Development of an expert system for on-line ventilation network analysis and graphic representation of mine ventilation parameters

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Synopsis

The expert system component of Knowledge Base System supports the analysis and interpretation phases of ventilation design with an algorithmic program used for the solution of alternate design. The paper describes the 'ES-VENT' knowledge based system developed at Central Mining Research Institute, Dhanbad, India for an on-line diagnosing of the ventilation problems using the 'IITMRULE' expert system development tool. In the 'IITMRULE' expert system tool, it has been decided to use a backward chaining reasoning process to reach the goal state i.e. the final conclusion. ES-VENT system is made of three modules: On-line Data, Diagnostics and KBS. Each module is being a collection of several programs. The paper mainly deals with the parameters affecting the ventilation of underground mines such as air-velocity, air pressure, temperature, dust, and humidity and gas contents. The graphical presentation of these parameters on the computer and the interactive part of the developed program is expected to help a ventilation officer to determine the changes in a ventilation circuit necessary to bring the mine ventilation to the desired value. Once such changes are physically effected, the display will indicate if the changes have brought the desired effect or not on ventilation.

Keywords: Ventilation network, on-line data, expert system, intelligent system, knowledge base, inference engine.

Introduction

The importance of ventilation analysis has increased in recent years as a means to determine the optimum ventilation design. The problem of ventilation is quite complicated due to a number of factors, such as increasing length and other complexities of airways, and difficult geological conditions. Therefore, it has been strongly felt that an intelligent ventilation analysis system, which could be applied to various situations to facilitate rapid and efficient operations in a mine, should be developed (Srivastava, *et al.*, 1995; Sinha, 1996). A system is said to be intelligent if it has the capacity to learn (acquire knowledge), analyse things and take the appropriate decision. As such a Human Transparent Decision Support System (HTDSS) may be useful and could be made effective if the maximum possible data about the mine are collected on an on-line basis. For this, data are processed to extract information and, information is further processed to generate knowledge. Systems applying artificial intelligence in the simulation of decision making processes, utilizing knowledge as an 'expert system' or a 'knowledge-based system' are currently attracting considerable interest in a wide range of medical, financial and engineering applications and undoubtedly they have great potential in many areas of mining engineering (Briton, 1987; Kissel and King, 1988; Nutter *et al*, 1986; Rossouw, 1995). Expert systems are a class of computer programs that have the ability to analyse inputs and diagnose problems, and then recommend solutions. The expert system 'ES-VENT' discussed herein derives the prediction of possible crises in the ventilation system from the available on-line ventilation data and suggests the relevant solution. The solution is reached after comparing its rule based in-built program with the database file and knowledge base made from the on-line ventilation data.

ES-VENT: An on-line expert system

The ES-VENT (Expert System for VENTilation) knowledge base system has been developed for on-line diagnosing of ventilation problems using the expert system development tool, IITMRULE. The IITMRULE was developed at Indian Institute of Technology, Madras, India. The ES-VENT system is made up of three modules: On-line Data, Diagnostics and Knowledge Base System (KBS). Each module is a collection of several programs; the overall structure of the system has been shown in Figure 1.

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 Paper received Sept. 2001; revised paper received Jan. 2002.

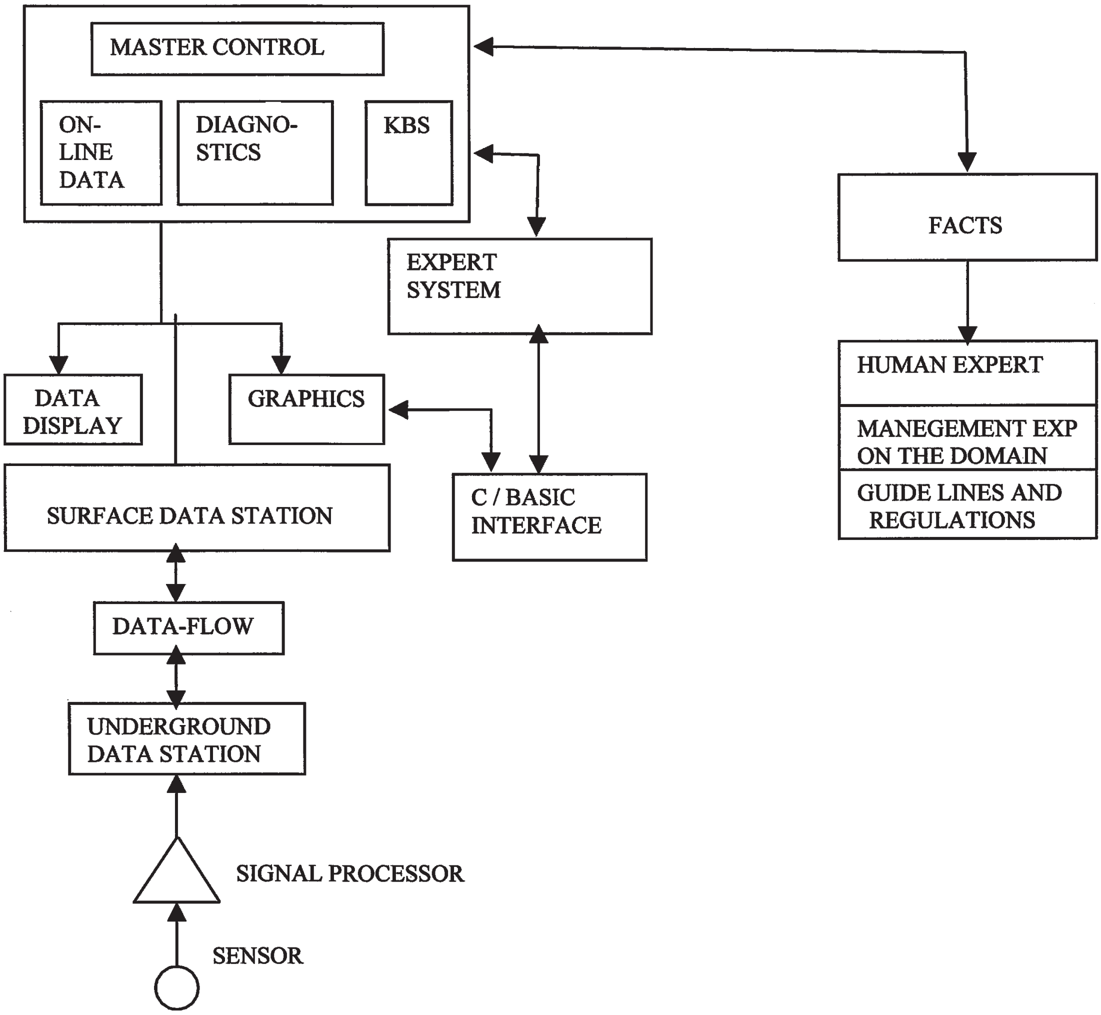

Figure 1—Overall structure of the ES-VENTI system

A number of on-line programs are run to achieve the desired results. These programs can be broadly grouped according to the task they are required to perform. For example, one group of programs is for on-line data collection from various sensors. A second group of programs is for the calculation of the desired parameters from available data and conversion of raw data into engineering data. This group of programs also incorporates data storage/retrieval in user's file and then display of the data file. A third group of programs is for graphical display of various parameters along with the graphically drawn mine plan. A fourth group of programs basically aims at simulating the effects of some arbitrary changes in the mine ventilation network. It is necessary to have a preview of these effects before the changes are actually introduced. Finally, there is the master control program, which controls and synchronizes the various programs and choice of the user for the desired outputs.

Knowledge Base System (KBS)

A distinctive feature of every expert system is its knowledge base. The construction of a knowledge base may be done by a system developed who interviews one or more expert persons in the field of interest, with the purpose of capturing the knowledge and judgment of the expert(s) into a collection of decision rules. The Knowledge Base System is designed around the inference engine that performs the necessary process, using the rules of the knowledge base to arrive at the conclusions and recommendations. In the IITMRULE expert system tool, it has been decided, primarily, to use a backward chaining reasoning process to reach a goal state i.e. the final conclusion.

The basic input of knowledge base organization is the literature survey and the consultations with the experts of the field. Here, it is important to mention that the development of KBS is possible, only when the problems are well defined and not wide. Considering this, for the present work, the ventilation aspect of a mine has been so chosen that the parameters affecting the ventilation of underground coal mines are only the air velocity, air pressure, temperature, dust, humidity and gas contents. The problems related to these parameters have been exhaustively exercised before creating knowledge base files.

For developing the KBS the user is expected to have an initial network representation of the mine ventilation system and design data such as K factors, resistance, threshold limits of parameters, etc. (Swaminathan, *et al.*, 1989). This will help in comparing and analysing the on-line data. During analysis, the expert system guides the user through a consultative session in which a series of general questions are asked concerning the ventilation system and design objectives.

Application and approaches

It is always desirable to select an appropriate expert system shell for any defined problem, as the suitability of the shell depends upon domain of the problem and its nature. Every shell has its own limitations and its own plus points. This implies approach in the shell selection to be very specific. In dealing with the 'ventilation' of underground mines, the application of IITMRULE as an expert system shell by the authors has been found satisfactory (Sinha and Bandyopadhyay, 1997). Recently, Object Oriented Programming Languages, like C++, which show much promise are emerging as a good approach for developing expert system.

For the development of on-line expert system for ventilation of underground coal mines the authors have decided 'IITMRULE' as a development tool. IITMRULE works with knowledge represented in the form of IF-THEN rules and provides a comprehensive shell for Rule Base Creation/Editing, Compilation, Inference using backward and forward chaining and database access in antecedents. Extensions to include functions in antecedents/consequences to IITMRULE are also available.

The interrelationship between IITMRULE and ES-VENT is shown in Figure 2. A typical rule in IITMRULE would have the form under ES-VENT:

RULE FOR DISTRICT#11
IF
    RCD in mg/m^3 <= 5
AND
    CD in g/m^3 > 30

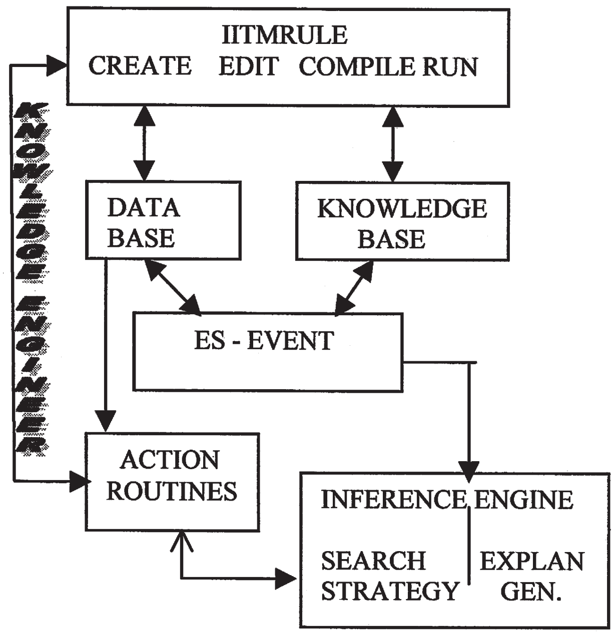

Figure 2—Block diagram showing the interrelationship between IITMRULE and ES-VENT

AND
    CD in g/m^3 < 60
THEN
    CLIMATIC CONDITION ON DUST IS 'HAZARDOUS'
AND COARSE DUST IS 'EXCESS'
AND FINE DUST IS 'O.K.'
AND VENTILATION IS 'POOR'
REMARKS
R#11
AUTHORS

Here, mg/m^3 and g/m^3 represent milligram per cubic metre and gram per cubic metre as units of respirable coarse dust (RCD) and coarse dust (CD) respectively.

This rule shows that the climatic condition on dust is 'hazardous' if the coarse dust exceeds 30 g/m^3 and so, the ventilation is 'poor'. However, the quantity of fine dust is within the safe limit. If CD exceeds 60 g/m^3, the rule-based program has no solution to the problem and in this case a fail message 'PROBLEM COMPLICATED, CONSULT REAL VENTILATION EXPERT. THANK YOU.' comes on the monitor. The template of a variable for consequences has been used as an advice or action for the problem described in the rule(s). The template attached with the sub-goal variable 'CLIMATIC CONDITION ON DUST' is ' ADVICE: If UNHEALTHY or/and HAZARDOUS, review FINE DUST & COARSE DUST'. The template attached with the other sub-goal variable 'CLIMATIC CONDITION ON CD' is 'ADVICE: IF EXCESS REVIEW COARSE DUST'. Again, the action associated with the value of the 'COARSE DUST' is 'ACTION: IF EXCESS, REVIEW DUST CONTROL MEASURES, and SPRAY ETC'. Thus the template appears as an 'advice' depending upon the goal/sub-goal variable and its 'value'. However, it is quite possible sometimes that the rule based programming of the problems pertaining to ventilation is beyond its scope and in this situation the ventilation officer or the manager has to solve such problem(s) with the consultations of the real ventilation experts. Thus obviously, a solution of the ventilation problem described, herein, is confined and based on the knowledge of only those experts with whom the authors have interacted. Further, there is a possibility of adding or modifying the solutions to any problem.

Development of the rule base expert system

In developing the rule based expert system, the literature has been reviewed and recognized experts have been consulted. Their thought processes, knowledge, and experiences have been documented and organized for rule-based programs. Depending upon the size and complexity of the knowledge base, the main topic i.e., the development of expert system for ventilation of underground mines (coal mines, specifically) has been divided into discrete manageable areas. In the course of its development, it was found useful and less cumbersome to subdivide the rules separately for the three mining sections — Trunk Intakes, Districts/Gate Road and Headings.

Goal variables, input and output of ES-VENT

The main GOAL VARIABLE in the ES-VENT is

'VENTILATION'. The value of 'VENTILATION' — 'good' or 'poor', depends upon the various factors and input data. Due to the complicated nature of ventilation systems, it becomes necessary and practically worthwhile to derive a few more GOAL/SUBGOAL VARIABLES. Two types of sub-goal variables have been introduced in the ES-VENT.

Climatic condition on the parameter

The parameters — temperature, air velocity, respirable coarse dust, coarse dust, methane, carbon monoxide, oxygen, carbon dioxide and Graham's Ratio have been represented by TEMP, AIR-VEL, RCD, CD, CH4, CO, O2, CO2 and GR respectively in the rule base.

In this type, the following sub-goal variables have been utilized:

- CLIMATIC CONDITION ON TEMP
- CLIMATIC CONDITION ON AIR-VEL
- CLIMATIC CONDITION ON DUST
- CLIMATIC CONDITION ON RCD
- CLIMATIC CONDITION ON C D
- CLIMATIC CONDITION ON CH4
- CLIMATIC CONDITION ON CO
- CLIMATIC CONDITION ON O2
- CLIMATIC CONDITION ON CO2
- CLIMATIC CONDITION ON GR.

The parameter (itself)

In this type of sub-goal variable, the following parameters themselves have been used:

- TEMPERATURE
- AIR VELOCITY
- FINE DUST
- COARSE DUST
- CH4
- CO
- O2
- CO2
- GR.

Each GOAL/SUBGOAL VARIABLE has been provided with the template facility, which gives conclusion remarks in the form of ADVICE/ACTION. If the ventilation is poor, it is advised to review the climatic condition on each parameter. It is also desirable to analyse which parameter of the ventilation system is not normal. As such, study of the sub-goal variable, i.e. the parameter, gives necessary information about the condition of the parameter as well as the solution in the form of action.

ES-VENT gives the display of rule based conclusions in three stages — the first stage gives the overall situation of the ventilation, the second stage displays the climatic condition of each parameter and the third stage fires the rules

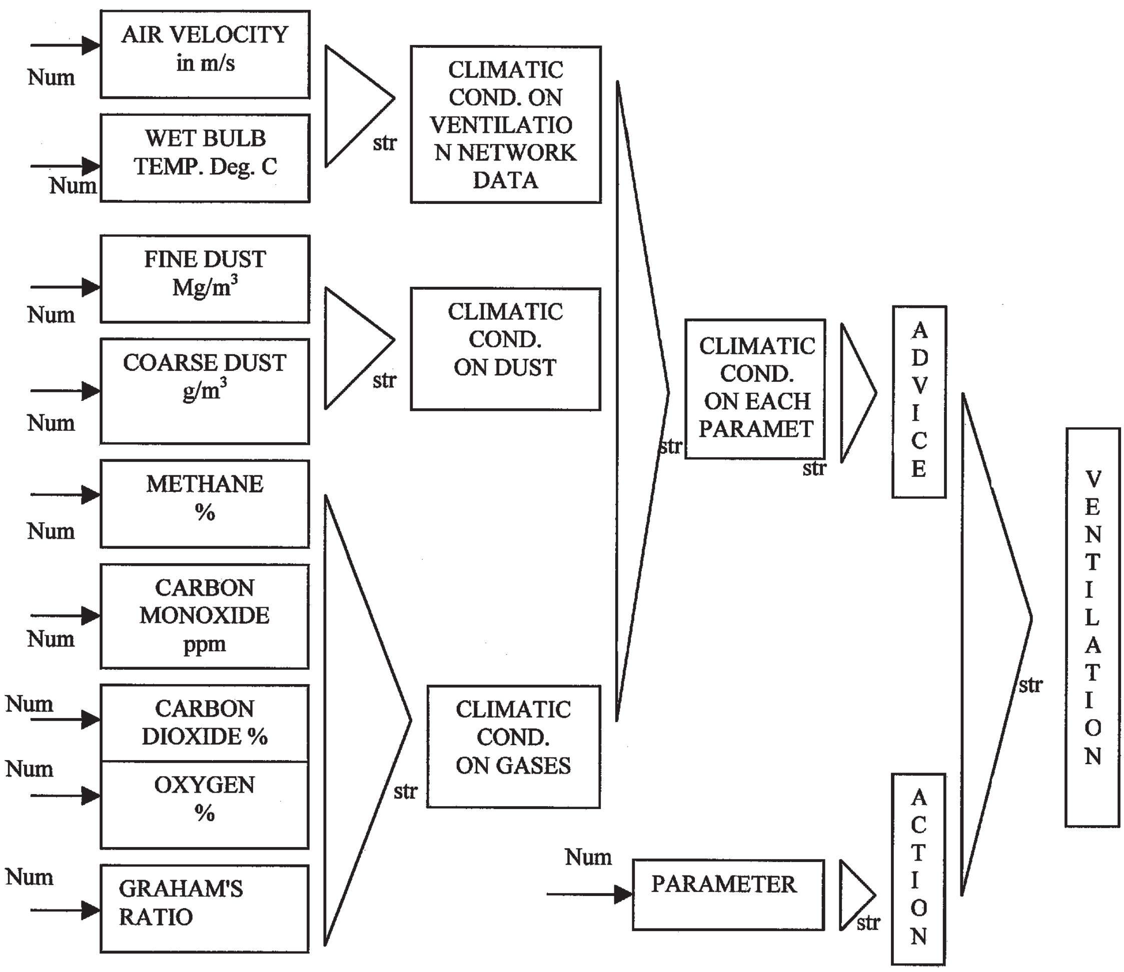

Figure 3—A dependency diagram

to give the action/advice in form of solution. To reach output, the rule base expert system consults the following data base files for three different sections of an underground mine:

1. INTAKES.DB [Data Base for Intakes]
2. DISTRICTS.DB [Data Base for Districts]
3. HEADINGS.DB [Data Base for Headings]

Dependency diagram

The relation between measured items and goal factors is called the dependency diagram, which is shown in Figure. 3. In this Figure the items, which are retained at both sides of the triangles, show the rules as knowledge base. The items at the left side represent a part of the prerequisite in the rules. The items at the right side show a part of the conclusion in the rules.

Graphics and simulation techniques

In a further development it has been contemplated that the incorporation of computer graphics and simulation to the on-line expert system will be additionally helpful in the ventilation network analysis. The overall understanding from the graphical view developed on the basis of database files may provide valid supports *vis-à-vis* the inference drawn from the expert system. The data file based on hourly averaged data is used for graphical plot of any parameter along with previously plotted mine section. The sequence of various stages in graphical representation right from on-line data collection to the display is shown by block diagram in Figure 4. The hourly average data file interacts with two fundamental data files: JUNDATA File and BRANCHDATA File. The file converts the hourly data into engineering data for each parameter in network data file.

The conversion involves a number of small and big computer programs as discussed above. The user can derive his or her own data file taking input from the network data file. To show the parameter values live, it is required to keep a mine plan in the computer. The user can then utilize the derived data file to represent the parameter graphically along with the mine plan.

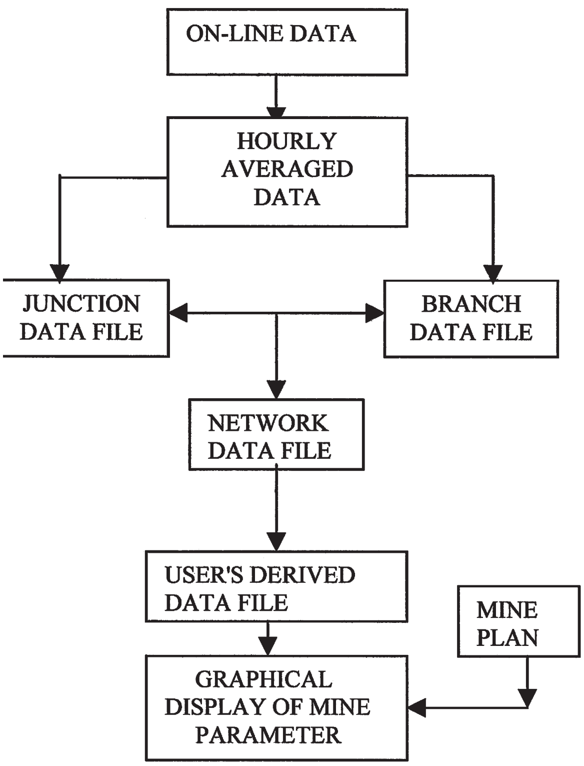

Figure 4—Block diagram of sequence of stages in graphical display

Graphical representation of parameters

There are at present six important parameters — air velocity, air pressure, temperature, humidity, methane and CO, which have, been considered for the graphical representation to represent the ventilation status of a mine section. One program has been developed to draw the layout of mine section, while another program creates graphical representation of any parameter based on the on-line data. Several graphical representations with colour display have been developed. This will help in visually observing the ventilation condition at the end of each shift or day or whenever desired. Any change made in the mine, affecting the ventilation will always indicate its effect on air quantities shown in the visual form to enable quick examination.

Ventilation network simulation

In the interactive mode, the user may specify the desired ventilation parameters of a mine in a typical question/answer session. The computer analyses the effect of the suggested changes in the ventilation circuit of the parameters and gives the possible solution to attain the desired value of parameters. Changing the variables of parameters, a solution in terms of viability, time target and economy, etc, may finally be implemented. This can be achieved on computer screen without really affecting the changes in ventilation circuit. The graphic representation on a screen will indicate parameters value desired in each arm against the theoretical value provided by computer based on suggested changes in the ventilation circuit. Once the modification in the ventilation circuit based on the chosen solutions are physically implemented, the display will also show the desired values of quantities as against the values of parameters achieved. The program, after interactive session, is brought back to normal cyclic mode by pressing one of the predefined function keys by the user.

Conclusions

It may be concluded from the above discussions that once the expert system is made on-line, the system becomes human transparent, that is, there is minimum of human interference. However, in case of complication or ambiguity, the system being rule based, gives an output in the form — 'all rules failed' or 'consult the real expert'.

The computer simulation and graphic representation capabilities of the system would enable ventilation officer in modifying the mine ventilation system from time to time as per need and to visualize the effected changes. Moreover, the system can always be upgraded or modified to suit specific conditions.

Acknowledgements

Authors would like to thank Dr S.C. Srivastava, Deputy Director (Retired), CMRI, Dhanbad for his valuable contributions and guidance for this very work. Authors are also thankful to Director, CMRI and Director, NRTC for giving permission for publishing this paper.

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First cement quarry to win prestigious award*

PPC Cement's Zoutkloof quarry at its De Hoek operation in the Western Cape was awarded a silver-merit award in the large opencast mining category in the national Excellence in Mining Environmental Management (EMEM) awards for 2001.

'This is the first time that a cement quarry has ever won an award in this competition. We are very proud of this achievement and would like to thank all the members of our Zoutkloof quarry team for their contribution and ongoing commitment,' said Pepe Meijer, General Manager of PPC Cement's De Hoek operation.

Over eighty companies took part in the regional 2001 EMEM Awards of which thirteen finalists were to take part in the national awards.

Criteria for judging included effective environmental management of critical impacts in accordance with Best Practice; operating an effective environmental management system; proper closure planning and implementation, and application of principles of Corporate Governance in achieving sustainable development.

In the large opencast mining category, the Gold Award went to Richards Bay Minerals, with the Silver Award being shared by the Palabora Mining Company and Anglo Coal Ltd's New Vaal Colliery, PPC Cement's Zoutkloof quarry followed with the silver-merit award and Iscor: Glen Douglas Dolomite with the bronze-merit award.

Mr T. Ramontja, of the Department of Minerals and Energy, presented the awards to the winners at the annual function of the South African Institute of Mining and Metallurgy held in Sandton, on 23 February 2002. ◆

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Soweto school strikes it lucky*

Ms Zodwa Nxumalo, the principal of Kwadeda attributed the recognition of her school to the good matriculation results the school has obtained in the past four years—the pass rate has been above 80%. The school, which has made great strides since it started in 1994, does not have facilities such as a library and a laboratory. The adoption by Mintek will go a long way in rectifying these problems, as well as giving the learners an opportunity to upgrade their maths and science marks. Last year Kwadeda was one of more than 100 schools in the country identified by the National Education Department to be dedicated to improved teaching and results in maths and science. The Adopt-a-School project is an initiative of Mintek's President and CEO, Dr Paul Jourdan, who is hoping that the concept will be replicated by other institutions and businesses on a national basis. ◆

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