EUROPEAN COMMISSION

European Research Area

Improving mining transport reliability (MINTOS)

Research Fund for Coal & Steel

Interested in European research?

RTD info is our quarterly magazine keeping you in touch with main developments (results, programmes, events, etc.). It is available in English, French and German. A free sample copy or free subscription can be obtained from:

Directorate-General for Research and Innovation
Information and Communication Unit
European Commission
1049 Bruxelles/Brussel
BELGIQUE/BELGIË
Fax +32 229-58220
E-mail: research@ec.europa.eu
Internet: http://ec.europa.eu/research/rtdinfo.html

EUROPEAN COMMISSION
Directorate-General for Research and Innovation
Research Fund for Coal and Steel Unit

Contact: RFCS publications
Address: European Commission, CDMA 0/178, 1049 Bruxelles/Brussel, BELGIQUE/BELGIË

Fax +32 229-65987; e-mail: rtd-steel-coal@ec.europa.eu

European Commission

Research Fund for Coal and Steel

Improving mining transport reliability (MINTOS)

Mr S. Bennett

Mines Rescue Service Limited
Leeming Lane South, Mansfield Woodhouse, Mansfield, Nottinghamshire, NG19 9AQ, UK

Mr M. Rossmann

Rittal GmbH & Co KG
Auf dem Stützelberg, 37545 Herborn, GERMANY

Prof. T. Winkler

Institute of Mining Technology KOMAG w Gliwicach
ul. Pszczyńska 37,44-101, Gliwice, POLAND

Mr P. Wiszniowski

Instytut Technik Innowacyjnych (EMAG)
ul. Leopolda 31, PL-40-189 Katowice, POLAND

Mr P. Morillo

Asociación para la Investigación y el Desarrollo Industrial de los Recursos Naturales
Margarita Salas, 14, Parque Léganes Tecnológico, 28918 Leganés, Madrid, SPAIN

Mr Z. Lubosik

Central Mining Institute
Plac Gwarków 1, 40-166 Katowice, POLAND

Mr D. Czoik

Kompania Węglowa SA
Ul. Powstańców 30, 40-039 Katowice, POLAND

Contract No RFCR-CT-2007-00003
1 July 2007 to 30 June 2010

Final report

Directorate-General for Research and Innovation

2012 EUR 25098 EN

Europe Direct is a service to help you find answers
to your questions about the European Union

Freephone number (*):
00 800 6 7 8 9 10 11

(*) Certain mobile telephone operators do not allow access to 00 800 numbers or these calls may be billed.

A great deal of additional information on the European Union is available on the Internet. It can be accessed through the Europa server (http://europa.eu).

Cataloguing data can be found at the end of this publication.

Luxembourg: Publications Office of the European Union, 2012

ISBN 978-92-79-22247-4

doi:10.2777/33900

ISSN 1831-9424

Printed in Luxembourg

PRINTED ON WHITE CHLORINE-FREE PAPER

Table of Contents

1 Final summary

Improved Mine Transport Power Provisions (WP1)

Work Package Objectives

The objective of WP1 was to identify the potential uses of environmental friendly alternative fuel technologies in underground environments and the benefits that could be gained by the EU coal mining industry from their introduction.

Task 1.1 Scoping study

The scoping study identified areas of mines and transport operations that could benefit from the use of renewable energy and reduced emission power provision. The Proton Exchange Membrane (PEM) fuel cell was chosen as the most appropriate fuel cell for further development, within a 300W and a 5kW model. The potential for use of biofuels within underground diesel engines was evaluated and the potential improvements for reduced emissions assessed.

Task 1.2 Risk Analysis

A risk analysis regarding the use of fuel cells in ATEX M1 and M2 areas was undertaken. A 300W fuel cell underwent a rigorous analysis, supervised by TÜV-NORD CERT GmbH. At the present time, the use of a PEM fuel cell in the M1 areas of a mine does not seem to be achievable. The risk analysis for biofuels included an examination of associated costs, in terms of biofuel production and financial incentives to encourage their use. Other health related issues are addressed within Task5.2.

Task 1.3 Additional applications

Additional mining applications of fuel cells were examined, in the areas of both mine transport and power generation. Immediate potential applications include emergency lighting, cap lamp charging, water generation and power supply for wireless LAN (WLAN) Access points.

Task 1.4 Prototype fuel-cell

A fuel cell system of 300W was built as an emergency power supply for use in underground „fresh air' areas. The unit was transported underground at Grube Fortuna mine and tested within the field trials of Task 6.1. It was not possible to test a 5kW FC because of environmental damage to the housing cabinet.

Summary of Results

At the present time the use of PEM fuel cells in „M1' areas is not feasible, since there must always be an opening to admit the reaction air. In this field, further research is necessary. A range of applications in other areas, with energy consumption below 1kW, were identified. Fuel cell systems are suitable for various safety, control, and monitoring applications. For the high energy requirements of production equipment, fuel cell technology is currently not appropriate.

The use of bio-fuels in underground diesel vehicles was found to be feasible, probably as blends; their use would be likely to result in reduced particulate emissions

Enhanced Transport Diagnostics and Management Information Systems (WP2)

Work Package Objectives

- Development of location and diagnostic data systems to enable the more efficient management of underground railway rolling stock

- Research and development of existing Supervisory, Control and Data Acquisition (SCADA) systems to improve the monitoring and control of underground transport equipment and monitoring of the mine environment

Task 2.1 Initial research and selection of technology

Several areas were researched in order to find appropriate solutions for the development of transport diagnostic and management systems, including that of SCADA technology. Wonderware's InTouch SCADA software was chosen to be developed for use in UK mines after a review of SCADA packages. Work was satisfactorily completed to transfer the control and monitoring of all underground plant and the monitoring of the mine environment at Daw Mill colliery from legacy systems to the SCADA software, InTouch.

Wireless location technologies were analysed with a view to their suitability and accuracy in tracking moving assets, resulting in the selection of the most reliable from available solutions. After a detailed market analysis of current tracking and localisation systems, a suitable tracking system, with Time-of-Flight ranging methods was chosen. Additionally, visualisation systems for 2D and 3D mine map representation were selected. Advanced diagnostic methods, relying on acoustic analysis and contactless temperature measurements were also studied. Both laboratory and in situ tests were carried out, in order to determine proper sensor selection.

Task 2.2 Development of sensor systems

Suitable acoustic sensors and a signal processing subsystem were selected for the machine diagnostics research. Tests in real conditions with spatial temperature rise observations helped to provide information on the requirements for the contactless temperature sensor. A sensor head for wheelset diagnostics was developed, combining both acoustic emission and contactless temperature measurement methods, in order to provide a broader scope of failure mode detection. A sensor system providing location, status and diagnostics information was successfully developed. The system consists of fixed infrastructure – location and remote diagnostics sensors, and a mobile part- sensor nodes located on vehicles. Flexibility of the transmission subsystem also ensures communication between moving vehicles and underground dispatchers. The developed system uses highly innovative solutions in order to lower the infrastructure cost and to provide additional benefits by extensive support for efficient transport fleet management.

Task 2.3 Development of demonstration applications

A 3D visualisation and corresponding demo tracking system was deployed at Grube Fortuna mine, for test purposes in WP6. A SCADA/GIS type application targeted to be used by underground dispatchers, as well as in surface control rooms, was developed, primarily to be used in monorail transport systems. Its main features include visualisation of vital information correlated with geographical information. The information is updated in real time and includes precise location and cruising direction of individual vehicles, their diagnostic status, and emergency alarms. It also delivers essential fleet management related features.

Task 2.4 Provision of Management Information

The transmission capabilities of the developed sensor system were used to provide a means of communication between the underground vehicle dispatchers and vehicle operators, supporting efficient transport system management. The GIS/SCADA application was equipped with the functionality of text message transmission, thereby providing an easy way to send commands, warnings and alarms to vehicle operators. The mobile sensor nodes to be located in train cabins were equipped with a dedicated user interface, enabling operators to send acknowledgements to receiver dispositions and to trigger alarms in emergency mode.

Summary of Results

Control and monitoring of all underground plant and the monitoring of the mine environment at Daw Mill colliery was transferred to the SCADA software „InTouch'. Wireless location technologies were analysed with a view to their suitability and accuracy in tracking moving assets. A demonstrator of the tracking system, consisting of mobile nodes, stationary nodes and visualisation software was developed and prepared for underground tests in the Grube Fortuna mine. An ATEX-compliant version of the location sensors was developed and interfaced to a µZist backbone transmission system. The resulting solution enables large area coverage.

Suitable acoustic sensors and a signal processing subsystem were selected for the machine diagnostics research. A sensor head for wheelset diagnostics was developed, combining both acoustic emission and contactless temperature measurement methods, in order to provide a broader scope of failure mode detection. A demonstration GIS/SCADA application for the underground dispatcher and mine control room was developed, enabling online visualisation of vehicle positions and heading directions and their diagnostic status.

It was concluded that the transmission capabilities of the developed sensor system can be effectively used for the provision of information which is vital from a fleet management point of view. Implementation of text command dispatching, warning and alarm broadcasting can improve both the efficiency of transport system operation and its safety. Implemented features provide a means for effective underground fleet management and for ensuring reliable operation of the transport process.

Improved Fire Control in Mine Transport Systems (WP3)

Work Package Objectives

Both diagnostic and location information can play a significant role in fire detection and fire fighting applications. One objective of this work package was to produce a more effective fire prevention and early-fire detection system for rail based transport, based on the sensor technology developed under WP2. Other aims were to develop a training simulation to facilitate the early and effective implementation of fire prevention and early-fire detection systems and to develop an on board engine compartment, cab and wheel arch fire fighting system which can be periodically tested and still retain an operational capability.

Task 3.1 Fire detection software

In the initial stage of the task, a simple demonstration application for wireless temperature monitoring of the engine compartment was developed. At a later stage, a regionally-assigned broadcast of a fire related alarm was implemented for software developed within Task 2.3. The developed solution relies on an interface to an acquisition and triggering module. For the purpose of the demonstration application, a dedicated interface in the form of an alarming region translation matrix was prepared.

Task 3.2 Development of training aids

A training aid simulator was developed in this task, to familiarise mineworkers with the correct procedures to follow in the event of a fire alarm. Four scenarios were developed, in conjunction with the mine operator, and the results of computational fluid dynamics modelling used in the visual displays of the spread of fire and smoke. The training simulator includes animated movies of crew evacuation.

Task 3.3 Water Mist Fire Fighting System

The major component of this task was the development of an on-board engine compartment, cab and wheel-arch fire-fighting system, which can be periodically tested and yet still maintain operational capability. Suitable spray nozzles were identified and tested on a „mock up' test vehicle where a fire was allowed to burn for 90 seconds and a 3-second water mist blast then applied. These tests and later trials on an underground diesel engine van were very successful. Finally a fully developed, working engine, cab and wheel arch water mist fire suppression system with testing capability was designed.

Summary of Results

The early fire detection research resulted in automatic fire alarm functionality being provided to vehicle operators. The developed scheme can also be expanded beyond fire related alarms, because the MAW module used in the scheme operates with a wide span of safety monitoring systems. A training aid simulator was developed to assist in the training of how to respond in the case of a fire alarm underground. Water mists can be used successfully to quench incipient vehicle fires. A full vehicle fire suppression system which can be tested without losing functionality was designed.

Aids for Planning, Organisation and Training in Transportation Safety Management (WP4)

Work Package Objectives

- Development of a joint free access WEB based platform for collaboration (integration) amongst transport designers and specialists in work safety, health protection and ergonomics to promote improved and unified transport system design and training standards.

- To evaluate the potential for augmented reality based solutions to provide information to operational mine staff for radically improving transport logistics management, maintenance or health and safety. The use of clip on displays or certified PocketPC equipment underground is now becoming more commonplace throughout the industry. A prototype AR system, based on this display technology, that has the capability to integrate and present information gathered from a wide range of sources to operational staff was to be produced and evaluated.

- Production of effective training resources to improve the reliability and performance of mining transport systems and promote the efficient and effective implementation of project solutions and developments.

Task 4.1

Joint working teams from three of the research partners were involved with transport system designers and service/maintenance personnel from 16 mines to evaluate a range of transport issues. These included the most common loads, the causes of the most serious accidents, transport systems for load types and training regimes. Subsequently a training workshop was held to identify the most pressing needs of the industry. The requirements for the WEB-based system architecture for Mine Transport Systems Planning were determined, and then used as an input to Task 4.3.

Task 4.2

In this task, a working team from the industry was established to identify all necessary information resources indispensable for the correct design of a transport system. The main outcome was a set of Guidelines for Mine Transport System Planning, which was input to Task 4.3 and included within the MINTOS Repository.

Task 4.3

In this task the prototype WEB based platform (MINTOS Repository) for the integration of specialists involved in the transport planning process was successfully developed. This is a platform for collaboration (integration) amongst transport designers and specialists in work safety, health protection and ergonomics. The platform is intended for use by all mining communities from European countries, in order to promote improved and unified transport system design and training standards. The repository contents include legal acts related to mine transport system design, catalogue cards for selected types of transportation, lists of loads, risk factors during manual handling activities, training materials for operators and fitters/servicemen, accidents that occurred during transportation operations, and check lists for designers and for people associated with the maintenance of transportation.

In addition, a prototype augmented reality (AR) system was developed which has the capability to integrate and present information gathered from a wide range of sources to operational staff.

Task4.4

Effective training resources to improve the reliability and performance of mining transport systems and promote the efficient and effective implementation of project solutions and developments, were established. A range of training material for a SCHARF monorail was developed. Other training resources, for the training of mine haulage crews, include the visualisation of accidents, together with their causes and means to avoid them.

Summary of Results

The MINTOS Repository and its supporting Internet platform which allows access to this knowledge and information repository were produced. Working groups made up from a comprehensive range of industry representatives were used to identify information requirements, establish Guidelines for Mine Transport System Planning and assess risk factors for transport system components. Furthermore, software to support traction calculations and the modeling of transport routes to enable analysis of collision points, operator fields of view and other related safety issues were developed and included in the system. A prototype augmented reality display system was produced to enable operational information and training support material to be presented on PDAs to mine staff.

Effective Monitoring and Control of Transport Related Health Hazards (WP5)

Work Package Objectives

The objectives were to investigate the potential for water mist exhaust scrubbing techniques to reduce diesel engine emissions and also to assess the potential value of specific additive technology in such conditioning systems. To further combat potential health hazards, an improved methodology to assess vibration in transport systems, where high crest factor shocks and transient vibration levels are encountered, was to be developed. A data base of vibration measurements collected from existing transport operation was to be established and used to assess risk and determine suitable vibration measurement and exposure sampling times. To more effectively identify and control health risk factors that can arise during loading and unloading operations, a system employing computer aided risk analyses which is based on video analysis and simulation of real world tasks was to be realized.

Task 5.1 Potential for water mist scrubbing of diesel emissions

In a series of bench trials, particulate and gas analysis demonstrated that the introduction of a water mist system resulted in a significant reduction of airborne particulates emitted from the diesel engine exhausts. Furthermore, the tests showed that the introduction of low cost, non irritant additives to the water mist scrubbing system can serve to further reduce particulate emissions. The results of the tests to reduce the gaseous content of the diesel exhaust showed little reduction.

Task 5.2 Impact of using biofuels on diesel engine emissions

Separate exhaust emission trials were undertaken on a diesel engine fuelled with two biofuels - commercially available biofuel B30, which complied with European Standard EN14214, and B50 which was 50% diesel and 50% vegetable oil. The associated particulate analysis demonstrated that lower levels of particulate tended to be generated using biodiesel. The introduction of a water mist system could give additional marginal reduction in airborne particulates. The introduction of low cost, non irritant additives to the water mist scrubbing system can further reduce particulate emissions, for some additives. Tests to reduce the gaseous content of the diesel exhaust again showed little reduction.

Task 5.3 Comparative assessment of vibration measurement methods

The work within this task was primarily to undertake a comprehensive set of field measurements of vibration levels on mining machines, in order to be able to compare whether the applicable international standards for vibration measurement adequately cater for mining environments, where significant transient „shock' loads are present.

Vibration measurements were made on sixty one items of mobile plant operating at five different coal mines in Spain. This represented a broad spectrum of real working conditions and a large cross section of machinery. The main finding was that, in the mining industry, high levels of vibration are experienced by mine workers which, in many cases, exceed the legal limits set out in the European Directive. Using the RMS (root mean square) parameter to assess the vibration exposure risk significantly underestimated the risk, when compared to using the VDV (vibration dose value), which was much better at accounting for „impulsive' characteristics.

Task 5.4 Determination of vibration measurement times

Allied to the measurements and comparative analyses conducted within Task 5.1, this task research examined the measurement times required in order to gain an accurate assessment of a worker's exposure to vibration. No precise statement on a „period of exposure' exists within the international standard. It was found that, for the case of machinery where the vibration is unknown, it is advisable to use a minimum measurement time of two hours.

Task 5.5 Vibration Database

In order to be able to collate and manipulate the vast amounts of data expected to be generated by the field measurements of vibration, a comprehensive database was developed in accordance with all the results of the measurements carried out. This database now provides the European mining industry, and industry generally, with an invaluable reference document for the identification of vibration risks in real operating environments.

Task 5.6 Identify mining situations with major incidence of vibration related health effects

As a consequence of the detailed analysis achievable using the database software, it was possible to determine the parameters and circumstances responsible for major incidences of vibration-related health effects in mine workers. Regarding the circumstantial parameters and the technical ones, the research clearly showed the influences of the local terrain (roadway conditions and roadway slope), driving habits (speed and aggression), the age of the equipment, loading of the equipment and the type and characteristics (granularity) of the material being transported.

Task 5.7 Identification of risk factors during the loading/unloading operations

Studies on risk factors associated with loading and unloading operations involved using various software tools to identify and assess the risks. In addition, video recordings of selected activities were made underground at two mines. These allowed analysis of loads applied to the musculo-skeletal system, with the results stored within the Mintos repository. Guidelines and recommendations for decreasing loads on the spine were created.

Summary of Results

The diesel engine exhaust trials demonstrated that the introduction of a water mist scrubbing system into the diesel exhaust can reduce particulate emissions on both conventional diesels and those powered with biofuels. With conventional exhaust systems, the particulate emissions when using biofuel blends were lower than with standard diesel. The reduction of particulates can be further enhanced by the introduction of low cost, non irritant additives to the water mist scrubbing system, but some of these were not as effective on biodiesel blends. Firm conclusions on potential beneficial changes to exhaust gas content by using additives could not be drawn and it is evident that further work is required in this area.

Whole body vibration measurements were made on sixty one items of mobile plant operating in five different coal mines in Spain. The measurements were made during the complete working shift, with subsequent analysis then undertaken to evaluate the effects of the influence of the impulsive component of the vibration, and to quantify the potential errors which could result from using shorter measurement time periods.

High levels of vibration were found which, in many cases, exceed the legal limits set out in EU Directive 2002/44/CE. In terms of measurement time, for the case of machinery where the vibration is unknown, it is advisable to use a minimum measurement period of two hours.

A dedicated software tool was developed to manage the large amount of data generated during the research and a comprehensive database established. Using this, it was possible to determine the parameters and circumstances responsible for major incidences of vibration-related health effects.

There was found to be a noticeable lack of authoritative vibration information available from machine manufacturers and a lack of data within international data bases. International vibration working groups contacted showed great interest in exchanging information and establishing future collaboration.

High health risk areas relating to loading and unloading of loads during transport operations were identified and analysed using computer aided risk analysis which was based on video analysis and simulation of real world tasks. Guidelines and recommendations for manual transportation of loads were produced.

Pilot Installations and Field Trials (WP6)

Work Package Objectives

- Field trials and demonstrations of fuel cell prototypes
- Deployment and testing of a pilot installation demonstrating the capabilities of the diagnostic/location sensor system
- Field trials of the WEB-site reference project of mining transport systems.
- Technology transfer demonstrations and workshops related to SCADA systems

Task 6.1 Fuel cell field trials

An emergency power supply for a locating system to locate buried miners and for emergency lighting was trialled using the 300W RiCell 300 fuel cell. The tests gave good insight into the behaviour of a PEM fuel cell, and showed that a fuel cell has the ability to serve as an emergency power source. During all tests, no hydrogen was detected outside the fuel cell cabinet, which showed in the field the high level of the developed safety concept. Minor malfunctions occurred during the functional testing (fast on/off cycles); however, these were not caused by the fuel cell itself, but by subsystems.

The 5kW fuel cell suffered environmental damage to the cabinet, which was supplied by Idatech, due to the high humidity present in the mine and consequently could not be tested. In future systems, either components need to be of better quality, or the cabinet needs to be air-conditioned. Nevertheless, the outcomes of the MINTOS project have influenced the direction of Rittal's technology decisions and further research is continuing in this area under private funding.

Task 6.2 Tests sensor systems

The initial sensor field trials at Guido mine enabled the performance of the real time location scheme in underground conditions, in a multi-sensor configuration, to be determined, and enabled improvements to the GIS/SCADA software to be made. Later, a full test installation at KWSA's Ziemowit mine, with mobile nodes installed in both cabins of a SCHARF monorail, then allowed trials of the precise location and heading direction of the vehicle to be undertaken successfully. The trials also allowed the performance of the wheelset diagnostics sensors to be assessed, together with the machine diagnostics link.

Direct co-operation with the end users, especially the mine staff at Ziemowit colliery during the tests, provided invaluable feedback with regard to desired modifications and improvements to the developed system, which resulted in user oriented optimisation from an early stage. From the tests carried out in real conditions, it was possible to verify operation of the developed sensor systems and controlling software. The tests proved robust operation of the location, diagnostic and transmission sub-systems.

Task 6.3 Field trials of mining transport systems planning

The two principal augmented reality based solutions driven from the MINTOS Repository were tested and refined. These were, the traction calculations aiding system which is designed for use by mining transport system designers; and the training programmes and control lists which are designed for use by operators and underground personnel carrying out transportation tasks. Both systems were trialed by personnel from selected KWSA mines and the training system was also tested at the SCHARF monorail manufacturer's works and at Murcki colliery

The required hardware and software were installed at each mine and training workshops run to familiarize the traction system testing teams with the use of the system. User manuals were also supplied. The testing teams operated the traction calculations system over a period of two months and then provided feedback to enable refinements to be made. The feedback from the testing teams largely confirmed the original design assumptions and enhancements to the system were proposed, including the incorporation of thirty characteristics of suspended locomotives manufactured by SCHARF and PIOMA within the MINTOS repository.

The operational trials of the AR training programmes were conducted using ultra mobile PC devices and ATEX certified PDAs and followed a similar procedure employing training workshops, but in this case with operators of suspended monorails and other personnel who carry out transportation tasks underground. Results from these field trials were used to guide improvements to the AR software and training programs. The new form of training was assessed very positively by the personnel at the mines.

Task 6.4 SCADA technology transfer workshops

Documentation to support SCADA technology transfer workshops was designed and produced. The documentation introduces discussion points designed to promote the exchange of ideas on possible performance enhancements. These discussion points were derived from discussions held with UK Coal HQ staff, Colliery Engineers, system suppliers and end users. In addition to possible performance enhancements the discussion points address issues such as hardware and software security in terms of potential consequences and impacts, the existence of common vulnerabilities, related testing issues and the development of good practice guidelines.

Following the completion of the technology transfer documentation arrangements for SCADA technology transfer workshops were progressed. One of these took place at EMAG in Poland in Spring 2010 and another at Daw Mill colliery in June 2010. Attempts were made to organise other workshops but encountered difficulties in terms of was getting commitment from mining companies to participate within the duration of the project.

Summary of Results

The field tests of the RiCell 300 showed that a fuel cell has the ability to serve as an emergency power source. Minor malfunctions during the functional tests were caused by subsystems; in future research, more development of the subsystems is required. The field trials on the 5kW fuel cell could not be carried out, since the unit suffered damage from the high humidity in the mine.

Tests of the sensor systems, developed within work package 2, were carried out in real conditions underground. Tests were undertaken in several stages at two coal mine locations - ZKWK Guido mine and KWK Ziemowit mine. During the tests, different components of the sensor system were trialled, in multiple configurations, and the results utilised as feedback during the final product bug-fixing and improvement stage.

Extensive field trials of the prototype Traction Calculations Aiding System and the prototype training system, which uses Augmented Reality technology, were undertaken in conjunction with a number of personnel at three KWSA mines. The AR training system was also tested at a manufacturer's works, SCHARF and at MURCKI Colliery. The Traction Calculation System, which is available on an internet platform, is addressed to the designers of mine transport systems. Both systems were assessed very positively by the colliery personnel.

The documentation developed to support the SCADA technology transfer workshops was well received and the two workshops were considered by the participants to be useful. Since the Mintos project was originally devised, SCADA technology has become much more widespread and there is an understandable tendency for mine operators to wish to liaise primarily with „local' consultancies and equipment suppliers from their own country. Consequently, the number of workshop it was possible to hold within the timescales of the project was limited.

Work Package 7 - Dissemination of Results

Work Package 7 was intended to provide reports and communications regarding the research results throughout the Mintos project. In addition to the interim, mid-term and final reports supplied to the Commission and TGC1, many other forms of dissemination were utilised during the project. A comprehensive list of these dissemination activities is presented within Section 5.

2 Scientific and technical description of the results

2.1 Objectives of the project

The primary objectives of the project were to:

- Improve mine transport power provisions by examining the use of alternative fuels and motive power sources including the use of fuel cell technology and biofuel diesels.
- Reduce transportation down time and maintenance costs through the use of advanced diagnostic techniques.
- Improve Fire Control in Mine Transport Systems to reduce the incidence and severity of transport system fires.
- Enhance mine management information via tracking and status monitoring techniques.
- Harmonise measures to determine and reduce diesel exhaust exposure.
- Provide advanced aids for planning, organisation and training in transportation safety management
- Ensure effective monitoring and control of transport related health hazards and reduce the adverse health and safety impacts.

2.2 Comparison of initially planned activities and work accomplished

Work Package 1

The major deviation concerns the fuel cell research undertaken by Rittal. It was originally envisaged that a 250W or 300W fuel cell (FC) based power supply would be developed and tested underground and that, following on from this, a 5kW FC would undergo a similar assessment. A number of 5kW fuel cells would be required to supply sufficient power for transport applications. The 300W FC underwent trials, but the research indicated that certification to ATEX M1 would not be achievable for a significant period of time. Furthermore, the 5kW FC suffered damage to its cabinet housing when installed underground, due to the climatic conditions and could not be tested. As a result of these two issues, it was not appropriate to undertake the power train/drive analysis originally planned.

A further minor deviation occurred with the delayed testing of the 300kW FC underground in Task 6.1.

Work Package 3

Trials of the developed onboard water mist fire fighting system were originally intended to be undertaken on a mining vehicle at a coal mine. However, operational difficulties at the mine prevented these from taking place. Successful „field trials’ were undertaken underground, however, on two vehicles owned by a rock salt mine.

Work Package 5

There was a minor deviation related to analysis of the vibration measurements, as reported in the mid-term report, due to the substantial amounts of data generated. However, this analysis was subsequently completed and did not affect the outcome of the research.

Work Package 6

As mentioned above, within the analysis of deviations for work package 1, there were delays to the underground testing of the 300kW fuel cell, because it was not possible to get access to the research site inside the Grube Fortuna mine. However, during the last semester of the project, access was obtained and the planned trials completed.

More workshops were originally planned as part of the technology transfer relating to SCADA installations. However, difficulties were encountered in terms of getting commitment from mining companies to participate. Nevertheless, the comprehensive documentation material produced for the workshops is available for further dissemination from the CIRCA web site.

2.3 Improved Mine Transport Power Provisions (WP1)

Work Package Objectives

The goals of WP1 consisted of the identification of the potential uses of environmentally friendly alternative fuel technologies in the underground environment and the benefits that could be gained by the EU coal mining industry from their introduction.

Also the development of a highly-available mine infrastructure power system based upon renewable, alternative and emission-free power-sources (fuel cell technology) was to be undertaken, with the objective of providing:

- Power supply without pollution
- Battery and Diesel-Generator substitution
- Less maintenance
- State-of-the-art technology with renewable energy sources
- Low noise emissions and improved working conditions for miners
- Improved financial competitiveness of the coal mines within the EU.

2.3.1 Task 1.1 Scoping Study

An initial component of the research included contributory information for a scoping study to identify areas of mines and transport operations that present optimum potential benefits from using renewable and equal-zero-emission energies. Other objectives were low maintenance systems and „state of the art' technology, in terms of renewable energy applicable in mines. Work included acquiring information in two areas, those of fuel cell technologies and diesel replacement bio fuels.

One of the major problems facing the mining industry and operating companies includes increasingly stringent diesel emission regulations. This creates limiting factors on the underground operation of vehicles using diesel fuel to provide motive power. Other motive power types, such as battery and cable powered electric vehicles, have limitations such as restricted operating time and „tramming' distances respectively. These factors require the potential for new technologies in the field of motive power sources for transportation purposes to be examined.

One such area of technology is that of fuel cell driven machines. The operation of a fuel cell is similar to that of a battery with the exception that it does not run down or require recharging, because a fuel cell is a power generator and not a power storage unit. Energy is produced in the form of electricity and heat while fuel is supplied. The basic design of a fuel cell consists of two electrodes which are wrapped around an electrolyte. Oxygen passes over one electrode and hydrogen is introduced over the other and this process results in the generation of electricity, heat and water. The official definition according to DIN IEC 62282-2 is "Fuel Cells are electrochemical devices, which change fuels like hydrogen or hydrogen similar gases, alcohols, hydrocarbons and oxidations into DC-current, heat, water and other by-products".

By including a „fuel reformer' within a fuel cell, hydrogen can be utilised from any hydrocarbon fuel source such as methane, methanol, ethanol, diesel and gasoline. The fuel cell harnesses the chemical energy of hydrogen and oxygen to generate electricity and water without combustion and thus without pollution. Other benefits include noise reduction, improved energy efficiency and the potential for energy security which has grown in importance in current times of inflating fuel prices.

After a detailed comparison of the different fuel cell types, it was concluded that the Proton Exchange Membrane Fuel Cell (PEMFC) and the Direct Methanol Fuel Cell (DMFC) were the most suitable for use in mining, due to their very good dynamic behaviour. The Direct Ethanol Fuel Cell (DEFC) cannot yet be referred to as „state of the art'. The high-temperature fuel cells are not suitable due to the high temperatures and the long run-up periods. The Phosphoric Acid Fuel Cell (PAFC) has a relatively poor electrical efficiency. The Alkaline Fuel Cell (AFC) requires pure hydrogen and pure oxygen which makes the operational management difficult and more expensive. Consequently, only DMFC and PEMFC remain feasible for use in mining. PEMFC has a clearly higher degree of efficiency and is operated with hydrogen of grade 3.5 (99.95% clean hydrogen); for newer systems, even grade 3.0 (99.9%) is sufficient. Thus, a considerably more environmentally-friendly operation than with methanol is ensured. In addition, it does not produce carbon dioxide, in contrast to DMFC. For this reason, Rittal decided to use the PEMFC and pushed the development of the 5 kW and 300 W versions, RiCell 5000 and RiCell 300.

Rittal used the Fortuna iron ore mine for the later studies of fuel cells. The mine has general underground environmental conditions, such as temperature, humidity, mud, transportability etc. which are comparable with fresh air areas of typical coal mines. Further conditions, such as coal dust and methane were studied in more detail within Task 1.2. In order to assist with these studies, contact was made and a visit paid to the RAG Anthrazit Ibbenburen coal mine, where underground ambient conditions are significantly different to those at Fortuna. There is significant interest there in the possibility of utilising fuel cells as replacements for batteries and in the area of power supply for telecommunication and control technology.

Initial trials were undertaken to transport a fuel cell enclosure into the underground workings at Fortuna, in order to clarify what kind of conditions need to be considered during the transportation process, for example typical size and weight problems. In addition, the mechanical stiffness of the product had to meet underground norms. The intention was to concentrate on the most compact design of equipment for future applications. Preliminary calculations were also undertaken regarding hydrogen purges into the mine atmosphere and the volumes of water which would be generated. One of the fuel cell systems was integrated into the power supply infrastructure of the research area. (See Task 6.1).

A detailed study was carried out into the state of the art regarding the storage of hydrogen in 700 bar pressure tanks and the storage of liquid hydrogen in cryogen tanks. Metal hydride storage tanks and 200 to 300 bar high-pressure steel cylinders were included in the study.

The usual storage pressures of conventional high-pressure tanks range between 100 and 300 bar. These tanks have a cylindrical shape, the material is made of steel in the simplest case and the tanks are available with volumes between 2 and 50 litres. A 50l cylinder with a storage pressure of 300 bar contains 1.3 kg of hydrogen, of which approximately 1 kg can be used at barometric pressure [3]. The Technical Regulation for Compressed Gases (TRG 280) applies to this cylinder.

The newly developed 700 bar high-pressure composite tanks consist of a thin-walled, seamless aluminium liner with carbon fibre laminate wrapped around it. The carbon fibre wrapping absorbs the high stresses of the internal pressure, whilst the liner assumes the task of a permeation barrier [4]. These tanks can store approximately 3.5 kg of useable hydrogen at a storage volume of 85.5 l [3]. Thermoset filament winding roving has established itself in the manufacture of composite tanks. The storage tanks are already used in city buses. This is a fleet test intended to demonstrate the road capability of hydrogen vehicles (EC funded Cute Project) [4].

Deep cold liquid hydrogen has a considerably higher energy density than compressed hydrogen. Thus, there are clear storage and transport advantages over compressed hydrogen. However, the high expenditure of energy required for liquefying (-253°C, about 30 % in relation to the specific energy content) is disadvantageous [4].

Due to the high energy loss during the storage of liquid hydrogen, the use of cryogen tanks is not recommendable. Conventional hydrogen high-pressure cylinders with a pressure of 300 bar have a relatively low volumetric energy density of 2.5 MJ/l [3] [10], but can be easily handled. Most modern 700 bar composite high-pressure tanks made by Dynetek reach volumetric energy densities of about 4.9 MJ/l [3]. According to manufacturer's data, metal hydride storage tanks made by Udomi or Treibacher contain 1000 NL (standard litres) of hydrogen at a cylinder volume of about 4.2 l. The outcome of this is a volumetric storage density of 2.57 MJ/l [3].

For use in vehicles, high-pressure composite tanks which have already proved their worth in the automotive industry are preferred, due to the largest volumetric storage density. Despite their high pressure of 700 bar, these tanks are safer than gasoline tanks [6].

For the use of a fuel cell as an electric power supply for control monitoring systems or communication equipment, the conventional 300 bar high-pressure storage tank made of steel is still the most cost effective solution according to the current state of the art. Filled cylinders are rented from the manufacturer and empty cylinders are returned to the manufacturer later on. If an autonomous time of 24 hours is assumed, 8 cylinders containing 50 litres each are required to operate a 5 kW fuel cell system.

Bio fuel is the generic term used to describe gas and/or liquid fuels that are organically derived from sources other than petroleum based fossil fuels. Bio fuels fall into two primary categories:

1. conventional bio fuels, produced from plants and crops such as sugar beet, rape seed oil or reprocessed vegetable oils and
2. advanced bio fuels, derived from gasified biomass materials.

Currently, the majority of bio fuels can be categorised as the conventional type. Although bio fuels have the potential to be used as total replacement road fuels, they are mostly used as blends, in varying proportions, with conventional petrol or diesel fuels.

In recent years, the use of diesel replacement bio fuels has been considered to offer substantial opportunities to reduce particulate material emissions from diesel powered machinery. Bio fuels can be used in currently operating diesel combustion engines without the necessity for engine tuning and adjustments, provided that the bio fuel to diesel blend does not exceed a certain percentage. The British and EU standard for diesel, BS EN 590, permits a bio fuel content of up to 5% by volume without affecting the vehicle manufacturer's warranty. Oil companies and vehicle manufacturers, working with bio fuel producers have agreed a standard – BS EN 14214 applicable to vegetable oils suitable for blending with conventional diesel, to ensure that the product meets the technical requirements of modern diesel engines (UKPIA, 2005).

An engine may operate within normal parameters with blends in excess of 5% by volume, but any such use may invalidate the vehicle's manufacturing warranty and over a period of time could cause damage to the engine and fuel system components.

Bio fuels are also usable in electrical-power-generators relating to CHP systems (combined heat and power). For these generator applications, rather than a bio fuel content of only 5% by volume being used, nearer to a 100% bio fuel, i.e. palm oil, rape oil, soya bean oil, sun flower oil and jatropha could be used. However, many factors need to be considered. On one hand a palm-oil operated combustion-engine has less emission content concerning CO and CO2 as well as NOX. On the other hand palm-oil is a renewable energy source and therefore CO2 compensated. Diesel engine operated vehicles have to follow a dynamic power curve, while a CHP system powered by bio fuels needs to operate at constant speed. CHP systems have much better energy efficiency (42 $\%_{el}$ and $47\%_{therm}$) than just combustion engines, because the heat is also used. Additionally an absorption-cooling system linked to the CHP could give benefits regarding energy usage and increased efficiency.

A further consideration is that nearly all hydrocarbons can be converted into pure hydrogen which then can be used within fuel-cells.

In the coal mining industry, the use of diesel powered vehicles is confined to manpower, materials and equipment / machinery transportation. The vehicles can be categorised as diesel locomotives, general purpose free steered vehicles (FSV) for transportation of materials, equipment and machinery and FSV multi-purpose vehicles which are used for personnel carriers in conjunction with materials etc. The use of diesel powered vehicles is more widespread in non-coal mines, quarries and surface mines.

Bio-diesel blends of up to 5% with conventional diesels have been available for some time without any reported problems. It is envisaged that with concentrations in excess of 20%, problems may be encountered in periods of cold weather, as a result of poor flow characteristics. The use of unprocessed vegetable oils could have the potential to be problematic, with respect to the collection of deposits in fuel pumps, filters and injectors.

In terms of their general environmental impact, bio fuels are considered as a more sustainable alternative to the conventional fossil fuel derivatives such as petrol and diesel, due to being produced from renewable sources. These renewable sources, as agricultural crops, are considered to absorb carbon dioxide from the atmosphere through the process of photosynthesis. Conversely, carbon dioxide is emitted as a result of energy consumption during harvesting and production processes.

Studies indicate that the overall carbon dioxide savings from bio fuels compared to conventional petrol and diesel vary between 20% and 70% depending on the type of crop and energy consumed in growing, harvesting, transporting and processing the crop into a fuel (UKPIA, 2005).

A major advantage when considering potential use in underground mining is that bio-diesel has a lower aromatic content, which means there will be a potential for a reduced level of toxic compounds within the exhaust gases and reduced particulate emissions. These reductions may be possible provided the conversion process, which produces fatty acid methyl esters, removes the glycerine by-product. This area of bio fuel technology was further investigated in Task 5.2 which examined bio fuel exhausts. A further method to lower these emissions is to convert the bio fuels into pure hydrogen, as mentioned above.

A significant disadvantage with respect to global environmental concerns is the expansion of agricultural land required for allocation to bio fuel crops. Detailed numbers and figures are presented in the article on bio fuels within National Geographic magazine (October 2007).

The UK Government responded to the EU Directive 2003/30/EU setting indicative targets for bio fuel use, by examining the feasibility of introducing a Road Transport Fuel Obligation (RTFO) as a means to boost the take up of bio fuels. A duty incentive of £0.20 per litre below conventional petrol and diesel was introduced in 2003 for bio-diesel and 2005 for bio-ethanol. The duty incentive has given a modest boost to the production of bio-diesel.

The main limiting factors are the high cost of production which was 3 to 4 times that of conventional petrol and diesel, and the available land mass in the UK deemed necessary for the production of crops in sufficient quantity to meet other than a very small proportion of the UK's demand for diesel fuel and petrol. The latter is difficult to address and it is considered that a better solution would be to use biomass in the production of heat and power rather than for conversion to liquid fuels. Furthermore, another vital requirement is the accredited and reliable sources of bio fuel feedstock supply, particularly for material imported from outside the EU (UKPIA, 2005).Therefore, the advantages and disadvantages of renewable hydrogen as an energy source compared to bio fuels needs to be investigated.

A report published by the European Environment Agency (EEA 2007) states that there is a large potential for bio energy production from agricultural biomass in Europe but acknowledges that the increasing demand for bio fuels raises concerns about additional pressure on Europe's farmland and environmental biodiversity.

The report states the following factors:

- the development of new bio energy crops needs to account for environmental risks associated with large scale bio energy production
- soaring energy prices and strong political support are driving the increase in biomass production but this increase must not contribute to further ecological strains which already exist from current agricultural production
- an analysis of the „environmentally compatible' potential of biomass production in 25 EU Member States was made and warns that Europe's biodiversity, waters and soils could be threatened unless significant protective measures are in place.

A range of recommendations are given for making energy cropping compatible with environmental issues and the report also promotes some general approaches to minimising the impact of biomass production on Europe's environment (Croner 2008).

If consideration is given to whether bio fuels can „deliver', the answer appears to be contingent upon fuel prices, as well as three other variables that directly influence the profitability and environmental impact of bio fuels: the cost and availability of feedstock, government regulation, and conversion technologies (Caesar et al 2007). Currently, car companies continue to sell vehicles with current engine designs but some offer flexible fuel vehicles which can use high-concentration bio fuels, conventional fuels or run on a proportional mix of fuels. The decision on the low carbon approach by car manufacturers will also determine the direction of fuel technology. Other approaches to provide motive power include hybrid and hydrogen-fuel-cell cars.

Bio diesel, though far from cost competitive with regular diesel currently, could in time be produced from „jatropha', which provides a low cost vegetable oil and can be cultivated on marginal land. Biomass-to-liquid (BTL) technology, a gasification process long used to convert coal into fuels, could eventually make it possible to produce high quality synthetic diesel and gasoline (Caesar et al 2007). Furthermore, continuing increases in fuel costs could also lead to a demand for coal gasification. This could lead to the resurgence of a new coal industry based on the ideology that coal is too useful to burn directly and would be better utilised for fuel and chemical synthesis.

Deliverable D1.1, reporting of renewable and possible alternative fuels and economic issues, was completed by the reporting material within the first two semester reports, which were posted to the Mintos project web site and the CIRCA site. This material was further supplemented by text reported within the mid-term report contributions, which are also on both web sites.

2.3.2 Task 1.2 Risk Analyses

A Risk Analysis of the use of fuel cells underground was completed.

Due to their great importance, the basic principles of explosion protection are briefly explained in the following text. A precondition of an explosion is that three factors come together:

1. an inflammable material
2. oxygen as an oxidant and
3. an ignition source.

The first two components, inflammable material and air, must be available in an appropriate proportion for an explosive atmosphere to form. The explosibility limit of hydrogen is at a hydrogen concentration between 4 and 75% in the air. The ignition temperature is approx. 560 °C and the minimum ignition energy is approximately 20mJ. Thus, hydrogen belongs to temperature category T1, which includes all materials with a minimum ignition temperature of 450°C [DIN EN 60079-0].

The Directives 94/9/EC (ATEX 100a / ATEX 95), 98/37/EC, 2006/42/EC are of great importance to the operation of systems in potentially explosive areas. On the basis of these directives, a number of standards were issued, e.g. DIN EN 1127-2.

In danger area 1, only M1 equipment is permissible, since such equipment features a very high degree of safety. It is permitted to continue to operate such equipment in the existing explosive atmosphere even in the case of rare device errors, because safe operation is ensured by the availability of two independent equipment safety measures, or the „double fault' security. In danger area 2, M1 and M2 equipment is permissible. In general, M2 equipment is suitable for mining, since it features a high degree of safety and is suitable for the tough ambient conditions. If explosive atmospheres exist, there must be the possibility of switching off, or safely switching the M2 equipment.

According to the standard for fuel cell technology, [stationary fuel cell power systems IEC 62282-3-1:2007 (German adoption DIN EN 62282-3-1:2007)], a safety analysis was undertaken on the 19”- fuel cell module (300W) [RiCell 300].

Figure 2.3.1 Fuel cell module 300W

For the safety of the system, all relevant parts (including the hydrogen storage/supply with the pressure reduction from 200/300 bar to 10 bar) were considered (Figure 2.3.1) and reviewed according to their risk potential, and provisions for ensuring or improving the safety level were described.

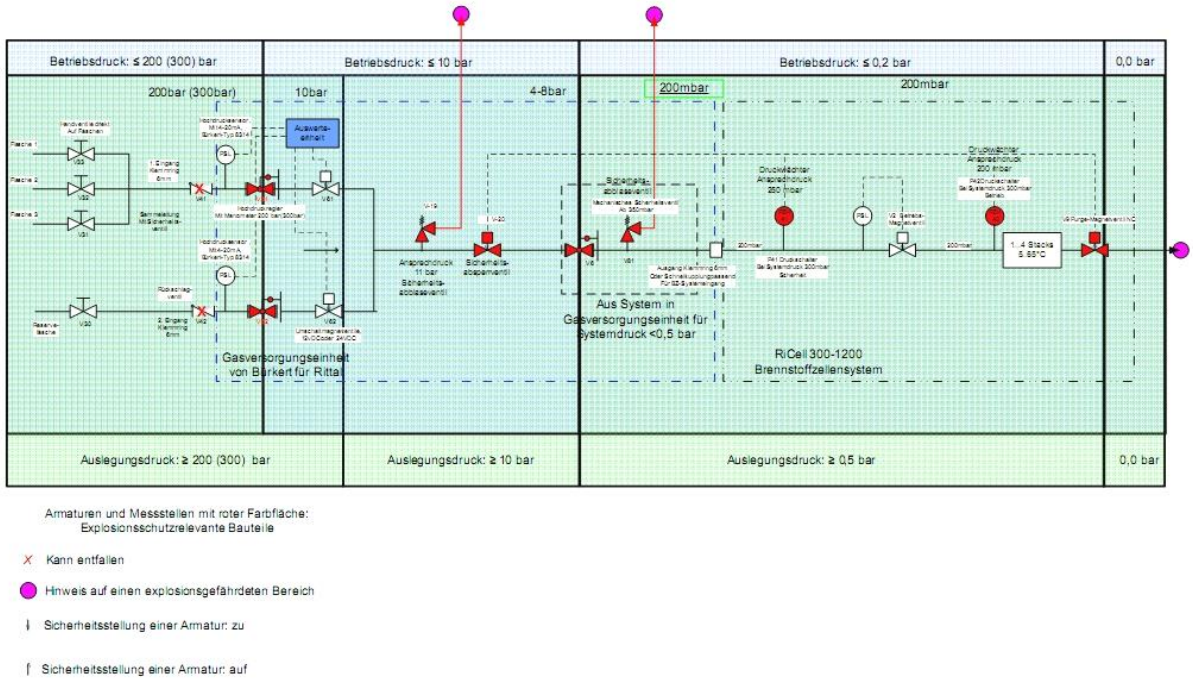


Figure 2.3.2 Different pressure sections with valves and safety-relevant valve positions

A SABINE risk, or safety, analysis was undertaken, in which the complete fuel cell system for mining applications was investigated and all relevant operational modes analysed.

SABINE is a joint project between different project partners (TÜV Rheinland Group, TÜV Immissionsschutz and Energiesysteme GmbH, Research Centre of Jülich, FEV Motorentechnik and Oel-Wärme-Institut GmbH) for the elaboration of basic concepts for safety analyses of process plants in stationary combined heat and power generation plants for the use of fuel cells below 70 kW capacity.

Firstly, the fuel cell system was investigated regarding all sub-systems and the system border and interfaces. The RiCell300 has six interfaces to its environment. Then all operating states of the system were assessed: - Off, standby, start-up, normal (undisturbed) operation, disturbed operation and shut-down

The results of the risk analysis worked out with TÜV NORD CERT GmbH are considered in parallel to this analysis.

- The system should be protected against light shocks, as well as transport related vibration.
- Possible faults (exposure of hydrogen, failure of cooling- and water pumps, failure of valves etc.) are detected by the controller, which shuts the system down to a safe mode.
- Examination regarding electromagnetic compatibility.

The fuel cell system was considered to be „technically gas-tight', because all components and materials were chosen in accordance with the given requirements and environmental conditions. Therefore, during normal (undisturbed) operation, no potentially explosive atmosphere is created by emergent hydrogen. This task was supervised by TÜV-NORD CERT GmbH, and documented under TUV-NORD Systems report number SEGB-2493/08 in June 2009.

Nevertheless, at the present time, the use of a PEM fuel cell in the M1 area of a mine does not seem to be achievable, since there is always an opening necessary to get the reaction air. Further research is required in this field.

2.3.3 Task 1.3 Additional applications

Task Objectives

In order to put the seminal fuel cell technology on a wider basis in mining applications and to adjust future developments according to several possible target applications, as well as to reduce costs through utilising high quantities, preferably as many applications as possible should be identified. Some of these are briefly described within this section.

Fuel cells are currently being developed for use in the mining industry especially for motive power of mine transportation vehicles. Other areas of use include those of power generation, instrumentation and illumination. Areas for motive power supply of mine transportation vehicles include locomotives, free steered vehicles (FSV), utility vehicles, people carriers and mono-rail systems.

Table 3.3.1 itemizes the operational equipment typical of mining, with the corresponding performances. The RiCell 300 and 5000 fuel cell systems would be especially suitable for the application in different control monitoring systems in the low performance range, in communication equipment, monitoring cameras, positioning systems and emergency lighting. This approach was followed in Rittal's research tunnel in the Fortuna Mine during the field trials stage of the research, in the second half of the project.

Another possible application is water management in mines. In the Auguste Victoria Coal Mine, for example, approximately 335 m^3 of water per hour accrue and must be pumped from 1000 m depth to the surface. For this purpose, pressure pumps and water slide valves are used which must be controlled and monitored. The electric power supply of the control monitoring system could be ensured by a fuel cell.

Table 2.3.1 Applications and performances

Applications in mining	Performances as individual components
Coal plough	800 –1600 kW
Shearer loader on armoured face conveyor	up to 2000 kW [2]
Armoured/chain scraper conveyor	about 400 kW
Trolley	up to 20 kW at 6 to 12 t bearing capacity
Monorail	up to 200 kW
Control monitoring systems (mine air, CO, methane, mine fans, monorail)	50 to 100 W [2]
Hoisting plant, hoist with three-phase motor as direct drive	270 to 4200 kW [2]
Emergency lighting	10 to 58 W
Communication equipment (loudspeakers, telephone)	10 W
Video monitoring	7 to 20 W

Emergency lighting

In case of a power failure such as a blackout above ground, or a power supply cable break in a section caused by an accident, or a planned switch-off for maintenance work, it is desirable to increase the security level underground by the installation of an individual power supply for emergency and/or maintenance lighting.

Darkness is an important psychological factor when working underground, especially during a catastrophic event where bodily functions are excessively burdened. With the installation of at least small „light islands', the stamina of the persons cut off from the outside world can be maintained.

In mines it is conceivable to mark dedicated security points (supply for water, food, first-aid materials, etc.) in order to make them easily visible and therefore ensure better accessibility.

Such lighting could also mark escape routes, describe alternative pathways, etc. It is recommended to build these units using state of the art LED-technology, since the power consumption is significantly lower, and also a special marking by coloured LEDs can be easily achieved. For example, the 1200mm long lighting shown in Figure 2.3.3 only requires 15W of power.

Additionally, LED lifetime and tolerance of vibration is significantly higher than for conventional illuminants.

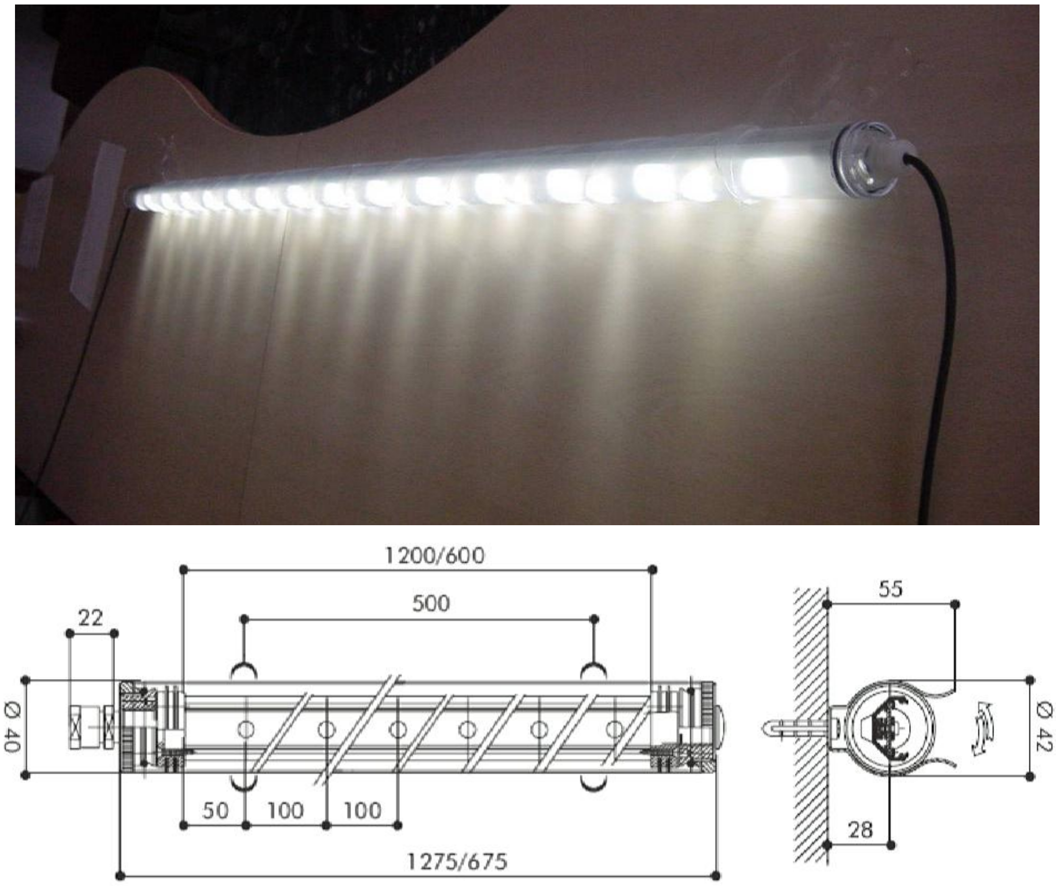


Figure 2.3.3 IP65 protected lighting in LED technology

The installation of an alternative power supply, independent from the regular network would have the advantage that, even if one or several segments need to be switched off during maintenance, power (and basic lighting) would be available on site.

Charging system for pit lamps

An essential part of every miner's equipment is a pit lamp. Whereas these have been fuelled in the past by carbide, and later with gasoline, more recently electrical systems have become state of the art.

Also in this application, LED technology is breaking through, since robustness, lifetime and energy consumption show significant advantages in comparison to the earlier systems. Nevertheless, the range (luminous period) is limited by the accumulator being used. Additionally, for ergonomic reasons, the size of the battery pack to be carried needs to be reduced.

A fuel cell system could be of interest during an emergency incident, as well as in remote areas during tunnel driving as a charging system for such pit lamps. It is well imaginable to have an autarkic fuel cell cabinet with integrated hydrogen storage, which can be transferred easily to the new gallery or pit.

Since accumulators have to be charged with DC voltage, and the output of a fuel cell is also direct current (DC), the overall efficiency of such a system would be increased in comparison to a system where the required DC has to be transformed and converted from the general mine power supply.

Generation of water

Though a fuel cell is primarily focussed on supplying electrical or thermal energy, it also produces additional „products', which may be of interest.

In the context of mine applications, especially the reaction product of hydrogen and oxygen should be considered. In case of a mine accident, it is assumed that all available water – which may be polluted anyway by the normal works – is contaminated and probably above the pollution index which is recommended for human consumption.

If it is not possible to evacuate the buried miners within a short period of time, or to supply provisions from the surface, the supply of drinking water is a vital requirement.

Since during the fuel cell reaction of hydrogen with oxygen only pure water is produced, so pollution is prohibited per se:

$$2H_2 + O_2 \longrightarrow \quad Energy + 2H_2O$$

Only the established guidelines for the consumption of pure water should be observed. This means, that mineral and micronutrients should be added in case of long term usage. If a fuel cell system is intended for this application, or if a system for emergency power supply is fitted for this additional benefit, appropriate additives (as tablet or powder package) can be placed in dedicated boxes within the system, for example directly beneath a drain bottle.

For this special application the low temperature PEM fuel cell (proton exchange membrane) is preferable for 2 main reasons:

1. Fuel cell needs pure hydrogen, which means the risk of pollution of the water by contamination of unwanted carbohydrates left after an unstable reformate process can nearly be neglected

2. With the low temperature, unwanted side reactions of possible gasses in the air are extremely unlikely.

Supplying access points in WLAN

One of the latest high-tech developments for coal mines has been wireless communication equipment for underground. There are pocket pc's (PDA's), WLAN access points (hot spots for underground), Bluetooth headsets, wireless cameras, etc.. All these parts have to have accumulator loading and be ready for use. The local access points must be powered to hold the communication area ready.

Some of this equipment (PDAs) are allowed to be used even if the methane concentration is above normal levels and parts of the mine are powerless. In this case, and of course others (emergency cases etc.) it is important to have communication to the surface. For this case it is necessary to have a fallback system to power the wireless communication network. Communication areas in the main road via access points are one of the targets to be continuously powered.

Equipment like PDA's have to be permanently recharged, to be ready for use. In regions of the mine not connected to the normal power network, fuel cell stations could be utilised for power supply.

2.3.4 Task 1.4 Prototype fuel-cell

Task Objectives

In order to provide a clean energy source for those applications with a low power demand, based on the requirement of 250W, a fuel cell system of 300W was built as an emergency power supply. The fuel cell (FC) 19"-plug-in module is the subassembly which provides the regenerative power. Figure 2.3.4 shows a schematic diagram of the FC module.

The FC was modified in such a way with quick-action couplings so that, in a service or failure case, quick and simple exchange of the module could be achieved.

It is integrated in a double-walled CS-Outdoor enclosure from Rittal in order to provide sufficient protection to the harsh environmental conditions underground.

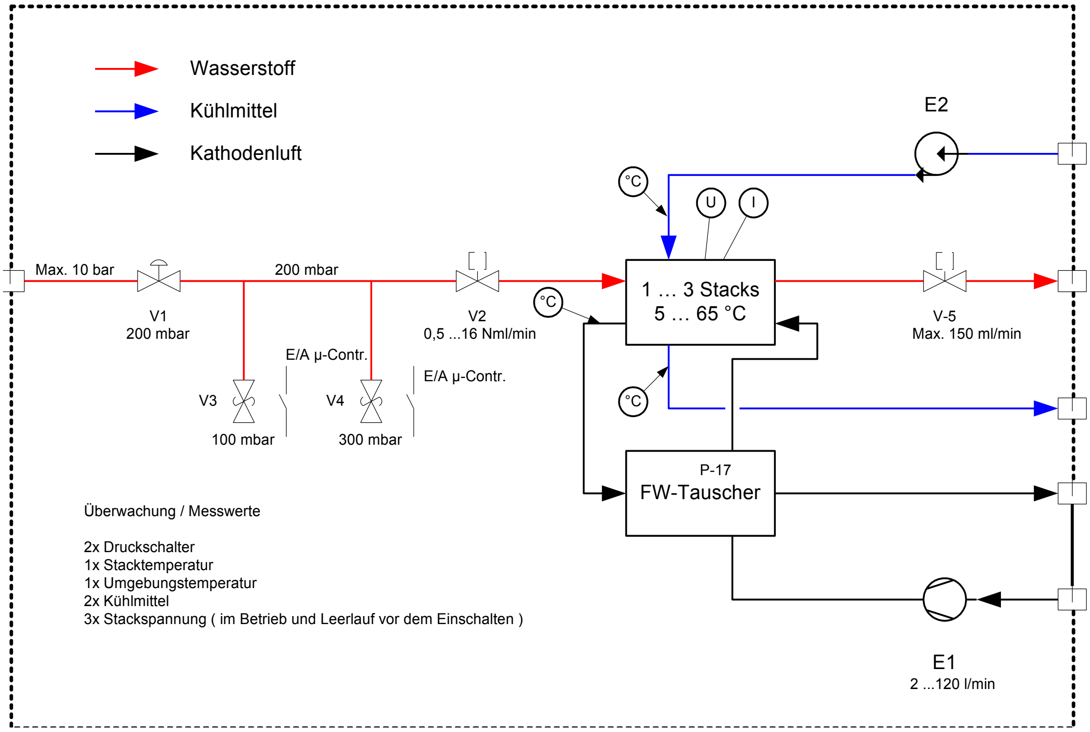


Figure 2.3.4 schematic diagram of the FC module

The fuel cell system was built up of the following main components:

1. Fuel cell module
2. Buffer batteries
3. Hydrogen storage (gas) + gas fittings
4. Power electronics
5. Outdoor cabinet

The system was developed for use in „fresh air' areas, and is shown in Figure 3.3.4.

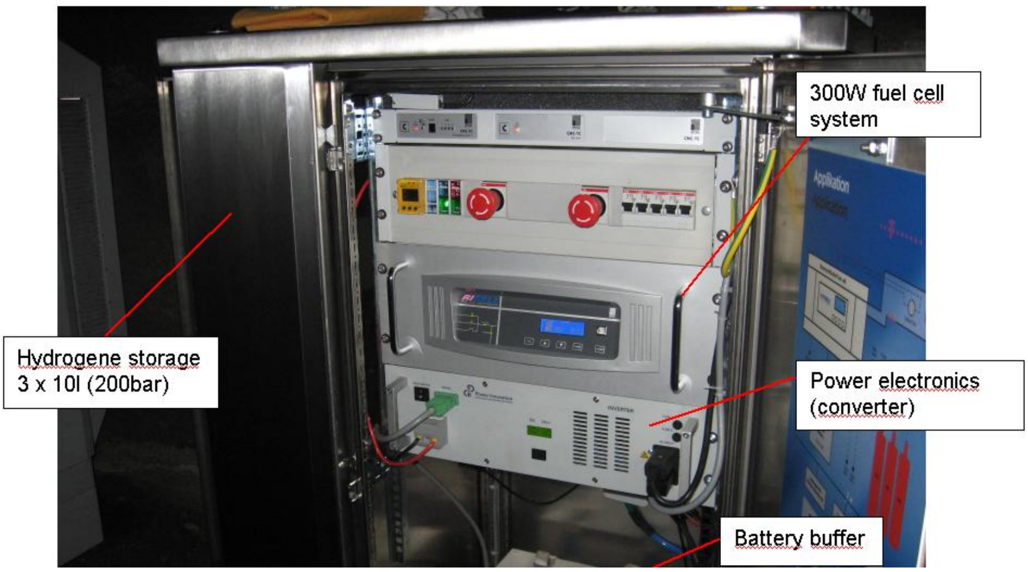


Figure 2.3.5 FC module integrated in an enclosure with gas storage and power electronics

Technical data of the system:

Reactants:	Hydrogen (purity grade 3.5)
	Atmospheric oxygene
Cooling:	Fluid cooling (glycol)
Voltages:	12VDC and 24VDC (230VAC, 48VDC with converters)
Output power:	300W
Hydrogen storage:	3 x 10l (200bar)
Ambient temperature:	+2°C until 50°C
Interfaces:	USB, Interface to Rittal CMC (Computer Multi Control)
Emissions:	Air, H2 (Purge), product water

Functional description:

During normal operation, the fuel cell (FC) is in standby-mode. The electrical system, consisting mainly of the battery buffer and the FC, is in parallel connection to the loads which need to be supplied in an emergency case and the primary power supply of those. The batteries can buffer short peak power demand, and supply the energy needed during the primary power-fault for an adjustable amount of time. If the voltage threshold is undercut, the fuel cell gets a starting signal and the FC takes over the energy supply, and additionally loads the battery buffer. If the primary power is available again, the upper voltage threshold is exceeded, and the FC returns independently to standby-mode.

In the same cabinet, but with clearly separated spaces, three compressed gas cylinders, each containing 10 litres (200bar) are installed, including a pressure regulator in order to provide appropriate system pressure. This application would provide backup power of 300W for approximately 24h, or 250W for 36h. For longer backup time, a larger gas enclosure for 2x, 4x, or 8x 50 litre gas cylinders can be coupled to the system, and/or 300bar technology used.

5kW fuel cell

A 5kW fuel cell and the cabinet shown below in Figure 2.3.6 was procured with the intention of conducting field trials as a part of Work Package 6 to determine if a higher output device could successfully power the entire lighting of the test mine in the event of a mains power failure.

Figure 2.3.6 5kW Fuel Cell Enclosure

The high humidity of the test mine combined with the fact that the supplier's system was not equipped with any protective mechanism such as heating or installation in the housing rapidly led to it failing to work correctly. Figure 2.3.7 illustrates some of the problems that result from the failure of the cabinet to protect the fuel cell system in a mining environment.

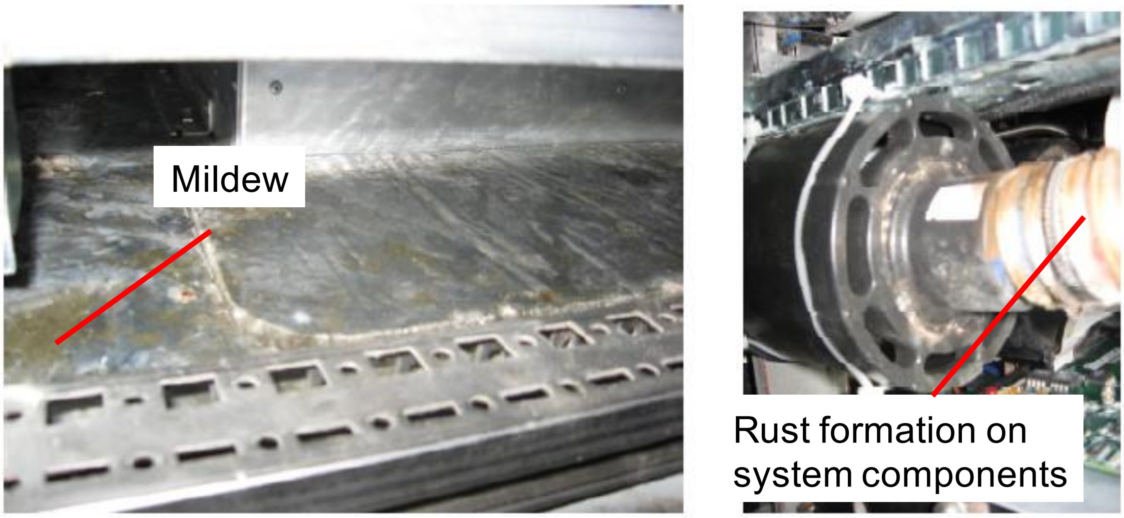


Figure 2.3.7 Degradation of 5kW Fuel Cell System

As the quality and the reliablity of the 5 kW unit was not sitable for use in a mining environment futher testing and devlopment concentrated on the use of the 300W FC module.

2.3.5 Conclusions for Work Package 1

After a detailed comparison of the different fuel cell types, it was concluded that the Proton Exchange Membrane Fuel Cell (PEMFC) and the Direct Methanol Fuel Cell (DMFC) are most suitable for use in mining, due to their very good dynamic behaviour. Of these, the PEM was chosen for further investigations with regard to the development of 5kW and 300W systems.

Risk analysis of the 300W fuel cell showed that it was suitable for „fresh air' areas of a mine; however, use in an M1 area is not achievable at present. Another key reason for it not being possible to use fuel cells in most mine transport systems at present is the power requirement. This research investigated systems up to 5kW, whereas 200kW would be required for monorail transport.

Several additional applications for fuel cells with an energy consumption of below 1kW were identified, especially those related to safety and control. One of these, use of a fuel cell as an emergency power supply, was used for further development as a prototype to be tested and evaluated within Task 6.1.

Bio-fuels could be used in underground diesel vehicles, offering reduced particulate emissions, but the engines would require tuning and adjustments. In practice the bio-fuels would need to be used as blends, probably up to a maximum of 5% by volume, in order not to invalidate the manufacturer's warranty. Higher percentage blends could be utilised in CHP systems.

A significant disadvantage of bio-fuels is that the cost of production is estimated at three to four times that of diesel.

2.4 Enhanced Transport Diagnostics and Management Information Systems (WP2)

Work Package Objectives

The primary objective of Work Package 2 was to conduct research and develop means to improve the monitoring and control of underground transport equipment and improve monitoring of the mine environment. To achieve this aim, a means for providing diagnostic, status and location information that would enable the more efficient management of underground railway rolling stock (trains/monorails) needed to be developed. This was to be achieved via the development of advanced sensor systems employing RFID technology that are able to transmit data via an ATEX certifiable wireless sensor network. Moreover, machine health status and diagnostic systems for underground mobile machinery which have the functionality of easily integrating with mine SCADA systems were to be developed along with 3D visualisation applications that can be used on mobile computing equipment such as PDAs.

2.4.1 Task 2.1 Selection of technology

In a number of European countries, including Poland, Germany and Great Britain, proprietary supervisory, control and data acquisition (SCADA) systems are in widespread use for controlling and monitoring underground plant and for monitoring the underground environment. These systems are based on fibre optic transmission backbones. The advantages of using a fibre optic transmission medium are:

a) total galvanic isolation between each end, due to no conductive path,

b) safe for use in hazardous areas,

c) light signals are impervious to interference from electromagnetic interference (EMI) or electrical cross talk,

d) light has a much higher bandwidth, or maximum data transfer rate, than electrical connections,

e) the signal in a fibre optic cable has a much lower loss rate, so its transmission distances are greater, than coaxial or twisted pair cable, before amplification is necessary,

f) there is no risk of an electrical shock when using fibre optic cables,

g) fibre optic cable is on average 10 times lighter than coaxial cable.

Wonderware's InTouch SCADA software was chosen to be developed for use in UK mines after a review of SCADA packages at the very beginning of the project. Various software packages are available, each with their advantages and disadvantages.

InTouch is a world leader (30% of the world's manufacturing plants employing over 20 people use Wonderware products) and it is also non PLC vendor specific. Although packages such as Rockwell's RSView, Siemen's WinCC and GE Fanuc's Intellution SCADA packages are stated to be capable of working with non Rockwell, Siemens and GE Fanuc PLC's, practical experience suggests that difficulties arise, such as configuring hardware connectivity. InTouch is also part of the Wonderware suite which includes InSQL, a data base product that is real time. InTouch is also intuitive to use, is evolutionary and can be used with previous versions relatively easily.

Although InTouch can operate on both personal computers and Macintosh machines, it was decided to use the personal computer (p.c.) version, because Windows® has predominance in the industrial market place. Furthermore, WonderWare and Microsoft are strategic partners, hence aiding both product development and customer support.

During the project, work was satisfactorily completed to transfer the control and monitoring of all underground plant, and the monitoring of the mine environment, at Daw Mill colliery from legacy systems to the SCADA software, InTouch. In total, over 22000 analogue and digital inputs to the SCADA system are either monitored or controlled. The system is configured with dual redundancy and uses both control and view nodes via a terminal server to sites around the colliery operating on a 100 MBaud Ethernet transmission backbone.

Location technology

Transport monitoring systems which are currently used in mines offer a cell-based localisation of mobile objects. This method allows very limited precision without real-time tracking. To offer a surplus to state-of-the-art technology, the MINTOS project investigated technologies that are based on the principle of distance measurement between mobile objects and stationary nodes. A technical research and market analysis led to two methods of distance measurements for further investigation:- a) Received-Signal-Strength-Indicator (RSSI) measurements and b) Time-of-Flight measurements. Both methods are applied on various transmission technologies (Infrared, Ultrasonic, WLAN, Bluetooth, several radio transmission implementations). The candidate technologies were intensively analysed with special regard to the demands of coal mining environments (Precision, Reliability, Installation complexity, power supply, etc.). Figure 2.4.1 below summarises the results of the analysis in the form of a technology specification matrix.

	868 MHz	2,4 GHz	Ultra Wide Band	Infrared	Ultrasonic	WLAN
Accuracy of localization	High	High	Very High	Low	Low	Low
Range of Coverage	High	High	Medium	Low	Low	High
Bandwith	Low	High	High	Low	Low	High
Data transmission	✓	✓	✓	✗	✗	limited
Hardware interfaces	✓	✓	✓	✗	✗	✗
Installation complexity	Low	Low	Very High	Medium	Medium	Medium
Transmission reliability	High	High	Medium	Low	Low	Medium
Equipment cost	Medium	Medium	Very High	Low	Low	High
Suitable for mining applications	✓	✓	✗	✗	✗	✗

Figure 2.4.1 Technology specification matrix for tracking systems

Following the results of the initial research, two evaluation kits were selected:- one system in the 868 MHz band, based on RSSI-measurements and a 2,4 GHz system using Chirp-Spread-Spectrum transmission (CSS) and Time-of-Flight (ToF) ranging methods. Both systems were evaluated underground. Tests and measurements revealed that, in the case of the 868MHz RSSI measurement system, both the transmission quality and the ranging performance did not perform well underground. Narrow tunnels led to reflections that had a massive impact on the narrow band signal. Solid, reliable communication was not possible beyond 40m. and no signal was detectable after 100m. The 2,4 GHz system, however, could perform in the same environment with very stable transmission at distances of up to 250m. The precision of the initial distance measurements was very good, with an average error of less than 1 metre.

Distance [m]	Measured [m]	Error [m]
5,3	5,1	0,2
10,0	10,6	0,6
14,6	14,7	0,1
19,8	20,0	0,2
24,9	25,0	0,1
34,9	34,9	0,0
39,6	39,8	0,2
45,3	45,9	0,6
49,7	50,5	0,8
101,5	101,0	0,5
	Average	**0,3**

Figure 2.4.2 Results of underground measurements with 2,4 GHz CSS - ToF system

The results of the tests, carried out by Rittal in the iron ore mine Grube Fortuna, were consistent with those observed in the case of tests in a coal mine, which had been carried out by EMAG in the course of a preceding project (NEMAEQ). Based on this experience, it was concluded that CSS technology is applicable for general mining applications and that it provides reliable transmission, with high precision of the ranging measurements. For this reason it was selected as the technology of choice for the vehicle location sensor development undertaken within task 2.2.

For the purpose of providing a three dimensional visualisation of the tracking application, a user interface based on the 3D-core component of XGraphic was selected. It allows free navigation in 3D models of mines and freely definable objects. An import of DXF and DWG (made with AutoCAD or Inventor) is possible. To maintain compatibility with current GIS/SCADA software and available 2D mine plans, a FlexGraphics based solution was selected.

Diagnostic techniques

Advanced techniques of acoustic emission-based detection of bearing failures were reviewed and laboratory tests with a 6209-RS bearing carried out, in order to establish requirements for the DSP subsystem. As a result, analogue to digital conversion resolution, processing power demands and buffering requirements were determined. ATEX suitability was assessed and it was decided to use a low power, fixed point, DSP subsystem proven in other EMAG's products, but with required modifications regarding the ADC and buffering block. These requirements were taken into account for the signal processing module of the sensor head developed within task 2.2.

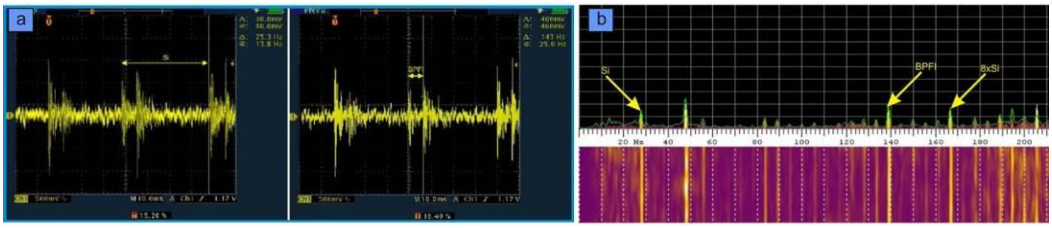


Figure 2.4.3 Laboratory tests of 6209-RS bearing: fault signatures (a) time domain (b) spectral

Several acoustic emission sensor types and their possible setups were analysed and tested in laboratory and real conditions to find one of sufficient performance. Finally an accelerometric sensor with direct coupling was selected, as a result of a number of in-situ tests carried out in real conditions in the KWK Ziemowit mine (see Figure 2.4.4). Data synchronisation methods were also investigated and the results used in task 2.2. Additional tests were also carried out in the Ziemowit mine to determine temperature rise distribution on faulty wheelset rollers and to provide the requirements for the detection of roller overheating. The results of these tests were utilised during the contactless temperature sensor development.

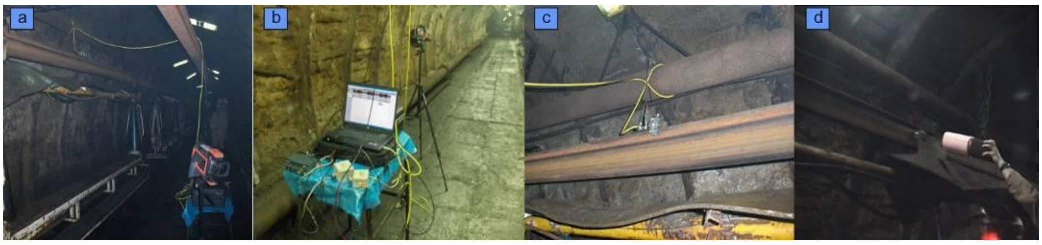


Figure 2.4.4 Tests in real conditions to determine acoustic emission sensor type and configuration

2.4.2 Task 2.2 Development of sensor systems

Location sensors with Ethernet interfaces

Based on the selected technology, a concept of the system, including all components, was derived. To transmit the collected data from the stationary nodes to the surface control room, Ethernet was selected as an information backbone. This interface is state-of-the-art technology and available in most European coal mines. It also allows a connection to the µZist communication system, which was developed within the NEMAEQ project. The board was laid out with regard to possible ATEX-M1 zone certification at the later ‚product' stage. The microcontroller AT91SAM7X was chosen, since it has a very low energy consumption (max. 90 mA at 1.8V), but still offers the required interfaces (Ethernet, USB, Serial). Figure 2.4.5 describes the electrical interfaces and components leading to the microcontroller.

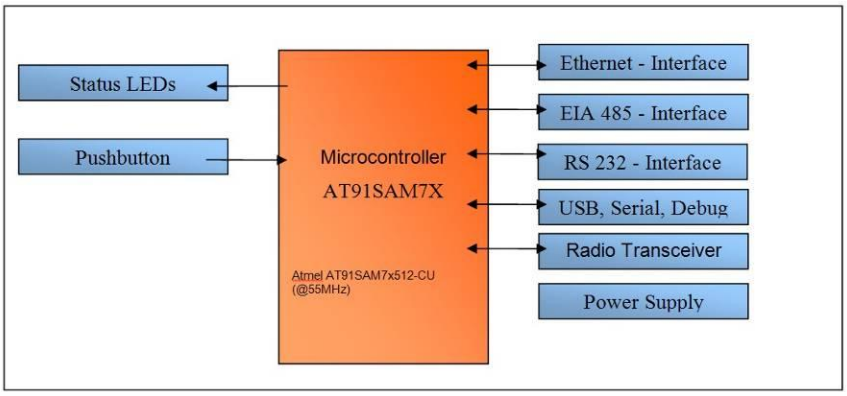


Figure 2.4.5 Electric components and interfaces of the stationary node

The collected ranging values are transmitted via Ethernet to the visualisation server which calculates the positions, based on a 3D model of the operational environment. The ranging values are transmitted as plain text. The firmware of the stationary nodes was set up on the open source Nut/OS microcontroller Operating System. It allows thread-based operations and offers a TCP/IP protocol stack (Figure 2.4.6). After booting up and initialising the TCP/IP connection, the system detects mobile nodes in its area of coverage and forces a ranging operation between both nodes. The ranging values of all nodes are stored and transmitted to the server every second. To permit a long battery lifetime and smaller battery sizes, the application of the mobile nodes was kept as simple as possible. Their only function after initialisation is the performance of ranging measurements with stationary nodes.

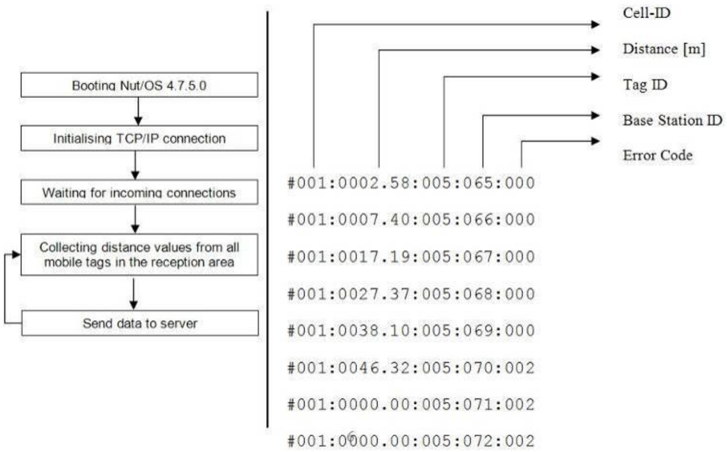


Figure 2.4.6 (a): Application flow chart of the stationary node
(b) Received string of distances at the visualisation software

Location sensors with intrinsically safe fieldbus interface

To ensure minimised infrastructure cost, an advanced and innovative solution of the transmission and power supply subsystem for the location sensors was developed. Advantage was taken of the requirement for a reduced number of intrinsically safe power supplies and low maintenance cost, because standard mining copper pair cable is used as a medium. Data is exchanged with individual sensors connected to the common fieldbus lines, which in turn are connected to µZist type multiplexers. The solution facilitates the connection of up to four branches (each 2000m long) per multiplexer, which itself contains up to 10 sensors, without exceeding the limits for intrinsic safety. The resulting maximum theoretical coverage is 8km of underground workings per single multiplexer. This leads to significant cost savings.

Apart from the transmission and power supply system, the sensor nodes were equipped with the newest revision of a microwave power amplifier and low noise pre-amplifier to ensure high output power and high sensitivity, in order to achieve a large area of radio coverage. The wireless transmission distance was measured at over 2km line-of-sight in an open space/surface environment and typically 350-500 metres line-of-sight in underground conditions. Such performance results in a lowering of infrastructure cost, since fewer nodes are required per unit length of roadway. The developed devices, dubbed LHU, are housed in alloy type high IP rating enclosures and are connected via high performance industrial connectors, to ensure reliable operation within the mining environment, which was verified during the field trials undertaken within WP6 (Figure 2.4.7).

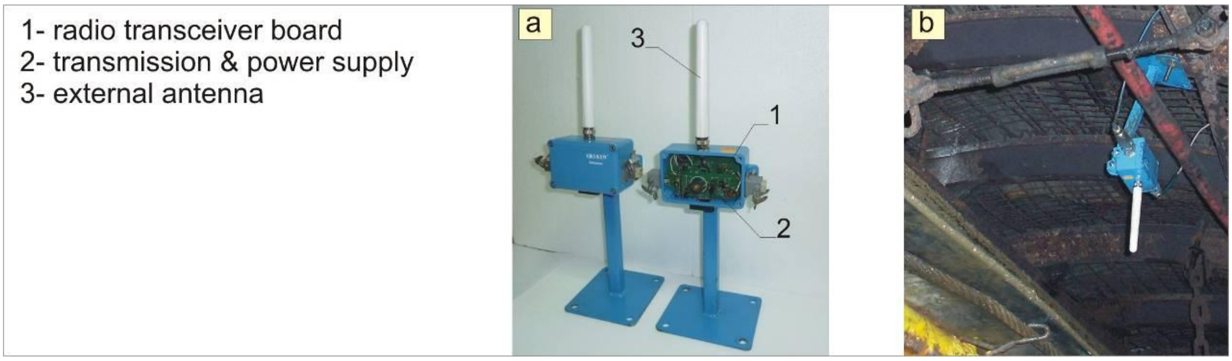


Figure 2.4.7 : (a) Location sensor type LHU ('base station'), (b) Mounting option

Vehicle mounted equipment – mobile nodes

In order to make the real time location process possible and also provide means for data exchange with moving vehicles, dedicated mobile nodes were developed. The devices can be mounted within the cabins of monorail or floor trains. The device, dubbed CDU, is housed in a stainless steel enclosure and is equipped with 4.3 inch colour display and six programmable user interaction buttons (Figure 2.4.8). It is based on a low power computing platform capable of running the WinCE or Linux operating systems. The developed device has the advantage over the currently available explosion proof PDAs in that it is based on a powerful and energy-efficient ARM Cortex A8 processor with 2D and 3D graphics acceleration and, most importantly, it also integrates the wireless location node electronics within a single enclosure.

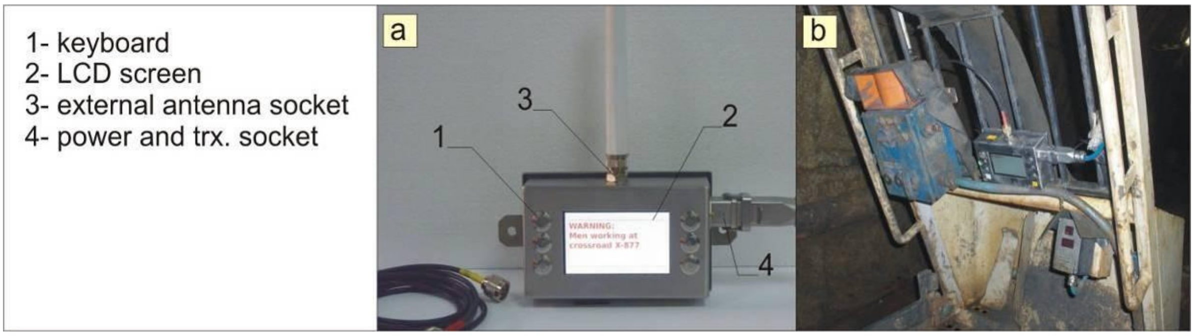


Figure 2.4.8 (a) vehicle mobile node type CDU , (b) Mounted in monorail cabin

Vehicle diagnostic subsystem

In order to provide for diagnostic and status information from vehicles, a solution based on wayside sensors and train uplink capabilities was employed. Based on methods researched within task 2.1, a dedicated sensor, a fusion of acoustic emission sensing and remote temperature monitoring, was developed (Figure 2.4.9). The initial concept for the device envisaged the deployment of a fibre optic connection to μZist multiplexers. However, it was found to be more sensible to use a uniform type of interface and, therefore, the final prototype of the developed device uses the same transmission and power supply interface as developed for the location sensors. In this case multiple distributed sensors can also be connected to the µZist data multiplexers. However, due to higher power consumption requirements, compared to the location sensors, „only' 5 devices can be connected to a single branch.

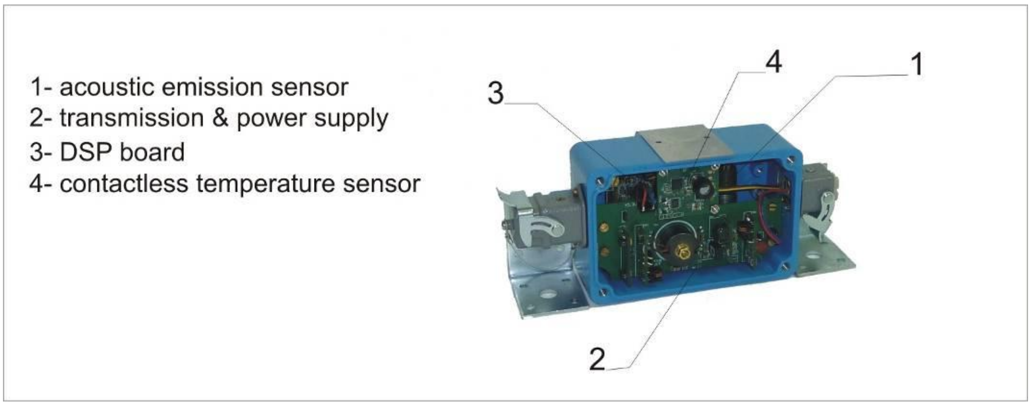


Figure 2.4.9 Wheelset diagnostics sensor type DHU

In order to maintain correct operation with a lower data throughput of the fieldbus interface, additional data buffering was ensured by use of a mobile SDRAM memory. The sensor uses state of the art techniques of low power digital signal processing, such as an energy efficient fixed point digital signal processor with DMA data pipelines and a low power, high sample resolution analogue to digital converter. The signal from the acoustic emission sensor is converted within an analogue to digital converter with 16-bit resolution, and then passed to the DSP for processing. Firstly the structural noise removal procedure is applied, to filter out enclosure resonances. Then, based on amplitude envelope analysis, the signal from the pre-buffer is cut into „chunks', representing the sampled signal of passing wheelsets. This helped to decrease the bit rate of the resulting stream and demands for computational power. The pre-processed data is sent to the main application where it is combined with synchronising information, i.e. timestamps and the distance to the nearest location sensor, referenced from the front or rear of the locomotive. Spectral and statistical trend analysis is then carried out and used for fault pattern recognition for each wheelset individually. Thanks to good practical accuracy of the location system, a simplified approach for spatial fault location, without the need for RFID tags on individual wheelsets, was possible. The only downside of this solution is that up-to-date train assembly information must be kept in the application's database, in order that relative distances are known. The scheme of this implemented acoustic emission based method is, in principle, able to detect at which wheelset the defect occurs. The method was found to operate reliably in cases where severe bearing damage had occurred. To complement the acoustic method, a dedicated digital pyrometric sensor was developed and then integrated with the complete diagnostic sensor head (Figure 2.4.10).

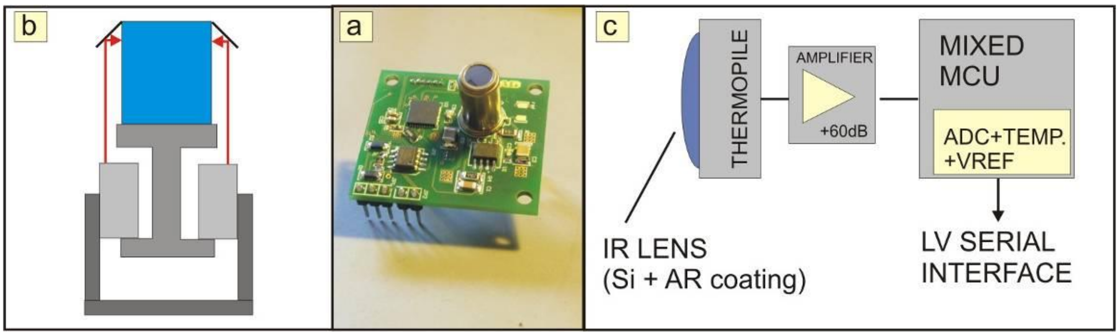


Figure 2.4.10 (a) contactless temperature sensor, (b) – operation principle, (c) block diagram

The infrared radiation emitted by the surface of the passing rollers is reflected by the 45° mirror. Then it passes the optical path of the sensing element (a lens with a protective window) and induces a voltage signal (in the range of micro-volts) within the thermopile element. The signal is then amplified by a 60dB amplifier and fed to the input of the A/D converter of the mixed signal microcontroller, to be sampled 250 times a second. This enables the provision of multi-point temperature measurements for each roller (at least 10 - 15 temperature readouts are performed, assuming the maximum allowable speed for the monorail). The samples are then processed by applying the ambient temperature offset correction.

Temperature readouts for the left and right side of the wheelset are then averaged and transmitted, along with the acoustic data frame, to be compared with threshold values within the main application. This method of measurement was found to be reliable for the early detection of poor lubrication and jamming conditions, thereby enabling, to some extent, preventive maintenance actions.

Locomotive diagnostic information data link

The diagnostic subsystem also provides a means for the on-line delivery of locomotive diagnostics data. For that purpose wireless link capabilities of the vehicle mobile node CDU can be used. Diagnostic information, such as engine temperature, pressure within the hydraulic system, status of electro-valves, is typically available on the vehicle’s PLC via various interfaces (i.e. RS,CAN-bus or wireless transmission). In order to enable access to this data, close co-operation with individual train manufacturers is required. EMAG was granted access to PLC diagnostic information from one floor-mounted train manufacturer, for the purposes of the first commercial installation (see exploitation of the results section).

2.4.3 Task 2.3 Development of demonstration applications

Demonstration application with tracking and 3D visualisation

A demonstration application was installed in the Fortuna ore mine. The mine had been equipped with a fibre optic backbone between the research mine segment and the mining control room at the surface. The research area was equipped with four base stations, covering an area of approximately 500 metres in three directions. The mobile tag was redesigned in a small and handy design; the final version, which is shown in the Figure 2.4.11 below, is operated by an Atmel ATMEGA64 microcontroller.

Figure 2.4.11 Redesigned mobile tag

The 3D visualisation software, which displays a model of the Fortuna mine, was installed in the mining control room. All measured data from the research area, at 150 metres depth, was collected and analysed in the control room. The system was comprehensively installed, in order to allow for further field trials at future dates.

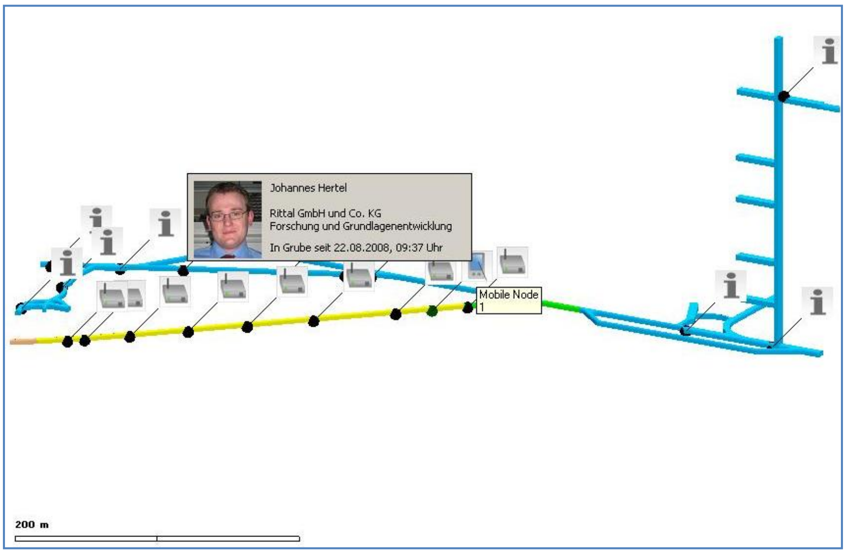


Figure 2.4.12 The 3D visualisation with a model of the Fortuna mine.

The implemented demonstration application in the Fortuna research mine segment formed a solid environment for tests and measurements in the field trials of WP6.

Demonstration GIS/SCADA application

A demonstration application for the underground vehicle dispatcher stand and the mine control room was developed. It integrates GIS/SCADA functionality and provides a means for the efficient management of an underground vehicle fleet and was primarily targeted at monorail transport. The geographical information is presented as a vector mine workings plan with all the advantages of vector representation (zooming, panning etc.). CAD mine plan drawings can be easily converted and imported from dxf/dwg files (all Polish mine plans are available in this popular format). Information from the SCADA subsystem is overlaid on the GIS map with the possibility to switch on and off any information layers. Several alternative options for the graphical user interface were evaluated as the software evolved. As a result of co-operation with the KWK Ziemowit mine (the future end-user) the current revision of the application offers both simplicity and the required functionality (see screenshot below).

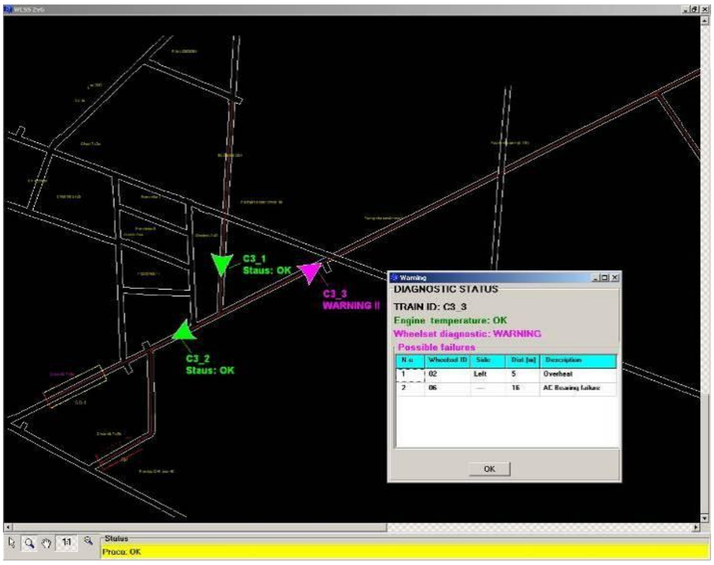


Figure 2.4.13 Mature revision of demo application (WLSS- formerly 'Train Manager')

The positions and heading directions of individual vehicles are calculated based on data from the location subsystem. They are presented, together with the identification numbers, in an animated graphical form which is updated at one second intervals. Status information is derived from data collected by the diagnostic subsystem. Different colours are used to distinguish between the normal state, alarms and warnings. In the case of diagnostic warnings, clicking on a highlighted vehicle icon opens the modal window with detailed information regarding any possible failure type and faulty component location. In the case of alarms initiated from the vehicle, a special mode is displayed immediately, regardless of the status of the window focus and selected region (see Figure 2.4.14).

Figure 2.4.14 Demo application –priority message type: alarm from vehicle

For the purpose of the underground train dispatcher stand, the application needs to be installed on an explosion proof PC. This was originally developed to be used with a GKP-09 computer. For the case of the mine control room, it is preferable to install the application on any large screen format PC.

2.4.4 Task 2.4 Provision of Management Information

The developed demonstration application provides dispatchers with an easy to use and straightforward means of facilitating the efficient management of the underground vehicle fleet. The dispatchers are provided with online-updated information on vehicle distribution, their diagnostic status and triggered alarms. Thanks to bidirectional wireless transmission provided by the distributed location sensors, LHU, the application enables interaction between the dispatcher and the vehicle operators. The dispatcher can send orders, warnings and other types of information by an implemented text message mechanism. Messages can be sent to individual vehicles or to their groups (as depicted below).

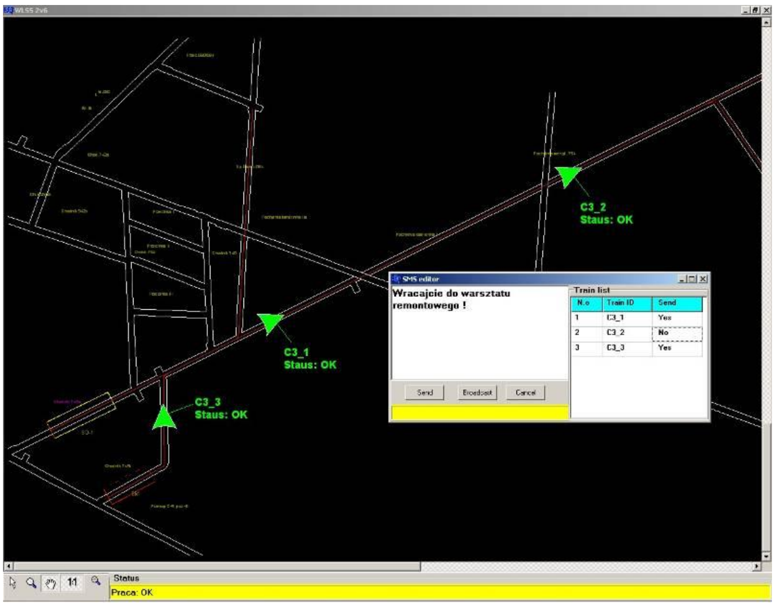


Figure 2.4.15 MIS features of demo application - sending text message commands

Messages are received by selected vehicle nodes and presented on the display of the cabin display CDU. Colour marking codes are used to differentiate between normal messages and warnings/alarms. Similar to the dispatcher application, the alarm messages have priority over regular messages and are displayed immediately, regardless of actual device state. Each message received must be acknowledged by pressing a dedicated button. In order not to lose any new incoming messages, for example in the instance that a message may not have been acknowledged, a FIFO mechanism was implemented.

Support for raising an immediate alarm from vehicles was also ensured. For that purpose, a dedicated button is used to trigger the immediate alarm, which is sent to the dispatcher application by means of the transmission uplink. For storing of the SCADA information a common approach employing an SQL database was used, in order to maintain compatibility with the other SCADA software (especially the SD2000 system).

2.4.5 Conclusions for Work Package 2

After assessment of a range of SCADA software packages to be installed for future use in UK mines, Wonderware's InTouch SCADA was selected. Work was then undertaken in conjunction with UK Coal to transfer all the control and monitoring of underground plant and the mining environment at Daw Mill Colliery to this software.

A detailed market analysis of current tracking and localisation systems was carried out and their applicability in underground environments evaluated. As a result, a suitable and extendable system was chosen for the tracking system, with Time-of-Flight ranging methods. Narrowband transmission and Signal-Strength based systems were discounted. Additionally visualisation systems for 2D and 3D mine map representation were selected. A study of diagnostic methods based on acoustic emission analysis was undertaken. Laboratory and in situ tests were carried out, resulting in the selection of suitable acoustic sensors and a signal processing subsystem. Tests in real conditions with spatial temperature rise observations helped to provide information on the requirements for the contactless temperature sensor developed subsequently.

A demonstrator of the tracking system, consisting of mobile nodes, stationary nodes and visualisation software was developed and implemented. The system was adapted and prepared for underground tests in an iron ore mine. An ATEX-compliant version of the location sensors, with innovative power supply and transmission, was developed and interfaced to a µZist backbone transmission system. The resulting solution enables large area coverage, with only limited resources required. A vehicle mobile tag with a simple user interface was developed. It takes part in the real time location process, as well as facilitating interaction with the underground dispatcher. A sensor head for wheelset diagnostics was developed, combining both acoustic emission and contactless temperature measurement methods, in order to provide a broader scope of failure mode detection.

The implemented demonstration application in the Fortuna research mine segment formed a solid environment for tests and measurements in the field trials of WP6. A demonstration GIS/SCADA application for the underground dispatcher and mine control room was developed. It enables online visualisation of vehicle positions and heading directions and their diagnostic status. The developed software also provides a means of simple and efficient interaction between vehicle operators and the underground dispatcher.

It was concluded that the transmission capabilities of the developed sensor system can be effectively used for the provision of information which is vital from a fleet management point of view. Features facilitating interaction between the underground dispatcher and the vehicle operators were successfully developed. Implementation of text command dispatching, warning and alarm broadcasting can improve both the efficiency of transport system operation and its safety. Implemented features provide a means for effective underground fleet management and for ensuring reliable operation of the transport process.

2.5 Improved Fire Control in Mine Transport Systems (WP3)

Work Package Objectives

Diagnostic and location information can play a significant role in fire detection and fire fighting applications. A prime objective of this work package was to produce a more effective fire prevention and early-fire detection system for rail based transport, based on the sensor technology developed under WP2. Other aims were to develop a training simulation to facilitate the early and effective implementation of fire prevention and early-fire detection systems and to develop an on board engine compartment, cab and wheel arch fire fighting system which can be periodically tested and still retain an operational capability.

2.5.1 Task 3.1 Fire detection software

Initial work in task 3.1 was dedicated to resilient over-temperature and fire hazard detection in the engine compartment of diesel monorails via the use of wireless sensors. A simple demonstration application enabling the configuration of sensors and the sending of information concerning detected temperature rise to the dispatcher's application was developed. As agreed with mine experts from Ziemowit colliery, it was found to be even more important to implement the transmission of fire related information (alarms/warnings) to vehicle operators. This feature relies on a downlink of the transmission subsystem, which is used for the manual or automatic fire alarm broadcast from the dispatcher's application to vehicles. For broadcasting of alarm signals set by the dispatcher manually a „region assigned broadcast' feature for the dispatcher application developed in T2.3 was implemented (see Figure 2.5.1).

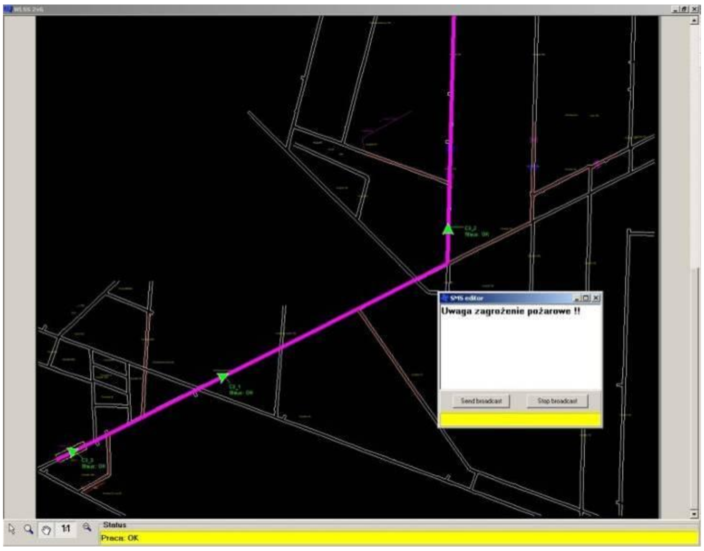


Figure 2.5.1 Region assigned alarm message broadcast

To achieve automatic operation, a dedicated control scheme was developed. It relies on an alarm dependency translation matrix which assigns a PA (alarm broadcasting equipment) to an individual region serviced by the wireless LHU station. Additionally the alarm/warning type, which is normally broadcast by the alarming system (such as SAT,STAR) is translated into a predefined text message to be broadcast. Such an approach enables the broadcasting of alarms and warnings to any vehicle entering the affected region. Primarily an interface with EMAG's SMP-NT fire monitoring system was envisaged but then a more versatile and multi-platform approach was introduced, as shown in Figure 2.5.2. Information on fire alarms from the mine's primary fire detection systems can be acquired from the MAW interface ([mgr inż. Grzegorz Mirek „Moduł akwizycyjno-wyzwalający typu MAW Dokumentacja Techniczno-Ruchowa' TIT EMAG).

The MAW module is a highly resilient type of interface acquiring alarm signals from gas and fire monitoring systems popular in Polish coal mines. It can operate with the following safety monitoring systems: SMP-NT, SMP-NT/A, ZEFIR, SWuP, KSP, KSP-2. For the purpose of the demonstration software, the translation function was integrated with the main application developed within task 2.3.

Taking advantage of the open architecture of the MAW module, it is also possible to develop a direct interface within the MAW module (no translation in the main application would then be required). Such an approach would also benefit from the redundant fail-safe architecture of the MAW module. An additional advantage is that the MAW module can be interfaced to virtually any fire/gas monitoring system, which would facilitate wide application in European/worldwide mines.

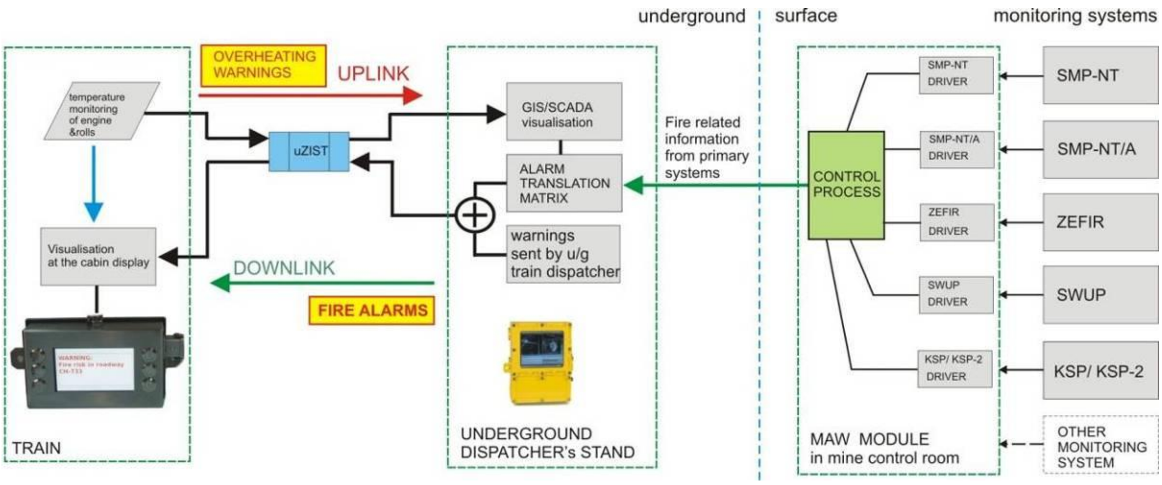


Figure 2.5.2 Integration with monitoring systems

2.5.2 Task 3.2 Development of training aids

To facilitate the early and effective implementation of the fire prevention and early-fire detection systems, a training aid simulation was developed. The content of the training simulation package is based on the following four underground transport crew evacuation scenarios, which were developed in collaboration with KWSA:

1. A methane ignition occurring during the assembly of roadway supports,
2. The migration of fire smoke along transportation roadways,
3. An exogenous fire in the engine compartment of a suspended monorail,
4. An indigenous fire in a tailgate.

To ensure the training simulation package presented accurate and realistic fire development and smoke migration scenarios, the following CFD (Computational Fluid Dynamics) models were developed:

- volume fraction of methane,
- volume fraction of carbon monoxide,
- velocity vectors of the analyzed atmosphere,
- smoke migration on the transportation roads

The resultant computer animated movie of crew evacuation provides training material which, in turn, provides an effective demonstration of the underground transport fire scenario outlined below:

1. The suspended monorail, after moving through a crossroads, moves through the ventilation dam and then further through the drivage. At the same time, after methane ignition, smoke overtakes the suspended monorail. The operator, after reaching the next crossroads, sees smoke and, according to regulations, stops the monorail and the miners put on chemical oxygen escape breathing apparatus.
2. Breathing apparatus works for one hour only. People go back on foot towards the ventilation dam.

3. Behind the ventilation dam, visibility is almost zero. Here the group divides into two. One of them moves along the designated rescue ways (upstream in the direction of the smoke source). The rest of them go to the other safety area towards the ventilation shaft. The personnel who were moving along the rescue way reach the stream of fresh air and are safe. Personnel who returned, due to time and the longer distance, are not able to reach the safe zone within 1 hour.

Selected scenes from the computer animated movie of crew evacuation developed by the project are shown below:

Figure 2.5.3 The suspended monorail moving through the crossroads

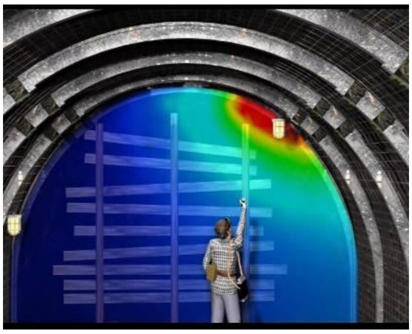


Figure 2.5.4 Methane source and incorrect measurement

Figure 2.5.5 Correct measurement position

Figure 2.5.6 Display of Measurement Results

Figure 2.5.7 Methane explosion occures

Figure 2.5.8 smoke migration through the ventilation dam

Figure 2.5.9 After one hour breathing apparatus stops working

Figure 2.5.4 illustrates a methane source; the methane distribution map is obtained from CFD calculations and shows how incorrect assessments of methane concentration can arise. Figure 2.5.5 shows the position required to obtain correct measurements and Figure 2.5.6 illustrates the display used to show the methane concentration values obtained.

Figure 2.5.7 shows the occurrence of a methane explosion and Figure 2.5.8 illustrates the propagation of smoke through a ventilation dam. These propagation patterns are also derived from the CFD models developed for this task. Finally, Figure 2.5.9 shows the situation after one hour when the chemical oxygen escape breathing apparatus stops working.

2.5.3 Task 3.3 Water Mist Fire Fighting System

The task objective was to develop an on board engine compartment, cab and wheel arch fire fighting system, utilising Watermist technology, which can be periodically tested and which will maintain operational capability.

The work was sequenced as follows: a) development of test equipment and test methodology, b) fire tests in simulated vehicle units, c) acquisition and preparation of a mine test site, d) underground full scale mine vehicle fire tests and e) development of a prototype vehicle watermist fire fighting system.

The choice of nozzles was based on the results of laser intephonerometer tests which were carried out at pressures of 50, 70 100 and 120 Bar. With increases of applied pressure over this range, from 50 to 120 Bar, the distribution of droplet diameters showed only a small reduction in droplet size, with the majority of droplets within the range 80 to 120 microns. After several miscellaneous tests, three nozzles were selected for a final range of trials. These nozzles were a single hollow cone RXT 1116 nozzle, a cluster nozzle V1, which utilised 5 forward facing hollow cone RXT 1116 nozzles and a new cluster nozzle V2 based on a refined version of the cluster nozzle V1. Several application pressures were tried, ranging from 130 to 50 Bar, and 80 Bar (8MPa) was selected as the working standard. At this pressure, the nozzles demonstrated a general effectiveness with minimal mist application. The V1 cluster nozzle and spray patterns for the three nozzles, an important factor in determining their effectiveness, are shown in Figure 2.5.10 to Figure 2.5.13

Figure 2.5.10 Cluster NozzleV1

Figure 2.5.11 Single HC Spray

Figure 2.5.12 3 Nozzle V1 Spray

Figure 2.5.13 Nozzle V2 Spray

A simulated vehicle test unit was constructed, using fire retardant timber and steel, with individual elements designed to represent the engine compartment, wheel arch and cab of an underground Free-Steered Vehicle (FSV). Initial testing with the different nozzles was undertaken using a portable lance, which was adapted to take each of the nozzle types. This allowed for the optimum position of the nozzles to be determined and these positions were then used during the subsequent trials when the nozzles were fixed at specific locations on the test unit. The positions utilised were 300mm above the centre point of the engine in the engine compartment, 700mm above the axle position in the wheel arch and 500mm above the steering column in the cab. The approximate flow rates for each of the nozzles, for a three-second application of the watermist spray, were 75cc for the hollow cone nozzle, 220cc for the cluster nozzle V1 and 150cc for the cluster V2.

Fires were initiated at each of the three locations using a diesel fuel / hydraulic oil mix and thermocouples placed to record the fire „seat' temperature and the „general body' temperature.

Each of the three nozzle types was tested in the engine compartment and six tests using each nozzle, and under the same conditions, carried out. All six tests carried out with the cluster nozzle V1 resulted in instantaneous flame extinguishment on application of the watermist. This nozzle demonstrated a very high level of effectiveness.

The results of the cluster nozzle V2 tests showed less effectiveness in flame knock-down capability. Two of the six tests required a second application of mist at 95 seconds to effectively extinguish the flame. In the remaining tests, the flame was extinguished at 2 to 3 seconds of the mist application period. The nozzle is still considered as being effective when considering the very small amount of water used to extinguish the fire. The difference in effectiveness, when comparing the V1 and V2 cluster nozzles, was considered to be an effect of the differing spray patterns. The spray pattern of the cluster nozzle V2 consists of more „singular' entrained mist jet streams, compared to the more uniform flooding effect of the cluster nozzle V1.

The six tests using the single hollow cone nozzle also demonstrated a high level of effectiveness of flame extinguishment with a single 3 seconds blast of mist. None of the six tests required a second application of mist, but the flame knock-down and extinguishment was not instantaneous as demonstrated with the cluster nozzle V1.

The results of the six tests in the wheel arch unit using the single hollow cone nozzle showed rapid cooling of the fire seat after the mist application. As with the engine tests, the flame was extinguished within the 3 seconds mist blast, but extinguishment was not instantaneous.

The results of tests in the cab unit using the cluster nozzles V1 and V2 showed that all of the six tests for both these nozzles were successful in extinguishing the flame within 3 seconds of watermist application. The cluster nozzle V1 again demonstrated instantaneous flame extinguishment.

The planned tests on underground vehicles at a UK coal mine could not be undertaken, because the mine test site became unavailable due to major operational difficulties experienced at the colliery. However, a rock salt mine in Northwest England offered to accommodate the trials underground, in old workings, using two scrap diesel transit vans, one being chosen for miscellaneous tests and the other chosen for a fixed system test.

The results of these underground fire tests carried out on the vehicle with the fixed extinguisher system generally compared very closely to the results obtained with the fire simulation units. The cluster nozzle V1 demonstrated high efficiency with instantaneous flame extinguishment in all tests. The single hollow cone nozzle extinguished the fires within the 3 second application period but again the flame was not extinguished instantaneously. The cluster nozzle V2 required a second application of mist on each test. The tests carried out in the second vehicle made use of the portable lance and the nozzles were place in several locations. The cluster nozzle V1 worked effectively with its ability to completely flood a void with mist. The single hollow cone nozzle and the cluster nozzle V2 demonstrated positional problems and the need to be sited correctly for effective extinguishment capability.

Following the overall success of these underground trials, a prototype vehicle fire extinguishing system was designed. The basic concept is a system where water is stored in tanks, which are pressurised with nitrogen and used for watermist applications. The chosen watermist nozzles will be positioned at key points around the test vehicles and connected to the pressurised water reservoir by suitably rated and reinforced hoses via a control manifold. A schematic layout is shown in Figure 2.5.14 and three views of the system installed on a mock-up vehicle structure, including the portable lance, are shown in Figure 2.5.15.

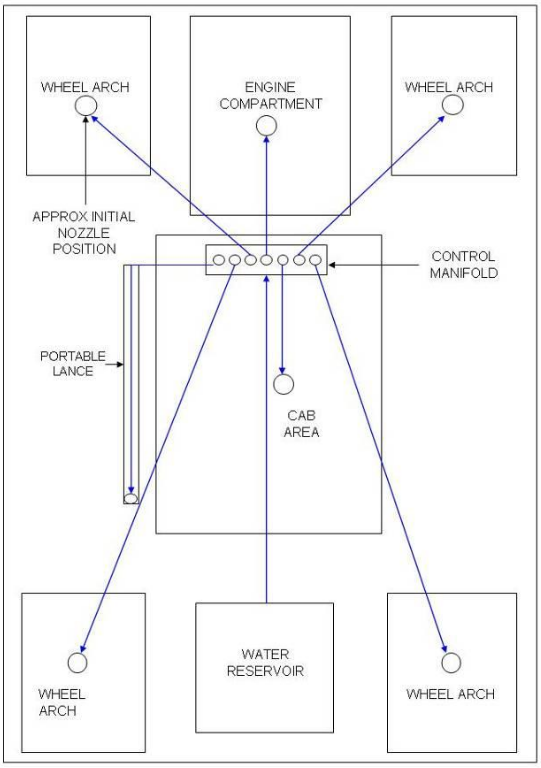


Figure 2.5.14 Schematic Layout

Figure 2.5.15 Prototype ystem suspended on a frame

The system is designed for simplicity, yet it offers a high level of fire protection with minimal amounts of water usage. The system is also robust, modular and can be altered to suit many variations and requirements of a fire suppression system. Furthermore, this system can be installed by mine personnel without special requirements, other than an understanding of pressurised systems and the associated precautions that must be adhered to when installing, servicing/maintaining/charging reservoirs or operating such systems.

Maintenance of the system is straightforward, with a specified periodical check which would conform to mine rules. The checks would incorporate examining the visual condition of the nozzles, nozzle brackets, exposed hoses/pipes, reservoir condition and contents gauge, and an operational check of each nozzle. Quick change couplings are proposed, to allow for easy reservoir changes, as required. It is intended that mica nozzle covers be positioned over all nozzles; these covers would then be blown off if the system is activated. With the reservoir containing 10 litres of water, a 3 second blast using 220cc with the cluster nozzle V1 gives approximately 45 blasts. In the event of a fire, it is recommended that the required valve(s) is left open, to completely ensure extinguishment, and the reservoir changed as part of the safety check and necessary repair work prior to any such vehicle being re-commissioned.

From all of the experimentation carried out with the three nozzle types, there is a strong indication that the system is extremely effective in fighting vehicular fires in the specific locations as chosen in this research component. Minimal amounts of water have been used which allows for the system to be checked without losing fire fighting capability. This is the only onboard vehicular fire fighting system that would allow a test/check to be made, yet still maintain operational integrity.

2.5.4 Conclusions for Work Package 3

The most important achievement of task 3.1 was providing the vehicle operator with automatic fire alarm functionality. The developed scheme can be expanded beyond fire related alarms, because the MAW module operates with a wide span of safety monitoring systems. Such functionality is complementary to classical „audio' alarm broadcasting but is characterised by a superior range (hundreds of metres), compared to the limited range of audio signalling alarm broadcast and, also, the alarm is not affected by acoustic noise.

The developed alarm broadcasting scheme will be exploited within the future products of EMAG, especially in integrated alarm systems for broadcasting gas and fire related alarm messages not only for transport systems but also for personal warning in day to day operations.

The training aid simulator, developed to familiarise mineworkers with the correct procedures to follow in the event of a fire alarm, provides a very realistic and visual training tool. Four scenarios were developed, in conjunction with the mine operator, and the results of computational fluid dynamics modelling used in the visual displays. The training simulator includes animated movies of crew evacuation.

The functionality of conventional fire fighting equipment can only be checked by discharging the fire suppressant; consequently it cannot be re-used. The key feature of the developed on-board engine compartment, cab and wheel-arch fire-fighting system is that can be periodically tested and yet still maintain operational capability. A 3-second test „blast' can be undertaken and the system still retains operability for a further 45 blasts.

2.6 Advanced Aids for Planning, Organisation and Training in Transportation Safety Management (WP4)

Work Package Objectives

WP 4 was intended to develop a joint free access WEB based platform for collaboration (integration) amongst transport designers and specialists in work safety, health protection and ergonomics. The platform is intended for use by all mining communities from European countries, in order to promote improved and unified transport system design and training standards. It is also meant to be used to evaluate the potential for augmented reality based solutions to provide information to operational mine staff to radically improve transport logistics management, maintenance or health and safety. The use of clip on displays or certified PocketPC equipment underground is now becoming more commonplace throughout the industry. A prototype AR system, based on this display technology, which has the capability to integrate and present information gathered from a wide range of sources to operational staff was to be produced and evaluated. The final objective of this work package was the production of effective training resources, to improve the reliability and performance of mining transport systems and to promote the efficient and effective implementation of project solutions and developments.

2.6.1 Task 4.1 Identification of Operational Information Requirements

Identification of all the information required for designing safe and efficient transportation systems was a main task objective. For this purpose a working team, consisting of GIG, KOMAG and KWSA representatives, was established. KOMAG, GIG and KWSA devised questionnaires regarding underground transportation systems in KWSA coal mines. The questionnaire inquiries were carried out by GIG in 16 KWSA coal mines. 78 people who design transportation systems and 81 people from a group servicing the transportation equipment, who all had a job seniority of longer than 15 years, were interviewed. The most important conclusions from the questionnaire inquiries were:

- Large and long components, as well as fine materials or spare parts, belong to the most frequently transported loads.
- The interviewed people indicated that suspended monorails with a diesel drive are the most suitable for transportation of large components.
- The highest possibility of serious or fatal accidents appears in the case of transportation of large loads.
- Training, in the form of lectures and practice at the workplace, prevail in the Polish mining industry.
- Employees expect to carry out training with the use of multimedia materials.

A working team, consisting of experts from KWSA Safety Management Office and each colliery involved in work safety and the design of transportation systems (2 people from KWSA Safety Management Office and 14 people representing 7 KWSA collieries), was established. Training workshops were organized and carried out with participation of the working team, presenting the MINTOS Project assumptions and the concept of the MINTOS Repository.

The users’ requirements were studied, in order to define the didactic (teaching) content of training materials. For this purpose the following work was undertaken:

- Identification of needs, as regards training the operators of suspended monorails, which was carried out at the ZIEMOWIT Colliery (Lędziny, Poland).
- Identification of the needs of suspended monorail manufacturers, as regards training the servicemen, which was carried out at Rybnicka Fabryka Maszyn RYFAMA S.A.(Rybnik, Poland).

- Analysis of the didactic content of training programmes which are used in practice, which was carried out in the following training centres: Zakład Doskonalenia Kadr KOMAG Spółka z o.o. (Gliwice, Poland), Kompanijny Ośrodek Szkolenia Spółka z o.o. (Knurów, Poland).

Identification and assessment of risk factors for the mining transport system components was undertaken. A review of the statistical data, focused mainly on the activities preceding accidents and the causes of accidents typically associated with mining transportation, was made. A database, delivered by the Centralny Ośrodek Informatyki Górnictwa S.A. (Central Mining Informatics Centre JSC.), from the last 10 years, that included records of more than 40 thousand accidents, was reviewed. A selection of the accidents which occurred during loading/reloading operations, together with those which were associated with: mechanical damage of the transportation equipment, failure of auxiliary tools, loss of stability of the transported load and manual work, was the main objective of the review. The accident rate was determined separately for inclined and horizontal transportation roadways. The probability of accidents occurring during the undertaking of specific activities was determined, and then the risk level estimated by the ALARP method (see Task 5.7).

The MINTOS Repository Structure, to support improved transport system design and planning was developed. The layered model of the knowledge repository, which meets the requirements for the design and use of underground mine transportation systems, is presented in Figure 2.6.1.

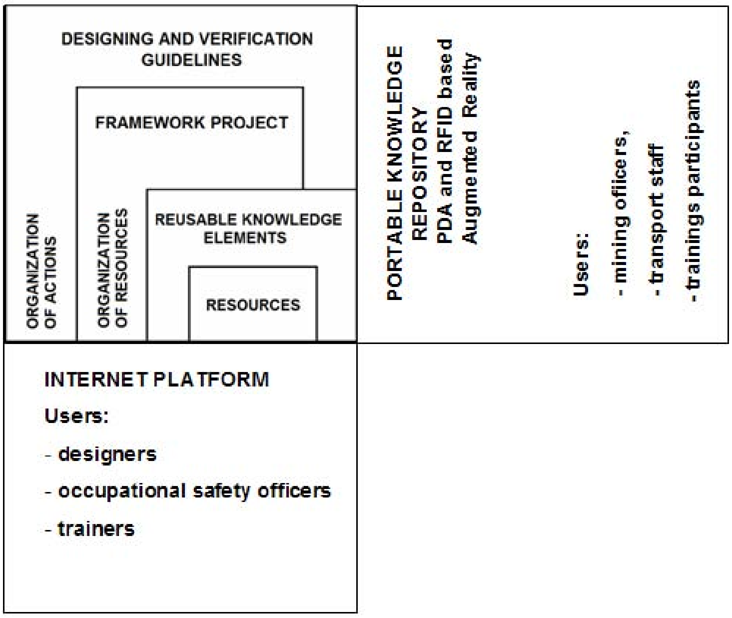


Figure 2.6.1 MINTOS Repository Structure

The external layer of the repository consists of Guidelines for Mining Transport System Planning and Verification. Control lists, with a specification of verification operations that should be carried out inside the currently assessed project, are the basic part of the Guidelines. Designers, occupational safety officers and trainers who provide safety training are the Guideline users.

The Framework Project structure is a result of the generalization of existing projects and legal regulations which are in force. It is divided into mining, mechanical and electrical parts, the content of which is precisely described in the form of: maps, documents, drawings, technical descriptions, calculations, etc. In the initial stage of the verification procedure, the Guidelines use the content of the Framework Project as input data. The Framework Project is also a place where verification results are given. Documents consistent with detailed users' requirements are created after completion of the verification process.

Resources, which are available in the form of Reusable Knowledge Elements, were placed in the MINTOS Repository. 3D models, drawings, computer simulations, maps, control lists, standards, legal acts, etc. are related to each other and are made available by the User Interface, e.g. Browsing Mode or Keyword Search.

Selected parts of the Guidelines (in the form of control lists) and Reusable Knowledge Elements (in the form of 3D Models, 2D Drawings, Simulations etc.) are available to Operational Personnel directly engaged in underground transportation operations. Pocket PCs (PDA/UMPC), as well as RFID technology and Augmented Reality, are used for this purpose.

WWW website of the MINTOS Project was created as a network web application, on the basis of a database, as well as scripts and programmes which operate on the www server and client explorer.

The detailed scheme of the system is presented in Figure 2.6.2. Applications, which operate on the server side, play a significant role in a suggested solution.

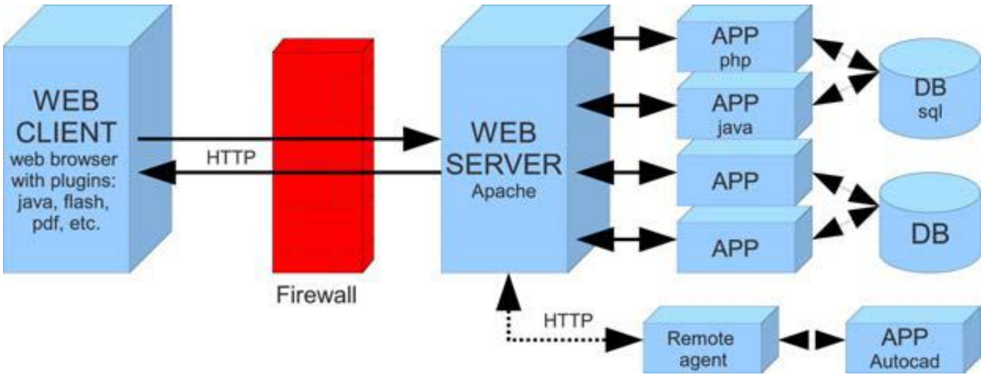


Figure 2.6.2 Detailed scheme of the system

The client interface was based on internet explorer, completed with programs (plugins) which ensure browsing the repository resources (pdf, office, flash, etc. documents) and starting the java applets. Protocol http, or its coded variant https, is used for communication between client and server. Finally, the Deliverable D4.1: “Requirements for the WEB-based system architecture for Mining Transport Systems Planning” was developed and is posted on the Mintos web site.

2.6.2 Task 4.2 Development of Guidelines for Mining Transport Systems Planning

The main objective of this task was to develop guidelines for Mining Transport Systems Planning. Analysis of the „state-of-the-art' and the needs of the final users to develop the standard in creation of the Mine Transportation Project, based on the internet platform, included the following:

- Questionnaire enquiries in KWSA collieries.
- Analysis of questionnaire inquiry results, as regards selection of transportation systems which are most frequently used, or which are planned for the future.
- Acquiring the projects of transportation systems and their analysis, as regards their content and separation of activities which can be improved upon, or speeded up, by computer methods.

When analyzing the results of the questionnaires, as regards transportation systems which are currently most frequently used in hard coal mines, or transportation systems of the future, the following groups of transportation means were specified:

- Winches – transportation on the floor – (mostly used).
- Suspended monorails with rope drive – (mostly used).
- Suspended monorails with diesel drive – (of the future).

Projects of existing transportation systems are the main source of information. They include data about the whole process of transportation system planning, required traction calculations and documents necessary during realization of the project. Existing projects of transportation systems were acquired from KWSA to analyze, on the basis of the results of conducted questionnaire enquiries, their content, to create a computer version of the frame project and to separate out those activities of process planning which can be improved upon, or speeded up, by computer methods.

Projects of transportation systems are saved in the MINTOS Repository in a form planned in the Frame Project, which is also a form of storing the system resources. Projects of transportation systems are stored in a database. Each project part is created by users of the MINTOS system by system functions. The MINTOS Repository also enables verification of a transportation system project on the basis of safety criteria. Information obtained from KWSA, as regards planning of mine transportation systems, enabled selection of the following tasks, which can be improved upon or speeded up by computer methods:

- Traction calculations.
- Modelling of transportation roads and transportation means to conduct additional analyses such as: analysis of collisions within transportation systems at selected points of the track, analysis of the field of vision of the operator of the transportation system, safety analysis.
- Creation of check lists for designers of the transportation system and for persons conducting underground transport or for service teams repairing transportation systems and maintaining the tracks.

Traction calculations are part of each project involving the transportation system. In the MINTOS Project, in the case of the transportation system project based on suspended monorails with their own drive, traction calculations include the following problems (steps):

- Configuration of road – step 1.
- Determination of permissible total weight of system – step 2.
- Selection of emergency braking cars – step 3.
- Formation of transportation system – step 4.
- Determination of braking distance of the transportation system – step 5.

Input data and calculation results from each step of the traction calculations are stored in a database of the frame project. After making all traction calculations, the user has the possibility to verify them and to print them in the form of a card of traction calculations.

KOMAG carried out a series of participatory sessions with the Mining-and-Geological Department of ZIEMOWIT Colliery within a realization of the task “Modeling of transportation roads”. Analysis of the planned track of the transportation system, as regards realization of the 3D computer model to make additional analyses and calculations by external experts, was the aim of the sessions conducted.

An illustration of a selected participatory session showing (a) Adobe Connect NOW software during realization of PD (Participatory Design) session and (b) a report in the form of an MS Word file is presented in Figure 2.6.3

KWSA developed Guidelines for the selection of safety equipment (diagnostics, monitoring, fire control), which are included within the MINTOS Repository. Also KWSA, together with KOMAG and GIG, identified the criteria set for Mining Transport Systems assessment: safety and health protection. These criteria were completed with the results obtained in Task 5.7 for the safety and health protection assessment for loading/unloading operations.

The process of verification of the transportation system project can be made in many ways, for example with the participation of external teams of experts responsible for the verification of selected project parts. Project verification can be realized after finishing the project process. However, due to the duration of implementation of the required possible changes, continuous verification of selected project parts, on the basis of agreements inside a team of mine experts and with the use of expert’s reports ordered to external experts, seems to be the most purposeful. The described process can be defined as a permanent process, i.e. continuously verified. Verification conducted by internal experts, e.g. workers from other colliery departments, can be conducted in a participatory mode, which is realized in a direct way (direct meetings) or remote way (with the use of internet technology).

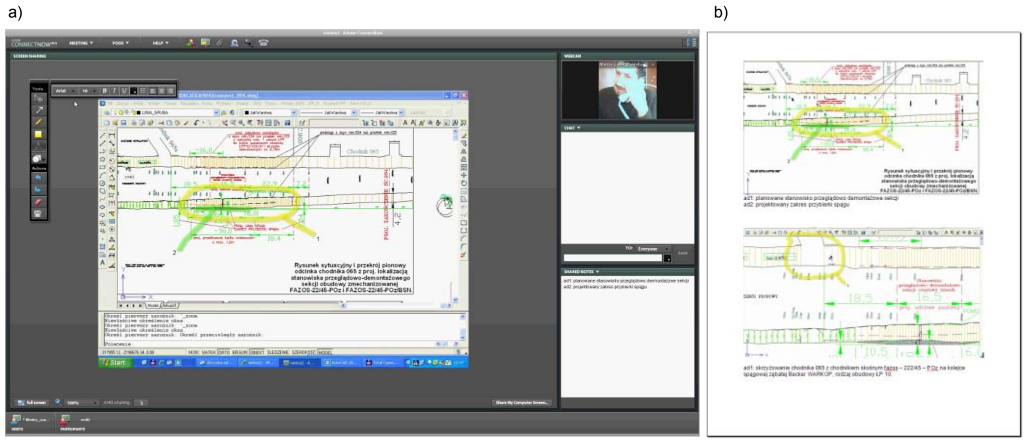


Figure 2.6.3 Participatory Design Session

Check lists were developed to support designers in the process of creating a transportation system project, assembly/disassembly and servicing of transportation means conducted by the mine services themselves, as well as to support transportation operations carried out by mining teams. An exemplary check list and an example of its presentation on PDA and UMPC portable computers are presented in Figure 2.6.4.

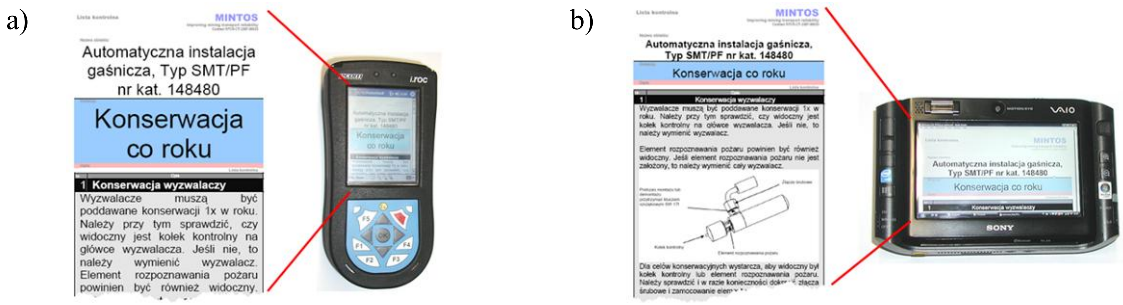


Figure 2.6.4 Specification of check lists prepared in PDF format for computers a) PDA and b) UMPC

Finally, Deliverable D4.2: “Guidelines for Mining Transport Systems Planning” was developed and posted to the Mintos project web site.

2.6.3 Task 4.3 Software and user interface development

The first main objective of this task was to develop the specification and prototype of the WEB based platform for integration of specialists involved in the Mining Transport Systems Planning Process (transport designers as well as specialists in work safety, health protection and ergonomics). The second main objective was to develop and evaluate a prototype AR system, to integrate and present information to operational staff.

Selection of the software environment which met the requirements of the WEB-based system architecture for Mining Transport Systems Planning, developed in Deliverable D4.1 was undertaken. Experience from realization of the IAMTECH project and eZ Publish software belonging to CMS (Content Management System) class were used during preparation of the MINTOS Repository. The structure of the MINTOS Repository in eZ Publish environment was developed by KOMAG. Main parts of the computer system were developed, together with Entry Points to the MINTOS Repository. A view of the MINTOS Repository homepage, placed on the local KOMAG server is shown in Figure 2.6.5.

ENTRY POINTS:

- Legal acts
- List of loads
- Training materials
- Check lists
- Catalogue cards of transportation means
- Manual activities – risk factors
- Accidents
- Frame project of transportation system

Figure 2.6.5 MINTOS Repository homepage and main Entry Points to the system

The MINTOS Repository Database was filled with system resources created within Tasks T4.1, T4.2, T4.4 and T5.7 including: legal acts, as regards mining transport system design, catalogue cards for selected types of transportation means, lists of loads, risk factors during manual handling activities (loading/unloading operations), training materials for operators and fitters/servicemen, accidents that occurred during transportation operations, check lists for designers and for people associated with the maintenance of transportation means and the frame project of the transportation system (implementation of the guidelines developed in Deliverable D4.2).

Development of Traction Calculation Aiding System

The individual steps of the traction calculations which were implemented into the MINTOS Repository as part of the frame project, are presented in Figure 2.6.6.

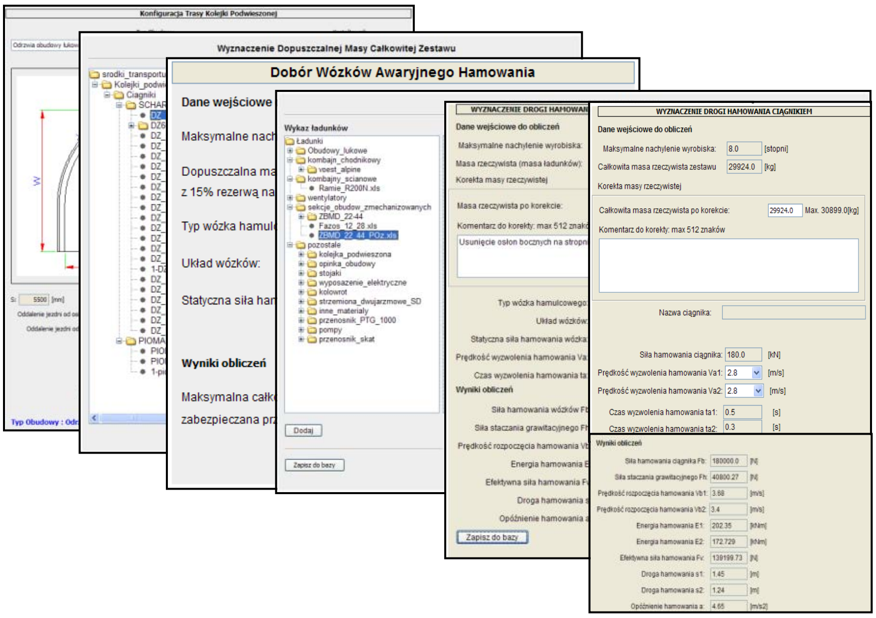


Figure 2.6.6 Dialogue windows of each step of the Traction Calculation Aiding System

Creation of reports from the Traction Calculation Aiding System is automated. Values of variables are taken from a database and inserted into the form by a generator of reports.

The structure of the created file can be modified and adapted to users' needs. Then the file with the results is downloaded to the local computer of the system user.

Development of workplace instructions creator

An Order of the Labour and Social Policy Minister from 26 September 1997 imposed an obligation on employers to acquaint workers with instructions in the workplace. These instructions refer to: technological processes connected with dangerous work, machines operating with and handling materials hazardous to health.

Workplace instructions are also used in coal mines, where a large percentage of them concern underground transportation. In order to simplify the process of creating this type of instruction, but also to provide quick access to their content, a creator of workplace instructions was developed.

KWSA provided about 60 currently used workplace instructions, which were a basis for further development of the workplace instructions creator. After analysing a group of instructions, repeatable knowledge elements were identified. These elements are:

- Legal base for instruction.
- General provisions.
- Detail provisions.
- Hazards characteristic in a workplace.
- Final provisions.

The complete information was gathered together in tabular form, but it can also be used in the form of a tree structure, as shown in Figure 2.6.7.

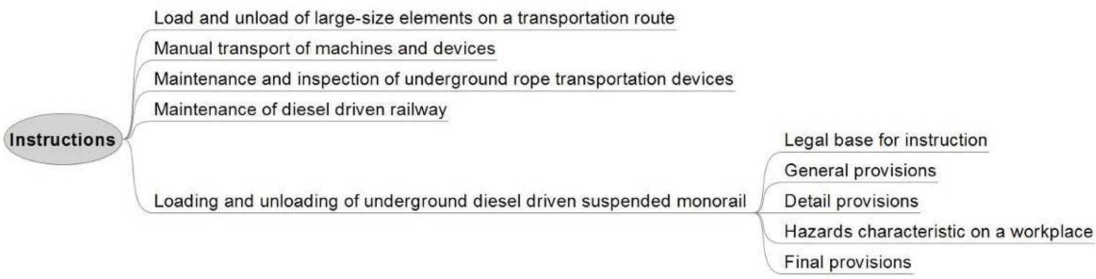


Figure 2.6.7 Workplace instructions shown as tree structure – general view

Development of software for the analysis of collision threats in mining haulage

One of the engineering tasks in mining haulage, which can be improved or accelerated using computer methods, is analysis of the route of the suspended monorail. The most important aim of this kind of analysis is to check the hazard of collision occurrence. In order to accelerate this task using computer methods, special software was developed. This software runs within AutoCAD environment and uses AutoCAD's solid modeling to analyze the route of the suspended monorail. Since AutoCAD is also the main tool used in Polish coal mines for creating drawings for transport system planning, these drawings can be implemented for collision detection. The main advantages of using CAD software for such tasks are as follows:

- Analysis can be done very quickly.
- There is the possibility of building models of any degree of complexity.
- There is the possibility of measuring the solid figures of collision obtained.

Development of miner's AR user interface supporting the decision process of individual end users at the operational level

Using the AMIRE Programmer's Library, a miner's user interface was developed, which can be used on a portable PC – UMPC. This interface supports the decision process of individual end users at the operational level

An example of the AR application supporting the decision process of individual end users at the operational level is shown in Figure 2.6.8. The AR application enables the UMPC to work in two modes: training mode and maintenance mode. In the training mode, the AR application introduces the user to machine building, its maintenance and recognition of failures. In maintenance mode, the AR application introduces the user to machine inspection and exchange of machine components.

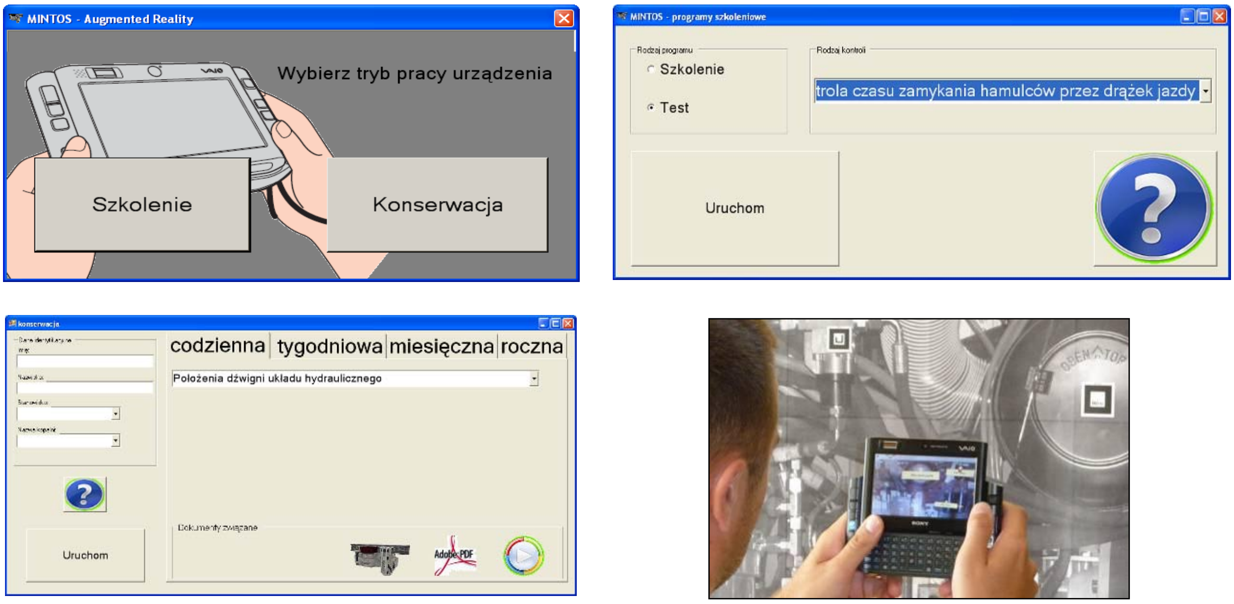


Figure 2.6.8 Example of AR application supporting the decision process of individual end users

Development of AR system prototype

The Augmented Reality system developed facilitates the training of workers directly at the workplace, which increases their efficiency. The training process can be conducted using the machine on which the course participants will work. The structure of the training stand, based on the AR technology is presented in Figure 2.6.9.

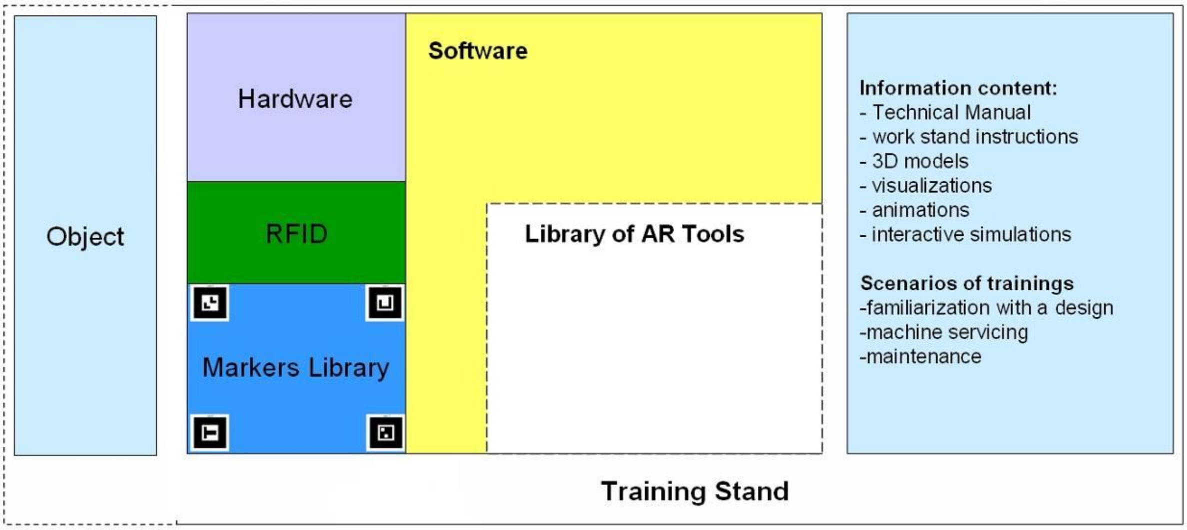


Figure 2.6.9 Structure of the training stand based on AR technology

Two independent types of the AR system for training purposes were developed: with the use of Markers Library and with the use of RFID technology.

Development of suitable application for 3D data presentation on Pocket PC equipment

Work Package 2 of the MINTOS project: "Enhanced Transport Diagnostics and Management Information Systems" deals, amongst other things, with the evaluation and development of tracking and positioning methods in mining environments. The knowledge and results derived from this task are also valuable for the planning, organisation and training in transportation safety management. The ultra mobile portable computer (UMPC) that operates as an augmented reality device may be extended with tracking and positioning information.

Implementation of the visualisation software to display the positioning information was prepared by RITTAL. Methods for the transport of the tracking information were evaluated. A WLAN connection can deliver the calculated positions from the server to the UMPC client.

The augmented reality system may be used to direct the worker to locations with service demands. It enables direct access to the defective machinery and safe orientation for the worker inside the mine. Figure 2.6.10 shows the combination of the tracking system and the training support using the augmented reality system.

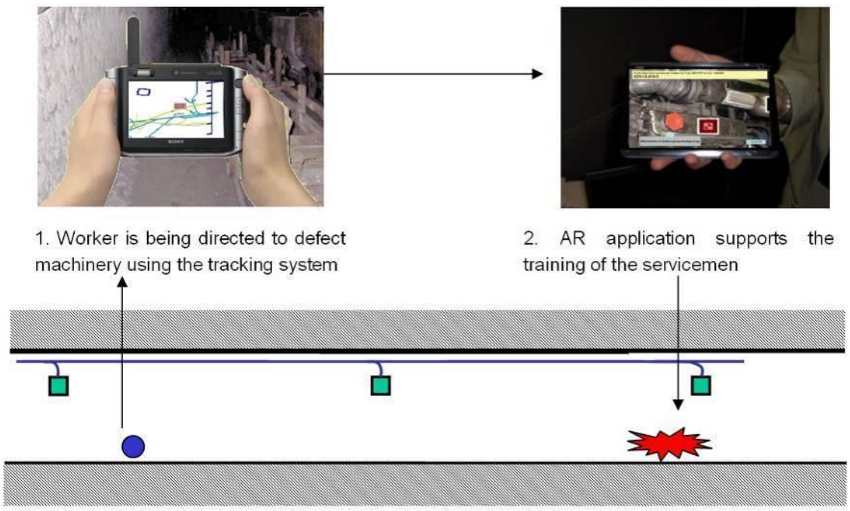


Figure 2.6.10 Possible combination of the tracking system and the augmented reality device

An e-IETM application was developed to enable access to knowledge resources based on RFID technology. It is a database application which identifies RFID tags and displays associated information stored in the knowledge base of the MINTOS Repository. The application interface was adapted for use on a UMPC. Figure 2.6.11shows an example of the software application which makes knowledge resources associated with RFID tags accessible.

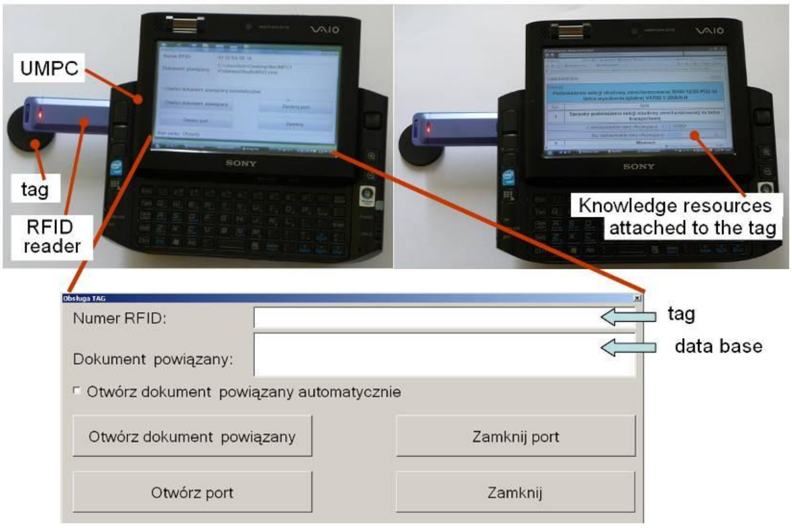


Figure 2.6.11 Example of e-IETM application linking RFID tags with MINTOS Repository resources

Finally, after finishing Task 4.3, Deliverables D4.3: “WEB based platform for Mining Transport Systems Planning” and D4.4: “Software and hardware prototype of an augmented reality system” were completed.

2.6.4 Task 4.4 Training Materials Development

The main objective of this task was to create effective training resources to improve the reliability and performance of mining transport systems and to promote the efficient and effective implementation of project solutions and developments. These resources, after inclusion into the MINTOS Repository and integration with the AR technology, were tested and evaluated within task T6.3: “Field trials of mining transport systems planning”. The following activities were carried out in Task 4.4:

Implementation of training programs into the IETM environment developed within the IAMTECH Project

During realization of the IAMTECH project, the concept of an Interactive Electronic Technical Manual (IETM) was developed. The concept of an IETM was used in the MINTOS project with reference to the SCHARF suspended monorail. The IETM of the SCHARF 1500/1800 diesel-powered suspended monorail locomotive was developed and included in the MINTOS Repository, to be integrated with training programs using AR technology, creating the prototype of AR supported training programmes. This prototype is addressed for the certified Pocket PC equipment (PDA with ATEX) for use in underground conditions and also for ultra mobile computers (UMPC) for the use on the surface (mine offices, training centres or machine producers’ plants). The following training programmes for the SCHARF 1500/1800 diesel-powered suspended monorail locomotives were developed:

- Control of fire extinguishing system.
- Control of power valve.
- Control of starting valve.
- Start up of Diesel engine.
- Start up of machine.
- Switching off Diesel engine.

Development of prototype of AR supported training program

Figure 2.6.12 presents the SCHARF monorail with markers plotted. It was the basis for the development of a prototype of the AR supported training program. The main purpose of creating training programs is to facilitate the process of acquiring the required knowledge by machine operators and maintenance crew.

Figure 2.6.12 Photograph of 'real world' object with marked AR patterns

The advantage of the training programmes is the ability to use them on the UMPC hardware. A procedure for the control of a fire extinguishing system is shown in Figure 2.6.13.

Figure 2.6.13 Example of a training programme realized in AR technology

Visualization and simulation of transportation operations

One of the elements of MINTOS Repository is visualization of best practice within transport operations (Figure 2.6.14). The training materials developed are based on mine haulage accidents official reports. Visualization of accidents, together with their causes and means to avoid them are the main content of the training material. These training resources can be easily used for the training of mine haulage crews.

Figure 2.6.14 Visualization of transport operations for a CLS-120 floor-mounted railway

2.6.5 Conclusions for Work Package 4

Interaction with a large number of experienced mining personnel enabled definition of all the necessary information required for designing safe and efficient transport systems to be obtained, which was the key objective of setting up the Mintos repository. The proposed structure and concept of the repository was introduced to work teams and requirements for the training of designers, planners and service personnel established.

Identification and assessment of risk factors for the mine transport system components was undertaken, by analysing a vast bank of historical data. The layered model of the MINTOS repository was then set up. Guidelines for the selection of safety equipment were also devised and included in the MINTOS repository. The criteria for health and safety within the Mine Transport System assessment were identified and completed with the incorporation of the loading and unloading recommendations from Task 5.7.

Existing and planned transport systems were analysed, in order to identify elements for improvement by using computer methods. The three key elements identified were traction calculations, modelling of roadways, and the creation of checklists for designers, operators and service personnel. Guidelines for transport systems planning were developed.

The prototype WEB based platform (MINTOS Repository) for the integration of specialists involved in the transport planning process was successfully developed, as well as the development and evaluation of a prototype augmented reality (AR) system to integrate and present information to operational staff. The AR system has the capability to integrate and present information gathered from a wide range of sources to operational staff.

Effective training resources were established through integration with the AR software and the implementation of obtained materials into the IETM environment developed in the IAMTECH project. A number of training programs for a SCHARF monorail were then developed.

2.7 Effective Monitoring and Control of Transport Related Health Hazards (WP5)

Work Package Objectives

- Investigate the feasibility of using water mist and additive technologies to develop a cost effective wet scrubbing system for the eradication of diesel particulate and gaseous matter from transport exhaust systems.

- To develop an improved methodology for evaluating the true vibration levels on mobile plant in coal mines, in line with the requirements of Directive 2002/44/CE, and to assess the level of vibration risk to workers

- To identify the principal risk factors associated with the loading and unloading operations involved with underground mine transport systems.

2.7.1 Task 5.1 Potential for water mist scrubbing of diesel emissions

The objective of this task was to investigate the feasibility of using water mist and additive technologies to develop a cost effective wet scrubbing system for the eradication of diesel particulate and gaseous matter from transport vehicle exhaust systems.

Test Apparatus: The Spray Nozzle: Initial testing of the system concentrated on establishing the optimum volume flow rate characteristics for the nozzles in sequence using a 12v pump developing a working pressure of 8 bar at the nozzle.

Figure 2.7.1 Test of Water mist Spray Nozzle

It was evident from these trials that, considering a selection criterion requiring a low volume flow rate to ensure that a practical amount of water is used which can be carried in a reservoir on an operating machine to give a long period of mist application, the only nozzle to be considered was the RXT 0060.T1, which delivered a „mist' average droplet size of 60 – 80 micron and gave the smallest flow of water over the test period.

Particulate Measurement: Diesel Engine Exhaust Emissions contain a complex mixture of gases, vapours, liquid aerosols and particulates. These substances are the products of combustion and the major constituents are - Nitrogen (N_2), Carbon Dioxide (CO_2), Water (H_2O), Carbon Monoxide (CO), Oxides of Nitrogen e.g. Nitric Oxide (NO) and Nitrogen Dioxide(NO_2), Oxides of Sulphur e.g. Sulphur Dioxide (SO_2), Various Hydrocarbons - Alcohols, Aldehydes, Ketones, Particulates (soot), and Polycyclic Aromatic Hydrocarbons (PAHs).

Dust, or more correctly aerosol, is split into three size ranges, which have different effects on the respiratory system of a human being. The smaller the particle size, the deeper into the lungs it can penetrate where it can settle onto the lining and not be ejected by the normal means of breathing out, coughing or travelling out in the lung mucus and therefore cause respiratory illness. The particulate research concentrated on this smaller particle size respirable fraction.

There are many different methods of taking air samples, but by far the most widely used and preferred is to connect a battery operated pump, which is capable of drawing air through the sampler at a constant rate and which contains a quartz filter medium which traps the solid particulate. Gravimetric analysis is usually used to measure results (i.e. by measuring the weight gain of the filter). This work was undertaken using an SKC sidekick pump (flow rate 2.2l/min) with a cyclone sampler to measure respirable dust. Whilst the normal sampling procedure is to mount the cyclone device within 30cm of a breathing zone it was coupled to the test rig to enable samples to be drawn directly from the exhaust (Figure 2.7.2).

Figure 2.7.2 Sidekick Pump and Cyclone Sampler attached to Test Rig

Prior to the commencement of full scale testing with the three diesel generators, trials were undertaken with one generator only, to ensure that a protocol for testing of diesel gaseous and particulate emissions was developed.

Figure 2.7.3 Test Rig with Three Engines

Additive Solutions: The additive solutions were carefully chosen to fulfil four parameters. These were: Safety to the personnel handling the solutions (COSSH), Cost of use, Chemical suitability for removal of particulates from exhaust emissions, and Chemical suitability for removal of potentially harmful gases from the exhaust emissions. In addition to water, nine solutions were selected, including 1% and 5% non ionic, anionic and amphoteric surfactants, Copper Chloride Solution, and 1Butyl 3Methylatimidazolium Tetrafluorobate solution.

Solution No	Additive Constituents
Water	None
Solution 1	1% Solution - Non irritant / <5% non ionic surfacant
Solution 2	5% Solution - Non irritant / <5% non ionic surfacant
Solution 3	1% Solution - <5%: anionic surfactants, phosphates, non-ionic surfactants
Solution 4	5% Solution - <5%: anionic surfactants, phosphates, non-ionic surfactants
Solution 5	1% Solution - 5-15% anionic surfactants, <5% amphoteric surfactants, <5% non ionic surfactants,
Solution 6	5% Solution - 5-15% anionic surfactants, <5% amphoteric surfactants, <5% non ionic surfactants,
Solution 7	0.1molar Solution Copper Chloride
Solution 8	5% solution 0.02 molar Solution Calcium Hydroxide
Solution 9	0.5m solution 1Butyl 3Methylatimidazolium Tetrafluorobate

Measurement of Gaseous Composition: The reduction of gases in the diesel exhaust fume was considered as a subsidiary theme. Whilst using watermist and watermist with additives to remove particulate matter in the exhaust stream, it was considered equally practicable to undertake a short combined study to determine the feasibility of removing/reducing gaseous products of combustion in the same exhaust stream. The gaseous composition of the exhaust emissions was measured by the collection of the exhaust gas in a Tedlar sample bag fitted with a spigot to allow the connection of Dräger tubes. The apparatus allowed for the simultaneous testing of organics, ketones (e.g. acetone, MEK), aromatics (e.g. benzene, toluene), alcohols (e.g. methanol, ethanol), aliphatic hydrocarbons (e.g. n-hexane, n-octane) and chlorinated hydrocarbons (e.g. perchloroethylene, trichloroethylene. In addition to the use of the Hazmat Simultest Kit, normal Dräger tubes were used to measure the following Carbon Dioxide, Carbon Monoxide, Nitrous Fumes and Sulphur Dioxide.

Results of Testing - Particulates

A sample of the results of the particulate testing is shown graphically in Figure 2.7.4. This indicates the level of particulates against the level found in a normal exhaust emission.

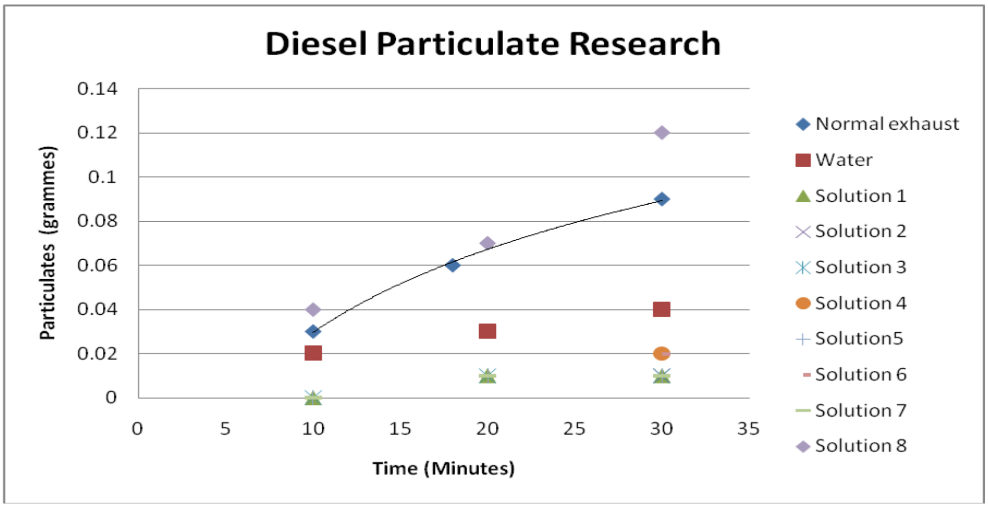
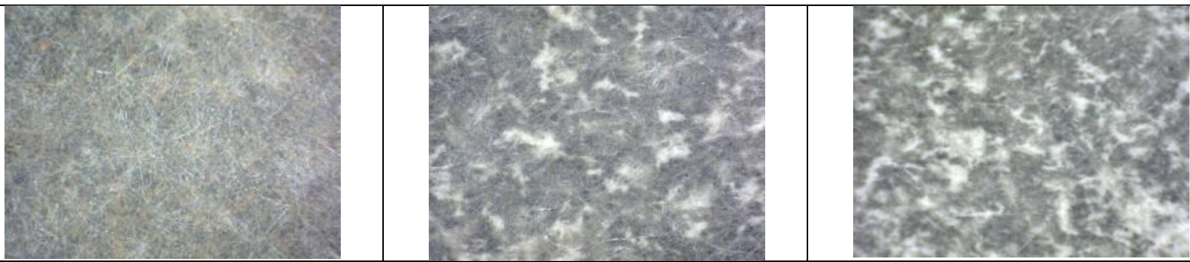


Figure 2.7.4 Graph showing sample results

The filter papers removed from the cyclone sampler cassette were photographed using a USB microscope at 200x magnification. The depositional patterns of the particulates captured are evident as are the variances in colouration. A representative sample of these for a 30 minute test run is shown in Figure 2.7.5. The results of the tests indicate that a water mist system is capable of significantly reducing the particulates generated by diesel engine exhaust emissions. The addition of a small quantity of anionic / non ionic surfactants can further reduce the level of particulates in the emissions. Problems were encountered with one solution (number 8) in maintaining a spray over a prolonged period, due to contamination of the nozzle, which in a practical mine environment would require replacement of the nozzle as routine maintenance of the system. The use of Calcium hydroxide appeared to be unsuccessful in reducing diesel particulate emissions as the weight of the filter paper increased over that of the normal diesel engine exhaust emissions. In all probability this was due to the collection of calcium carbonate on the filter paper.



Dry Engine Exhaust	Water Spray Only	Solution 3

Figure 2.7.5 Filter papers from the cyclone sampler cassette

Water: In line with the testing protocol the water samples were tested for: pH (pre and post injection), Specific Gravity (pre and post injection), and change in weight of filter paper after decanting (post injection only). The water samples collected indicated a considerable change in pH from slightly acidic / neutral to acidic, with an average value of the discharge water of 3.3. The alkaline calcium hydroxide solution only showed a small reduction in the pH.

The specific gravity of the solutions changed very little, even though there were visible changes in solution colouration. The water samples collected were decanted (500ml) through a weighed filter paper which was then air dried and re-weighed. These all showed an increase in weight as solid matter from the chamber was discharged in conjunction with the water. The filter papers were also photographed using a USB microscope at 200x magnification to highlight the residue left after decanting.

2.7.2 Task 5.2 Impact of using biofuels on diesel engine emissions

Task Objectives

The objective of Task 5.1 was to investigate the feasibility of using water mist and additive technologies to develop a cost effective wet scrubbing system for the eradication of diesel particulate and gaseous matter from transport vehicle exhaust systems. That task, concentrated on running tests with commercial (red) diesel, typically used at coal mines.

Task 5.2 was designed to determine the impact of selected diesel replacement biofuels on the exhaust emission content of a diesel engine by running a series of bench trials and associated particulate and gas analyses and hence assessing the likely health impacts arising from the introduction of these alternative fuels. The test apparatus was identical to that used in Task 5.1.

Two biofuel blends were tested, a) a commercially available biofuel, which is 15% recycled cooking oil, 15% rapeseed oil and 70% diesel (B30) and b) a mixture of 50% diesel and 50% vegetable oil (B50).

The additive solutions used in the tests were identical to those in the previous tests, namely water and nine others, including 1% and 5% non ionic, anionic and amphoteric surfactants, Copper Chloride Solution, Calcium Hydroxide and 1Butyl 3Methylatimidazolium Tetrafluorobate solution. The particulate, gas analysis equipment and solution test procedures remained the same as before.

Results of Testing: - Particulates

A sample of the results of the particulate testing is shown below. This indicates the reduced level of particulates for B30 and B50 fuels against the level found in a normal exhaust emission under normal operating conditions. The situation is less advantageous however when the water mist spray is applied.

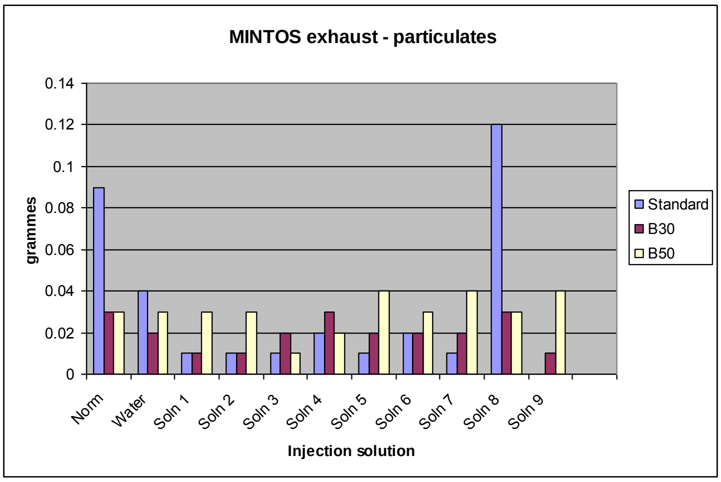


Figure 2.7.6 Graph showing all results

The filter papers removed from the cyclone sampler cassette were photographed using a USB microscope at 200x magnification. The depositional patterns of the particulates captured are evident as are the variances in colouration. A representative sample of these for a 30 minute test run is shown in Figure 2.7.7. The results of the tests indicate that a water mist system is capable of marginally reducing the particulates from the engine exhaust emissions generated by diesel/biofuel blends (B30). The addition of a small quantity of some anionic / non ionic surfactants can further reduce the level of particulates in the emissions.

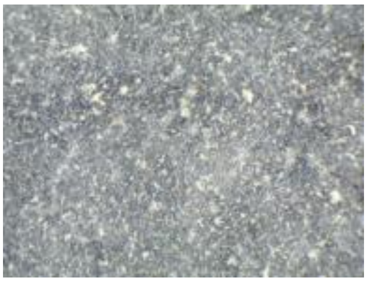
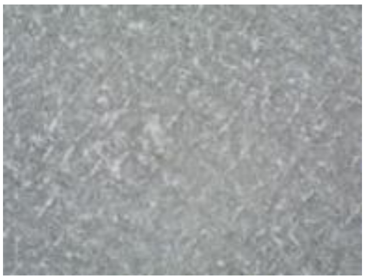
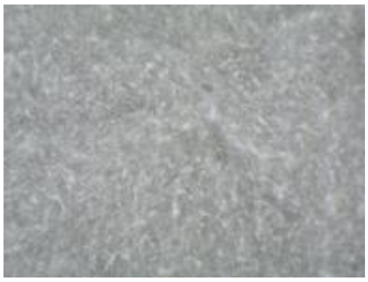
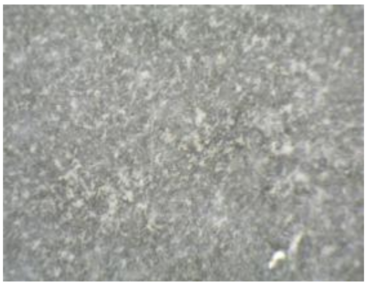
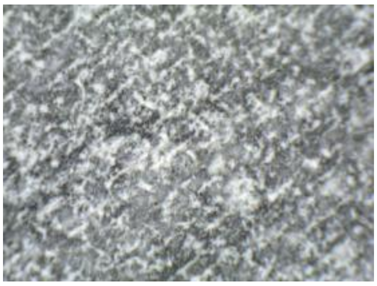
Dry Engine Exhaust	Water Spray Only	Solution 1
		
		

Figure 2.7.7 particulates for B30 diesel (top) and B50 diesel (bottom)

Results of Testing: - Solution

In line with the testing protocol the water samples were tested for: pH (pre and post injection), Specific Gravity (pre and post injection), and change in weight of filter paper after decanting (post injection only). The water samples collected indicated a considerable change in pH from slightly acidic / neutral to acidic with a decrease in average value of the discharge water of around 3.1.

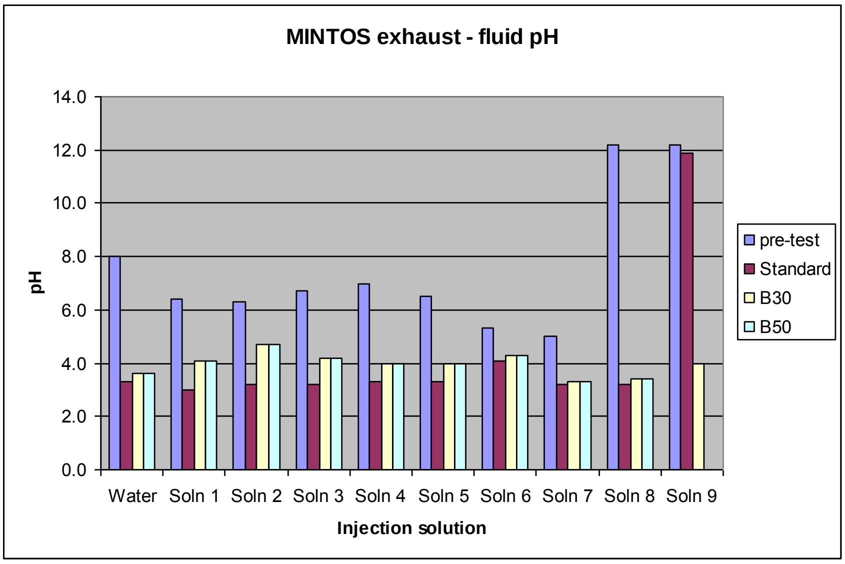


Figure 2.7.8 Exhaust Fluid pH

The specific gravity of the solutions changed very little even though there were visible changes in solution colouration. The water samples collected were decanted (500ml) through a weighed filter paper which was then air dried and re-weighed. These all showed an increase in weight as solid matter from the chamber was discharged in conjunction with the water. The filter papers were also photographed using a USB microscope at 200x magnification to highlight the residue left after decanting.

Results of Testing: - Gases.

The result of the tests to reduce the gaseous content of the diesel exhaust did not show significant beneficial changes. Gases tested for included Carbon Dioxide (%), Carbon Monoxide (ppm), Nitrous Fumes (ppm), Sulphur Dioxide (ppm), Ketones (ppm), Aromatics (ppm), Alcohols (ppm) Aliphatics (ppm) and Chlorinated Hydrocarbons (ppm). This component of the study would require further research in terms of increasing the range of molarities used. A selection of the analyses is shown below in Figure 2.7.9 -Figure 2.7.11. It is noticeable that the aromatics from the biodiesel blends were no lower than with diesel. Tests for Sulphur Dioxide, Ketones, Alcohols, Aliphatics and Chlorinated Hydrocarbons show even less or no change.

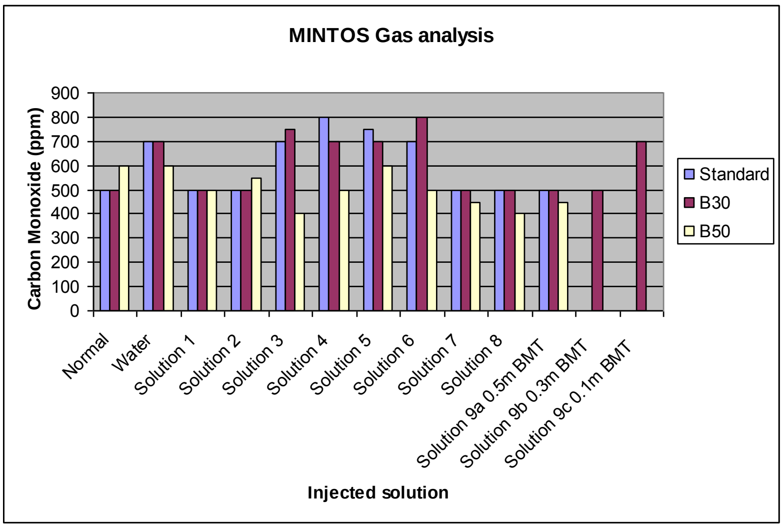


Figure 2.7.9 Gas analysis for Carbon Monoxide for Standard, B30 and B50 diesel fuels

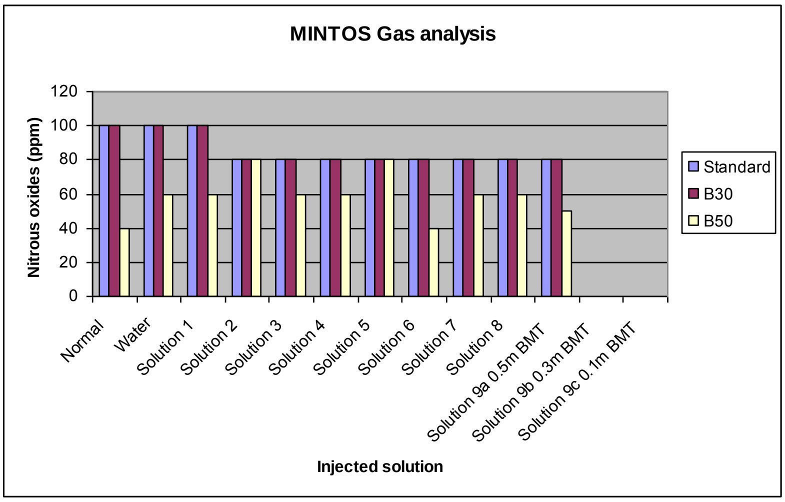


Figure 2.7.10 Analysis for Nitrous Oxides for Standard, B30 and B50 diesel fuels

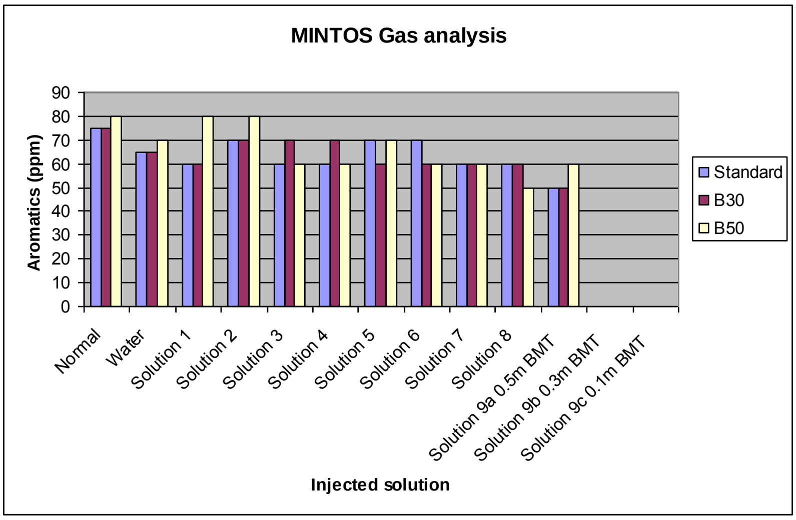


Figure 2.7.11 Gas analysis for Aromatic Hydrocarbons for Standard, B30 and B50 diesel fuels

2.7.3 Task 5.3 Comparative assessment of vibration measurement methods

The objective was to collect real measurements to verify if, in the sector of the mining industry, measurements of vibration according to the parameters mentioned in the current standard ISO 2631-1 and with the specified parameters in ISO 2361-5 are comparable, for the case of impulsive values of vibration, or if, on the contrary they are significantly different.

Description of activities and discussion

European Directive 2002/44/EC on the exposure of workers to the risks arising from physical agents (vibration) is based on the ISO 2631-1 standard on how to measure and analyze the effects of vibration on the workers. However ISO 2631-1 takes into account transient shocks poorly, especially those which occur rarely due to high crest factors, occasional shocks and transient vibrations.

Vibration assessment for comfort, perception, etc. depends on the crest factor exceeding a threshold value. There are studies and research suggesting that actual vibration magnitudes are considerably high than the values which may be obtained using ISO 2631-1 measurement procedures. Even publication of ISO 2361-5, which is a later standard, already expressly mentions impulsive values of vibration and is much more restrictive regarding their determination than is the 2631-1version.

In this task, alternative or complementary measurement approaches and assessment parameters for situations in which these sudden, or impulsive movements exist were compared and evaluated. These occur, for example, when driving mobile machinery in tracks with pot-holes or tracks with bad maintenance conditions.

Vibration measurements were carried out in five coal mines, covering a total of 61 mobile machines. Measurements were made of the vibration factors RMS (Root Mean Square) and VDV (Vibration Dose Value). For each of the sampled machines, a file was created taking into account the machine characteristics, such as: manufacturer, model, age, and also details were recorded of the particular operational conditions at the time of the measurement. This additional information was fundamental in order to obtain a set of valid conclusions, as well as facilitating the generation of a database. The results obtained are reported below under Task 5.4.

2.7.4 Task 5.4 Determination of vibration measurement times

Task Objectives

Vibration assessment depends strongly on the duration of exposure. In the ISO 2631-1 standard, no precise statement is provided on what is meant by "period of exposure". What is required is an exposure time of below or above 10 minutes, which depends on different circumstances; however, it is unclear under which circumstances each of the two time dependencies should be used.

The objective of the task was to define the minimum time of vibration measurement. Tests were carried out during complete working shifts.

Description of activities and discussion

The accurate determination of the vibration level is of maximum importance, in order to avoid underestimation or overestimation of the vibration risk. In the study carried out, two types of measurements were undertaken:

- Uninterrupted measurement over several minutes, recording the values at each 1- second interval.
- Uninterrupted measurement over periods of time generally greater than one hour, recording the values at each 1 minute interval.

The results obtained using the first type of measurement enabled more specific analysis. The exposure to vibration during specific moments of a task or working cycle were analysed, for example, such as those that occur at discontinuities in the tracks, strong slopes, un-programmed stops, etc.

Obtaining the value of vibration transmitted for the whole day, however, when less detail is required, is simplified using the second type of measurement. For those measurements, the values were recorded once per minute.

In each case, the minimum operating time of the mobile equipment which allowed for sufficient information to be acquired in order to ensure that the true values of the vibration acceleration were obtained, was registered. This value enabled the determination of the time of measurement necessary for every type of machine.

An alternative to measuring during a predetermined period of time is to adapt the measurement to consider just complete working „cycles'. This is possible when the tasks are clearly repetitive and the cycles are well identified and are absolutely equivalent. In this case, the cycle can turn out to be representative of the real total value. This case commonly occurs during work carried out by dumper trucks. A similarity of acceleration values in different whole cycles was observed, including, in each cycle, the tasks of loading, transportation with a load, unloading and transporting without a load.

Where it was possible to identify different tasks during a specific cycle, individual measurements of each task were made, in order to be able to analyse in detail the vibrations of any task.

The daily exposure values of vibration were obtained from the different measurements carried out on the mobile equipment when they were working. These measurements were undertaken during representative periods of work, weighting the values to a reference period of 8 hours.

The overall results obtained in the analyses of the effective values of exposure to vibration on all the equipment investigated, are shown in Figure 3.7.12. For the case of the factor RMS, it can be seen that only 5% of the equipment was higher than the threshold, or limit value, established by the Directive -1,15 m/s2- whereas 62% exceeded the „action' limit of 0,5 m/s2 and only 33% were below this value. The total number of items of equipment on which the study was realized was 61.

The VDV graph shows that only 5 % of the vibration dose values of the mobile equipment studied were lower than the action value, whereas all the others were higher than the action value. Furthermore, 20 % of the equipment exceeded the established limit of 21 m/s2.

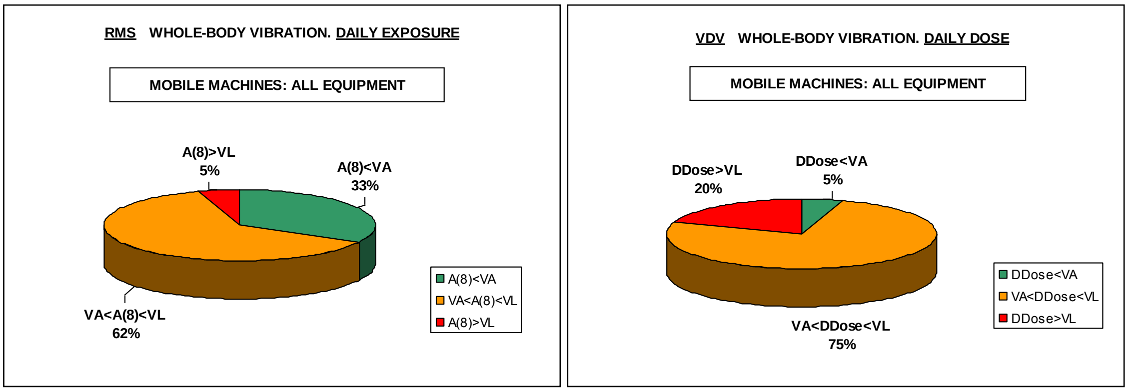


Figure 2.7.12 RMS and VDV Evaluation

Within the mining industry, the existence of jobs with similar machinery and, sometimes, apparently similar tasks, means that measurements based on short periods of time can be considered sufficient to accurately determine the exposure to vibration. However, the type of tasks or cycles of work that machines develop cannot always be considered to be similar.

In order to establish an acceptable time of measurement, a complete analysis of the working day for any mobile equipment is needed. If the necessary premises as far as homogeneity of the cycles occur, using a multiple of cycles to measure the daily values can be an acceptable criterion. Actually it is necessary to take careful precautions to guarantee that the cycle is really representative.

For the specific case of dumpers, little variation in the cycles of work throughout a working day is observed. This would imply that it is possible to calculate the exposure to vibration during a day by means of extrapolating the measured value in a single cycle of work to the total number of cycles. Nevertheless, considering the changes due to the normal evolution of a mining operation, it is not possible to be certain that a cycle of work will stay exactly the same in the long term.

Tests were carried out during complete shifts and later the minimum times of vibration measurement required to guarantee that the evaluation of the level of exposure in the mine was correct and trustworthy was ascertained. Finally, a statistical analysis of data was conducted, in order to obtain a recommended measurement time according to each case.

The amount of data collected and available (3,600,000) makes the statistical treatment of the data highly complex. This statistical treatment was carried out using a specialized software program.

Normality tests were made on the distribution data, grouped in four groups depending on the type of work performed: All, Cyclical, Non-Cyclical, and Occasional.

Data were differentiated according to whether they were grouped in minutes or seconds, until a maximum time period of two hours was reached. The Kolmogorov-Smirnoff and Shapiro-Wilk tests were applied, assuming normal when the significance of at least one of the two indices was above 0.05.

In order to analyze the degree of deviation of each one of the intervals of measurement analyzed against the real value of the measurement for every machine, a statistical study was realized. This was done for both RMS and VDV values.

61 machines, from which was extracted the percentage of data that diverged by more than 10% and 20% from the real value of the measurement applicable to the whole work period, were analysed in total. In order to adjust the mentioned discrepancies that happen using the Student's t-test, another study was undertaken. This study consisted of quantifying the percentage of those samples that came closer to the real measured value- maximum error of 10% - 20%.

In all cases, as the range of measurement increases, the percentage of samples tested that deviate from the real value decreases. Therefore it is concluded that increasing the measurement time interval implies that the values obtained are more indicative of the real value.

The determination of the ideal interval of measurement time needed to assume reasonable representation of the real measurement over the whole working day is required. Considering a few admissible mistakes of 10 % in the real value, it is possible to conclude that the time of measure must be set at around two hours. In the case of machines with perfectly definite cycles, and without excessively big cycles, the duration of the sample analysis may be reduced to periods of one hour.

2.7.5 Task 5.5 Vibration Database

Task Objectives

The first objective was to collect real measurements to produce a database elaborated by studying a wide range of real cases in mines.

The second objective was to compare with other European databases. The current Directive contemplates the possibility of evaluating the risk of vibrations of a machine, by realizing vibration analysis or for comparison with suitable information. It was anticipated that the database established within the MINTOS project would be used in terms of collaboration with other data bases under construction in Europe, for instance, in Sweden and Germany.

Description of activities and discussion

As a consequence of Tasks 5.3 and 5.4, a database was developed, based on a wide range of real cases in mines.

According with the project objectives, assessments of vibration on different mobile machines during complete cycles of work were carried out. Measurements were made on five different coal mines during the usual working activities of each mobile machine.

The daily exposure value to vibration is obtained from the different measurements carried out on the mobile equipment when they were working. These measurements were realized on representative periods of work, weighting the values to a reference period of 8 hours. Other parameters were considered, to develop an extensive database with the following field values of RMS and VDV, Maximum value, Peak, Peak to Peak and MTVV.

Test sessions for each piece of equipment selected were undertaken during the complete shift. Operators were instructed to go about their normal routines during the test session. The vibration measurement equipment was mounted on each machine, with each accelerometer calibrated prior to the initiation of testing at each mine site. The vibration signal was sent to a special data logger. Finally, data were downloaded to a PC computer for data analysis.

The measurement results were contained in an Excel sheet. For each machine, there is an average of 4000 measures of values as PEAK, P-P, MAX, RMS and VDV in each axis (X, Y, Z), shown as channel 1 (X), 2 (Y) and 3 (Z), which provides a matrix of 15 columns x 4000 rows = 60,000 elements.

With measurements carried out on 61 machines; the total data analyzed was approximately 3,600,000 (not all machines have the same number of measurements, with 4000 the average figure). To manage this bank of data a dedicated software tool was developed. With this software, a detailed study of the levels of exposure to vibration was carried out on all the equipment that made up the database.

Later, specific parameters that affect the results of exposure to vibration were assessed, including measurement time, work type, status of tracks, slopes, age of machine, type of seat, suspension type and tyre pressures.

Thanks to this tool, it was possible to reach the aim of achieving a comprehensive database to prepare a statistical representation of typical vibration levels affecting workers in the mining sector. A database in accordance with all the results of the measurements carried out was developed.

Relating to the second objective, the database generated in this task was offered to collaborate with other data bases existing in Europe. Databases consulted were the following:

a. KARLA state database für Arbeitsschutz, Germany.

It has 2999 data of whole-body system data and 1658 data for the hand-arm system. Contact was established and they showed great interest in the MINTOS data information.

b. GKV and HAV Database. Department of Public Health and Clinical Medicine at Umeå University, Sweden.

Contact was also made with them. When this database was set up, it was considered as a reference in Europe, but now it has been outdated by the German one KARLA.

c. Banca Dati Vibrazioni – (ISPESL, Istituto Superiore Prevenzione e Sicurezza sul Lavoro, Italy. (Updated in May 2009)

This one includes 857 vehicles with 1531 data and 1293 tools with 1075 measurement data. Contact with them was also made.

d. Spain

There is a database that was developed by the Ministry of works and Social Affairs - (INSHT) Instituto Nacional de Seguridad e Higiene en el Trabajo. Contact was established with them.

2.7.6 Task 5.6 Identify mining situations with major incidence of vibration related health effects

The objective was to analyse the technical origin of existing mining vibration problems, in order to assist employers in the correct use of the machinery in their exploitations and to develop protection measures to eliminate or at least reduce vibration risks.

Description of activities and discussion

From the deep analysis of the results obtained during the MINTOS project, it can be inferred that besides the machine itself, there are other decisive factors in the risk of exposure to vibration. These are presented below:

- **Exposure Time** - The exposure time is a decisive factor in the risk assessment of vibration. There is no doubt that the higher the time of exposure, the risk increases. Generally at a mine, the time that a worker is exposed to vibration due to the use of mobile machinery, normally corresponds to almost the total working time, which in many cases is more than 8 hours. If necessary, an effective measure to reduce the exposure time could be to make breaks at work and try to rotate jobs. Working on different machines that emit different levels of vibration, can "compensate" the high levels of vibration to which a worker may be subjected from one particular piece of equipment.

- **Track Conditions -**Adequate maintenance of the road surface also contributes to the daily exposure to vibration. The level of vibration that affects the worker increases as a result of the bumps, potholes, obstacles, stones, etc. The slope is one factor that contributes to increasing the risk. If the machine is going up over a track, the vibration level is generally lower, because the speed is also usually much lower. But if it is descending, the speed increases and consequently this increases the level of vibration.

- **Load of the Equipment -**The load and its proper distribution on the machine is an important factor in dumpers and trucks. It was shown that the risk of vibration is much higher in these vehicles when they are unloaded than when they are loaded. In most cases, in mining this factor is linked to the slope and the speed. That is to say, in earthmoving operations a dump truck normally tends to move loaded, ascending and at low speed, or to move without load and faster downhill. In the first case, the risk of exposure to vibration is normally lower than in the second case, unless other factors are involved in addition to the load, slope and speed

- **Type and Characteristics (Granularity) of Material -** The type of material affects the vibration produced in excavators mainly, but also in other equipment such as bulldozers, graders and loaders. Material removal operations are affected by the kind of material and blasting characteristics and whether the material is torn from the beginning or end of blasting. If the explosion has been insufficient the level of vibration in machines is more acute. This also occurs when it comes to the final blasting of material.

- **Stability and Speed of Driving -** The type of driving and speed also increase the risk due to vibration in the use of mobile machinery. A driver jerking along the truck, twitching and shaking in conjunction with high speed, exponentially increases the risk to workers and also has serious consequences for the machine.

- **Deterioration of Equipment** - The age of machines contributes to a higher risk of exposure to vibration. Similarly, if proper routine maintenance of work equipment is not carried out, this accelerates the deterioration of the machine and damping systems, and thereby increases the risk of vibration.

2.7.7 Task 5.7 Identification of risk factors during the loading/unloading operations

The main studies undertaken were firstly to identify the high risk areas relating to the loading and unloading of loads during transport operations, to video these operations at two mines, to specify computer based tools to enable simulation of these operations, to undertake risk analysis by analysing the musculo- skeletal loadings and then to make recommendations for minimising the risk.

The scenes of high risk manual transportation operations were identified, in conjunction with mining personnel. These manual transport operations included the holding of objects, loads or materials by one or more workers, and the movement of these objects by means of:- carrying, lifting, placing, pushing, pulling, moving, rolling and transportation.

Video recording of loading/unloading operations was performed at the following mines:

- ZIEMOWIT Colliery.
- RYDUŁTOWY - ANNA Colliery.

Video recordings were made at the sites of manual operations associated with transportation - in a material station (e.g. reloading of transported material from floor-mounted railways to suspended monorails), and a final station (e.g. moving the frames of arch supports).

Selected recorded activities are shown in Figure 2.7.13.

Figure 2.7.13 Selected registered loading/unloading operations

The following tools were then used for risk identification and risk assessment:

- 3D Studio MAX – for visualization of motion recorded in the form of a video film.
- ErgoMAX – software for ergonomic analyses.
- 3DSSPP – software for biomechanical analysis of the loads applied to the musculo-skeletal system for a selected body posture.
- Author software developed in the KOMAG Centre, operating in MS EXCEL environment and used for determination of angles specifying body posture and their export to 3DSSPP software in the form of a text file.

Methods for motion capture and analysis of the load to the musculoskeletal system were then developed. Subsequently, biomechanical calculations were made, to determine the following:- compression loads of the spine, shear loads of the spine, loads and moments acting on intervertebral discs in each axis and the percentage of the population able to take a determined posture in each joint.

All the results obtained were transferred to the MINTOS Repository.

Furthermore 13 case studies were developed, and the advantages and disadvantages of loading techniques to be learnt from their analysis were presented.

Finally, guidelines and recommendations for manual transportation of loads, as regards methods of decreasing the loads between the most loaded vertebrae of the spine were created. In this task both individual worker and working teams were studied. An exemplary result obtained by the method is shown in Figure 2.7.14.

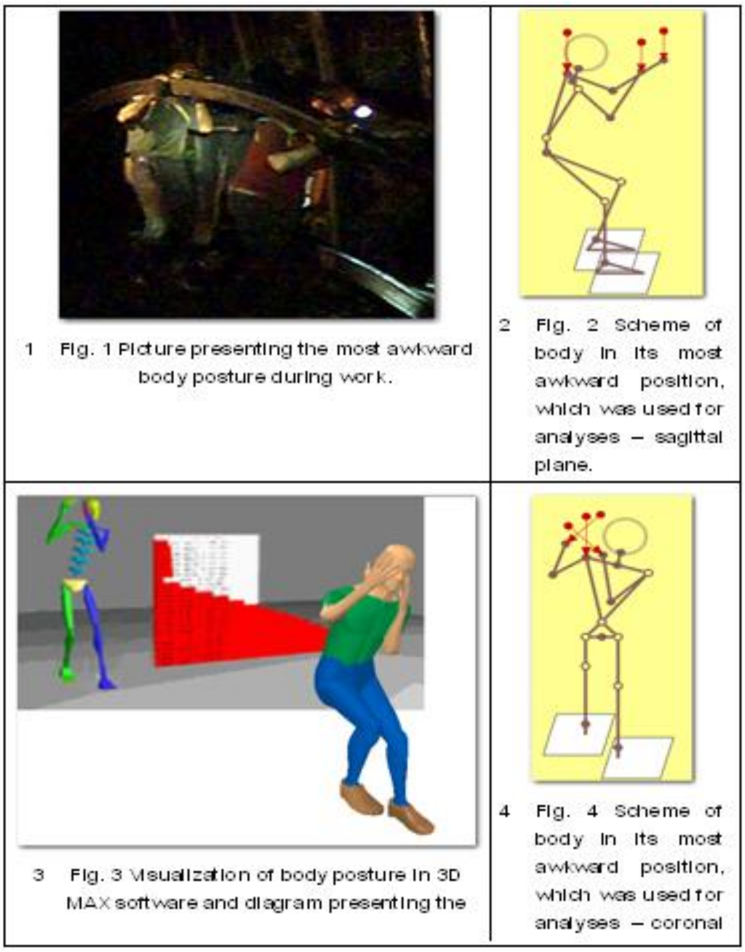


Figure 2.7.14 Example of application - Carrying an arch support on the shoulder

2.7.8 Conclusions for Work Package 5

The tests undertaken in task 5.1 showed that the introduction of a water mist system resulted in a significant reduction of airborne particulates emitted from the diesel engines. The introduction of low cost, non irritant additives indicated that further reductions can also be made. The result of the tests to reduce the gaseous content of the diesel exhaust showed little reduction. This component of the study requires further research, in terms of increasing the range of molarities used.

Exhaust emission trials were undertaken on a diesel engine fuelled with commercially available biofuel (B30), which complied with European Standard EN14214, and B50, which was 50% diesel and 50% vegetable oil. The results show a reduced level of particulates for B30 and B50 fuels against the levels found in a normal exhaust emission under normal operating conditions. The situation is less advantageous however when the water mist spray is applied. The addition of a small quantity of some anionic / non ionic surfactants can further reduce the level of particulates in the emissions.

Vibration measurements were made on sixty one items of mobile plant operating in five different coal mines in Spain. The measurements were taken at the operator's position, in accordance with the ISO Standard ISO 2631 for determining levels of whole body vibration. The measurements were made during the complete working shift, with subsequent analysis then undertaken to evaluate the effects of the influence of the impulsive component of the vibration, and to quantify the potential errors which could result from using shorter measurement time periods.

The main conclusions reached were that, in the mining industry, high levels of vibration are experienced by mine workers which, in many cases, exceed the legal limits set out in Directive 2002/44/CE. Using the RMS (root mean square) parameter to assess the vibration exposure risk significantly underestimated the risk when compared to using the VDV (vibration dose value), which was much better at taking into account any „impulsive' characteristics within the vibration signal. It is recommended that consideration is given to revising European standards for mine vibration levels, taking into account differences using VDV and RMS parameters.

Regarding the circumstantial parameters and the technical ones, the research clearly showed the influences of the local terrain (roadway conditions and roadway slope), driving habits (speed and aggression), the age of the equipment, loading of the equipment and the type and characteristics (granularity) of the material being transported.

In terms of the measurement time periods required to acquire an accurate evaluation of whole body vibration exposure risk, it was found that, for the case of machinery where the vibration is unknown, it is advisable to use a minimum measurement time of two hours.

A dedicated software tool was developed to manage the large amount of data generated during the research and a comprehensive database established. As a consequence of the detailed analysis achievable using this software, it was possible to determine the parameters and circumstances responsible for major incidences of vibration-related health effects.

Two further conclusions from the vibration research were, firstly, that there is a noticeable lack of authoritative vibration information available from machine manufacturers and, secondly, that there is a lack of data within international data bases. Accordingly, international vibration working groups were contacted and these have shown great interest in exchanging information and establishing possible collaboration. It is recommended that a collaborative association be maintained with database managers both within and outside the European Union to obtain a global database on the vibration levels affecting workers in the mining sector.

High health risk areas relating to loading and unloading of loads during transport operations were identified and analysed using computer aided risk analysis which was based on video analysis and simulation of real world tasks. Guidelines and recommendations for manual transportation of loads were produced.

2.8 Pilot Installations and Field Trials (WP6)

Work Package Objectives

Objectives included field trials and demonstrations of the fuel cell prototypes developed within task 1.4, deployment and testing of a pilot underground installation to evaluate the capabilities of transport tracking and diagnostics systems, field trials of the MINTOS web site reference project for mine transport systems and technology transfer demonstrations and workshops relating to SCADA systems.

2.8.1 Task 6.1 Fuel cell field trials

In a test application of a fuel cell at the Rittal research tunnel at the Grube Fortuna mine, an emergency power supply for a locating system to locate buried miners and for emergency lighting was integrated.

In the case of a failure of the mine's power system, the fuel cell takes over 100% of the supply, through the fuel cell operating in a hybrid circuit with a battery-supply on a bi-directional inverter. Operational parameters assessed included the output power of the system, and the temperature and humidity effects of the environment. In addition, the corrosion behaviour of the fuel cell housing was investigated.

For the test purposes, the mine mains power was switched off and the function of the emergency lighting was tested for a specified duration. The mine mains were switched off by means of the main switch, thus simulating a mains failure. Firstly, the battery is meant to assume the supply load. The fuel cell system is in "stand-by mode" and, as soon as the battery voltage is less than 22V-24V, it must automatically start and supply the load and charge the battery. The switch-on voltage is firmly preset in the software program. The battery current, the fuel-cell voltage and the fuel-cell current, the ambient temperature, the housing temperature (inner temperature) as well as the hydrogen consumption are measured for the purpose of proof and evaluation for further improvements. The hydrogen reserve is dimensioned for a test duration of approximately 48 hours, and is provided in the housing of the fuel cell. If the energy of the hydrogen is insufficient, the cylinders (3 x 10l (200bar)) can be exchanged during the operation. A midi GL200 data logger made by Graphtec is used as data logger.

Interval tests: measurements were taken at an interval of approximately 1.5 hours to establish cooling and restarting behaviour. The results obtained are shown below in Figure 2.8.1.

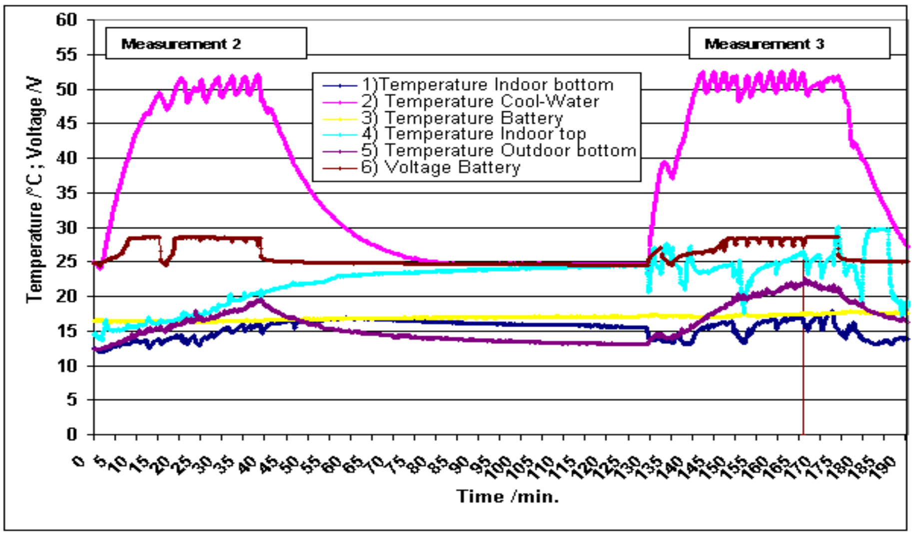


Figure 2.8.1 Interval Test Results

Endurance tests: the fuel cell system was run for periods of 90 minutes to determine average power and hydrogen consumption. The output power and consumption of the fuel cell system is shown in Figure 2.8.2.

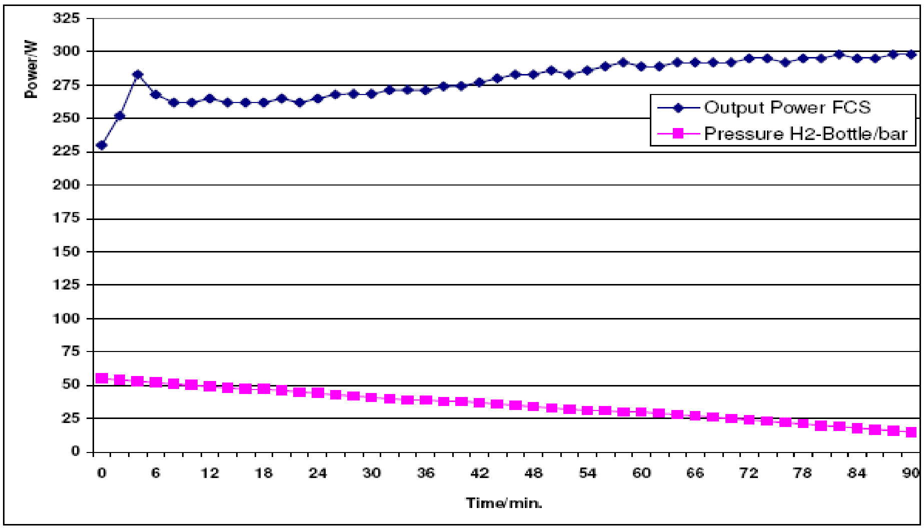


Figure 2.8.2 Output rating and consumption of the fuel cell system

Functional tests: the fuel cell system was switched on and off within short periods of time to determine the impact on output power and the potential for failures. An extract from the table of the results obtained is shown below in Figure 2.8.3

Functiontests On/Off	Load/W	Function (OK;NOK)		Comment
1 [Start/Stop]	330	☑	OK	-
		☐	NOK	
2 [Start/Stop]	330	☑	OK	-
		☐	NOK	
3 [Start/Stop]	330	☑	OK	-
		☐	NOK	
4 [Start/Stop]	0	☐	OK	Failer H2-Purge
		☑	NOK	
5 [Start/Stop]	316	☑	OK	-
		☐	NOK	

Figure 2.8.3 Functional test results table

Failure investigation: Despite the fault during test 4, the system continued to work again without any further problems. It was found that during a purge, the pressure regulator may occasionally induce oscillations. This was not a failure of the fuel cell but was related to pressure regulator performance and so could be easily resolved in next generation products.

The field trials on the 5kW fuel cell could not be carried out, since the unit suffered damage from the high humidity in the mine.

2.8.2 Task 6.2 Tests sensor systems

The first sensor system trials were carried out at Guido mine, level 320, in ventilation workings and a low seam face area. The test configuration enabled the performance of the real time location scheme in underground conditions, in a multi sensor configuration, to be determined. In particular, these tests were intended to:

- verify correct operation of the location system (hardware and GIS/SCADA software),
- assess downlink robustness,
- estimate maximum working distance between location heads required for reliable operation,

These tests also helped to validate proper operation of the network protocol and to introduce improvements to an early revision of GIS/SCADA software.

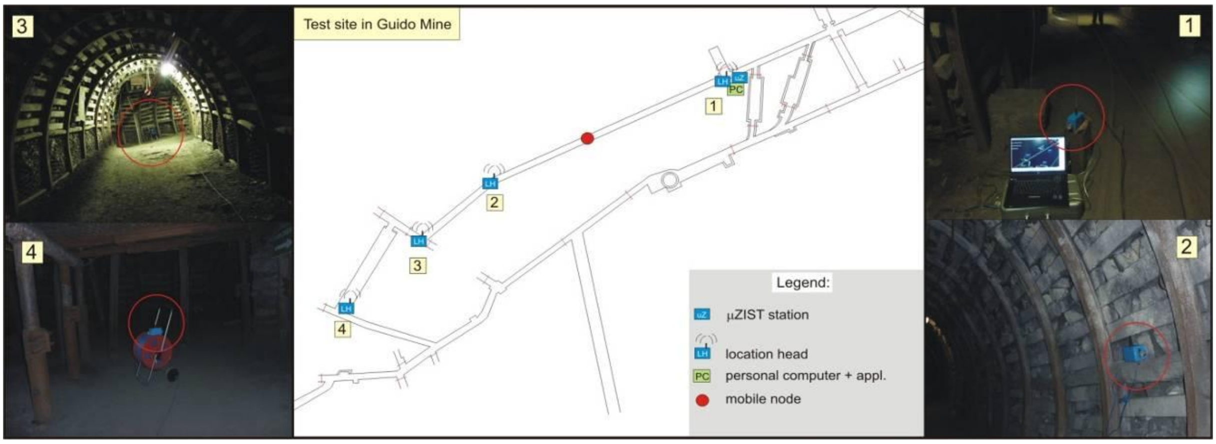


Figure 2.8.4 Underground tests carried out in Guido mine (Zabrze, Poland)

The satisfactory results of the tests at Guido mine ensured that the system was ready for being deployed in more harsh and hostile environments. After introduction of the required improvements, the decision was made to deploy a test installation in Ziemowit mine that belongs to KWSA. The mine was selected because of safety factors (very low methane hazard), as well as for the reason that there are Scharf monorail trains operating as one means of transportation. Hence, it was possible to perform testing of all system components in real conditions on the target platform. The test installation covered roughly 900m of underground workings (distance between first and the last location head).

Figure 2.8.5 Underground tests carried out in mine KWK Ziemowit (Ledziny, Poland)

During the tests, the behaviour of different system components was observed and analysed. The LHU sensors were located in an underground roadway, some of them in sections between automatically opening ventilation dams with steel doors. The LHU sensors and the wheelset diagnostic head DHU were linked with the backbone transmission subsystem based on µZist multiplexers. The developed location scheme relies on sequentially operating mobile nodes, CDU, installed in both cabins of the monorail train. This mechanism makes it possible to determine the precise location and heading direction of the vehicle. During numerous trials in various underground workings of Ziemowit mine, the longest possible range of a single LHU station was determined to be over 800m in line of sight conditions, with typical average coverage between 350 and 500m. Such results combined with the utilised communication/location scheme make it possible to distribute LHU sensors with a relatively large distance (400-800m) between stations. Thanks to advanced raw data filtering, the typical location accuracy observed at the GIS/SCADA dispatcher application was better than 2m, even at the maximum allowable monorail speed.

The wheelset diagnostic sensor DHU was tested with regard to operation of the implemented acoustic and contactless overheating detection methods. During the tests it was found that the acoustic method was able to detect advanced stages of bearing fatigue. In the case of light fatigue of the inner or outer race, the signal to noise ratio was insufficient for reliable operation. It was concluded that the method is appropriate for „post-mortem' rather than „preventive' diagnostics, but nevertheless it indicated rollers to be replaced. The contactless temperature based method worked reliably in the case of poor lubrication and jamming conditions, which gives the prospect of preventive maintenance actions. Also for the case of light bearing fatigue, but at heavy roller loads, fault detection with this method was possible. The tests were carried out with a DZ1500 Scharf monorail where some diagnostic signals are available at the drive PLC. However, at that stage it was not agreed with the manufacturer to get access to these data. Despite this, the machine diagnostics link of the CDU mobile node was successfully trialled, with test software which had fields for machine diagnostic data in transmission datagrams (for engine temperature, hydraulic pressure and electro-valve statuses). Its functionality is now used for the transmission of diagnostic data from floor mounted locomotives in a commercial system for the ZG Polkowice-Sieroszowice mine.

The reliability of the uplink and downlink was tested, together with text commands dispatching and alarming functionality. Sending text commands from the dispatcher's GIS/SCADA application was tested with positive results. Similarly, features of acknowledgement and alarm triggering from the cabin equipment were found to work reliably. The management functionality was received with much appreciation by the mine staff. Based on their comments, slight modifications with regard to colour and size of fonts for different signalling modes were introduced to the graphical interface of the cabin display. The user interface of the GIS/SCADA application was also constantly improved during the course of the project, with very valuable feedback obtained during the field trials stage. Modifications to the GIS/SCADA visualisation module were successively implemented according to suggestions from staff at the Ziemowit mine. The final revision was found to operate in a stable and user friendly way.

Details of the ATEX compliance status of all the sensors developed within this research element are given in Appendix II.

2.8.3 Task 6.3 Field trials of mining transport systems planning

Task 6.3 provided for the testing and refinement of the augmented reality based solutions developed in Work Package 4. The materials included in the MINTOS Repository, which were used to conduct tests of the systems and the industry trials are outlined below.

Field Tests for mining transport system designers

A traction calculation questionnaire was developed for system designers, referring to the following main topics:- the route configuration of the suspended monorail, determination of the maximum allowable load of the transportation set, selection of emergency brakes, formation of a transportation set, determination of braking distance, sketch of the transportation set and collision testing.

In order to help the end user to work with the created software, a thirty four page manual was created, describing the traction calculations aiding system. The manual covers the following main topics:

- Description of the system.
- Logging in to the system.
- Project management.
- Description of each step of traction calculations.

Following selection of the test sites for the transport system planning, appointment of testing teams, installation and configuration of required hardware and software, a separate workshop for each testing team was organized at three KWK mines (Ziemowit, Bielszowice & Halemba). The main purpose was to acquaint the team with the traction calculations aiding system. The developed user manual for traction calculations was additional help for the team.

After the training workshops, designers of the mine transport system tested the operation of the system, based on the WEB-site reference project. Tests of the system consisted of the creation of projects of the mine transport system and undertaking traction calculations. All traction calculations were documented in the form of a „traction calculations' report.

During the tests, teams collated remarks about the system functionality. After two months of testing the system functionality, the questionnaires were completed. The main results of the completed questionnaires were:

- The user interface of the traction calculations aiding system was designed properly.
- Small modifications regarding the determination of braking distance probably should be implemented.
- The database of transportation means should be extended with additional devices.
- Formation of the transportation set could be extended with the possibility of adding the load just by determination of its weight.

The results from the questionnaires and remarks from the testing team formed the basis for making corrections within the MINTOS Repository software and resources. A number of changes were made, including the incorporation of thirty characteristics of the suspended locomotives manufactured by SCHARF and PIOMA, and the inclusion of additional data regarding the most frequently transported materials such as: pumps, clamps, frames of supports, etc. into the database.

Field Tests for operators of suspended monorails and underground personnel carrying out transportation jobs

Training programmes and control lists were tested using ultra mobile PC devices and ATEX certified PDA devices. Questionnaires for the assessment of these training programmes were developed, covering the following main topics:

- General questions about the training programmes based on AR technology.
- Assessment of selected training modules.
- Assessment of the test module.
- The possibility of using multimedia glasses during training.
- Use of RFID technology to enable access to instruction via PDA during machine operation.

Sites for testing the AR software and training programmes were selected and testing teams appointed. Following the installation and configuration of the necessary hardware and software, workshops for testing teams were organized. The main purpose of these workshops was to acquaint the testing teams with use of the AR software and the content of the training programs.

Typical content of the check lists, which were tested during surface and underground trials, is illustrated in Figure 2.8.6.

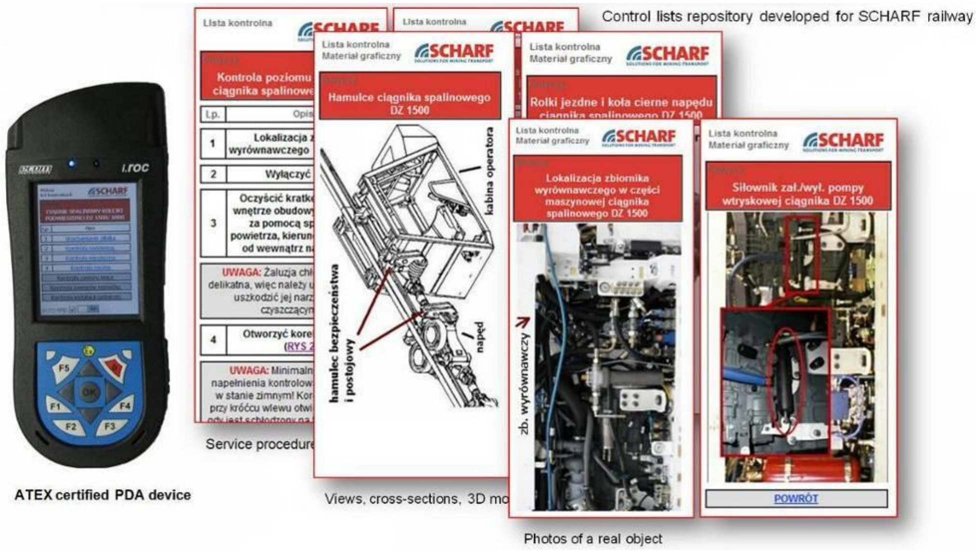


Figure 2.8.6 Control lists repository developed for SCHARF railway

During the tests, the testing teams collected remarks about system functionality and questionnaires were completed at the end of each test session. The main results from the questionnaires were as follows:

1. Use of software for RFID supported training is easy and understandable.
2. Information displayed when approaching a computer to a tag is legible, but in a few cases it could be extended.
3. Use of software for RFID technology allows easier memorizing of the location of different components.
4. The division of service procedures into particular steps and the use of additional films and animations contribute to easier and faster learning.
5. The use of multimedia glasses during training simplifies the learning process.
6. Instructions displayed on the PDA computer are very helpful during machine operation but they should be extended.

The results from the questionnaires and the remarks from testing teams provided the basis for making improvements to the AR software and training programs. The main improvements included:

- More accurate and detailed descriptions.
- Improvement of the presentations of the 3D model.
- Increasing the text size within the procedure of description labels.
- Increasing the text size and modification of colours.
- Adding a 2D sketch from the Technical Manual to describe machine components.

Figure 2.8.7 Underground test of RFID prototype system

Training workshops

Two training workshops were carried out. One of these was for the top management of KWSA, to ensure that they were familiar with the progress of the MINTOS project and to acquaint them with the new technologies being developed within the project. The topics addressed by the workshops are presented in Appendix 1:

2.8.4 Task 6.4 SCADA technology transfer workshops

Task Objectives

Description of activities and discussion

Discussions took place with UK Coal regarding the current surface and underground operational and programming aspects of their SCADA system, to allow the formulation of documentation necessary for conducting technology transfer demonstrations and workshops. Documentation, in the form of a manual describing the historical development, key concepts and the SCADA systems currently in use in the UK, along with an accompanying PowerPoint presentation was produced.

This documentation was designed to establish common definitions and base-line understanding of mine SCADA systems and hence act as a starting point for wider discussions to facilitate comparisons with approaches used by other EU partners and promote exchange of ideas and future development concepts.

The historical background to SCADA in the UK Coal Industry included in the documentation describes the industry's development routes starting from legacy direct wired remote control systems, moving on through the introduction of MINOS (MINe Operating Systems) to the use of Programmable Logic Controllers (PLCs). The historical development and fundamental concepts of communication protocols and their related standards are addressed, including the use of Local Area Networks (LAN), IEEE Standard 802.33.4 and Ethernet Protocols. The development and typical usage of transmission media such as using thick coaxial cable, UTP cabling, fibre optics and the related components such as network hubs, switches, bridges and routers are also outlined.

Having established the historical development routes and inherent challenges posed by the use of these technologies in a mining environment, the documentation then illustrates the current state of the art in the UK by outlining the UK Coal SCADA system at Daw Mill Colliery.

Based on the discussions held with UK Coal HQ staff, Colliery Engineers, system suppliers and end users, discussion points were developed and included in the documentation to promote further the exchange of ideas on possible performance enhancements. Furthermore, issues of hardware and software security are introduced to promote discussion in terms of potential consequences and impacts, the existence of common vulnerabilities, related testing issues and the development of good practice guidelines.

The technology transfer documentation was completed and arrangements for some SCADA technology transfer workshops progressed. One of these took place at EMAG in Poland in Spring 2010 and another at Daw Mill colliery in June 2010. Attempts were made to organise other workshops, but a key difficulty was getting commitment from mining companies to participate. Since the Mintos project was originally devised, SCADA technology has become much more widespread. Furthermore, there is an understandable tendency for mine operators to wish to liaise primarily with „local' consultancies and mining equipment suppliers from their own country.

2.8.5 Conclusions for Work Package 6

The field tests of the 300W RiCell 300 gave good insight into the behaviour of a PEM fuel cell underground, and showed that a fuel cell has the ability to serve as an emergency power source. During all tests, no hydrogen was detected outside the FC cabinet, which showed the high level of the developed safety concept.

Minor malfunctions during the functional tests (fast on/off cycles) were caused not by the fuel cell itself, but by subsystems. For the prototype built during this programme, the focus had been on the fuel cell itself. In future research, more development of the subsystems is required.

The 5kW fuel cell suffered environmental damage to the cabinet, which was supplied by Idatech, due to the high humidity present in the mine and consequently could not be tested. In future systems, either components need to be of better quality, or the cabinet needs to be air-conditioned. Nevertheless, the outcomes of the MINTOS project have influenced the direction of Rittal's technology decisions and further research is continuing in this area under private funding..

The initial sensor field trials at Guido mine enabled the performance of the real time location scheme in underground conditions, in a multi-sensor configuration, to be determined, and enabled improvements to the GIS/SCADA software to be made. Later, a full test installation at KWSA's Ziemowit mine, with mobile nodes installed in both cabins of a SCHARF monorail, then allowed trials of the precise location and heading direction of the vehicle to be undertaken successfully. The trials also allowed the performance of the wheelset diagnostics sensors to be assessed, together with the machine diagnostics link.

Direct co-operation with the end users, especially the mine staff at Ziemowit colliery during the tests, provided a valuable feedback with regard to desired modifications and improvements to the developed system, which resulted in user oriented optimisation from an early stage. From the tests carried out in real conditions, it was possible to verify operation of the developed sensor systems and controlling software. The tests proved robust operation of the location, diagnostic and transmission sub-systems.

Field trials of the prototype Traction Calculations Aiding System and the prototype training system, which uses Augmented Reality technology, were undertaken in conjunction with a number of personnel at three KWSA mines. The AR training system was also tested at a manufacturer's works, SCHARF and at MURCKI Colliery. The Traction Calculation System, which is available on an internet platform, is addressed to the designers of mine transport systems.

The required hardware and software were installed at each mine and training workshops for the traction system held with selected mine teams. User manuals were also supplied. The design teams operated the traction calculations system over a period of two months and then provided feedback to enable refinements to be made. The results of the tests largely confirmed the original design assumptions and enhancements to the system were proposed, including the incorporation of thirty characteristics of suspended locomotives manufactured by SCHARF and PIOMA within the MINTOS repository.

The operational trials of the AR training programmes followed a similar procedure of training workshops, but in this case with operators of suspended monorails and other personnel who carry out transportation tasks underground. The training programmes and control lists were tested using ultra mobile DC devices and ATEX certified PDAs. The new form of training was assessed very positively by the personnel at the mines.

The documentation developed to support the SCADA technology transfer workshops was well received and the two workshops were considered by the participants to be useful. Since the Mintos project was originally devised, SCADA technology has become much more widespread and there is an understandable tendency for mine operators to wish to liaise primarily with „local' consultancies and equipment suppliers from their own country. Consequently, the number of workshop it was possible to hold within the timescales of the project was limited.

2.9 Dissemination of Results (WP7)

Work Package Objectives

Work Package 7 was intended to provide reports and communications regarding the research results throughout the Mintos project. In addition to the interim, mid-term and final reports supplied to the Commission and TGC1, many other forms of dissemination were utilised during the project. This section provides a list of these. Further exploitation of the project results is presented within Section 5.

Work Package 1

Rittal issued a number of publications concerning the underground tracking system and its application in the Grube Fortuna mine. Furthermore, the mine itself was equipped with a sign at its entrance describing Rittal's activities and the funding of the Mintos project provided by the European Commission.

Reviews in newspapers, TV broadcasts, and conference presentations included:-

1. Dipl.-Ing. Martin Roßmann, "Rittal testet Technologien im Bergwerk", Bergbau (November 2008) - Magazine for raw materials production Within this article, the: Grube Fortuna research mine segment was described and the tracking system developed within WP2 described, focussing on mining applications
2. Dipl.-Ing. Martin Roßmann, "Zuverlässige Gehäuselösungen von Rittal", Glück auf (Mai 2008) - Magazine for raw materials production
3. Sven Jessen, "Rittal forscht unter Tage", Wetzlarer Neue Zeitung (Juni 2008) – Regional daily newspaper
4. Friedrich Schmitt, "Stollen, Strecke, Sohle, Schacht" – Wetzlarer Neue Zeitung (Juli 2008) – Regional daily newspaper
5. "Rittal testet Technologien in Fortuna" - Gießener Allgemeine Zeitung (Juli 2008) - Regional daily newspaper
6. "Forschungsstollen eröffnet" - Lahn-Dill Wirtschaft (September 2008) – Trade journal
7. "Zukunftssicherheit für den Bergbau" – VDI Nachrichten (November 2008) – Specific journal for engineers
8. Hessischer Rundfunk "Hessenschau" broadcast on regional TV-station, 02.07.2008 - 19.30
9. Deutsche Welle TV – broadcast on TV-station (german+english), 25.03.2009 (several times + internet). In addition to the tracking system installed within the research mine, this also covered the fuel cell system operating as an emergency backup energy supply.
10. RTL Regional – „Guten Abend RTL" broadcast on TV-station, 29.07.2009 - 18.00
11. Presentation during VDEI meeting (Association of German Railway Engineers) – 12.05.2010
12. Rittal GmbH & Co KG, "Personenortung unter Tage", RFID im Blick - Magazine with focus on RFID-technologies, 07/08.

MRSL present a detailed report of all RFCS research activities to the UK Safety and Health in Mines Research Advisory Board on an annual basis. The members of this committee are comprised of representatives from the UK Health and Safety Executive, the Mines Inspectorate (including the Chief Inspector of Mines), mining companies, universities, mining Trades Unions and mining Institutes. In addition to submission of the report, a formal presentation of project results is given to the committee. Over the last 4 years, the report has included the results of all the work packages in the Mintos project in which MRSL was involved. The next presentation, summarizing the project results, will be given in April 2011.

Work Package 2

A paper was submitted by EMAG and a lecture presented during a scientific and technical conference:

Wiszniowski, Przemyslaw. „WLSS Bezprzewodowy System Wspierania Logistyki dla Transportu Podziemnego' conference „Innowacyjne Maszyny i Technologie – Bezpieczeństwo" Szczyrk 2011.

The paper describes the sensor developments undertaken within work package 2 and their subsequent deployment in underground trials in work package 6.

The WLSS system developed within task 2.3 was presented at the Embedded World conference and expo Nürnberg in 2011.

The WLSS system was also submitted to the „Gorniczy Sukces Roku' competition:- „WLSS™. System wspomagania logistyki dla transportu dołowego'

Recently a draft paper was submitted to the 22nd World Mining Congress & Expo to be held from 11-16 September 2011 Istanbul ; Przemyslaw Wiszniowski, „Wireless Logistics Support System for Underground Transport' (Intelligent Mining and Automation cluster).

Work Package 4

As a result of the coordinated research of KOMAG, GIG and the mining company KWSA within work package 4, the following papers were written:-

1. Winkler T.: *Organizacja zasobów wiedzy projektowej i eksploatacyjnej w cyklu życia maszyn i urządzeń górniczych* (eng. *Arrangement of resources of designing and operational knowledge in life cycle of mining machines and equipment*). Szkoła Eksploatacji Podziemnej 2009. Materiały Konferencyjne. Instytut Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk. Sympozja i Konferencje nr 74. Kraków 16-20 luty 2009.
2. Winkler T., Chuchnowski W., Dudek M., Tokarczyk J., Szewerda K.: *Narzędzia internetowe wspomagające weryfikację projektów transportu podziemnego w świetle kryterium bezpieczeństwa* (eng. *Internet tools supporting verification of underground transportation designs in the light of safety criterion*). I Międzynarodowa Konferencja „Problemy bezpieczeństwa w budowie i eksploatacji maszyn i urządzeń górnictwa podziemnego", Ustroń 17-19 czerwca 2009.
3. Winkler T., Dudek M., Michalak D., Tokarczyk J., Szewerda K.: *Weryfikacja projektów podziemnego transportu górniczego w rozproszonym środowisku projektowym* (eng. *Verification of designs of underground mining transportation in a dispersed designing environment*). Konferencja Techniki Urabiania TUR 2009. 15-18 września Krynica-Zdrój.
4. Winkler T., Dudek M., Chuchnowski W., Michalak D., Tokarczyk J., Rozmus M.: *Zarządzanie wiedzą w procesie kształtowania bezpieczeństwa w podziemnym transporcie górniczym* (eng. *Knowledge management in the process of safety formation in underground mining transportation*). 33rd Conference of Safety in Mines Research Institutes, Wisła, September 15-18, 2009.
5. Dudek M.: *Badanie kolizyjności transportowanych ładunków z otoczeniem w środowisku programów CAD* (eng. *Analysis of the collision threats of transported loads in CAD software environment*). V Międzynarodowa Konferencja "Bezpieczeństwo pracy urządzeń transportowych w górnictwie", Ustroń 4-6 listopada 2009.
6. Michalak D., Rozmus M., Jaszczyk Ł.: *Możliwości zastosowania technologii Augmented Reality i RFID w szkoleniach pracowników transportu* (eng. *Possibilities of applying Augmented Reality and RFID technologies in training of transportation operators*). V Międzynarodowa Konferencja "Bezpieczeństwo pracy urządzeń transportowych w górnictwie", Ustroń 4-6 listopada 2009.
7. Winkler T.: *Oparte na wiedzy planowanie procesów w podziemnym transporcie górniczym* (eng. Knowledge-based planning of processes in underground mining transportation). KOMTECH 2009, Innowacyjne, bezpieczne oraz efektywne techniki i technologie dla górnictwa. Człowiek - Maszyna - Środowisko, Instytut Techniki Górniczej KOMAG, Gliwice 2009.
8. Michalak D., Jaszczyk Ł., Lesisz R., Rozmus M.: *Zastosowanie technologii Augmented Reality w szkoleniach użytkowników kolejek podwieszonych* (eng. *Applying of Augmented Reality technology in trainings of users of suspended monorails*). KOMTECH 2009, Innowacyjne, bezpieczne oraz efektywne techniki i technologie dla górnictwa. Człowiek - Maszyna -

Środowisko, Instytut Techniki Górniczej KOMAG, Gliwice 2009.
9. Dudek M.: *Zastosowanie modelowania przestrzennego do analizy kolizyjności na trasach kolejek podwieszonych* (eng. *Applying of solid modelling for analysis of collision occurrence on suspended monorails routes*). KOMTECH 2009, Innowacyjne, bezpieczne oraz efektywne techniki i technologie dla górnictwa. Człowiek - Maszyna - Środowisko, Instytut Techniki Górniczej KOMAG, Gliwice 2009.
10. Tokarczyk J., Chuchnowski W., Szewerda K.: *Weryfikacja obliczeniowa i doświadczalna zawiesi i złączy szyn kolejek podwieszonych* (eng. *Computational and experimental verification of slings and joints of suspended monorails*). KOMTECH 2009, Innowacyjne, bezpieczne oraz efektywne techniki i technologie dla górnictwa. Człowiek - Maszyna - Środowisko, Instytut Techniki Górniczej KOMAG, Gliwice 2009.
11. Winkler T., Dudek M., Chuchnowski W., Michalak D., Tokarczyk J., Rozmus M.: Narzędzia internetowe upowszechniające wiedzę o projektowaniu i eksploatacji maszyn i urządzeń górniczych (eng. *Internet tools disseminating knowledge about designing and operation of mining machines and equipment*). Materiały na konferencję: XIX Szkoła Eksploatacji Podziemnej 2010, Kraków, 22-26 lutego 2010.
12. Winkler T., Dudek M., Chuchnowski W., Tokarczyk J.: *Internet tools supporting planning of underground mining transport*. Aachen International Mining Symposia. Mineral Resources and Mine Development. RWTH Aachen, 26th and 27th May 2010.

Many training workshops involving personnel from mining companies and equipment suppliers were also undertaken during the course of the project.

Work Package 5

Aitemin published various technical papers to assist in the dissemination of the MINTOS project results. Primarily, these were technical papers submitted to congresses, but also included the publication of the AITEMIN Annual Report – „Memoria'. Another important element of the dissemination was Aitemin's web page -www.aitemin.es.

The AITEMIN „Memoria' has an issue of more than 1000 copies and is spread to partners across the Spanish mining company sector, together with Universities, Central Governmental and Local government Administrations and Technological centres.

Based on the results of the project, a „Guide to the Risks of Exposure to Vibration in Mobile Machinery used in Mining industry' was produced. This guide was published by AITEMIN in June 2010. Further dissemination was undertaken during a technical meeting celebrated at the Mining Engineers University of León.

This meeting was funded by the Spanish Ministry of Industry. The software program developed in the MINTOS project was published in a CD format, with some 200 copies issued. The Leon meeting was very successful, with more than 70 professionals, mostly from the mining industry, attending, but also with personnel from other related industries, such as building, tunnelling, public works and representatives belonging to the central and autonomous government, universities, consultancies and insurance companies.

As a result of the success of the event, especially by the Spanish mining sector, it is expected that there will be a repetition of the technical congress in other cities, such as Madrid, at the end of 2010.

For the following year 2011, plans are in place to continue with further dissemination of the project at different mines and cities in Spain. It has been agreed that funding will be available from the Spanish Ministry of Industry. Also a new technical congress is planned for Seville, in the south of Spain, together with the publication of a further 200 copies of the „Vibration Guide'.

The past events and this future programme guarantee the dissemination of the results of the MINTOS project to the majority of workers in the mining sector in Spain and elsewhere.

A conference presentation was also made at the 1st National Congress of Industrial Minerals, which took place on the May 25-28, 2010 in Saragossa (Spain). The paper presented was entitled „Response of the extractive sector in relation to the requirements to counteract the risks of exposure to noise and vibration Prospects for improvement'. The authors were Madera, J. and Morillo, P.

A further published document was:

Madera, J., Morillo, P. Riesgo por Vibraciones en la Industria Extractiva: Situación del Sector Respecto a las Exigencias Legales. Published in scientific journal "Canteras y Explotaciones". Nº 498, pp. 21-25. July 2008.

3 Conclusions

From the scoping study, the Proton Exchange Membrane Fuel Cell (PEMFC) was chosen for further investigations with regard to the development of 5kW and 300W systems, due to its very good dynamic behaviour. Risk analysis of the 300W fuel cell showed that it was suitable for „fresh air' areas of a mine and arrangements were made for it to be tested underground.

The field tests of the 300W RiCell 300 gave good insight into the behaviour of a PEM fuel cell underground, and showed that a fuel cell has the ability to serve as an emergency power source. During all tests, no hydrogen was detected outside the FC cabinet, which showed the high level of the developed safety concept.

Minor malfunctions during the functional tests (fast on/off cycles) were caused not by the fuel cell itself, but by subsystems. In future research, more development of the subsystems is required. Nevertheless, use in an M1 area is not achievable at present.

The 5kW fuel cell suffered environmental damage to the cabinet, due to the high humidity present in the mine and consequently could not be tested. As a result, full transport-scale studies of power trains were not applicable. In future systems, either components need to be of better quality, or the cabinet needs to be air-conditioned. Nevertheless, the outcomes of the MINTOS project have influenced the direction of Rittal's technology decisions and further research is continuing in this area under private funding..

Several additional applications for fuel cells with an energy consumption of below 1kW were identified, especially those related to safety and control.

Bio-fuels could be used in underground diesel vehicles, offering reduced particulate emissions, but the engines would require tuning and adjustments. In practice the bio-fuels would need to be used as blends, probably up to a maximum of 5% by volume, in order not to invalidate the manufacturer's warranty. Higher percentage blends could be utilised in CHP systems. A significant disadvantage of bio-fuels is that the cost of production is estimated at three to four times that of diesel.

Trials of a water mist system applied to diesel engine exhausts showed that the introduction of a water mist resulted in a significant reduction of airborne particulates emitted from the diesel engines. The introduction of low cost, non irritant additives indicated that further reductions can also be made. Trials with a diesel/bio-fuel blend showed marginal reductions in emitted particulates when water sprays or additives were used

The result of the tests to reduce the gaseous content of the diesel exhaust showed little reduction. This component of the study requires further research, in terms of increasing the range of molarities of the additives used.

Wonderware's InTouch SCADA was selected as the preferred software package for deployment in UK mines. Work was subsequently undertaken in conjunction with UK Coal to transfer all the control and monitoring of underground plant and the mining environment at Daw Mill Colliery to this software.

Documentation to support SCADA technology transfer workshops was designed and produced. The documentation illustrates the current state of the art in the UK by outlining the UK Coal SCADA system at Daw Mill Colliery and introduces discussion points designed to promote the exchange of ideas on possible performance enhancements. In addition to possible performance enhancements the documentation addresses issues such as hardware and software security in terms of potential consequences and impacts, the existence of common vulnerabilities, related testing issues and the development of good practice guidelines.

Arrangements for two SCADA technology transfer demonstrations and workshops were progressed, but attempts to organise other workshops encountered difficulties in getting mining companies to participate.

After a detailed market analysis of current tracking and localisation systems for use in underground environments, a suitable and extendable system was chosen for the tracking system, with Time-of-Flight ranging methods. Diagnostic methods based on acoustic emission analysis were studied and laboratory and in situ tests carried out. Suitable acoustic sensors and a signal processing subsystem were then identified. Tests in real conditions with spatial temperature rise observations helped to provide information on the requirements for the contactless temperature sensor developed subsequently.

A demonstrator of the tracking system, consisting of mobile nodes, stationary nodes and visualisation software was developed and implemented. An ATEX-compliant version of the location sensors, with innovative power supply and transmission, was developed and interfaced to a μZist backbone transmission system. The resulting solution enabled large area coverage, with only limited resources required. A vehicle mobile tag with a simple user interface was developed. It takes part in the real time location process, as well as facilitating interaction with the underground dispatcher. A sensor head for wheelset diagnostics was developed, combining both acoustic emission and contactless temperature measurement methods, in order to provide a broader scope of failure mode detection.

A demonstration GIS/SCADA application for the underground dispatcher and mine control room was developed. It enables online visualisation of vehicle positions and heading directions and their diagnostic status. The developed software also provides a means of simple and efficient interaction between vehicle operators and the underground dispatcher.

The transmission capabilities of the developed sensor system can be effectively used for the provision of information which is vital from a fleet management point of view. Features facilitating interaction between the underground dispatcher and the vehicle operators were successfully developed. Implementation of text command dispatching, warning and alarm broadcasting can improve both the efficiency of transport system operation and its safety. Implemented features provide a means for effective underground fleet management and for ensuring reliable operation of the transport process.

Initial sensor field trials at Guido mine enabled the performance of the real time location scheme in underground conditions, in a multi-sensor configuration, to be determined, and improvements to the GIS/SCADA software to be made. Later, a full test installation at KWSA’s Ziemowit mine, with mobile nodes installed in both cabins of a SCHARF monorail, then allowed trials of the precise location and heading direction of the vehicle to be undertaken successfully. The trials also allowed the performance of the wheelset diagnostics sensors to be assessed, together with the machine diagnostics link.

Direct co-operation with the end users, especially the mine staff at Ziemowit colliery during the tests, provided a valuable feedback with regard to desired modifications and improvements to the developed system, which resulted in user oriented optimisation from an early stage. From the tests carried out in real conditions, it was possible to verify operation of the developed sensor systems and controlling software. The tests proved robust operation of the location, diagnostic and transmission sub-systems.

An important safety achievement resulting from the project was the provision of a vehicle operator with automatic fire alarm functionality. The developed scheme can be expanded beyond fire related alarms, because the MAW module operates with a wide span of safety monitoring systems. Such functionality is complementary to classical „audio’ alarm broadcasting but is characterised by a superior range (hundreds of metres), compared to the limited range of audio signalling alarm broadcast and, also, the alarm is not affected by acoustic noise.

The developed alarm broadcasting scheme will be exploited within the future products of EMAG, especially in integrated alarm systems for broadcasting gas and fire related alarm messages not only for transport systems but also for personal warning in day to day operations.

A training aid simulator which was developed to familiarise mineworkers with the correct procedures to follow in the event of a fire alarm, provides a very realistic and visual training tool.

The functionality of conventional fire fighting equipment can only be checked by discharging the fire suppressant; consequently it cannot be re-used. The key feature of the developed on-board engine compartment, cab and wheel-arch fire-fighting system is that can be periodically tested and yet still maintain operational capability. A 3-second test „blast' can be undertaken and the system still retains operability for a further 45 blasts.

Interaction with a large number of experienced mining personnel enabled definition of all the necessary information required for designing safe and efficient transport systems to be obtained. The proposed structure and concept of the repository was introduced to work teams and requirements for the training of designers, planners and service personnel established.

Identification and assessment of risk factors for the mine transport system components was undertaken, and the layered model of the MINTOS repository set up. Guidelines for the selection of safety equipment were also.

Existing and planned transport systems were analysed, in order to identify elements for improvement by using computer methods. The three key elements identified were traction calculations, modelling of roadways, and the creation of checklists for designers, operators and service personnel. Guidelines for transport systems planning were developed.

The prototype WEB based platform (MINTOS Repository) for the integration of specialists involved in the transport planning process was successfully developed, as well as the development and evaluation of a prototype augmented reality (AR) system to integrate and present information to operational staff. The AR system has the capability to integrate and present information gathered from a wide range of sources to operational staff.

Effective training resources were established through integration with the AR software and the implementation of obtained materials into the IETM environment developed in the IAMTECH project. A number of training programs for a SCHARF monorail were then developed.

Field trials of the prototype Traction Calculations Aiding System and the prototype training system, which uses Augmented Reality technology, were undertaken in conjunction with a number of personnel at three KWSA mines. The AR training system was also tested at a manufacturer's works, Scharf and at Murcki Colliery.

The design teams operated the traction calculations system over a period of two months and then provided feedback to enable refinements to be made. The tests largely confirmed the original design assumptions and enhancements to the system were proposed, including the incorporation of thirty characteristics of suspended locomotives manufactured by SCHARF and PIOMA within the MINTOS repository.

Operational trials of the AR training programmes were undertaken with operators of suspended monorails and other personnel who carry out transportation tasks underground. The training programmes and control lists were tested using ultra mobile DC devices and ATEX certified PDAs. The new form of training was assessed very positively by the personnel at the mines.

Measurements of whole body vibration were made on sixty one items of mobile plant operating in five different coal mines in Spain. Measurements were made during the complete working shift, with subsequent analysis then undertaken to evaluate the effects of the influence of the impulsive component of the vibration, and to quantify the potential errors which could result from using shorter measurement time periods.

In the mining industry, high levels of vibration are experienced by mine workers which, in many cases, exceed the legal limits set out in Directive 2002/44/CE. Using the RMS (root mean square) parameter to assess the vibration exposure risk significantly underestimated the risk when compared to using the VDV (vibration dose value), which was much better at taking into account any „impulsive' characteristics within the vibration signal. It is recommended that consideration is given to revising European standards for mine vibration levels, taking into account these differences.

The research also showed the influences of the local terrain, driving habits, the age of the equipment, loading of the equipment and the type and characteristics of the material being transported.

In terms of the measurement time periods required to acquire an accurate evaluation of whole body vibration exposure risk, for the case of machinery where the vibration is unknown, it is advisable to use a minimum measurement time of two hours.

A dedicated software tool was used to develop a comprehensive database of the measurement results. As a consequence of the detailed analysis achievable using this software, it was possible to determine the parameters and circumstances responsible for major incidences of vibration-related health effects.

Two further conclusions from the vibration research were, firstly, that there is a noticeable lack of authoritative vibration information available from machine manufacturers and, secondly, that there is a lack of data within international data bases. Accordingly, international vibration working groups were contacted and these have shown great interest in exchanging information and establishing possible collaboration. It is recommended that a collaborative association be maintained with database managers both within and outside the European Union to obtain a global database on the vibration levels affecting workers in the mining sector.

4 Exploitation and Impact of the Research Results

Work Package 1

A second prototype of the fuel cell developed within task 1.4 and trialled in task 6.1was presented at various shows and trade shows, for example Tunnel symposia, the Hannover Trade Show, and other specialised events.

There have also been a number of expressions of interest in the use of the special fuel cell from a range of other industries, including railway and tunnel applications, traffic control and broadband distribution. Such systems would integrate the fuel cell module, gas storage and power electronics specific to the customer's application. Many other industries perceive the mining industry to be a leading industry, in terms of environmental demands. It is well known that a system which can function properly in a mine environment can be easily adapted to the demands of other industries.

Work Package 2

Sensors developed within task 2.2, together with the software developed within tasks 2.3 and 2.4 form an advanced system which can be used for support of underground vehicle based transport logistics. A mature revision of the system was dubbed WLSS (Wireless Logistics Support System) and is now available as a commercial product. The first commercial application of the system is currently being deployed by EMAG for the KGHM mine ZG Polkowice-Sieroszowice in an adapted revision, to support a floor mounted train transport system. The installation will cover approximately 17km of underground workings. Modular design of the transmission system µZist, which is used there as a backbone, will be also employed to realize digital CCTV monitoring of critical areas. The resulting solution will be a solid tool for underground fleet management and will enable significant efficiency and reliability improvements of the transport system. The system is planned to be fully operational by late Spring 2011.

It should be mentioned that the developed solution offers an attractive alternative to any competing wireless monitoring systems currently based on WLAN or leaky feeder technologies. This is from both performance and price points of view, due to the developed advanced transmission and power supply solution of distributed sensors, which have resulted in low infrastructure costs. The scope of application is not limited to coal mines; the system can be used in any type of underground mine. The capabilities of the location technology also make it possible to adapt the system for tracking other mobile and „nomadic' assets, such as personnel, important machines etc. In such instances, the resulting system would provide a total solution for assets management. The diagnostic sensors can be easily adapted for the monitoring of rotating parts of machines (gearboxes, drives etc.). By virtue of the intrinsically safe design and the ability to operate with fieldbus interfaces, complex distributed online diagnostic monitoring systems for underground mining machines can be realized.

A Chinese delegation representing the Chinese coal mining authorities visited the Grube Fortuna mine in December 2009 and was very interested in the application of the underground tracking system. The delegation is looking for a system to increase the safety of the staff in Chinese mines.

A petty patent has been given in Germany (DE 202008005467, 27.08.2009) to Rittal.

Undisclosed PCT-applications have been filed in the following countries; Australia, Austria, Brasil, Canada, Chile, China, Germany, New Zealand, Poland, Russia, Republic of South Africa, Switzerland, USA

Work Package 3

The wireless alarm broadcasting scheme developed under Task 3.1 can be used as complementary to existing audio based solutions but offers much higher alarming range and efficiency, especially in environments characterised by high levels of acoustic noise. The field of applications is not only limited to fire related alarms, thanks to operation with the versatile MAW module. Additionally the system can be expanded to be also used with personal alarming devices, which again broadens the field of its application.

The vehicle fire suppression system is of particular interest to the UK Mines Inspectorate and to the owners of the rock salt mine in the northwest of England. The system developed is the only onboard vehicle fire fighting system that allows checks to be made on its functionality without being „fully discharged' and hence losing its operational capability. Arrangements had been made for a detailed presentation of the MINTOS results to the mines inspector responsible for transport safety, but unfortunately he became seriously ill and was not at work for many months. It is expected that the presentation will be made in the first half of 2011.

Work Package 4

Prototypes of the Traction Calculations Aiding System and the Training System that use Augmented Reality were tested in real conditions by the personnel of selected mines grouped in the Coal Company JSC. The training system was also tested at a suspended monorail manufacturer's site. Test results proved the design assumptions and the new form of training was well received by mine employees. Both systems will be commercialized and adapted to the industrial conditions after the end of the project.

The Training System is intended for operators of underground transportation means and for mine personnel that are involved in the transportation process. The main advantage of the technology is that images of real object can be complimented by additional information. The innovative approach to training enables not only delivery of knowledge about a given transportation component to knowledge users, but it can also shape the competence of operators of machines. The training can be carried out directly at the place of machine operation, on the machine on which the operator will work.

Currently the Traction Calculation Aiding System is implemented as a pilot system in a KWSA colliery. Furthermore, the developed computer system for aiding the designing process is currently at the implementation stage in the Coal Company JSC in Poland, which is the largest company of its kind in Europe. JSC employs 66 thousand people, its coal production capacity is approximately 55 mio. tonnes per year and its net profit in 2009 was about 5 mio. EUR.

The JSC Coal Company's Board has found that use of the internet tools to aid the design process of transport systems effectively improves the quality of the designs of transport routes and, as a result, also improves the mineworkers' safety. Such a system minimizes the probability of an accident on the transport route, by supporting the designer in taking decisions about the selection of proper transportation means and about configuration of the transportation route.

Work Package 5

Future collaboration with the Technical Committee for standardisation of AENOR /AEN/CTN 81 "Prevention and personal protection methods in the workplace" number 6, "vibration and mechanical shocks" has been offered, together with supply of the MINTOS data, once dissemination has been approved. This collaboration has been welcomed and accepted by this standardisation Committee.

Also this offer will be made to the CEN/TC 231 Committee. It is considered to be an essential step in endeavouring to put the specificities of the mining sector in the international environment.

Contact has been made with working groups in Austria and Germany, who have shown interest in exchanging information and establishing possible collaborations, and contact has also been made with other international groups.

5 List of Figures

6 List of Tables

7 List of acronyms and abbreviations

Acronym	Meaning
µZist	Integrated Intrinsically Safe Transmission System – resulting from RFCS NEMAEQ project (product of EMAG)
2D, 3D	two/three dimensional
3D Studio MAX	Visualization software used to display motion recorded in the form of a video film
3DSSPP	software for biomechanical analysis of loads applied to the musculo-skeletal system,
A/D	Analogue to Digital
ALARP	As Low As Reasonably Practicable
CAD	Computer Aided Design
CCTV	Closed Circuit Television
CDU	Cabin Display Unit
CSS	Chirp-Spread-Spectrum
DHU	Diagnostic Head Unit
DMA	Direct Memory Access
DSP	Digital Signal Processor / Processing
dxf/dwg	popular CAD drawing format
ErgoMAX	software for ergonomic analyses
FIFO	First In First Out
GIS/SCADA	Geographical Information System / Supervisory Control and Data Acquisition
GKP-09	Mining Explosion Proof Computer (product of EMAG)
LHU	Location Head Unit
MAW	„Modul Akwizycyjno Wyzwalajacy' (transl. Acquisition And Triggering Module) – (a product of EMAG)
RMS	Root Mean Square
SAT, STAR	alarm broadcasting / dispatching systems (product of Telvis company)
SCADA	Supervisory, Control and Data Acquisition software
SD2000	GIS/SCADA application (product of EMAG)
SDRAM	Synchronous Dynamic Random Access Memory

SMP-NT	or SMP-NT/A, ZEFIR, SWuP, KSP, KSP-2 – Safety monitoring systems (from various vendors EMAG, Prunella, Haso, Carboautomatyka)
VDV	Vibration Dose Value
WLAN	Wireless Local Area Network
WLSS™	Wireless Logistics Support System (new product of EMAG)

8 List of References

References

[1] RAG Anthrazit Ibbenbüren GmbH [information received during a visit in 2008]

[2] Trade journal "Glück Auf" May 2008 [article Bucyrus International p.211-214; Water drainage at the Auguste Victoria Mine, p.227-229]

[3] Rittal, internal calculations of 2009 [determined on the basis of the gas laws, density, pressure, volume and compressibility factor according to Kuchling; Pocket Book of Physics]

[4] www.linde-gase.de (2009) – document Technology 1 [abstract from "Energy World Hydrogen" TÜV South; energiewelt-Wasserstoff.de]

[5] Sven Geitmann [specialist book: Hydrogen and Fuel Cells 2004, trade journal: Sun, Wind and Heat 11/2003: "How safe is the storage of hydrogen?"]

[6] Initiative of the Federal Land of Lower Saxony on Fuel Cells, [Summer School Hannover 2008; Dr.-Ing. Thomas Unwerth (Volkswagen), Automobile Fuel Cell Systems]

[7] www.Energieportal24.de/Wasserstoff/Herstellung/Herstellungskosten [2009]

[8] David L. Barnes, Arnold R. Miller [FY 2003 Progress Report: Hydrogen, Fuel Cells, and Infrastructure Technologies, Tunneling and Mining Applications of Fuel Cell Vehicles]

[9] B. Pohl [Forward-Looking Power Supply in Tunnel Infrastructures – Fuel Cells in Tunnels, diploma thesis 2009]

[10] Daniel Kopte [Design, Set-up and Test of a Storage System for an Autonomous Electric Power Supply with Photovoltaic and Reversible Fuel Cell, diploma thesis 2004]

Bibliography

Anil K. Jain, Robert P.W. Duin, Jianchang Mao "Statistical Pattern Recognition: A Review" *IEEE Transaction on pattern analysis and machine intelligence, Vol. 22, No. 1, January 2000.*

Anon, (2000), *Fuel Cells 2000: Fuel Cell Basics – Applications*, Fuel Cell Propulsion Institute, available at http://www.fuelcells.org [10th October 2007]

Anon, (2005), *Mining New possibilities: Fuel Cells May Find Promising Niche in Underground Equipment*, Publication: Diesel Progress, North American Edition, available at http://www.goliath.ecnet.com [10th October 2007]

Bruzelius Kristoffer, D. Mba "*An initial investigation on the potential applicability of Acoustic Emission to rail track fault detection*", NDT and E International, 37 (7), pp. 507-516, 2004

Caeser, W.K., Riese, J., Sietz T., (2007), *Betting on Bio fuels*, The McKinsey Quarterly, No2, 2007 pp54-63.

Croner, (2008), Croner Select – news and commentary on compliance issues affecting your business: *Potential for Bio energy in Europe is Large*, available at http://www. croner.co.ul/croner/jsp/Editorial [10th October 2007]

D. Mba "Acoustic Emissions and monitoring bearing health", Tribology Transactions, 46 (3), pp. 447-451, 2003.

Dasika Ratna Deepthi, K. Eswaran, "Pattern Recognition and Memory Mapping using Mirroring Neural Networks", *Paper #336, accepted in IEEE International Conf. on Emerging Trends in Computing, ICETiC Jan. 2009.*

Drummond G.R., Mills C. J., Watson J. F., and Walter T. "*USING WIDE-BAND ACOUSTIC Emission to Determine Changes in The Condition of Rolling Element Bearings*", Imes Ltd., Foster Miller Technologies, Inc.

DSK, (2007), *Fuel Cell Drive System for Mobile Applications in Underground Coal Mining*, DSK – Technical Innovation Management, available at http://www.steinkohle-portal.de [10th December 2007]

EEA, (2007), EEA Technical Report No 12/2007: *Estimating the Environmentally Compatible Bioenergy Potential from Agriculture*, available at http://reports.eea.europa.eu/technical_report_2007_12/en [10th December 2007]

Howard C. Choe, Yulun Wan, Andrew K. Chan "*Neural pattern identification of railroad wheel-bearing faults from audible acoustic signals: Comparison of FFT, CWT, and DWT features*", [1]SWI Technologies, Bryan, Texas , [2]Department of Electrical Engineering Texas A&M University.

Huadong Wu, Mel Siegel, and Pradeep Khosla,"Vehicle Sound Signature Recognition by Frequency Vector Principal Component Analysis", *IEEE Transactions on instrumentation and measurement, Vol. 48, No. 5, October 1999.*

James I. Taylor & D.Wyndell Kirkland „The Bearing Analysis Handbook"

Krishnappa G, Donovan M. "*Railway Bearing Diagnostics:Laboratory Data Analysis*", National Research Council Canada, Vancouver, Canada, September 1999.

Lynch, F., (1998), *Under Environmental Pressure, Mining Industry Takes a Serious Look at a Fuel Cell Alternative to Diesel*, NHA News Publication, 1998

Miller, A.R., (2001), *Fuel-Cell Mine Vehicle –Development and Testing*, Fuel Cell Propulsion Institute, Denver, CO 80226-0130, USA, available at http://www1.eere.energy.gov [10th October 2007]

NIOSH, (2004), *Hydrogen – Powered Mine Vehicle Reduces Miner Exposure to Diesel Emissions*, available at http://www.cdc.gov/niosh/nas/mining [10th October 2007]

Taylor James I. "*The Vibration Analysis Handbook*", VCI 2003, ISBN:0964051729.

Timothy A. Dunton, "*An Introduction to Time Waveform Analysis*", Universal Technologies Inc.

UKPIA, (2005), *FAQ's – Bio-Fuels*, available at http://www.UKpia.com/faqs/biofuels.aspx [10th October 2007]

9 Appendices

Appendix I – Topics Address During Training Workshops

KOMAG and GIG organized two training workshops for mining industry personnel. The objective of training workshops was to make industry personnel familiar with new technologies developed within the project.

1. "Knowledge-based creation of work conditions in underground mine transportation system"
   GIG, 11th June 2010
   Subject of workshops:
   1. Methods supporting the creation of safe work conditions in underground mine transportation system – Teodor Winkler, Prof. Ph.D. Eng.
   2. Traction Calculations Aiding System for suspended monorails with own drive – theoretical part – Jarosław Tokarczyk, Ph.D. Eng.
   3. Analysis of collision occurrence on transportation routes of floor-mounted railways and suspended monorails – Marek Dudek, Ph.D. Eng.
   4. CFD simulations of pollutants propagation in mine atmosphere – Wojciech Chuchnowski, Ph.D. Eng.
   5. State-of-the-art technologies in creation of safe work conditions and in machines maintenance –Dariusz Michalak, Ph.D. Eng. & Magdalena Rozmus, Ph.D. Eng.
   6. Traction Calculations Aiding System for suspended monorails with own drive – practical part – Jarosław Tokarczyk, Ph.D. Eng.

2. "Tools aiding shaping of safe work conditions in underground transportation"
   GIG, 26th November 2010
   Subject of workshops:
   1. Methods aiding shaping of safe work conditions in underground mining transportation – Teodor Winkler, Prof. Ph.D. Eng.
   2. Traction Calculations Aiding System for suspended monorails with own drive – introduction and practical part – Wojciech Chuchnowski, Ph. D. Eng., Jarosław Tokarczyk, Ph.D. Eng.
   3. Analysis of collision occurrence on transportation routes of floor-mounted railways and suspended monorails – introduction and practical part – Marek Dudek, Ph.D. Eng.
   4. State-of-the-art technologies in creation of safe work conditions and in machines maintenance – Dariusz Michalak, Ph.D. Eng., Magadalena Rozmus, Ph.D. Eng., Łukasz Jaszczyk, M.Sc. Eng.

Appendix II - ATEX Compliance of Equipment Developed within the MINTOS Project

All of the sensors developed under Work Package 2 have been designed and laid out to ensure that final commercial revision of the devices can be readily produced and certification to ATEX-M1 zone standards achieved. The layout circuits and components employed in the production of these devices were assessed on an on-going basic throughout the development cycle, by engineers with long-term experience of IS design and ATEX requirements.

Two location sensors, the LDU (fixed roadway sensors) and the CDU (in-cab sensors), along with the diagnostic sensors, are now integral parts of a Wireless Logistics Support System (WLSS) which is being made available to mines on a commercial basic.

Currently, the CDU sensors are powered from the M2 power supply system of the locomotive; whereas the other sensors are remotely powered from uZIST multiplexers and can operate in hazardous zones regardless of CH4 concentration. However, work beyond the end of the project is planned to produce an M1 version of the CDU by incorporating internal battery back-up elements. This will enable the unit to function even when the train is completely stopped and powered down.

The first commercial application in the KGHM ZG Polkowice-Sieroszowice mine did not require formal ATEX certification as it is a non-gassy mine. In this case, formal certification procedures were carried out to industrial grade EMC compliance and environmental protection requirements. The next commercial installation, which is expected to start in the second quarter of 2011, will also not require formal ATEX certification. However, it is expected that a fully ATEX-M1 certified version of the system will be produced following completion of this second installation and will be available to the coal industry from Q3/Q4 of 2011.

European Commission

EUR 25098 — Improving mining transport reliability (MINTOS)

S. Bennett, M. Rossmann, T. Winkler, P. Wiszniowski, P. Morillo, Z. Lubosik, D. Czoik

Luxembourg: Publications Office of the European Union

2012 — 104 pp. — 21 × 29.7 cm

Research Fund for Coal and Steel series

ISBN 978-92-79-22247-4

doi:10.2777/33900

ISSN 1831-9424

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- via EU Bookshop (http://bookshop.europa.eu);
- at the European Union's representations or delegations. You can obtain their contact details on the Internet (http://ec.europa.eu) or by sending a fax to +352 2929-42758.

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

Priced subscriptions (e.g. annual series of the *Official Journal of the European Union* and reports of cases before the Court of Justice of the European Union):

- via one of the sales agents of the Publications Office of the European Union (http://publications.europa.eu/others/agents/index_en.htm).

KI-NA-25098-EN-N

The project addresses improvements to mine transport management, safety and health.

Fuel cells have the potential to provide clean efficient power underground, but significant further development is required before they meet the safety and power requirements of coal mine transport systems. However, a range of alternative fuel cell applications were identified. Bio-fuels could be used as blends in underground diesel engines to reduce exhaust particulates; alternatively, wet scrubbing of the exhaust using water mists will also reduce particulates.

Advanced wireless sensors and software were developed to form an improved system for underground vehicle transport logistics and diagnostics. The incorporation of novel data transmission and distributed sensor power supply systems provides a high-performance, low-cost wireless monitoring system.

A scheme of an automatic fire alarm system for vehicle operators was devised, which can be expanded to other safety monitoring systems. A novel onboard fire fighting system, which can be periodically tested and still maintain its operational capability, was designed and a fully functional operational prototype produced.

A comprehensive joint open access WEB-based platform was developed for use by transport system designers and specialists in transport health and safety. A prototype augmented reality system was developed to enable operational mine staff to radically improve logistics management and maintenance.

Whole body vibration levels encountered by vehicle operators exceed legal limits in many cases due to the impulsive nature of the vibration. A database of transport-related vibration exposure profiles was produced and recommended minimum vibration measurement times derived.

ISBN 978-92-79-22247-4

9 789279 222474

doi:2777/33900

Publications Office