulation:
  - 1) Transmission voltages
  - 2) Machine voltages
  - 3) Transformers
  - 4) Parallel feeds
  - 5) Ring feeds
  - 6) Radial feeds

- Specific requirements for electrical reticulation in underground coal mines

Fault level and rupturing capacity

Types of switchgear in general use:

- 1) High voltage
- 2) Medium voltage
- 3) Low voltage

- Principles of current Interruption by:

- 1) Bulk oil circuit breakers
- 2) Minimum oil circuit breakers
- 3) Vacuum circuit breakers
- 4) Sulphur hexafluoride (SF6) circuit breakers
- 5) Vacuum contactors
- 6) SF6 contactors
- 7) Air-break contactors
- 8) Air-break Isolators
- 9) Fuses
  - a) High rupturing capacity
  - b) High speed for electronic circuits

- Maintenance and operation of various switchgear types:

- 1) Bulk oil circuit breakers
- 2) Minimum oil circuit breakers
- 3) Vacuum circuit breakers
- 4) Sulphur hexafluoride (SF6) circuit breakers
- 5) Vacuum contactors
- 6) SF6 contactors
- 7) Air-break contactors
- 8) Air-break isolators

- General principles of electrical protection:

- 1) Phase faults
- 2) Overload
- 3) Earth faults
- 4) Zones of protection
- 5) Discrimination

- Functions of protective relays:

- 1) Over current
- 2) Overload
- 3) Earth fault
- 4) Biased differential

- 5) Continuous earth monitoring
  - 6) Pilot (Solkor type)
  - 7) Neutral earth resistance monitor
- General principles of protective relays:
    - 1) Electromechanical - instantaneous
    - 2) Electromechanical - IDMT
    - 3) Electro-mechanical - Buchholz
    - 4) Biased differential type
    - 5) Feeder fault isolation by pilot wire relay (Solkor)
    - 6) Electronic relays
  - Tripping circuits - types, maintenance and testing.
 

The appropriate systems in use on the mine which may include:

    - 1) Battery tripping systems
    - 2) Potential transformer tripping systems
    - 3) Current transformer tripping systems
    - 4) Capacitor discharge tripping systems
    - 5) Shunt tripping
    - 6) No-volt tripping
    - 7) Direct-acting tripping
    - 8) Recognising symptoms of protection systems that are operational and those that are not.
  - Power transformers:
    - 1) Configuration
    - 2) Vector groups
    - 3) Impedance voltage
    - 4) Air cooled
    - 5) Oil cooled - non-hermetically sealed
    - 6) Oil cooled - hermetically sealed
    - 7) Harmonic transference of different configurations
    - 8) Paralleling of transformers - vector groups
    - 9) Earthing of transformers - neutral earthing compensators, neutral resistors
    - 10) Protection - single transformer
    - 11) Protection - parallel transformers
    - 12) Protection - multiple transformers off single circuit breaker
    - 13) Protection - differential
    - 14) Protection - thermal
    - 15) Protection - Buchholz
    - 16) Protection - surge/lightning
    - 17) Protection by means of secondary side circuit breakers

- Potential and current transformers
  - 1) Features
  - 2) Burden on current transformers
  
- Management of electrical systems
  - 1) Drawings
  - 2) IEC standardised symbols
  - 3) Isolation and lock out procedures
  - 4) Permit to work
  - 5) Record keeping
  - 6) Provision of safety equipment
  - 7) Codes of practice
  - 8) Communication systems
  
- Cables
  - 1) Cross linked poly-ethylene (XLPE)
  - 2) Paper insulated lead covered (PILC)
  - 3) Poly-vinyl-chloride insulated (PVC)
  - 4) Ethyl-vinyl-acrylic insulated (EVA)
  - 5) Synthetic rubber insulated
  - 6) Core screens - function - electrical fields , phase fault prevention
  - 7) Core screens - type -tape, metallic braid, semiconductive
  - 8) Phase/earth and phase/phase voltage ratings
  - 9) Flexible cable lay-up - voltage drop
  - 10) Current capacity -cooling, installation
  - 11) Fault capacity
  - 12) Flame retardancy and testing methods
  - 13) Protection implications of volt drop on low voltage systems
  
- Substations
  - 1) Design - surface
  - 2) Structure
  - 3) Access/egress doors
  - 4) Earthing
  - 5) Transformer bays - fire damage limitation
  - 6) Ventilation
  - 7) Alternate feeds - spare incomer, bus coupler
  - 8) Affects on fault level and safety precautions for 7)
  - 9) Safety equipment
  - 10) Tools
  - 11) Record keeping

- 12) Design - underground
  - 13) Structure - fire damage limitation
  - 14) Siting
  - 15) Dangers of dust and dust control
  - 16) Ventilation and smoke control
- Overhead lines
    - 1) Conductor layout
    - 2) Impedance
    - 3) Conductor supports - suspension towers, tension towers, poles, earthing of structures
    - 4) Insulation grading of wood and steel poles
    - 5) Lightning protection
    - 6) Potential differences between "earth potential" and "potential of general body of earth"
    - 7) Induction due to adjacent overhead lines
    - 8) Induction due to lightning discharges
  - Boreholes
    - 1) Cased and uncased - conductive and non-conductive casings
    - 2) Protection against lightning
  - Explosion protection techniques
    - 1) Flameproofing - Ex d
    - 2) Intrinsic safety - Ex i
    - 3) Increased safety - Ex e
    - 4) Other techniques - encapsulated - Ex m, pressurised and purged-Ex p
    - 5) Non-approved techniques for underground in Mines
  - Standards
    - 1) SABS IEC 79 series
    - 2) Other SABS standards
    - 3) SABS codes of practice
    - 4) Classification of gases and dusts
    - 5) Temperature classification
    - 6) "U" certification of flameproof enclosures
    - 7) Repair of explosion protected equipment
  - Certification of explosion protected equipment
    - 1) What is and is not certified
    - 2) Responsibility of mine

- Potential dangers with flameproof equipment
  - 1) Short circuits in flameproof enclosures
  - 2) Phase barriers
  - 3) Corona
  - 4) Component ratings
  - 5) Temperature rise
  
- Typical features of gate end boxes and other flameproof switchgear
  - 1) Overcurrent protection and back-tripping
  - 2) Overload and earth fault protection
  - 3) Earth fault lock-out protection
  - 4) Pilot wire protection:
    - a) Reasons that PWP is not intrinsically safe
    - b) Functions
    - c) Abuses
  - 5) Isolation
  - 6) Interlocking - mechanical and electrical techniques
  
- Mobile substations
  - 1) Advantages and disadvantages of various primary isolation arrangements
    - a) No isolator
    - b) On-load and off-load isolators
    - c) Circuit breakers
  - 2) Secondary/primary back-tripping
  - 3) Primary side terminations for continuous earth monitors for "feed through" arrangements
  - 4) Primary side phase fault dangers
  - 5) Overload protection by secondary circuit breakers
  
- Earthing of underground equipment
  - 1) Philosophy:
    - a) Earth fault limitation
    - b) Touch potentials
    - c) Potential equalisation
    - d) Lightning discharge dissipation
    - e) Gas/dust ignition dangers
  - 2) Techniques:
    - a) Neutral resistors - rating, over-temperature
    - b) Over voltage and transient effects of medium voltage earth fault limitation using neutral resistors



- c) Earth fault current/earth fault protection grading
  - d) Use of roof bolts
  - e) Insulated and partially insulated resin-set roof bolts
  
- 3) Symptoms of earthing system faults
  - a) Severe damage due to phase-earth-phase faults
  - b) Phase-phase faults in cables
  - c) Excessive phase fault tripping
  - d) Cable insulation damage due to phase to earth voltage disturbance
  
- Drives
  - 1) Alternating current (AC) motors - squirrel cage and wound rotor
    - a) Current/speed characteristics
    - b) Torque/speed characteristics
    - c) Rated, pull-out, starting, stall torque
    - d) Affects of rotor resistance on a), b) and c)
    - e) Affects of d) on multi-motor drive arrangements
    - f) Motor cooling
    - g) Soft starting- electronic and rotor resistance
    - h) Speed control - operational aspects and affects on motor ratings and performance
    - i) Speed control - affects on power system, harmonics, resonance
  
  - 2) Synchronous motors
    - a) Basic characteristics - rated, pull-out, starting, stall torque
    - b) Basic characteristics - excitation, power factor
  
  - 3) Direct current (DC) motors
    - a) Types - shunt, series, compound, separately excited
    - b) Characteristics of motor types
    - c) Speed control - operational aspects and affects on motor ratings and performance
    - d) Speed control - affects on power system, harmonics, resonance
  
- Power factor correction
  - 1) Power factor controllers
  - 2) Condensers
  - 3) Faults on condenser banks
  - 4) Protection of condenser banks
  - 5) Safety aspects
  - 6) Switching of condensers

- 7) Surge limitation
- 8) Affect of harmonic resonance
- 9) Synchronous motors

### **1.1.3 Training Methodologies**

Engineers having overall responsibility for electrical plant will in all probability have received formal tertiary education. It is accordingly likely that they will acceptably familiar with many of the concepts listed in the previous section, although, from an examination of university and technicon curricula, it is certain that there will be subjects that they will not have studied at all. Also, it is probable that much of their previous instruction will have been relatively theoretical and will not have covered issues of unique interest to collieries (such as for example the danger of importing stray currents into underground workings, the earthing of electrical equipment in strip mines, or explosion protected equipment). It is therefore necessary that some pre-testing be undertaken by the training authority to determine the extent of the training requirements.

The basis of training these engineers should be a reference training document that covers all of the issues listed earlier, both as a training aid and for later use by the engineer as a reference document.

While the training of engineers will rely on self-study and lecturing to a great extent, the tremendous value of exposing engineers to experiential training should not be underestimated. These engineers should accordingly be afforded regular access to mock-ups, simulators and other "hands-on" training aids.

## **1.2 Engineers not having Overall Responsibility for Electrical Plant**

### **1.2.1 Introduction**

The operation and maintenance in the sections in a mine will be under the direct control of engineers who do not necessarily have the overall responsibility of the electrical plant on the mine. These engineers are presumed to make "on-the-spot" decisions from time to time on matters related to the electrical plant in their sections. In addition, the day-to-day management will be under their control. It is therefore imperative that, regardless of their academic discipline, these engineers have some appreciation of electrical issues. While it is not necessarily intended that these engineers should be able to solve all electrical problems, they should be trained to the extent that they are able to appreciate their weaknesses and strengths in electrical engineering, and recognise when it would be appropriate for them to call on specialist advice.

## 1.2.2 Technical Requirements

It is recommended that these engineers are trained, and preferably tested, in the following matters

- Regulations
  - 1) Electrical regulations

General principles of electrical reticulation:

- 1) Transformers
  - 2) Parallel feeds
  - 3) Ring feeds
  - 4) Radial feeds
- Specific requirements for electrical reticulation in underground coal mines
  - A basic awareness of fault level and rupturing capacity and the influence of reticulation components on fault level
    - 1) Transformers - voltage, rating, impedance voltage
    - 2) Cables and overhead lines
  - Maintenance and operation of the switchgear types in use on the mine

The basic differences in the switching capabilities of circuit breakers, isolators - on-load and off-load - and contractors

- General principles of electrical protection:
  - 1) Phase faults
  - 2) Overload
  - 3) Earth faults
  - 4) Zones of protection
  - 5) Discrimination
- Functions of protective relays:
  - 1) Overcurrent
  - 2) Overload
  - 3) Earth Fault
  - 4) Continuous Earth Monitoring
  - 5) Neutral Earth Resistance Monitor
- Tripping circuits - maintenance and testing of the systems in use on the mine

- Recognising symptoms of protection systems that are operational and those that are not.
- Power transformers:
  - 1) Voltage, current and kVA rating
  - 2) Vector groups
  - 3) Air cooled
  - 4) Oil cooled - non-hermetically sealed
  - 5) Oil cooled - hermetically sealed
  - 6) Earthing of transformers - neutral resistors
  - 7) Protection - single transformer
  - 8) Protection - parallel transformers
  - 9) Protection - multiple transformers off single circuit breaker
  - 10) Protection by means of secondary side circuit breakers
- Management of electrical systems
  - 1) Drawings
  - 2) Isolation and lock out procedures
  - 3) Permit to work
  - 4) Record keeping
  - 5) Provision of safety equipment
  - 6) Codes of practice
  - 7) Communication systems
- Cables
  - 1) Basic knowledge of core screens - function - electrical fields, phase fault prevention
  - 2) Core screens - type -tape, metallic braid, semiconductive
  - 3) Flexible cable lay-up - coiling and non-coiling types
  - 4) Voltage drop
  - 5) Current capacity -cooling, installation
  - 6) Fault capacity
  - 7) Flame retardancy
  - 8) Protection implications of volt drop on long, low voltage cables
- Substations
  - 1) Design - surface
    - a) Access/egress doors
    - b) Transformer bays - fire damage limitation
    - c) Ventilation
    - d) Alternate feeds - spare incomer, bus coupler

- e) Awareness of affects on fault level and safety precautions
  - f) Safety equipment
  - g) Tools
  - h) Record keeping
- 2) Design - underground
  - a) Structure - fire damage limitation
  - b) Siting
  - c) Dangers of dust and dust control
  - d) Ventilation and smoke control
- Overhead lines
  - 1) Conductor supports - suspension towers, tension towers, poles
  - 2) Earthing of structures
  - 3) Awareness of lightning protection
  - 4) Awareness of potential differences between "earth potential" and "potential of general body of earth"
  - 5) Induction due to adjacent overhead lines
  - 6) Induction due to lightning discharges
- Boreholes
  - 1) Cased and uncased - conductive and non-conductive casings
  - 2) Protection against lightning
- Explosion protection techniques
  - 1) Flameproofing - Ex d
  - 2) Intrinsic safety - Ex I
  - 3) Increased safety - Ex e
  - 4) Non-approved techniques for underground in mines
- Standards
  - 1) SABS IEC 79 series
  - 2) The SABS standards
  - 3) SABS codes of practice
  - 4) Classification of gases and dusts
  - 5) Temperature classification
  - 6) "U" Certification of flameproof enclosures
  - 7) Repair of explosion protected equipment
- Certification of explosion protected equipment
  - 1) What is and is not certified
  - 2) Responsibility of mine

- Potential dangers with flameproof equipment
  - 3) Short circuits in flameproof enclosures
  - 4) Phase barriers
  - 5) Corona
  - 6) Component ratings
  - 7) Temperature Rise
  
- Typical features of gate end boxes and other flameproof switchgear
  - 1) Overcurrent protection and back-tripping
  - 2) Overload and earth fault protection
  - 3) Earth fault lock-out protection
  - 4) Pilot wire protection:
    - a) Reasons that PWP is not intrinsically safe
    - b) Functions
    - c) Abuses
  - 2) Isolation
  - 3) Interlocking - mechanical and electrical techniques
  
- Mobile substations
  - 1) Advantages and disadvantages of various primary isolation arrangements
    - a) No isolator
    - b) On-load and off-load isolators
    - c) Circuit breakers
  - 2) Secondary/primary back-tripping
  - 3) Primary side terminations for continuous earth monitors for "feed through" arrangements
  - 4) Primary side phase fault dangers
  - 5) Overload protection by secondary circuit breakers
  
- Earthing of underground equipment
  - 1) Philosophy
    - a) Earth fault limitation
    - b) Touch potentials
    - c) Potential equalisation
    - d) Lightning discharge dissipation
    - e) Gas/dust ignition dangers
  
  - 2) Techniques
    - a) Neutral resistors - rating, over-temperature
    - b) Earth fault current/earth fault protection grading
    - c) Use of roof bolts
    - d) Insulated and partially insulated resin-set roof bolts

- 3) Symptoms of earthing system faults
    - a) Severe damage due to phase-earth-phase faults
    - b) Phase-phase faults in cables
    - c) Excessive phase fault tripping
    - d) Cable insulation damage due to phase to earth voltage disturbance
- Drives
    - 1) Basic knowledge of alternating current (AC) motors
      - a) Current/speed characteristics
      - b) Torque/speed characteristics
      - c) Rated, pull-out, starting, stall torque
      - d) Motor cooling
      - e) Awareness of electronic soft starting
      - f) Awareness of speed control - operational aspects and affects on motor ratings and performance
    - 2) Direct current (DC) motors
      - a) Types - shunt, series, compound, separately excited
      - b) Characteristics of motor types
      - c) Speed control - operational aspects and affects on motor ratings and performance
  - Safety aspects of power factor correction equipment

### **1.2.3 Training Methodologies**

The comments with regard to electrical engineers (see section 1.1.3, apply equally to these engineers).

## **1.3 Foremen**

### **1.3.1 Introduction**

Foremen generally have had less tertiary education than is required for engineers to be accepted to sit the certificate of competency examinations. It is therefore unrealistic to expect foremen to be trained to the same level of understanding as engineers on identical subject matter.

However, foremen invariably comprise the available source of advice for artisans, particularly with reference to technical, rather than skill-related matters. The awareness

by foremen of these matters will place them in a position to know when they are capable of giving advice, or conversely, when to refer matters to an engineer. By improving the foreman's knowledge, the possibility of wrong actions being taken in ignorance is decreased.

### **1.3.2 Technical Requirements**

The following training, and preferably testing, is recommended:

- Regulations
  - 1) Electrical regulations
  - 2) Mine codes of practice
  
- Basic principles of electrical reticulation:  
Knowledge of:
  - 1) Transformers
  - 2) Parallel feeds
  - 3) Ring feeds
  - 4) Radial feeds
  
- Knowledge of the basic requirements for electrical reticulation in underground coal mines
  
- A basic awareness of fault level and rupturing capacity and the influence of reticulation components on fault level
  - 1) Transformers - voltage, rating, impedance voltage
  - 2) Cables and overhead lines
  
- Basic knowledge of the maintenance and operation of the switchgear types in use on the mine - supplemented by substantial practical training, preferably "hands-on"
  
- Knowledge of the basic differences in the switching capabilities of circuit breakers, Isolators - on-load and off-load - and contactors
  
- Knowledge of the basic principles of electrical protection:
  - 1) Phase faults
  - 2) Overload
  - 3) Earth faults
  - 4) Zones of protection
  - 5) Discrimination



- Knowledge of the functions of protective relays:
  - 1) Overcurrent
  - 2) Overload
  - 3) Earth fault
  - 4) Continuous earth monitoring
  - 5) Neutral earth resistance monitor
  
- Knowledge of the tripping circuits - maintenance and testing of the systems - in use on the mine
  
- Basic knowledge of power transformers:
  - 1) Voltage, Current and kVA Rating
  - 2) Vector groups
  - 3) Basic knowledge of the different operational and maintenance requirements of air cooled, oil cooled - non-hermetically sealed and oil cooled - hermetically sealed transformers
  - 4) Earthing of transformers - neutral resistors
  
- Power transformers:
 

Awareness of :

  - 1) Protection requirements for:
    - a) Single transformers
    - b) Transformers in parallel
    - c) Multiple transformers off a single circuit breaker
  - 2) Protection requirements by means of secondary side circuit breakers
  
- Knowledge of the management of electrical systems
  - 1) Requirements with regard to drawings
  - 2) Isolation and lock out procedures
  - 3) Permit to work
  - 4) Record keeping
  - 5) Provision of safety equipment
  - 6) Codes of practice
  - 7) Communication systems
  
- Cables
 

Knowledge of:

  - 1) Core screens - type -tape, metallic braid, semiconductive
  - 2) Flexible cable lay-up - coiling and non-coiling types
  - 3) Voltage drop
  - 4) Current capacity -cooling, installation
  - 5) Protection implications of volt drop on long, low voltage cables

Basic Knowledge of :

- 1) Core screens - function - electrical fields , phase fault prevention
- 2) Fault capacity
- 3) Flame retardancy

- Awareness of the requirements for substations

- 1) Design - surface

- a) Access/egress doors
- b) Transformer bays - fire damage limitation
- c) Ventilation
- d) Alternate feeds - spare incomer, bus coupler
- e) Affects on fault level and safety precautions for d)
- f) Safety equipment
- g) Tools
- h) Record keeping
- i) Housekeeping and maintenance

- 2) Design - underground

- a) Structure - fire damage limitation
- b) Siting
- c) Dangers of dust and dust control
- d) Ventilation and smoke control
- e) Containment and fire damage limitation for oil-filled switchgear or transformers
- f) a), d), e), h), l), j) and k) above

- Overhead lines:

Basic knowledge of

- 1) Conductor supports - suspension towers, tension towers, poles
- 2) Earthing of structures

Knowledge of

- 1) Lightning protection
- 2) Potential differences between "earth potential" and "potential of general body of earth"
- 3) Induction due to adjacent overhead lines
- 4) Induction due to lightning discharges

- Boreholes:

Awareness of:

- 1) Cased and uncased - conductive and non-conductive casings
- 2) Protection against lightning

- Explosion protection techniques
  - Knowledge of:
    - 1) Flameproofing - Ex d
    - 2) Intrinsic safety - Ex i
    - 3) Increased safety - Ex e
    - 4) Non-approved techniques for underground in mines
  
- Standards
  - Knowledge of:
    - 1) "U" Certification of Flameproof Enclosures (A typical "U" certificate should be obtained to demonstrate the significance of this type of certification. Ideally an equipped enclosure with both the "U" certificate and the equipper's certificate, as well as both labels should be obtained for this purpose.)
    - 2) Repair of Explosion Protected Equipment (The possibility of non-licensed repairers carrying out work for which they are not entitled and which can lead to dangerous practices should be the focus.)
    - 3) Basic details of the training given to licensed repairers.
  
  - Awareness of:
    - 1) SABS IEC 79 series
    - 2) Other SABS standards
    - 3) SABS codes of practice
    - 4) Classification of gases and dusts
    - 5) Temperature classification
  
- Certification of explosion protected equipment
  - Knowledge of:
    - 1) What is and is not certified
    - 2) Responsibility of mine
  
- Potential dangers with flameproof equipment
  - Knowledge of:
    - 1) Short circuits in flameproof enclosures
    - 2) Phase barriers
    - 3) Corona
    - 4) Component ratings
    - 5) Temperature rise
  
- Typical features of gate end boxes and other flameproof switchgear
  - Knowledge of
    - 1) Overcurrent protection and back-tripping
    - 2) Overload and earth fault protection

- 3) Earth fault lock-out protection
- 4) Pilot wire protection:
  - a) Reasons that PWP is not Intrinsically safe
  - b) Functions
  - c) Abuses
- 5) Isolation
- 6) Interlocking - mechanical and electrical techniques

**Note:** For items 1) to 4) the use of a mock-up of a typical system incorporating these components is strongly advised. The mock-up should, ideally, allow for the demonstration of typical abuses and the affect they have on the safety and operation of the system, as well as the ability to introduce faults on the system. Items 5) and 6) should be "hands-on" training.

- Mobile substations

Knowledge of:

- 1) The functions that are and are not provided by various primary isolation arrangements
  - a) No isolator
  - b) On-load and off-load isolators
  - c) Circuit breakers
- 2) Secondary/primary back-tripping
- 3) Primary side terminations for continuous earth monitors for "feed through" arrangements
- 4) Primary side phase fault dangers
- 5) Overload protection by secondary circuit breakers

**Note:** Items 2), 3) and 5) should ideally be supported by mock-ups available for demonstration purposes.

Item 1) should allow for "hands-on" training on the types of primary switches in use on the mine.

- Earthing of underground equipment

Knowledge of:

- 1) Philosophy:
  - a) Earth fault limitation
  - b) Touch potentials
  - c) Potential equalisation
  - d) Lightning discharge dissipation
  - e) Gas/dust ignition dangers

2) Techniques:

- a) Neutral resistors - rating, over-temperature
- b) Earth fault current/earth fault protection grading
- c) Use of roof bolts
- d) Insulated and partially insulated resin-set roof bolts

3) Symptoms of earthing system faults

- a) Severe damage due to phase-earth-phase faults
- b) Phase-phase faults in cables
- c) Excessive phase fault tripping
- d) Cable insulation damage due to phase to earth voltage disturbance

**Note:** These matters are most easily dealt with by means of diagrams and drawings.

The use of physical specimens to demonstrate item 3) is advisable.

- Drives

- 1) Basic knowledge of alternating current (AC) motors

- a) Current/speed characteristics
- b) Torque/speed characteristics
- c) Rated, pull-out, starting, stall torque
- d) Motor cooling

- 2) Direct current (DC) motors

- a) Types - shunt, series, compound, separately excited
- b) Characteristics of motor types
- c) Speed control - operational aspects and affects on motor ratings and performance

- Safety aspects of power factor correction equipment

### **1.3.3 Training Methodologies**

It is strongly recommended to include practical training for both foremen and electricians. The practical training includes "hands-on" operation of equipment under guidance, as well as the provision of certain mock-ups to demonstrate characteristics and safety features of some items of plant. The provision of simulators to facilitate acquaintance with operating and maintenance procedures on more sophisticated plant, such as continuous miners and long wall systems, is also strongly recommended.

Reference should be made to the recommendations in the report dealing with the desirability to support the theoretical training with software based multi-choice type questions.

## **1.4 Electricians**

### **1.4.1 Introduction**

The training of electricians should be aimed at:

- Ensuring that their knowledge of the matters they would be required to deal with is adequate in all respects; and -
- Providing awareness training on those issues that they should refer to engineers or foremen.

Electricians who act as foremen from time to time should ideally receive the same training as that recommended for foremen. However, these electricians should be trained in the details referred to below as optional.

### **1.4.2 Technical Requirements**

The following training, and preferably testing, is recommended:

- Regulations
  - 1) Electrical regulations
  - 2) Mine codes of practice
- Basic principles of electrical reticulation:  
Basic knowledge of:
  - 1) Transformers
  - 2) The dangers associated with parallel feeds and ring feeds
- Knowledge of the basic requirements for electrical reticulation in underground coal mines
- A basic awareness of fault level and rupturing capacity and the influence of reticulation components on fault level
  - 1) Transformers - voltage, rating, impedance voltage
  - 2) Cables and overhead lines

- Basic knowledge of the maintenance and operation of the switchgear types in use on the mine - supplemented by substantial practical training, preferably "hands-on"
- Knowledge of the basic differences in the switching capabilities of circuit breakers, isolators - on-load and off-load - and contactors
- Knowledge of the basic principles of electrical protection:
  - 1) Phase faults
  - 2) Overload
  - 3) Earth faults
  - 4) Zones of protection
  - 5) Discrimination
- Knowledge of the functions of protective relays:
  - 1) Overcurrent
  - 2) Overload
  - 3) Earth fault
  - 4) Continuous earth monitoring
  - 5) Neutral earth resistance monitor

**Note:**

- a) Depending on the responsibilities of electricians with reference to the type of equipment they are intended to work with, it is desirable to have mock-ups on which the typical protection relays in their section can be demonstrated.
  - b) Ideally, the mock-up should, in addition to demonstrating the relay characteristics, allow for the concept of discrimination to be demonstrated.
  - c) For electricians whose sections consist only of in-bye equipment the mock-ups mentioned in the section dealing with "typical features of gate end boxes and other flameproof switchgear" will serve the above purpose.
- Knowledge of the tripping circuits - maintenance and testing of the systems - in use on the mine
  - Basic knowledge of power transformers:
    - 1) Voltage, current and kVA rating
    - 2) Vector groups
    - 3) Basic knowledge of the different operational and maintenance requirements of air cooled, oil cooled - non-hermetically sealed and oil cooled - hermetically sealed transformers
    - 4) Earthing of transformers - neutral resistors

**Note:** Some electricians have been known to directly earth the neutral terminal of a transformer despite the presence of a neutral resistor. This matter must be addressed in the above training.

- Power transformers:

Awareness of :

- 1) Protection requirements for:
  - a) Single transformers
  - b) Transformers in parallel
  - c) Multiple transformers off a single circuit breaker
- 2) Protection requirements by means of secondary side circuit breakers

**Note:** This training was included in the section for foremen and might appear to be superfluous to electrician's needs. However, electricians must be aware of the necessity to maintain the protection requirements of secondary circuit breakers if these are the only means of protecting a transformer against overload.

- Knowledge of the management of electrical systems

- 1) Requirements with regard to drawings
- 2) Isolation and lock out procedures
- 3) Permit to work
- 4) Record keeping
- 5) Provision of safety equipment
- 6) Codes of practice
- 7) Communication systems

**Note:** The electrician's responsibilities towards the management system should be the main focus of this training.

- Cables

Knowledge of:

- 1) Core screens - type -tape, metallic braid, semiconductive
- 2) Flexible cable lay-up - coiling and non-coiling types
- 3) Voltage drop
- 4) Current capacity -cooling, installation
- 5) Protection implications of volt drop on long, low voltage cables



**Note:** With reference to 1) the importance of maintaining a low resistance earth path through joints and terminations must be stressed. Reports of single or a few wires being used to carry the earth through joints are commonplace. On medium voltage systems these connections would be likely to act as a fuse in the event of an earth fault, and so destroy the earth return path.

Awareness of :

- 1) Core screens - function - electrical fields , phase fault prevention
- 2) Fault capacity
- 3) Flame retardancy

- Awareness of the requirements for substations

- 1) Design - surface

- a) Access/egress doors
- b) Transformer bays - fire damage limitation
- c) Ventilation
- d) Alternate feeds - spare incomer, bus coupler
- e) Affects on fault level and safety precautions for d)
- f) Safety equipment
- g) Tools
- h) Record keeping
- i) Housekeeping and maintenance

- 2) Design - underground

- a) Structure - fire damage limitation
- b) Siting
- c) Dangers of dust and dust control
- d) Ventilation and smoke control
- e) Containment and fire damage limitation for oil-filled switchgear or transformers
- f) a), d), e), h), l), j) and k) above

**Note:** Items 1) d) and 1)e) would be essential only to electricians whose duties include switching in medium voltage substations. However, the awareness of the affects that paralleling of systems would have on fault levels and the implication with regard to switchgear rupturing capacities could optionally be explained to all electricians.

- Overhead Lines:

Basic Knowledge of:

- 1) Conductor supports - suspension towers, tension towers, poles
- 2) Earthing of structures

Knowledge of

- 1) Lightning protection
- 2) Potential differences between “earth potential” and “potential of general body of earth”
- 3) Induction due to adjacent overhead lines
- 4) Induction due to lightning discharges

**Note:** This training is only essential for electricians whose section includes overhead lines.

- Boreholes:

Awareness of:

- 1) Cased and uncased - conductive and non-conductive casings
- 2) Protection against lightning

**Note:** This training is only essential for electricians whose section includes boreholes, whether at the surface or underground.

- Explosion protection techniques

Knowledge of:

- 1) Flameproofing - Ex d
- 2) Intrinsic safety - Ex i
- 3) Increased safety - Ex e

Optionally, a knowledge of:

- 1) Non-approved techniques for underground in mines

- Standards

Optionally, a basic knowledge of:

- a) Certification of flameproof enclosures (a typical “U” certificate should be obtained to demonstrate the significance of this type of certification. Ideally an equipped enclosure with both the “U” certificate and the equipper’s certificate, as well as both labels should be obtained for this purpose.)
- b) Repair of explosion protected equipment (The possibility of non-licensed repairers carrying out work for which they are not entitled and which can lead to dangerous practices should be the focus.)
- c) Basic details of the training given to licensed repairers.

- Certification of explosion protected equipment  
Optionally, a knowledge of:
  - 1) What is and is not certified
  - 2) responsibility of mine
  
- Potential dangers with flameproof equipment  
Knowledge of:
  - 1) Short circuits in flameproof enclosures
  - 2) Phase barriers
  - 3) Corona
  - 4) Component ratings
  - 5) Temperature rise
  
- Typical features of gate end boxes and other flameproof switchgear  
Knowledge of:
  - 1) Overcurrent protection and back-tripping
  - 2) Overload and earth fault protection
  - 3) Earth fault lock-out protection
  - 4) Pilot wire protection:
    - a) Reasons that PWP is not Intrinsically safe
    - b) Functions
    - c) Abuses
  - 5) Isolation
  - 6) Interlocking - mechanical and electrical techniques

**Note:** For items 1) to 4) the use of a mock-up of a typical system incorporating these components is strongly advised. The mock-up should, ideally, allow for the demonstration of typical abuses and the affect they have on the safety and operation of the system, as well as the ability to introduce faults on the system.

Items 5) and 6) should be “hands-on” training.

- Mobile substations  
Knowledge of:
  - 1) The functions that are and are not provided by various primary isolation arrangements
    - a) No isolator
    - b) On-load and off-load isolators
    - c) Circuit breakers
  - 2) Secondary/primary back-tripping

- 3) Primary side terminations for continuous earth monitors for “feed through” arrangements
- 4) Primary side phase fault dangers
- 5) Overload protection by secondary circuit breakers

**Note:** Items 2), 3) and 5) should ideally be supported by mock-ups available for demonstration purposes.

Item 1) should allow for “hands-on” training on the types of primary switches in use on the mine.

- Earthing of underground equipment

Knowledge of:

- 1) Philosophy:

- a) Earth fault limitation
- b) Touch potentials
- c) Potential equalisation
- d) Lightning discharge dissipation

- 2) Techniques:

- a) Neutral resistors - rating, over-temperature
- b) Earth fault current/earth fault protection grading
- c) Use of roof bolts
- d) Insulated and partially insulated resin-set roof bolts

- 3) Symptoms of earthing system faults

- a) Severe damage due to phase-earth-phase faults
- b) Phase-phase faults in cables
- c) Excessive phase fault tripping
- d) Cable insulation damage due to phase to earth voltage disturbance

**Note:** These matters are most easily dealt with by means of diagrams and drawings

The use of physical specimens to demonstrate item 3) is advisable.

- Drives

- 1) Basic Knowledge of alternating current (AC) motors

- a) Current/speed characteristics
- b) Torque/speed characteristics
- c) Rated, pull-out, starting, stall torque
- d) Motor cooling

## 2) Direct current (DC) motors

- a) Types - shunt, series, compound, separately excited
- b) Characteristics of motor types
- c) Speed control - operational aspects and effects on motor ratings and performance

- Safety aspects of power factor correction equipment

**Note:** The discharging of a condenser via resistances of different values could be considered as a demonstration unit.

### 1.4.3 Training Methodologies

As far as is possible, the training of electricians should be carried out using practical methods as described above for foremen. The practical training should include "hands-on" operation of equipment under guidance, as well as the provision of appropriate mock-ups to demonstrate characteristics and safety features of some items of plant. The provision of simulators to facilitate acquaintance with operating and maintenance procedures on more sophisticated plant, such as continuous miners and long wall systems, is also strongly recommended. The electricians training should consist of even more practical demonstrations and "hands-on" work than that described for foremen.

## 1.5 Mine Workshop Personnel

Licensed repairers of explosion protected equipment are required to attend courses on the explosion protection techniques for which they are licensed. These courses cover more detail than the average mine electrical personnel member is likely to be conversant with. In addition, the licensing procedure requires that designated persons employed by the repairer demonstrate their competence by means of an examination.

It is strongly recommended that mine workshops that carry out repairs on explosion protected equipment follow the same procedure as independent repairers. Ideally the mine workshop should obtain a licence from the approval authorities.

Even in the event that this is not done, responsible appointed persons in the workshop should undergo the course and examination under the auspices of the approval authorities.

## 1.6 Cable Repairers

For those mines which operate their own cable repair workshops, the training given below is recommended. It is assumed that the person in charge of the workshop is a qualified electrician who would have received the training listed for electricians. The repairers are usually semi-skilled workers who carry out some of their tasks without direct supervision.

- Hot spots in badly made connections
- Affects of water penetration into a cable via bad sheaths or joints
- The importance of earthing systems
- The responsibility of cable repairers towards the health and safety of fellow workers.

## 2 AWARENESS TRAINING

### 2.1 Introduction

The concept of awareness training is to provide the trainee with a reasonable understanding of the hazards of electricity and the reasons for the procedures or codes of practice that apply to the individual, or in the case of mine and production management, the reasons for the codes of practice applicable to the electrical engineering staff members.

Awareness training for purchasing and stores personnel is an exception to the general rule, since in this case the focus would be on the awareness that components and replacement parts for explosion protected equipment must be supplied in accordance with the certification conditions for that equipment.

### 2.2 Senior and Production Management

Senior and production managers should be made aware of the following:

- Short circuits and Energy Release Following Electrical Faults
  - \*1) Relating energy release in short circuits to recognisable values such as equivalent quantity of explosive.
  - 2) Damaging effects of energy release on flameproof equipment.
  - 3) Potential for injury to persons and ignitions as a result thereof.

- Overloads on electrical equipment
  - 1) Rating of equipment by introducing concept of heat generated by electrical equipment and heat loss from equipment.
  - 2) Possible ignitions as result of equipment overloads.
  - 3) Typical abuses of overload protection.
  
- Earth faults
  - 1) Electrocution danger.
  - 2) Ignition of gas or coal dust.
  - 3) Ignition of gas, coal dust or blast initiation in the presence of electrical storms.
  
- Basic concept of protection against electrical faults
  - 1) Typical types of protection and how they operate.
  - 2) Recognising symptoms of protection systems that are operational and those that are not.
  
- Identified reasons for electrical staff using unsafe practices. The reasons are listed in the SIMRAC COL 316 report.

## 2.3 Production Personnel

Production personnel including mine overseers and shift bosses should receive awareness training in the following:

- Overloading of electrical equipment and the possible consequences.
  - 1) Reasons for preventing overloads
  - 2) Danger of ignition of coal from overloaded equipment.
  - 3) Electrical protection against overloads.
  - 4) Reasons for using dedicated gate end boxes with correct overload settings.
  
- Cables
  - 1) Danger to life from damaged cables.
  - 2) Ignition of gas or coal dust from damaged cables.
  - 3) Overheating of cables.
  - 4) Basic understanding of electrical cable protection systems, particularly pilot wire systems.
  - 5) Recognising electrical system failures.
  
- Isolation - Based on the type of equipment in use and the requirements of the mine codes of practice, production personnel should be trained on what equipment may be isolated and when and how it should be done.

- Danger of tampering with electrical equipment
- Ventilation for electrical equipment - The potential danger associated with blocking the normal airflow to electrical equipment should be stressed. In addition, interfering with the cooling arrangements for electrical equipment by covering the equipment with stone dust, sheets, other material or pieces of other equipment should be pointed out.
- Procedures to be followed in the event of an electrical fire
- Energy release from electrical short circuits in recognisable terms
- Potential for "hot spots" as a result of cable or cable joint damage.

## **2.4 Commercial and Purchasing Personnel**

The possibility of head office purchasing or commercial departments influencing purchasing policy must be considered. Awareness training of the relevant staff might be required. The following awareness training is recommended:

- Basic knowledge of the need for certification and the certification process for explosion protected equipment.
- Understanding of the responsibilities of the purchaser, user and supplier of explosion protected equipment.
- In the event that the mine store is involved in administering equipment repairs:
  - 1) An awareness of the legal requirements with regard to the repair of explosion protected equipment.
  - 2) Basic knowledge of the certification process for licensed repairers of explosion protected equipment.



## **Appendix 2**

### **COUNTRIES SELECTED FOR OVERSEAS VISITS**

The rationale for selecting the various countries that were visited is described below:

#### **United Kingdom**

South African coal mines have been closely associated with the coal industry in the United Kingdom for many years. Much of the equipment used in local coal mines in the past was sourced from Britain or from local representatives of British principals.

South African specifications for explosion protected equipment were initially based on British Standards. Many of the employees in the early coal mining days had previously worked for the British National Coal Board, later British Coal Corporation.

Despite the move locally to the use of International Electrotechnical Commission (IEC) standards, British coal mining technology and skills still have a substantial influence on the local coal mining industry. A reasonable number of British born persons are still employed on South African mines and equipment based on British equipment still preponderates, particularly in the electrical field and with longwall mining methods.

Equipment for use on British coal mines was traditionally carefully scrutinised by the nationalised coal board. The board established a substantial research and development operation which was involved in acceptance trials for mining equipment and which, in most cases, was the precursor to final approval by Her Majesty's Inspector of Mines. The equipment surveillance was very thoroughly carried out and was exemplary in terms of thoroughness, although the lengthy procedure was criticised in most other mining countries.

#### **Poland**

Poland, which is a major coal producer, was chosen for a visit because it is still heavily under the influence of socialist ideologies, even though the country is now adopting many principles of Western democracy and free economic activity. More importantly however, it was envisaged that, due to the multi-national nature of Eastern Europe, the Polish coal industry may well have to contend with having to train people from diverse cultural, educational and economic backgrounds. It was hoped that insight would be gained into how mines deal with newly emancipated communities, and that this would provide guidance as to appropriate methods of training in South Africa, where the population has suffered educationally and economically for many years from the repressive ideology of apartheid.

## **Germany**

Knowledge of the German mining industry by project team members was reasonable in terms of equipment, but inadequate for analysis of the essential issues regarding legislation and training. Germany was considered to be a country with a sophisticated workforce of German born citizens, but with the perceived need for the German coal mining industry to employ foreigners with potentially limited linguistic skills and uncertain schooling and academic training. This was considered to be an area in which similarities with the local coal mines existed.

Due to the relatively economically protected nature of the German coal mining industry, it was envisaged that Germany may well provide insight into how training issues could be addressed in an environment where the cost of good training may not be as much of a constraint on what could be offered, as it possibly is locally where the industry is not subsidised.

## **United States of America**

Members of the project team had been acquainted with United States coal mining for a couple of decades. The members' perception of the United States was of loose control and minimal legislation over formalised training and education, but with a high focus on performance of individuals. The lack of prescriptive legislation in terms of employment of skilled persons was counter-balanced by an extremely litigious legal system.

Latterly, the Federal Government had been increasing the levels of activity in both legislation and in health and safety surveillance. These developments were considered worthy of further study, in addition to investigating the methods used by mines to reduce their liability in legal terms by means of the selection and training of personnel.

## **Australia**

Australian coal mining was reportedly similar to South African mining in many respects. Privatised coal mining and a heavy focus on export markets, were similarities.

Australia was reported to differ from South Africa in terms of legislation, approval processes for explosion protected equipment and appointment and training of responsible persons. The project team were aware of the fact that Australia made use of a substantial number of national standards for mining equipment, in addition to standards related to explosion protection of equipment.

In addition, the mining regulations and equipment approval practices were the responsibility of the various states. Consequently, it was possible to view two systems within one country, namely those of the two major coal producing states of New South Wales and Queensland.

## **China**

The project team had decided to include at least one country where a reasonable proportion of the people employed in coal mines would have had limited exposure to industrialisation or mechanisation and might, in other respects, have come from disadvantaged backgrounds.

Initially India had been selected, but China was eventually chosen on advice from individuals who had fairly extensive experience of coal mining in both countries.

In addition, China was also a country which had experienced political change and was currently in the process of adjusting to a free market economy.

## **Appendix 3**

### **THE GOVERNMENT CERTIFICATE OF COMPETENCY**

#### **3.1 Introduction**

Machinery safety standards on a mine will to a major extent depend on the efforts of mine engineers. For this reason the technical competence of engineers is paramount if the performance of the engineering team is to be improved. The current situation is discussed in detail in this Appendix.

#### **3.2 The Certificated Engineer**

In both mining and other industries, a person appointed in general charge of machinery must be the holder of a Certificate of Competency for Engineers, except in cases where the installed capacity of machinery is below 2500 kilowatts.

The Certificates of Competency are issued by a Commission of Examiners to persons meeting the academic and experiential criteria listed below, and who successfully complete an examination set by the Commission.

In order to qualify for the examination, candidates must have:

- an appropriate BSc degree in mechanical or electrical engineering;
- completed a mechanical or electrical course to exit level (N4) at a Technicon, or
- completed a Technical College course in mechanical or electrical engineering to T6 level.

Furthermore, prior to writing the examination, the candidate must have received practical training to the satisfaction of the Commission of Examiners. The practical training required by the Commission includes at least two years of appropriate experience in South African mines. (Certain exemptions apply in respect of experience gained elsewhere. Furthermore for Technical College candidates who completed certain apprenticeships such as boilermaking, welding, instrument mechanic etc., longer periods of practical experience are required.)

The candidates holding the Technicon and Technical College qualifications must have completed a prescribed curriculum as defined by the Department of Minerals and Energy (see Appendix 13). It is important to note that the curricula for electrical and mechanical engineers differ in some respects.

Holders of BSc degrees may be exempt from the paper on Plant Engineering provided that they have had three years of appropriate post-graduate experience and have been registered as Professional Engineers.

## **3.3 The Certificate of Competency Examination**

### **3.3.1 Objectives of the Examination**

Since candidates for the Certificate of Competency examination have prescribed academic qualifications, the objective of the examination must presumably be to test a candidate's ability to:

- apply the theory acquired academically in practical situations the candidate will encounter on the mines he/she is likely to be employed on;
- make engineering decisions that will ensure health and safety on the mines he/she is likely to be employed on; and
- make appropriate decisions where either past experience or academic knowledge does not cover any particular situation that could endanger safety and health.

The current examination system does not ideally meet the objectives set out above, for the following specific reasons:

- The scope of the examination covers engineering technology in every type of mining encountered in the country, including off-shore oil wells.
- The examination covers both electrical and mechanical engineering in one examination, although the certificates issued are designated as either electrical or mechanical, depending on the prior academic training of the candidate.
- A reasonable proportion of the questions in the paper on Plant Engineering test the candidate's theoretical knowledge (thereby replicating, to some extent, prior academic training), rather than the application of theory to practical situations.
- Questions that have no bearing on health and safety matters are common.

Each of these issues is further discussed below.

### **3.3.2 Scope of the Examination**

An attempt is made to cover the practical application of engineering technology in all types of mines by selecting appropriate examination questions. The types of mines include hard rock mines without ignitable gas, hard rock mines where ignitable gas may be present, strip, opencast and other surface mining and quarrying activities, shallow coal mines, adit mining and deep level coal mines, as well as oil and gas producing off-shore platforms.

There is obviously a certain amount of commonality in the practical engineering applications on these mines, but there is also great diversity that arises from the various mining techniques that are applied. The Utopian situation would be one where all engineers are completely competent to handle the engineering matters concerning health and safety on any type of mine or oil well. The investigations however indicated that not all holders of Government Certificates of Competency for Engineers had the requisite knowledge to safely manage the electrical issues specifically related to underground collieries.

Areas of commonality that exist for most underground mines is in the technology involved in hoisting (winding), main electrical reticulation systems, specific requirements for operation of diesel powered equipment, ventilation, conveying, and to a lesser extent, pumping. Compressed air systems, environmental cooling, strata support equipment (of the type used in deep level mines) and hydropower do not apply to coal mines. To some extent, hazardous area engineering is of less importance in hard rock mines and of no importance in surface mining activities, but is vitally important in underground coal mining and oil producing platforms.

It is therefore obvious that the range of subject matter covered by the examinations results in a limited opportunity for the Commission of Examiners to evaluate a candidate's competence in one specific field of expertise.

Unlike the examinations and certificates for mine managers, there is no distinction made in the engineering examination between coal and hard rock mines. Furthermore, it is possible for candidates to select questions relating to their specific practical training and areas of expertise, and to avoid any questions relating to a number of engineering disciplines. This applies particularly to hard rock trained candidates, where a candidate can usually accumulate sufficient marks to pass the examination without answering any questions on hazardous area engineering or coal mining. Similarly, a candidate with a mechanical engineering background can usually pass the examination without attempting any electrical questions. (The converse is generally not true i.e. electrical candidates would have to have some proficiency in mechanical engineering.)

The examination in the present form is thus not able to determine the competence of engineers in all matters that are likely to require their attention, and which are required for them to carry out their duties with regards to health and safety.

### **3.3.3 Electrical and Mechanical Engineering**

Most other countries require engineering staff to demonstrate their competence in either electrical or mechanical engineering. Where examinations are written, these are specific to the engineer's academic and training discipline, either mechanical or electrical.

Conversion from one discipline to the other is possible, but only after demonstrating that appropriate and adequate experience has been gained, and after writing and passing a further examination that concentrates on the particular discipline and/or type of mine.

Furthermore, in some areas such as the states of New South Wales and Queensland in Australia, a distinction is made between the certificates and examinations in the particular discipline for open cast and underground coal mines.

Candidates in these countries are consequently far more completely evaluated for competence in the practical application of technology for the type of mining to which they will be exposed.

Furthermore, bearing in mind that no distinction is made between electrical and mechanical engineers in terms of engineering appointments, with the legislation in its present form, the examination should require mechanical engineers to indicate their competence in electrical engineering in general, and electrical protection in particular, these being areas where the investigations revealed the competence of engineers on mines to be particularly poor. The structure of the examination does not permit this, as is discussed in greater detail below.

### **3.3.4 Practical Content of the Examination**

The examination should be aimed primarily at determining the candidate's ability to apply academically acquired knowledge to practical situations in such a manner as to facilitate health and safety underground. Unfortunately, the availability to the examiners of questions that adequately test this particular competence are limited. By comparison, engineering text books contain many questions of a theoretical nature which may be used for the examination. Consequently, the easy access that examiners have to this type of question leads to a fair proportion of the questions merely testing theoretical knowledge. In the light of the prescribed academic qualifications that a candidate must hold before writing an examination, such questions fail to achieve the ends for which the examination is intended.

In addition, the examination should cover safety and health related issues in far greater depth than those dealing purely with the application of technology which has no direct affect on health and safety. Scrutiny of past examination papers indicates that this is not generally the case. A reasonable proportion of the available marks concern matters which do not have a direct bearing on safety and health.

However, criticism of the system is simpler than providing a solution to the above mentioned shortcomings of the examination. Since questions dealing with the practical application of technology to safe working are not available in any text book, examiners

attempting to set this type of question have to rely on their knowledge of typical safety related issues and to structure their questions based on that knowledge. Since all of the members of the Commission of Examiners occupy full time positions in the DME or the mining industry, continually providing fresh questions of a suitable type is an arduous task. This matter does however require attention.

### **3.3.5 Examination Structure**

Candidates are required to successfully pass two examination papers, one on Legal Knowledge and the other on Plant Engineering.

Although the Commission issues either electrical or mechanical Certificates of Competency, engineers with academic qualifications and experience in either of the disciplines write the same examination papers. The paper on Plant Engineering normally consists of a set of three compulsory questions, and four optional questions of which two must be answered. In order to cover both the electrical and mechanical disciplines, the examination is structured in such a way that questions relevant to both disciplines are included in the paper on Plant Engineering. Usually the compulsory questions are chosen to cover both mechanical and electrical matters. However, as stated below, a candidate is able to pass the examination if only one compulsory question is answered correctly.

The candidate may attempt any two of the four optional questions. There is no constraint on the questions the candidates answer, other than the three compulsory questions. Each question counts 20 marks and the candidate must achieve at least 50 marks to pass the examination. This implies that a candidate who gets 20 marks for each of the optional questions only needs to obtain 10 of the possible 60 marks available from the compulsory questions in order to pass the examination. Consequently, despite attempts to cover as wide a range of subject matter as possible in the compulsory questions, candidates can pass the examination with very limited knowledge of the subjects matter tested by the compulsory questions.

### **3.3.6 Criteria for Passing the Examination**

A further issue for consideration is the means by which a candidate for a certificate is evaluated. Currently, the pass mark in South Africa is 50 per cent. Evaluation purely by means of a pass mark can result in candidates being successful due to their expert knowledge in some aspects of engineering, but totally ignorant of other important, and potentially safety related, aspects.

As mentioned above, the present means of attempting to evaluate the candidate, is by making use of selected compulsory questions in the examinations. However, it is still



possible for candidates to avoid the compulsory questions to a large degree, and yet obtain a pass mark. Ideally, the compulsory questions should be able to cover all the essential, and potential safety related aspects, and not afford a candidate the chance to pass the examination without demonstrating adequate competence in these areas.

Notwithstanding the above, only about 25 per cent of the candidates who sit the examination are successful. Forcing candidates to demonstrate a certain minimum competency in the compulsory questions will probably result in the pass rate falling even further. Possible reasons for the low pass rate are considered below.

### **3.3.7 The Current Pass Rate**

In the light of criticism relating to over-reliance on questions which test a candidate's academic knowledge, and due to the academic prerequisites for acceptance as a candidate, the pass rate should be reasonably high. Since this is not the case, the reasons for the low pass rate require discussion.

Firstly, the questions in the examination might in some cases deal with technology that was covered by the candidates in the early stages of their academic studies. Assuming that a candidate has completed at least a two-year period of practical training (and many will have completed far more post-academic training), the theory that the candidate might be required to apply would have been covered at least four years previously during his/her studies. The candidate might therefore have forgotten the theory, while his/her most recent experience and expertise may have been focused on issues of practical engineering. It is also probable that the candidates are no longer as skilled at sitting examinations as they were during their years of formal study.

Secondly, the extent of the coverage of the examination must, in the present circumstances, be extremely wide. Compared with a student in the academic situation who is able to prepare for each subject prior to writing, the preparation for the certificate examination is far less focused and covers vastly greater subject matter.

### **3.3.8 Additional Requirements for Coal Mine Engineers - Evaluation of Explosion Protected Equipment**

The issue of evaluation of explosion protected equipment was addressed in Enabling Output 2 (d), where reference was made to the specialised nature of the work involved in evaluation of explosion protected equipment for safe operation. Most coal mine engineers interviewed were unaware of their responsibilities in terms of the present system of certification. However, when this requirement was pointed out to them they indicated that their workload would not allow them to carry out these duties. In the few cases where the engineer being interviewed appreciated these responsibilities, they

assumed that the required evaluations were undertaken by their sub-ordinates. However, no evidence was forthcoming of engineering supervisors being appointed for this duty, although in a few cases the supervisors were reportedly told to inspect equipment. However, as is mentioned in Appendix 7 - Certification/Approval of Explosion Protected Equipment, the evaluation requires expert knowledge which an electrical supervisor is highly unlikely to have.

The average mine engineer is also not likely to have the expert knowledge required for evaluating explosion protected equipment. Despite this situation, no questions on this subject have yet been set in either the Plant Engineering or Legal Knowledge examinations. It is also very difficult to perceive an examination for engineers being structured in such a way as to provide proof of a candidate's capability in this regard. The above shortcoming is most suitably addressed by a change in the certification process.

### **3.3.9 Administration**

Concern has been expressed in the past, by representatives of the Department of Minerals and Energy, regarding the extent of the resources already required to administer the many certificates of competency currently required to be examined and issued in terms of the present Act and regulations. The resources required will increase even further, in the event that separate examinations for electrical and mechanical and/or hard rock and coal mining certificates are instituted. An additional burden on the Commission of Examiners will also arise.

## **3.4 Recommendations regarding the Government Certificate of Competency Examination**

### **3.4.1 General Recommendation**

With particular reference to coal mines, a scheme that requires separate examinations for electrical and mechanical engineering, and is specifically for coal mines, would greatly increase the potential to evaluate candidates, and would put South African practice in line with that of most major coal producing countries. With regard to electrical safety, such an approach would greatly improve the competence of engineers in those areas which are currently poorly understood.

### **3.4.2 Mine-type Specific Certificates of Competency**

The ideal approach for optimal training for, and certification of, engineers would be to make the certificates mining type specific. Separate certificates for opencast/strip mines, hard rock mines and coal mines would be ideal, with supplementary examinations being required to convert from one type of certificate to another.

As an example, surface mining engineers require additional knowledge in overhead line installation, diesel engines, off-road earth moving equipment and the danger of the transfer of potentially lethal ground voltage disturbances on cable fed machines. Winding practice is of little importance although, in common with deep level mines, steel rope maintenance and operation would be required. Knowledge of materials handling equipment and compressors would also be relevant.

Underground coal mining engineers would require superior knowledge of hazardous area engineering. If mechanical engineers are to take responsibility for electrical plant, all mechanical engineering graduates of tertiary institutions would be required to complete a course in electrical reticulation and protection. The same would apply to any university electrical graduates who had not completed a course in protection engineering.

Three major objections to this approach are likely. Firstly, the Department of Minerals and Energy would have a substantial additional administrative load. But, as discussed below, the examinations need not be administered by the Department.

Secondly, mining houses with diverse mining activities prefer to be able to transfer their engineers between mines at will. This would not be possible under type-specific certificates unless time limited exemption is granted for the engineer to complete the requisite course(s) for the mine to which he/she has been transferred.

Thirdly, it is presently a difficult task to identify suitable questions for the single examination. This problem will increase in direct proportion to the number of different examinations that will result from the above proposals.

The disadvantages of having mine-type specific qualifications should however be weighed against the safety related disadvantages of the present system, and the benefits of improved training and evaluation of engineers.

Two approaches to solving the problem of the examinations are proposed. Firstly, to overcome the problem of finding adequate questions, a call on engineering practitioners to provide typical examples of incidents that have occurred in practice, for use as a basis for examination questions, may assist.

Regional inspectors and practising engineers who are members of the engineering associations, the Association of Resident Engineers and the South African Colliery Engineers Association, could be requested to assist in this regard. Head Office consultants could also be a source of examination material.

The assistance can be in the form of very short descriptions, forwarded to the Commission, of typical problems that have occurred in practice. The Commission could then formulate a library of questions using this information. In addition, for fiery mines, similar assistance could be requested of members of the South African Flameproof Association.

An alternative approach would be to require that additional mine-type specific courses, concentrating on the typical hazards associated with that type of mining and the application of technology thereto, be completed before a candidate be allowed to sit the Certificate of Competency examination. The obvious agencies to provide this additional training would be tertiary educational institutions; the universities and technicons, although other training establishments could also be considered with appropriate DME approval. It is however unlikely that universities and technicons would be willing to include subject matter that may be regarded as too specific to the mining industry, in their general undergraduate courses. However, they may very willing to offer suitable courses on a post-graduate or occasional basis. It may even be possible to structure the required courses to be undertaken largely by correspondence.

The practical nature of the required courses would probably require that practising mining industry specialists assist in the design, presentation and evaluation of the courses. Training institutions that are currently active in the mining industry, such as the Colliery Training College and mine training centres, may be better able to develop suitable courses, because of their easier access to the requisite practising industry specialists.

It is envisaged that an examination candidate would have completed courses in the specific subjects which he/she would require for the mine on which he/she is to work, and in the area of responsibility (mechanical or electrical) that he/she would specialise in.

The following procedure for issuing a certificate, and the form of the certificate, would then apply:

- The certificate would be issued as an electrical or mechanical certificate based on the candidates academic and training related discipline.
- The certificate would contain details of the supplementary safety and practically oriented courses that the candidate had completed.
- Any additional supplementary courses completed at a later stage in the engineer's career would be entered on the certificate.

The benefits of this scheme are that:

- the course material and examinations can be focused on a specific discipline and the type of mine the engineer is to be employed on and the type of hazards that may arise;
- preparation for the examinations will be simpler due to the reduced field covered by the examination;
- the engineer's employer (manager) will be certain of the areas of expertise of the engineer and so be in a position to discharge his/her duties as detailed in section 7 of the Mine Health and Safety Act;
- the engineer can change from one type of mine to another, or from one discipline to the other, by completing additional courses;
- the system is flexible enough to allow additional courses to be included, and to be required of engineers, as new technologies (such as hydropower and ultra-deep winding) are implemented in mines; and
- if incidents occur which indicate that the engineer was weak in a particular area of technology, he/she could be required by the Department of Minerals and Energy to redo a particular course as a pre-requisite for renewing the certificate.

### **3.5 Practical Training of “Engineers in Training”**

The examination is acknowledged to presently purely sample the candidate's competence to apply his academically acquired knowledge in practical situations. The extent of the candidates practical training is therefore an important prerequisite.

The candidate's employers are required to substantiate the candidate's stated list of practical training received. This in theory ensures that the candidate has received training in a sufficiently wide range of engineering matters to allow the sampling affect of the examination to determine, with reasonable accuracy, the candidate's suitability to carry out the legal responsibilities of an engineer.

However, from the personal experience of the project team members and various formal and informal discussions held with Certificated engineers in industry, the practical training rarely covers the subject matter a newly appointed engineer is required to deal with.

The reasons for this state of affairs are largely due to four factors, namely:

- The candidate can usually not be adequately exposed to all matters within the two year minimum period of the practical training programme. A well constructed and carefully monitored programme can come close to providing the necessary coverage. However, in many cases the training and allocation of the candidate to various engineers who are to be the candidate's mentors is the responsibility of an operating

engineer. This leads to the situation where the engineer, who is more concerned with his daily activities than supervising a trainee's training, overlooks the training needs of the trainee

- In matters such as electrical protection systems the work is rarely carried out on the mines due to the lack of knowledge of mine engineers in this matter. Generally the trainee gets best exposed to those matters that the mentor is most comfortable with. This somewhat incestuous situation does not lend itself to proper exposure to those areas of expertise which are least known or understood by practising engineers.
- Unless a procedure for moving engineers from one type of mine to another is practicable or in place, the candidate will only have acquired practical experience in one type of mining. If granting a certificate to a candidate that had successfully passed the examination was subject to the requirement that the candidate is only appointed on the type of mine on which he acquired the practical experience, the limitation on experience gained in various types of mining would be in order. However, having passed the examination, the Certificated engineer is entitled to work on any type of mine.
- In cases where mines are understaffed or under financial pressure, the trainee might be employed to fulfil productive roles without any attempt at providing him/her with the necessary experience. In effect, the trainee would therefore not have acquired wide enough practical experience to satisfy the examiners. However, numerous cases are known, or have been reported, where the trainee's range of experience has been falsified in order to satisfy the pre-conditions for acceptance as a candidate. This is particularly the case where engineers are urgently required by an organisation, or where a particular trainee is required for a position on a mine or within a group of mines.

### **3.6 Conclusion**

The engineer is the most important person in ensuring that machinery is safely applied, operated and maintained. His/her competence is thereof paramount to the performance of an engineering team. The current procedure for certifying the engineer's competence is inadequate and in many cases engineers are required to accept responsibility for matters for which they are insufficiently trained.

To expect the owner or a manager to be responsible for determining the competence of an engineer or to comply with the requirements of section 7 of the Act in this regard is unrealistic.

To address the situation the certification of engineers should be subject to either:

- more specific discipline and mine-type certification based on the current system; or

- certification which details the specific post-graduate practically oriented courses the engineer has completed

The latter approach has a number of benefits to the engineer and his/her employers, and to health and safety in industry and is therefore strongly recommended.

# Appendix 4

## APPOINTMENT OF ENGINEERS

### 4.1 Legal Requirements

In terms of the Mine Health and Safety Act, Act No 29 of 1996:

Clause 7 (1) To the extent that is *reasonably practicable*, every *manager* must: - ...

- (d) consider an *employee's* training and capabilities in respect of *health* and *safety* before assigning a task to that *employee*; and
- (e) ensure that work is performed under the general supervision of a person trained to understand the *hazards* associated with the work and who has the authority to ensure that the precautionary measures laid down by the *manager* are implemented.

Clause 7 (2) A *manager* may appoint any person with qualifications as *prescribed* to perform any aspect of the functions assigned to *managers* by *this Act*.

Furthermore, in terms of clause 2.13.1 of the Regulations:

At any mine or works where -

- (a) the designed rating of machinery used in the generation of power, together with the power supplied from outside sources, exceeds the equivalent of 2500 kilowatts, or
- (b) any winding plant intended for conveying persons is installed all machinery shall subject to regulation 2.13.6.1, be under the general charge of an engineer who shall be appointed in writing by the manager.

(Regulation 2.13.6.1 refers to the length of time the mine may be operated without an engineer and the need to appoint a competent person in that event).

Regulation 2.13.1 does not require the appointment of a Certificated engineer or stipulate that the engineer should be either a mechanical or electrical engineer. However, Definition (6B) in Chapter 1 of the Regulations, states that an "engineer means a person who is the holder of an appropriate mechanical or electrical engineer's certificate of competency appointed in terms of these regulations."

What is unclear in this definition is whether the word "appropriate" refers to an appropriate electrical or mechanical certificate or whether it refers to a mining certificate instead of a surface industry certificate. The fact that separate electrical and mechanical certificates are issued would support the first interpretation, and that the manager should consider the discipline in which the certificate was issued when making an appointment.



It may therefore be argued that the manager should appoint an electrical engineer to be in direct or general charge of the electrical equipment on a mine. Clauses 7 (1) (d) and (e) of the of the Mine Health and Safety Act (quoted earlier), supports this approach, as these clauses require that the manager consider the training and capabilities of the employee when making an appointment, and a mechanical engineer would probably not have appropriate training and capabilities, nor be able to understand the hazards associated with electrical systems.

However, clause 7 (2) of the MH&SA, by virtue of the reference to prescription, might in turn be taken to indicate that no such prescription on the appointment of an engineer of either discipline is given in terms of the Act or regulations. In practice, electrical engineers are usually not specifically appointed to take responsibility for electrical equipment.

Furthermore, judging from comments of managers, the need to appoint electrical engineers is not recognised by them. In fact most managers interpret the non-prescriptive detail of engineers' appointments to indicate that any engineer can be appointed to take responsibility for any engineering matter. Furthermore, the fact that electrical and mechanical engineers write an identical examination for the Government Certificate of Competency is interpreted to support the view that all Certificated engineers may be regarded as being equally conversant with both electrical and mechanical technology.

However, the interpretation of the definition of an engineer by the Department of Minerals and Energy, is that "appropriate" refers to the engineer being the holder of a "Mines" and not a "Factories" certificate of competency. Reportedly, where the meaning of a regulation requires interpretation, normal practice is accepted by the courts as precedence. In this case, electrical engineers are not normally appointed to be in charge of electrical equipment.

The absence of differentiation between electrical and mechanical engineers when appointing engineers in charge of electrical equipment and systems in underground coal mines, appears to be in conflict with other indicators that the two disciplines should not be regarded as equivalent when making such appointments. Specifically:

- curricula at universities, technicons and technical colleges for the two disciplines vary; (Refer to Appendix 3 - The Government Certificate of Competency )
- certificates of competency differentiate between competency in mechanical and electrical engineering, and
- if the holder of a certificate of competency in one discipline wishes to acquire a certificate in the other, proof of additional experience in that discipline is required by the Commissioner of Examiners.

## 4.2 Assessment of an Engineer's Competence by the Manager

In discussions with staff of the Department of Minerals and Energy, they stated that they regarded it as the responsibility of a manager of a mine to determine the competency of any engineer that they appointed on their mine. The project team believes that this view is difficult to support.

In the first instance, the manager of a mine is required by law to appoint an engineer to take responsibility for matters of a mechanical or electrical engineering nature on a mine. This is an *ipso facto* acknowledgement that the manager requires engineering expertise that he/she does not have. It is therefore unrealistic to expect the manager to have sufficient engineering knowledge to evaluate the competence of an engineer.

Secondly, if the Commission of Examiners considers the engineer to be competent by appraisal of his academic training and practical experience and the passing of an examination, the manager is hardly likely to be able to achieve greater insight into the an engineer's competence, purely on the basis of an interview or the perusal of a curriculum vitae.

Furthermore, in many cases that the project team are aware of, a manager does not distinguish between electrical and mechanical engineers when making engineering appointments.

The process whereby the competence of engineers is evaluated must therefore be re-examined if an improvement in the competence of engineers is to be achieved.

## 4.3 Tertiary Education

The project team investigated the curricula of selected universities and technicons on one matter which was identified as being particularly poorly understood by the engineers who were interviewed on the mines. This related to the practical understanding of aspects of electrical protection, such as fault levels, switchgear breaking capacities, protection relays, zones of protection and protection discrimination.

The investigations conducted during mine visits indicated that electrical engineers were generally more conversant with the hazards associated with electrical equipment, than were mechanical engineers. One exception of note was a mechanical engineer who had personally acquired substantial electrical knowledge through his own on-going efforts to obtain education in electrical matters. This person was possibly the engineer with the greatest knowledge of electrical protection theory among those interviewed.

Technicians and Technical Colleges are required to provide academic grounding in electrical protection engineering. The curricula prescribed by the Department of Minerals and Energy for these institutions, requires that some of the subject matter to be taught to mechanical engineering students, with more detailed instruction for electrical engineers. Universities, in most cases, offer electrical protection as an optional course to electrical engineering students only. It was reported that the course is not popular. Many electrical engineering university graduates do not therefore have adequate knowledge of protection theory, let alone its practical application.

The reasons for the low levels of knowledge of electrical protection among engineers of both disciplines requires further investigation.

## **4.4 Appointment of Electrical Engineers**

As reported elsewhere, the requirement in other major coal producing countries for electrical engineers to be appointed to be in charge of electrical equipment in collieries differs from the situation in South Africa, where no such appointments are required. The extent to which the local situation may compromise safety is addressed in this section.

As mentioned in the section dealing with the observations made during mine visits, protection technology is poorly understood by most practising engineers. The possibility of providing specific training courses in the technology is discussed in Appendix 3 - Government Certificate of Competency. However, the theory of protection is possibly best grasped by electrical engineers, which may mean that mechanical engineers cannot safely take responsibility for the electrical matters.

Electrical issues that are vital to safe operations in underground coal mines include:

- electrical protection schemes;
- the selection of switchgear for the prevailing faults levels in an electrical system;
- the ability of existing switchgear to break a fault on the system when the system parameters change;
- the ability to evaluate or assess the suitability of the contents of flameproof enclosures; and
- the ability to understand the intricacies of intrinsically safe systems and other electrical explosion protection technologies.

It is proposed, in some quarters (notably the DME) that clause 7 (1) (e) places the onus on the mine manager to ensure the competence of the engineers that he appoints. This clause reads: "To the extent that it is reasonably practicable, every manager must .... ensure that work is performed under the general supervision of a person trained to

understand the hazards associated with the work and who has the authority to ensure that the precautionary measures laid down by the manager are implemented”, As was discussed elsewhere, managers are generally not in a position to adjudicate on the competence of engineers.

An examination for, and the awarding of, a Certificate of Competency which is specifically for electrical engineers must therefore be considered as an aid to the manager in deciding the competence of engineers to supervise electrical issues. In the case of underground coal mines, the appointed electrical engineer should also be conversant in issues such as explosion protection technology. In order to address this matter an underground coal mine specific Certificate of Competency would be necessary. In both cases the examination could be structured in such a way that the candidate would be forced to successfully answer questions on the core electrical issues that affect safety underground, in order to pass the examination.

A further consideration is that, in practice, mechanical matters tend to occupy most of an engineer's time. Electrical issues that do not have an immediate impact on production tend to take a back seat to the more pressing matters. Consequently, even electrical engineers occupying positions of a general nature tend to pay little attention to electrical engineering.

## **4.5 Conclusion**

At issue is whether an electrical engineer should be appointed in charge of electrical equipment on mines. With the present Act and regulations the manager would appear to be at the mercy of a legal judgement, in the case of a mechanical engineer being liable for an accident which is caused by electrical technology of which he is ignorant. The matter of engineering appointments must at least be clarified, and some method of ensuring that electrical systems in coal mines are properly engineered, maintained and operated must be decided. The present system is inadequate in this regard.

# **Appendix 5**

## **THE COLLIERY TRAINING COLLEGE**

### **5.1 Introduction**

The Colliery Training College was visited during 1996. During finalisation of the report it was learnt that the Collieries Committee had appointed a Working Group to review the services provided by the College. A copy of the Review was obtained and the College was revisited to determine the degree to which pertinent views of the project team corresponded with those of the Working Group and the College management.

In most cases that apply to the subject matter of the project, the findings and recommendations of the Working Group closely follow those of the project team. The course of action proposed by the College management also conform with the views of the project team. In certain respects research on this project had progressed further than, or in more detail to, the present courses of action being undertaken by the College management. The matters are considered in the rest of this appendix.

### **5.2 Equipment**

The electrical equipment used as demonstration models for trainees is either no longer used on mines or is archaic. Modern equipment is both more complex and contains more diagnostics aids for trouble shooting than the equipment that is currently typically used for training. An approach was made to manufacturers to determine whether they would be prepared to assist the College in acquiring pieces of modern electrical equipment.

The response of the manufacturers was positive. In many cases, pieces of equipment that were condemned for use in hazardous areas but could be returned to operating status could be made available to the College free of charge or at low cost.

In addition, through co-operation with the coal mining industry, the manufacturers could be persuaded to support the College.

In addition to the flameproof equipment, the acquisition of mock-ups of typical coal mine electrical systems should be acquired to allow for demonstrations of the safety features of, and recommended practice with, these systems. In particular, a pilot wire system and a typical low voltage protection system showing the transformer secondary, gate end box back-tripping and gate end box over current, overload and earth fault protection

components is strongly recommended. The mock-ups should be designed to facilitate the demonstration of typical malpractice and the effect these have on the system performance.

### **5.3 Course Content**

In the main body of the report mention is made of the low opinion that electricians, to a great extent, and foremen to a lesser extent, have of the training at the College. However, the responses to the questionnaires indicated that unrealistic expectations accounted for a lot of the negativity. In particular, training on the specific types of equipment the trainee would encounter on the mine was repeatedly stated as a shortcoming. Such training should obviously be the responsibility of the industry.

Another matter which was commonly recorded was an over-emphasis on reading electrical drawings. However, manufacturers who are frequently called to assist mines in maintaining equipment report that mine electricians' skills in reading electrical drawings are particularly low.

It is surmised that this apparent contradictory situation arises as a result of manufacturers' drawings being difficult to interpret. Experience has shown that in many cases the drawings are not well laid out and/or follow a methodology substantially different from normal electrical drawings.

It is strongly recommended that to overcome this problem, a two pronged approach is adopted. Firstly, industry should pressurise manufacturers to make their drawings more user friendly. Secondly, manufacturers supplying equipment to the College should include packs of drawings and maintenance manuals for the equipment to enable the College to train apprentices on the types of drawings they will encounter in practice as well as to indicate to them the maintenance aids that are available. (In the latter regard, manufacturers state that in many cases maintenance manuals are kept in the stores or in engineers' filing systems, and are not made available to the maintenance staff.)

### **5.4 Post Qualification Training**

Apprenticeship training should aim to provide the apprentice with an overview of the tasks he/she would encounter as an artisan. However, the artisans responsibilities are likely to require knowledge which it is not feasible to include in an apprentice training programme. For this reason post qualification training is strongly recommended. This training can either be provided by industry or by a training institute such as the College.

In the main report, recommendations were made on the benefits of introducing industry accredited training to offset the cost of training in the light of the high skilled labour

turnover being encountered. The College is in a good position to provide such training in post-qualification subject matter.

Furthermore, refresher training is also advocated, and this, if combined with an industry accredited certification system, is also ideally suited to an accredited industry training facility.

## **5.5 Courses for Engineers**

Recommendations are made elsewhere for the existing Government Certificate of Competency examination system to be modified to include additional mine-type specific courses for engineers. Should this approach be followed, then it is possible that the College could play a role in implementing such a system.

## **5.6 General Issues**

- 1) The distances between sections in a coal mine makes the concept of a multi-skilled or multi-disciplined artisan force very attractive. However, investigations revealed that the levels of knowledge of electricians is currently less than desirable. Care must be taken to ensure that the general skills levels are not further diluted by multi-skilling.
- 2) The presentation by staff of the College included items on advanced training of artisans. The establishment of a career in "artisanship" has been mooted for many years in the mining industry. There is currently no career path for artisans as such. If artisans want to improve their prospects they are obliged to become foremen or leave the industry.

Not all good artisans make good foremen. In some cases artisans would prefer to remain as artisans if acknowledgement for superior ability was available. Other European countries have introduced the concept of "Master Artisans" with reported success. The use of "Master Artisans" for the more demanding technical work, together with multi-skilled artisans for the day-to-day maintenance can obviate the criticism of multi-skilling in 1) above.

In the case of the artisans that leave industry, a fair proportion are re-employed by suppliers as technicians. Ultimately the mining industry pays for these technicians at rates considerably higher than the cost of the artisans if they had remained in the industry. This cost is a hidden cost which is reflected in the cost of equipment or spares.

- 3) The problem with on-the-job training has been with the mining industry for a few decades. Older foremen and artisans complain that on-the-job training in the modern context is inferior to that of twenty or more years ago. Currently artisans are reportedly too busy or disinterested in training and mentoring. Undoubtedly, on-the-job training is not meeting the requirements for the provision of highly competent artisans. This issue will need to be addressed by the industry.
  
- 4) Opencast and strip mining did not form part of this project. However, the proposal by the Collieries Committee to include aspects of opencast/strip mining at the College is supported. In particular, the special requirements for earthing of mobile substations and mobile cable-fed machines requires attention.



# Appendix 6

## ATTITUDES

### 6.1 Introduction

Enabling Output 2 (e) lists possible reasons why staff may indulge in malpractices. Following underground visits to coal mines, discussions with personnel on the mines and at head offices, evaluation of the responses to the questionnaires used during mine visits and arising from the personal experience of the project team, it has become clear that attitudinal problems can be grouped into a number of areas that predominate. These are discussed in the rest of this appendix. Where appropriate, anecdotal evidence is reported in order to illustrate the issue discussed.

### 6.2 Absence of Codes of Practice

On one mine, a three-section switchboard was found to be operating with both bus-couplers and all three incoming circuit breakers closed. The fault level on the board was calculated to be in excess of twice the rupturing capacity of the switchgear. None of the mine staff were aware that this was potentially dangerous, although one member mentioned that operating with bus-couplers and incoming breakers closed was prohibited on a mine he had worked on previously. He was not aware of the reason for this. There was no code of practice prohibiting this practice.

The above mentioned case could also be ascribed to lack of adequate training, or could have been a case of a mine operating without a resident electrical engineer or an engineer with adequate knowledge of protection theory.

On all the mines, very few engineers or electrical staff were aware of what the rupturing capacity of switchgear meant or how it could be identified. The majority were however aware of the need to replace moulded case circuit breakers with units of the same "kA rating" (sic). However, ignorance of the meaning of the "kA rating" could easily lead to malpractices in emergency situations.

This is also a clear example of risks not being identified due to the engineering staff's ignorance of the subject.

### 6.3 Ignorance of Codes of Practice, Regulations and Good Practice

Relatively few cases of hazards arising from this cause were identified. Of those that were, the failure to recognise good practice, together with inadequate of codes of

practice by virtue of the risks not having been correctly identified, prevailed. Typically, ignorance of the limitations of minimum oil switchgear in particular, and to a lesser extent, bulk oil switchgear, to clear faults without examining and/or replacing oil and examining current breaking parts was detected. These issues were not included in the mines' codes of practice.

## **6.4 Failure to Understand the Reasons for the Codes of Practice and Regulations**

It is likely that a number of malpractices can be ascribed to electrical staff being unaware of the reasons for regulations or sections of codes of practice. A typical example is the abuse of pilot wire systems which manufacturers and repairers report to be widespread.

The following anecdote illustrates this issue. Electricians in hazardous areas of the mine were asked if they were aware of the requirement not to install pilot wire diodes in the gate end boxes. Without exception the electricians claimed to be aware of the rule. When questioned as to whether they adhered to this rule, some claimed to have disregarded it. However, they stated that when they had done so the system continued to work correctly. Further questioning revealed the fact that the electricians were not aware that this practice removed a number of the designed safety features built into the pilot wire system.

A number of fatalities, serious injuries and near misses have been caused by maloperation of pilot wire systems.

## **6.5 Lack of Training**

In addition to the examples given above, electricians and foremen raised the issue of new equipment being introduced to sections without the electrical personnel having been trained on the equipment. In many cases the equipment was more sophisticated than that they had been working on and required a knowledge of procedure and fault finding techniques.

## **6.6 Failure to Provide Follow-up Training**

The training given to apprentices is generally satisfactory, although some improvements in content are required and the equipment in the training centre on which apprentices are trained is unsuitable. In addition, on-the-job training is reported to be failing to meet requirements in many cases.

However, by the time an apprentice qualifies as an electrician and starts to work independently, some of the training has been forgotten. Consequently the reasons for certain practices is no longer apparent to the electrician. The failure of electricians to recognise the danger of tampering with pilot circuits, mentioned above, is a case in point.

## **6.7 Advice or Training given Irregularly or Spontaneously by other Personnel who are used to Disobeying the Codes of Practice and Regulations**

One instance was reported where production management had recommended that a certain electrician be appointed to train others. The motivation for the recommendation was based on the fact that the individual, and some others that he had trained, had the least downtime from electrical faults. Investigation by mine staff revealed that the electrician was defeating the electrical protection systems and training others to do the same.

## **6.8 Perceived Rewards following Malpractices**

In the case reported above, the particular electrician was viewed by the production personnel as being the best man on that shaft. By comparison, those that were working safely were not rewarded in any apparent way. Instead the perception of the electricians was that they were being damned for the downtime on their sections as a result of the operation of electrical safety systems. An electrician or supervisor that can eliminate electrical downtime will receive praise from the production personnel.

In addition, malpractices are relatively unlikely to be detected and the punitive measures are not perceived to be serious. Rewards for working safely are not apparent to the perpetrators of malpractices and are considered to be of lesser effect than the censure that results from lost production.

## **6.9 Malpractices Work with no Apparent Safety Implications**

The primary reason for disregarding rules appeared to be that the particular activity had been occurring for long periods of time without incident. Some of the malpractices would be potentially serious in coal mines with a much higher incidence of methane than is generally the case in South Africa.

One particular incident served to illustrate the situation. During one of the mine visits, a member of the project team had not been identified as such by the miner in the section. When the miner was requested by the manager to test for gas before the electrician worked on live equipment, he complained to the team member that this was only being done because managers were present. He told the team member that they never tested for gas when work was carried out on live equipment, and no accident had yet occurred. This happened to be a mine with an above average incidence of methane.

A further example is the practice of many mine staff, and even of some head office consultants, when setting overload relays, to do so on the basis that the equipment and/or cables being fed by the circuit breaker can withstand a 10 per cent overload without damage. The relay is then set on the next highest available setting. In some cases this setting could be as much as 20 per cent above the required value. In addition, in virtually every case, no cognisance was taken of the dead-band on electro-mechanical relays, which is usually taken to be 15 per cent. The settings in use would therefore range from 27 to 52 per cent above the rating of the equipment, with potentially serious consequences in the event of continuous overload.

The likelihood of this practice leading to problems is relatively low, and it is further perceived to be a low risk because it has occurred over long periods without problem. However, although of low probability, an event that results in severe overheating of cables or equipment can lead to a disastrous fire.

## **6.10 Peer Pressure and Pressure from other Personnel**

In some situations, electricians have been treated with scorn by their peers for sticking rigidly to the rules. Disregarding rules is considered to be "macho, and mining is a macho profession."

Responses from interviewees indicated that they are frequently pressurised by production personnel into taking short cuts that could lead to serious accidents. Failure to do so would reportedly result in victimisation and censure.

## **6.11 The Belief that the Risks Resulting from Disobeying the Codes of Practice and Regulations are Manageable**

The practice of setting the overload relays in gate end boxes to maximum settings is very widespread. The reason for this practice is that all gate end boxes are then available for any machine in the section, which reduces downtime in the event that the gate end box feeding a production machine becomes faulty.

In addition, on one mine, some potentially serious cases were identified of situations where transformers were unprotected against sustained overloads. The responses of the engineering staff indicated that they were of the opinion that the risk was manageable. However, a multiple fatality fire was caused by a similar condition in conjunction with other simultaneous events.

Another serious malpractice on the same mine was the failure to provide overload protection to underground oil-filled transformers. This resulted from the practice of feeding a number of transformers from the same medium voltage switch. This practice is acceptable if the secondary side of the transformer is adequately protected by circuit breakers in close proximity to the transformer terminals. In the cases mentioned the secondary protection was totally inadequate and situated far from the transformer.

The transformers were, in addition, situated in the intake airways immediately adjacent to coal pillars and had no fire fighting apparatus at hand and no means of containing burning oil.

The mine staff had not identified this practice as a hazard and no code of practice existed with regard to underground transformers and substations.

## **6.12 Lack of Dissemination of Information Regarding Serious Accidents**

Situations were identified which were identical to, or worse than, a situation that had resulted in multiple fatalities from a fire that had been caused by electrical equipment. Electrical staff on the mines where these conditions existed did not have any insight into the causes of the prior accident, and could therefore not be expected to take any precautions to ensure that a similar mishap could occur in their mines.

It is presumed that this situation arose as a result of the potential for a criminal or civil case arising as a result of the accident, and the information thus being *sub-judice*. In addition, the DME may be concerned that disseminating comment on the accident may result in the Department being accused of pre-judging the cause of the accident.

The elapsed time between accidents and legal action can result in important safety-related information being withheld for years. Consequently, the possibility of an identical accident occurring on other mines, must be a matter of concern.

## 6.13 Motivation

One of the mines visited by the team was an old mine using old equipment or equipment manufactured or repaired by the mine. It was immediately apparent that attention to safety matters, knowledge of the staff and pride in achievement was high. The standard of safety was considered by the project team to be very high.

By comparison, a modern high production mine was visited where the attitude of the staff to potential problems identified by the project team members was considered to be noticeably uncaring. The mine was well staffed with experienced and well qualified engineering personnel. It transpired from discussions that the mine was having production problems and that the engineering staff considered that they were being victimised as a result. They also indicated that they did not have time to consider matters of safety, which were in any event of lesser importance, in their opinion, to maintaining production.

A third mine, staffed by relatively inexperienced personnel, was found to be very well organised, with high electrical safety standards. It was of interest to note that the production management on this mine took a keen interest in the engineering matters and were reported to be highly supportive of the maintenance personnel. The engineering staff were found to be highly motivated, proud of their achievements and very keen to learn.

From the above it appeared that the attitudes toward safety were directly proportional to the motivation of the engineering staff.

## 6.14 Conclusion

The project team detected cases where all of the reasons that could be advanced for personnel not working safely, as listed above, were apparent.

Many of these cases indicated a clear need for training. However, for the training to be beneficial the other matters that lead to malpractices must be addressed if a culture of safe working is to be instilled in mine staff.

## **Appendix 7**

### **CERTIFICATION/APPROVAL OF EXPLOSION PROTECTED EQUIPMENT**

Regulation 21.17.2 requires that "Except where written exemption has been granted by the regional director, all electrical equipment used in a hazardous area shall be explosion protected and certified as such by an inspection authority approved by the Director General. Provided that the regional director might require codes of practice for the use of such apparatus."

Thus in terms of the current regulations for South African mines, equipment used in hazardous areas must be certified as being explosion protected. This regulation requires that a recognised test authority examine or test equipment as necessary to determine if it complies with standards relevant to the type of explosion protection technology the equipment utilises. Other matters that determine the suitability for use or safety of the equipment are not required to be tested or evaluated by any authority.

In particular, the explosion protection evaluation only tests the ability of a flameproof enclosure to avoid a methane explosion inside the empty enclosure igniting methane in the surrounding air. The certification authority does not pay any attention to the engineering of the equipment that will be placed inside the enclosure, or the manner in which it will be laid out. The suitability of the equipment in this regard is required to be evaluated by the mine engineers, who bare sole responsibility in the Regulations for this evaluation. None of the engineers who were interviewed during the work reported here were aware of their responsibilities for carrying out such assessments of flameproof equipment, and all assumed that, because the equipment had been certified as flameproof, that it was safe to use underground.

By comparison, other major coal mining countries have specifications for the design details, component selection, structural and constructional details which are intended to ensure the suitability and safety of the equipment. The equipment is tested accordingly. The means of assessment or evaluation differs in the various countries.

In Great Britain, the evaluation procedure is carried out by the Health and Safety Executive (HSE), with the certification previously being the responsibility of the government operated Mine Equipment Certification Service (MECS). The inspectors employed by the HSE are experienced ex-mine employees who call on their expertise to interpret the ability of equipment to meet desired safety standards, in addition to ensuring that all documentation indicates that the equipment complies with the applicable standards. This evaluation or assessment is designed to ensure that the equipment is "pitworthy" or "fit for purpose". A document entitled: "Pitworthiness guidance to

Applicants seeking Certification of Apparatus for use in British Mines” is used as a guide for evaluation.

Quoting section 5 of the above mentioned guide: “The legal requirement to approve certain kinds of electrical equipment is one of the reasons that HMIM take an active interest in the certification of electrical equipment for use in British mines.”

However, interpretation of the document relies on experience and an above-average knowledge of potential failure modes and the health and safety implications thereof. Section 6 of the guide states: “Over a period of many years the knowledge of HMIM has grown as a result of experience, investigations of accidents, dangerous occurrences and incidents and know-how gained either at first hand or passed on as a result of contacts with operational personnel.”

The guide referred to is very generalised and the system relies to a great extent on the experience and knowledge of the members of the Inspectorate.

New South Wales makes use of a number of individuals, approved by the Chief Inspector of Mines, who are known as Accredited Assessment Authorities (AAA’s) to evaluate equipment and approve the fitness for purpose of the equipment. The AAA’s scrutinise the test reports and all documents pertaining to the equipment to ensure that compliance with explosion protection and mine equipment standards are indicated. In addition they may choose to inspect the equipment or call for additional testing.

Queensland only calls for certification, but the process is similar to that for both New South Wales and Great Britain. In this case the assessment is carried out by a group led by a highly experienced individual at (SIMTARS). The group consists of the tester, the head of the electrical test section referred to above and any other engineer who was not responsible for or involved in the testing.

In China, testing is carried out at certification and assessing authorities that fall under the control of the Ministry of Energy. The testing and evaluation process includes design, component, structural and construction requirements to the national standards. The fitness for purpose evaluation is an integral part of the testing and certification process and is carried out by various experienced individuals in the test stations.

In Germany, the Mining Authority is very active in the inspection and certification of equipment. In addition, the Mining Authority authorises certain mine staff to act as Technical Experts. All repaired equipment is inspected by the Mining Authority, as well as by the mine’s Technical Expert. All equipment for use in hazardous areas is designed in accordance with the relevant European Standard. The situation in Poland is similar to that in Germany, in that the European Standards are applied. All certification and testing of equipment for hazardous areas is undertaken by a central testing authority.



## Appendix 8

### ACCIDENT STATISTICS

#### 8.1 Statistics

An investigation into the number and type of incidents involving electricity in South African coal mines indicates that electricity accounts for relatively few accidents, fatalities and injuries. The accidents listed as electrical that have occurred on coal mines from 1984 to 1995 are indicated in the table below.

ACCIDENTS RECORDED AS ELECTRICAL ACCIDENTS*						
YEAR	NUMBER OF ACCIDENTS	NUMBER KILLED	NUMBER INJURED	PER CENT OF TOTAL ACCIDENTS	PER CENT OF TOTAL KILLED	PER CENT OF TOTAL INJURED
1984	26	2	29	3,2	2,7	3,6
1985	15	0	20	1,9	0,0	2,6
1986	12	0	12	1,7	0,0	1,8
1987	8	2	7	1,4	1,6	1,3
1988	4	0	4	1,3	0,0	1,3
1989	10	1	9	3,5	2,5	3,3
1990	8	1	9	2,7	2,9	3,0
1991	4	0	5	1,5	0,0	1,9
1992	2	1	1	0,8	2,9	0,4
1993	4	0	4	1,9	0,0	2,1
1994	5	3	2	3,0	7,9	1,3
1995	5	0	6	2,8	0,0	3,6
<b>Totals</b>	<b>103</b>	<b>10</b>	<b>108</b>	<b>2,1</b>	<b>1,7</b>	<b>2,1</b>

\*Source - "Statistical Summary of Accidents Reported to the Government Mining Engineer Report" for the period 1984 to 1995.

All the figures in the table are those listed in the accident category "Electrical" in the relevant report. The percentage columns in the table show the number of accidents and the number of persons killed or injured as a percentage of the overall numbers of accidents and persons killed and injured for each year.

Prior to 1988 the accident statistics were not separately recorded for surface and underground. The figures in the table for the period 1984 to 1987 include both surface and underground, whereas from 1988 only underground accidents are considered, since these fall within the scope of the project.

As reported in Enabling Output 3 (a), the reason for injury or death is categorised in the statistics, whereas the causative agent might in fact fall into another category. The determination of the causative agent involves relying on the memory of the Inspectorate, or otherwise the examination of accident reports which might possibly involve electricity as the causative agent.

It was not feasible to examine the files of each accident which could have been caused by electricity, and the figures must therefore be taken as those attributable to electricity as the direct cause of injury or death.

## **8.2 Comment on the Statistics**

In order to develop strategies to limit accidents in the workplace it is desirable to be able to trace and track the basic causes of mine accidents. Modern computer data bases are powerful enough to record more information on accidents than is presently recorded. This should be investigated as a means to control accidents in the mines.

## **8.3 Release of Information to the Industry on Accident Causes**

It is appreciated that some accidents could be the subject of legal process and the information might therefore be *sub judice*. For this reason, the basic cause of the accident might be apparent but not be categorised until the legal process has been completed.

However, based on the observations of the project team during visits to mines, conditions almost identical to those which are likely to have caused a serious accident with multiple fatalities some years ago are fairly widespread in the mines. The information regarding that particular accident has reportedly not been divulged, presumably for the above reasons. Mines have consequently not examined their systems to determine whether similar situations occur. This implies that further accidents of a similar nature may occur due to the slowness of the judicial process.

The withholding of information regarded as *sub judice*, but which could contribute to a reduction in accidents, needs to be addressed.

## **8.4 The Risks Associated with Electrical Accidents**

As reported in Enabling Output 3 (a), the risks associated with electrical accidents can be broadly classified as either:

- highly likely to occur, but leading to minimal deaths or injury; or
- having a low likelihood of occurring, but with a high probability of resulting in multiple deaths or injuries

The former tend to be types of accidents falling outside the scope of this project. These accidents are associated with direct contact with live parts which result in severe burns to the individual or death due to electrocution. Invariably the accidents are caused by failure to apply recognised safety measures, failure of equipment or methods of protection or human error.

Despite the fact that this type of accident cannot be classified as being due to fires or ignition by electricity, the training required to control such accidents forms an integral part of good electrical engineering practice. The application of good engineering practice cannot be classified in terms of fire or non-fire related issues. The training guidelines presented in Appendix 1 therefore address these matters as well as those that fall within the scope of the project.

The latter type of accident involves cases where the system is inadequate for the reasons listed in the Enabling Outputs, and which can give rise to a major explosion or a fire. The particular danger with this type of accident is that the inadequacies of the system could have been present for many years without any serious incident occurring during that time. Staff therefore become complacent, and with time might even fail to recognise the potential for an accident as a result of the inadequacies.

However, it was apparent during mine visits that the shortcomings in the proper engineering and maintenance of electrical reticulation systems are a particularly poorly understood aspect of electrical engineering. In a disturbing number of cases the potential for an accident was not recognised by any of the mine staff, even after the hazard was pointed out by the project team members.

## **8.5 Reporting of Events**

During the investigations, many instances of electrical system or protection failures which resulted in serious electrical faults were reported to the project team. These faults often result in extensive damage to equipment and the release of high levels of energy.

Typical instances of damage are:

- Flameproof equipment exploding.
- Covers or doors being blown off flameproof enclosures.
- Holes burnt into flameproof enclosure walls.
- Cable fires or localised cable explosions.

These events had not resulted in injury or the ignition of gas or other ignitable material and hence were not reported to the Inspectorate. However, most of these events, in the presence of other factors, could have resulted in very serious fires, injury or fatalities.

Failures of safety devices on winding plant are required by law to be reported, whether or not injury or death was the result. Similarly failures of electrical protection should be a reportable incident since an even more serious event could occur as the result of the failure of an electrical system.

## **Appendix 9**

### **ENGINEERING SUPERVISORS**

With few exceptions, electrical and mechanical supervisors are not evaluated for their technical knowledge or for their ability to support an engineer. In the present circumstances, where in many instances a mechanical engineer is responsible for electrical equipment, the need for an electrical supervisor with adequate technical competence is obvious.

In general, electrical supervisors are selected from the more experienced electrical staff. Normally supervisors are expected to be able to assist electricians in their duties. However, the experience they had gained might be that related to the easiest way to get a job done and the best methods of satisfying the production personnel. It is conceivable that such supervisors could have a major negative affect on safe working practices.

With particular reference to electrical protection, it is unlikely that a supervisor would have any suitable knowledge unless this had been provided on an ad hoc basis or had arisen from outstanding individual effort and initiative. The general inadequacy of the technical knowledge of supervisors was confirmed by the response to the simple questions included in the interview questionnaires.

South African mining law does not recognise any engineering supervisors other than engineers. Mining supervisors of different levels are recognised by law, and certain practical experience, training and competence prerequisites are defined for these supervisors. These supervisors are appointed in terms of the law.

In the mining/production discipline, the law presumably identifies the need for persons with superior knowledge and skills to be available to assist the appointed managers in the carrying out of their duties. This matter was addressed by the Leon Commission, with particular reference to Shift Bosses and Mine Overseers, when recommendations were made to structure the individuals' job definitions to allow them to carry out their supervisory duties.

For some reason, the need for similarly appointed supervisors to assist engineers does not appear to have been recognised. With particular reference to mechanical engineers responsible for electrical systems, the engineer will, by necessity, be forced to rely on electrical supervisors. An objective method of evaluating the competence of these supervisors must be implemented, and the responsibilities of these positions legally prescribed.

# Appendix 10

## PERCEPTION

### 10.1 Introduction

Perceptions of various role players can and will have a bearing on the efficacy of any training strategy. The affect of the perceptions will vary and have different end results depending on the management level at which the perceptions are held.

Investigations revealed that the perceptions of senior management and production managers and supervisors can have a substantial bearing on the recognition of training needs and the performance and attitudes of engineering staff.

### 10.2 Senior Management

In general senior management appeared to support the concept of training to improve the skills levels of employees. Any training aimed at increasing safety on mines is well received and given tacit support by senior management. However, training invariably has the short term effect of reducing available man power. This must be considered in the light of staff shortages, particularly of skilled staff, production targets, staff turnover and perceived benefits of training. There is thus the possibility that senior management may not, in practice, give adequate support to training if the release of staff from their normal duties leads to production losses.

An aspect that could not be researched in depth, but which will have a bearing on senior management's perception of training needs, is the degree to which management are aware of the levels of knowledge required by electrical staff to competently handle their tasks. Based on previous experience, and the limited amount of investigation which was carried out during the project, management at senior and intermediate levels are only marginally aware of the extent of knowledge required by engineering staff, of the extent to which this knowledge is gained during formal craft training and tertiary education, and the degree to which engineering technology on coal mines differs from that in other branches of industry, whether mining or otherwise.

In particular, mining engineering graduates tend to accept the need for certification of candidates for a Mine Managers' Certificate of Competency to be coal or hard rock mining based. However, they do not perceive any need for the same distinction to be made in the case of engineers.

Furthermore, mining engineers in general tend to hold the view that the tertiary education and basic training of engineers with either an electrical or mechanical background has no bearing on the ability of an engineer to accept responsibility for, or the competence to carry out, work of an electrical or mechanical nature.

### **10.3 Production Management**

A production manager's primary goal is to ensure that production targets are met. While attempting to perform their function adequately they will also be aware of the need to maintain an acceptable level of safety within their section, or the mine in general.

However, they have a very limited awareness of the electrical technology in their sections and are not in a position to evaluate the technical competence of engineers, foremen and electricians, or the extent to which safety measures are being applied by electrical staff.

Their requirements, as far as the electrical supply to their sections is concerned, is for absolute minimal downtime in the power supply. Consequently, they will base their evaluation of electrical personnel on the degree to which electrical downtime occurs in their section. The extent to which this attitude contributes toward electrical personnel bypassing safety devices would not necessarily be apparent to, or is usually not considered by, production management. A number of instances were reported during the investigatory stage of the project of production management considering particular electricians and foremen to be superior performers. These same staff members were however considered by other engineering personnel to be amongst the worst offenders in terms of interfering with safety devices, and being guilty of other unsafe practices.

### **10.4 Engineering Staff**

The perception of engineering staff of the levels of competence of electrical personnel, and their opinions of formal and on-the-job training given to electrical personnel on coal mines, varied greatly. Of interest was the fact that, in general terms, the respondents who demonstrated the greatest levels of competence based on the questionnaires that were completed, were most critical of both issues. It would be expected that respondents with the lowest levels of knowledge would in all likelihood have less awareness of what the acceptable levels of knowledge and training would be.

Electrical staff tend to be influenced by the performance criteria that they perceive production management to apply. Young engineers, foremen and electricians are certain to recognise that, in the opinion of production management, the best electrical staff are those that experience least electrical down time. In addition, recognition from whatever source for working correctly and safely is not as likely to be apparent. The

aforementioned engineering staff will have experienced the aftermath of down time in the section, with consequent loss of production. Human nature will obviously sway these categories of staff towards the sort of performance that is rewarded verbally, or potentially in career path terms, and away from that which results in censure.



# **Appendix 11**

## **STAFF TURNOVER**

### **11.1 Introduction**

In comparison with other countries, the level of staff turnover is a matter of concern and has direct implications with regard to training. A comparison is given below.

### **11.2 China, Poland, Germany and United Kingdom**

The staff turnover in each of these countries is very low. The stability of the work force yields more benefits from training than would be the case in countries with less stable work forces.

In China and Poland the opportunities for employment outside the coal mining industry are limited. Chinese employees in the nationalised mines enjoy tax-free benefits not available to the average person, such as housing and post-school training.

In both Britain and Germany, the coal mining industry has been shrinking, leading to a surfeit of trained individuals available to those mines which are still operational. In Germany unskilled work is largely carried out by "gastarbeiters" from mainly Mediterranean countries, but skilled work is still largely carried out by highly skilled locals.

### **11.3 United States of America**

A feature of the American coal mines is that they are mainly staffed by people drawn from communities local to the mines, and staff turnover is relatively low due to limited employment opportunities in most mining regions. Specialist skilled staff in various categories is usually obtained from outside the immediate community.

### **11.4 Australia**

Figures regarding staff turnover were not available, but from discussions it would appear that staff turnover, particularly of skilled staff, is relatively low.

Australia is, however, reported to be experiencing similar problems to South Africa in that coal mining is not regarded as a particularly desirable career. Furthermore, salaries paid by non-mining industries are compatible with those of the coal mines, while non-mining industries are perceived to offer a better working environment and safer working conditions.

## 11.5 South Africa

In comparison with the other countries visited, the staff turnover of skilled staff on South African collieries is cause for concern.

Staff turnover is reported to be a relatively major problem in the South African mining industry in general, and in coal mining in particular. The problem has reportedly increased dramatically over the last three years. Among the reasons put forward for the situation are the following:

- Growth of the South African economy.
- Increased employment opportunities for skilled staff due to a very marked decrease in apprentice training in the last two decades.
- Removal of tax free benefits previously available to mine employees resulting from the imposition of "perks tax".
- Parity of salaries in non-mining industries with those in mining.
- Failure of mining to maintain the perception of a "career for life".
- Affects on supervisors of union activity in the mining industry.
- The status of engineering personnel within the company and "socially" vis-à-vis production personnel.
- Irregular hours of work and call-outs.
- Working conditions, including health and safety aspects of mining in comparison with other industries.

The focus of this project does not include the resolution of, or recommendations on, the above, but these issues are raised for reasons of completeness in assessing training needs and problems associated therewith. The affects that high levels of skilled labour turnover will have on the effectiveness and cost of training are obvious.

To some extent staff turnover of skilled personnel is related to movements within the coal mining industry. The extent to which this occurs and the concomitant extent of electrical personnel entering the industry from other sources, such as gold mines, was not investigated during this project.

However, it is likely that a reasonably high proportion of the turnover is due to intra-industry movements. This would tend to indicate that the impact of turnover on the cost and logistics of training due to this factor could consequently be reduced. Unfortunately, unless a standardised method of evaluating the competence of electricians (or foremen) is available, the employing coal mine cannot be certain of the competence of a person that was previously employed on another coal mine.

In addition, the scope of work of an electrician on a coal mine is relatively wide, including hazardous area work, outbye work, medium and high voltage switching and medium and high voltage cable connections, amongst others. The employing mine should therefore, in addition to determining the previous coal employment of an applicant, determine the areas of expertise of the applicant. To a certain degree the employer will purely accept the applicant's word for the information gained. Ideally the employer should evaluate the new employee for a period of time.

However, the higher the turnover, the less time will be spent on evaluation and the sooner the new employee will be required to be gainfully employed. A means to overcome the uncertainty regarding a new applicant's experience and competence, and further to reduce superfluous training, is the introduction of standardised training schemes. A person who has satisfactorily completed such a scheme should be issued with a standardised industry certificate stating the scope of work for which he/she has been trained, for example, medium voltage switching.

It would be desirable for the above mentioned certificates to be of limited duration, say 2 to 5 years, with re-testing required prior to re-issue of the certificate.

In conjunction with the certificate, a screening test for new applicants involving possibly multi-choice type questions could be drawn up. Such a pre-screening operation could identify training needs for ex-coal mine employees as well as skilled staff from other industries.

The above proposal appears to require more time spent on training and administration, but would also result in greater certainty on the part of the employer of the competence of individuals and would allow greater focus on specific training needs and avoid unnecessary training.

## **Appendix 12**

### **REPORT ON OVERSEAS VISITS**

#### **12.1 Production**

The coal production rates of the various countries are reported purely to indicate the relative size of the coal mining industry in these countries.

In descending order of annual overall production rate, the following figures were taken from the Minerals Bureau report - "Operating and Developing Coal Mines in South Africa -1996":

Country	Production (Mt.)pa
China	1253 *
United States of America	577
South Africa	206
Australia	195
Poland	135
Germany	54
United Kingdom	53

\* A large number of small producers supply coal to villages and farmers in the immediate surroundings of the mine. The production from these small operations is estimated. However, privatised mining operations account for over 50 per cent of total Chinese coal production.

#### **12.2 Depth of Mines and Mining Techniques**

Views are often expressed by the local industry that mining regulations and procedures for equipment approval in foreign countries is more stringent due to the higher methane levels in those mines and the difficulties in mining at greater depths. For this reason a brief summary of the coal mines in these countries is included in the report.

This section is not intending as a complete study on the subject matter, but rather to give a brief overview of the types of mines. This is done in order to put the matters reported elsewhere in perspective.

## **12.3 China**

All the major mines are deep. No major producer mines at under 400 metres below surface and the average depth of these mines was estimated to be over 500 metres. Coal seams were generally approximately 2 metres thick, although some mines had coal seams of over 20 metres width.

As a result of the depth of mines, most of the mines utilised longwall mining techniques using shearers, armoured face conveyors and hydraulic self-advancing props.

The mines are reported to be very gassy.

## **12.4 United States of America**

The coal seams in the United States vary greatly from the shallow, very wide seam mines immediately east of the Rocky mountains to relatively deep, narrow seam operations in the eastern United States. Strip mining, bord and pillar mining using continuous miners, longwall mining, "punch mining" in worked out strip mines and on exposed seams in hilly areas, as well as mining from adits, comprise the mining techniques in use.

The occurrence of gas varies greatly from very gassy underground mines to some "punch mines" where gas has not been detected, but which are classified as gassy.

## **12.5 Poland, United Kingdom and Germany**

In most underground mines the coal seams are relatively narrow (below 2 metres seam width) and the mines are fairly deep, generally over 300 metres in depth. In these mines, longwall mining predominates.

Some strip mining using truck and shovel, draglines or machines similar to stockpile reclaimers for overburden removal, occurs in Germany and the United Kingdom. Bucketwheel excavators are used fairly extensively on German lignite mines and any other coal mining operation where relatively wide coal seams and soft overburden occur.

The mines are generally more gassy than South African coal mines, although some mines have reportedly very little gas present.

## **12.6 Australia**

New South Wales mines are generally underground mines using either bord and pillar or longwall techniques. Queensland mines are a combination of strip mines similar to

South African mines or underground mines using either bord and pillar or longwall mining equipment.

In general the Australian coal mines are reported to be much more gassy than South African coal mines.

# **Appendix 13**

## **TECHNICON AND TECHNICAL COLLEGE SYLLABI FOR PLANT ENGINEERING**

Full details of the syllabi for Technicians and Technical Colleges for Plant Engineering are contained in the document "Examinations for the Mechanical and Electrical Engineer's Certificate of Competency for Mines and Works (Revised August 1995)" issued by the Department of Minerals and Energy.

From the above mentioned document, a summary of the subject matter covering electrical engineering which both electrical and mechanical engineering students are required to complete is as follows:

- Direct current machines including generators and motors
- Efficiency of direct current machines
- Alternating voltage and current
- Single and three phase circuits
- Transformers
- Production of a rotating magnetic field
- Characteristics of synchronous generators and motors
- Three phase induction motors
- Semi-conductor devices
- Electric lamps and illumination
- Electric power transmission and distribution
- Short circuit conditions
- Circuit breakers
- Underground cables
- Insulators
- Overhead lines
- Economics of power supply
- Maximum demand
- Power factor correction
- Explosion proof equipment
- Lightning protection

The additional subject matter that is required for electrical engineering students includes:

- Alternator windings
- High frequency transients
- Methods of earthing
- Protection

Storage of energy

Rectification

Fault discrimination (Mechanical students complete a basic course)

Communication

Basics of data transmission

Some of the courses which mechanical students are required to complete, but which are not required for electrical students are:

Heat transfer

Fuels and combustion

Strain energy due to direct stresses

Shear stress in beams

Struts and buckling

Fatigue failure

Properties of different types of ropes

Reinforced concrete

Retaining walls

The above indicates that there are differing requirements for the two disciplines. Some of the subject matter can impact on health and safety. The divergence indicates that the areas of responsibility of mechanical and electrical engineers would be expected to differ.