DOHEMS®—technology to improve risk assessments and early detection

by C.J. Badenhorst* and N. Van Wyk*

Synopsis

The scope of this project was to research, develop and eventually produce a personal occupational hygiene and safety exposure monitor system to assist in recording and analysing various stress factors that could affect the health, wellness and safety of employees, i.e. that could result in injury or ill health of workers, create stress build-up within individual workers that could negatively affect worker alertness and safety, and, may even result in permanent disability or death. Utilized systems at the time were all reactive, whereas the DOHEMS (Proactive Digital Occupational Hygiene and Safety Exposure Monitoring) System enabled the measurement of exposure (and associated risk) in a proactive manner via real-time exposure and digitized recordings. The idea of the development was to create a unit that is so cost effective, small and light that every worker can use a system on a daily basis. The development will eventually replace current, bulky and expensive monitoring equipment. The device must be a portable battery operated device and monitor the immediate working environment by periodic sampling for vibration, noise, toxic gasses (NO/NOX/CO/VOC, etc.), body temperature and heart rate. The samples must be time and date stamped, utilizing a real-time clock (RTC) synchronized with the closest regional secondary time source and related to synchronized real-time video captured samples. These samples are then recorded onto a rugged non volatile storage device with the capacity to store a vast number of samples covering the entire working shift of eight (8) hours plus. The system has been fitted with a clear visual local alarm indication system, indicating any excessive exposures or stresses, for the worker's supervisor to respond to. This system allows for a pro-active approach. The system is also a wireless system (to the external environment) so as to not affect the mobility of an employee and flameproof to allow for use in explosive environments.

Keywords : safety, digital, exposure, monitoring, proactive.

System summary

The present system concept relates to an environmental exposure and physiological monitoring, processing, recording and analysis system. It comprises user-worn data acquisition; processing and warning components; the complementary central management and analysis computer system; and, more particularly, the smart analysis of the data that provides for proactive diagnosis and warning of working conditions that could be unsafe or workplace environmental conditions that could be unsafe or unhealthy. The system monitors workplace conditions and related occupational exposures, as well as physiological responses to those stressors—it does not monitor employee work performance. The system trade mark intended is 'Digital Occupational Hygiene Exposure Monitoring System (DOHEMS)'.

Information technology and health and safety management

Anglo Platinum Group ICT (information, collaboration and technology) ensures that projects undertaken conform to strategic business objectives. In addition to developing an internal competency in the management of information, both within Group ICT and the business as a whole, the delivery of a business process-based solution, along with the quest for better information, is a non-negotiable strategic objective for the DOHEMS project.

At present there is a clear need for the current methods of identifying and managing health and safety risks to be improved upon in the mining industry. In brief, currently all measurements are done according to legislation and at regular time intervals. Unfortunately the shortcomings of this kind of measurement strategy is that employees are told of the potential exposure after the event and the data collation and analysis period is rather prolonged as each parameter is individually monitored and difficult to collate. This also leads to human error in terms of data capturing in spreadsheets and text reports.

With a proactive approach, leading indicators can be captured, the employee warned at the point of potential unacceptable workplace conditions, and the data collected with additional physiological and environ-

* *Anglo Platinum.*

This paper was first published at the SAIMM Conference, Hard Rock Safety, 28–30 September 2009.

mental data all simultaneously. This is no longer data but actual information made available for the employee, the supervisor, and to the company corporate decision makers responsible for the health and safety of employees.

Background

The system originated as a result of working with the mining industry. Currently occupational health, hygiene and safety are core drivers in the mining industry, with governing institutions relying on regular sample measurements and inspections being carried out with relatively bulky dedicated test equipment. The intention of the system is to provide consolidated and consistent monitoring of all the physiological and environmental information that will support a healthier and safer working environment. Similar systems are in production for the sport and military sectors.

The scope of this project was to research, develop and eventually produce a personal occupational hygiene and safety exposure monitor system to assist in recording and analysing various stress factors that could affect on the health, wellness and safety of employees, i.e. that could result in ill health of workers, create stress build-up within individual workers that could negatively affect on worker alertness and safety, and, may even result in permanent disability or death. Utilized systems at the time were all reactive, wherreas the DOHEMS enables the measurement of exposure (and associated risk) in a proactive manner via real-time exposure and collated digitized recordings. The idea of the development was to create a unit that is so cost-effective, small and light that every worker can use a system on a daily basis. It is anticipated that the development will eventually replace current, bulky and expensive monitoring equipment. The device must be a portable battery operated device and monitor the immediate working environment by periodic sampling for dust particles, vibration, noise, toxic gasses (NO/NOX/CO/VOC, etc.), body temperature and heart rate. The samples are time and date stamped, utilizing a real-time clock (RTC) synchronized with the closest regional secondary time source and related to synchronized real-time video and audio captured samples. These samples are then recorded onto a rugged nonvolatile storage device with the capacity to store a vast number of samples covering the entire working shift of eight hours. The system has been fitted with a clear visual local alarm indication system, indicating any excessive exposures or stresses, for the worker's supervisor to respond to. This system allows for a proactive approach. The system is also being investigated for use as a wireless system (to the external environment) as not to affect the mobility of an employee and intrinsically safe to allow for use in explosive environments.

DOHEMS®

The present system generally comprises user-worn equipment and the complementary central management computer system, further described below. The novel features of the present system are readily evident from their description, specification and achievements to date.

Description

The User-worn equipment comprises the sensors and the data acquisition and processing unit (DAPU). The DAPU is also referred to as the DOHEMS Instrument. The central management system (CMS) comprises the software programs and data storage, data processing algorithms, and information feedback.

Specification

The DAPU is a compact, portable, self-powered and ruggedized unit that is fitted onto a harness that is worn by the person. The DAPU is responsible for collecting sensor data, performing on-board processing of measured data, providing alarms to the person wearing the DAPU, storing data and information, and providing the data and information to the CMS through wire or potentially wireless connectivity. Wireless connectivity facilitates transmission of live remote monitoring and alarms. The system must comply with safety standards as well as any additional ruggedization requirements for the mining industry environment.

Refer to Figure 1 for an example of a DAPU and harness.

The sensors are managed by the DAPU and these sensors are either built into the DAPU or harness according to each specific end-user application. Refer to the example in Figure 2, but note that additional environmental and physiological parameters may be added.

The CMS is the off-board computer system and software responsible for the retrieval, storage, analysis and presentation of data recorded and processed by the DAPU. Refer to Figure 3 for a system functional block diagram. The CMS data tier is used to store and retrieve information. This consists of the database, file servers and existing ERP systems. The information is passed to the logic tier for processing and then eventually back to the end user.

The CMS logic tier manages the business logic. This tier coordinates the application, processes commands, makes logical decisions, evaluates, and performs calculations. It is also used to move and process data between the two surrounding layers. The CMS presentation tier is the top-most level of the application and consists of the various user interfaces. The main function is to present the data in a format the end user can understand and interact with. The end user will issue commands to the system through this tier.

DOHEMS consists of the following functional elements:

- Body temperature sensor
- Heart rate sensor
- Particle sensor
- Pressure sensor

Figure 1—DAPU and harness

Figure 2—Sensors

- ➤ Dry bulb temperature sensor
- ➤ Humidity sensor
- ➤ Noise level sensor
- ➤ Environmental vibration sensor
- ➤ Toxic and dangerous gases sensors
- ➤ Video camera
- ➤ Nonvolatile storage device
- ➤ System controller and time and date stamping mechanism
- ➤ Battery pack, power supplies and charger
- ➤ Excessive stress alarm indicators and personalized identification.

Real-time data recording

During an employee's work shift, the DAPU will measure both physiological and environmental data. The measured values are stored in a data file, which will be imported into the CMS at the end of a working shift.

Data are recorded using external and internal sensors. Internal sensors will be inherent to the DAPU, while external sensors are connected to the hard hat (safety helmet) and linked to the DAPU.

Video and audio recording is captured in addition to the sensor data. The audio recording ise initiated by the employee and can be used to report any potential problem or situation that requires further investigation. The video recording is active during the entire data recording period.

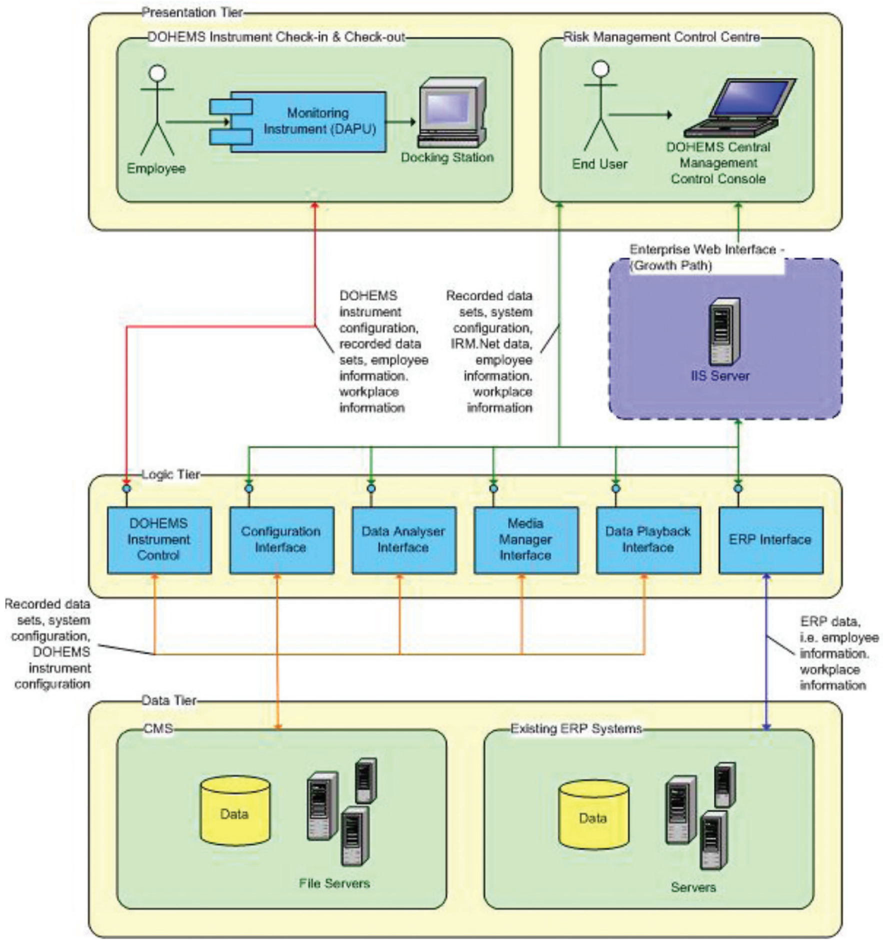

Figure 3—Central management system

Overexposure warning

Part of the DOHEMS concept is to provide proactive responses to hazards in the working environment. To this end the DAPU warns the employee when exposure to a dangerously high level of an environmental hazard or an abnormal physiological measurement is detected.

The warning is easily noticeable and informs the employee what parameter has been exceeded. As an example, this feature can be used to warn an employee that the noise levels are dangerously high and that hearing protection should be worn.

The DAPU provides a means for the employee to record acknowledgement of the warning.

Reporting

The CMS provides an interface that allows reports to be generated for a selected recording, specific employee or a specific day. The reports provide clear and easy to understand statistical analysis of the selected parameter. The reports can be exportable to both Microsoft Excel spreadsheet format and Adobe PDF documents. Where relevant, it is possible to select a specific parameter on a report to further investigate more detailed data for that sensor or parameter.

Benefits of implementing DOHEMS

- Integration of personal and environmental exposure measurement
- Increasing collated data sampling will result in increased visualization of actual health and safety conditions
- Provides new methods to relate the sum and duration of all exposures affecting individual fatigue
- Creates a transparent and auditable employer/employee platform for more informed decisions
- Increased insight leading to informed risk control and accelerated risk escalations (see Figure 4).

Figure 4 depicts the DOHEMS influence on other components in the risk management framework.

Detailed description of a preferred embodiment

DOHEMS is intended for initial use in the South African and international mining sector. As such it will be a South African developed cost-effective solution that is ruggedized, compact, reliable, and easily maintainable, and that provides accurate useful information that will enhance occupational hygiene, health and safety in working environments.

Although various aspects of the system have been described with respect to specific embodiments, alternatives and modifications will be apparent from the present disclosure, which are within the spirit and scope of the present system.

Therefore, although the present system has been described and illustrated, it is to be clearly understood that this is by way of illustration and example only, and is not taken by way of limitation.

We believe that DOHEMS is a helpful system. The described system is both cheaper and simpler to manufacture and it also offers performance advantages compared to conventional systems and devices.

Product development

The DOHEMS project ise researching and developing a prototype system, by the application of system technology on Anglo Platinum mining operations, and then will develop a product that will support the increased sampling of hygiene exposure elements. This is achieved through an incremental strategy (also sometimes called 'preplanned product improvement'), which determines user needs and defines the system requirements, and then performs the rest of the development in a sequence of builds. The 'builds' are summarized as:

- Experimental development model
- Advanced development model
- Beta model (also known as a pre-production model).

The proof of concept (POC) stage of the project was carried out with the objective of building an experimental development model (EDM) and proving that existing technology building blocks could be combined to ensure simultaneous data parameter capture with associated video and audio, and that the data could be presented in an effective information display and report capability.

This was successfully achieved and demonstrated at RPM Mogalakwena Section where live testing was carried out in June 2009.

Obvious shortcomings of POC stages of any project are that requirements tend to 'creep' as unknowns become known. However, the scope creep of this particular project was swift in that the unknowns were detected reasonably early in the phase, which has allowed for team focus on core objectives.

A further objective achieved to date is sensor accuracy. As DOHEMS is intended to support the hygiene leading indicator philosophy, the accuracy of sensors is not as important as their reliability thereof for consistent monitoring and trend monitoring of parameters. However, testing to date of certain parameters indicates extremely accurate measuring, while some of the other parameters require some rework in terms of accuracy and reliability of data for information management and decision making.

The packaging or enclosure of the measuring unit was not an objective in the POC phase of the project. The packaging affects the functional performance of the measuring unit as well as the 'wearability' of the unit by employees. If it is not non-intrusive enough, the unit may be discarded by the employee and as such valuable hygiene leading indicator information could be lost. During the POC

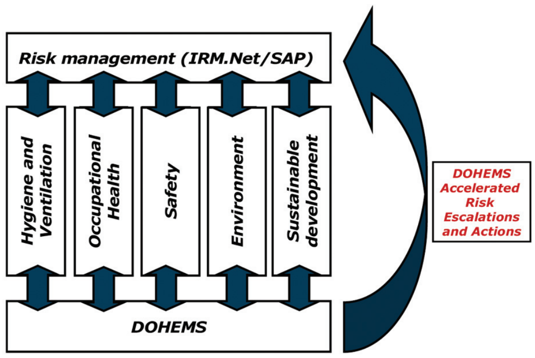

Figure 4—DOHEMS in relation to the risk management framework

stage the decision was taken that DOHEMS packaging was to be very rudimentary. This decision was adhered to; however, from results it is obvious that the measuring unit's packaging will require attention.

Communication and change management

The DOHEMS system is being introduced ultimately to save lives and to improve the quality of life for all employees, contractors and visitors and their families. The system will have a significant impact on employees as it will replace the current monitoring equipment that is being used with a small and light unit. The safety and occupational hygiene exposures will now be measured in a real-time manner, monitored remotely and feedback given immediately. This unit will be one that every employee should aspire to wear.

It is important to ensure that a sound change management and communication strategy is in place to manage the product ownership process company-wide. Such a programme is intended to focus on buy-in and involvement from the leaders of the project and business units as well as the affected individuals.

During the proof of concept phase it became evident that a strategy that is measurable and sustainable is needed to allow the implementation process to gather acceptance company-wide. The organization's responsibility towards safety, health and occupational hygiene must be elevated throughout this implementation. General awareness is of utmost importance and employees must be given an opportunity to voice their opinion. Employees are already faced with information overload, therefore communication vehicles that provide for brief, positive and to the point messages will work best. During the pilot phase, which follows the proof of concept, the product will be taken to four production sites for further testing before rolling out Group-wide. Although the 'rollout' of the system is small initially, it is important to create awareness and buy-in at all levels right from the start. Information sharing between sites is encouraged, employee representatives' (i.e union and associations) involvement is critical and the site specific communication channels will be used as a means of keeping employees up to date.

Target audiences will be correctly identified so that a targeted communications approach for each group may be created, to proactively overcome any objections and or resistance which any interested and affected sector may present. Relevant communication and media channels will be considered to support the requirements, for example creative poster campaigns, DVD programmes, The Source website, in-house magazines, and so forth.

Throughout the implementation process, the change management programme must continually strive to support the overall objectives of DOHEMS. Ongoing consultation and engagement with key stakeholders will be necessary to ensure that the right message reaches the right persons at the right time.

Next steps for DOHEMS

The immediate next steps of DOHEMS will be to reduce the size of the unit. Software development will be continued for enhanced data analysis and algorithm refinement. The project team will undertake safety and environmental testing on the unit, as well as further functional testing of the system and unit at live sites, including the underground environment.

Conclusion

At present, the mining industry relies on regular exposure measurements and inspections being carried out using relatively bulky, dedicated test equipment in order to identify the personal and environmental risks facing employees in their workplaces.

Only one risk factor can be monitored during a working shift; however, the presence of a single risk factor might not be a concern, while the presence of a combination of factors could indicate extreme danger. Additionally, current technology is unable to integrate and collate monitoring data into a single view, or provide a visual recording of specific environmental conditions. Other shortcomings include an inability to pinpoint excessive exposures in correlation with workplace conditions, limited personal alarm and warning systems, and an inability to accurately measure the sum of accumulated exposures that contribute to fatigue.

DOHEMS overcomes all these problems. It is a personal automated and integrated data acquisition and processing system that can measure various exposures simultaneously, including personal and environmental exposure measurements, and has a built-in personal alarm and warning system.

The compact, lightweight, fire-resistant DOHEMS can simultaneously measure a range of exposures, as well as the individual's core body temperature and heart rate, which give an immediate indication of the level of stress being experienced.

A miniature video camera provides a visual record of the environment, allowing for the correlation of stress indication measurements with the physical environment.

Employees can wear the DOHEMS instrument, which contains the sensors and data acquisition and processing unit (DAPU), on an unobtrusive harness or belt. The DAPU collects sensor data and performs an on-board processing of measured data. Based on this, it can provide real-time alarms to the wearer. It can also store data and information, and provide it to the central management system through wired or wireless connectivity.

The central management system is an off-board computer system and software that is responsible for the retrieval, storage, analysis, and presentation of data recorded and processed by the DAPU.

DOHEMS can also provide a historical perspective of the stress factors to which each individual employee is exposed on a shift, or weekly and monthly basis. Using algorithms, this information is then used to evaluate the risk profile of each employee, and thus allows for preventive measures to be taken, such as redeploying the individual to another job function, or modifying his shift work, or even providing additional training in functions that are seen to cause unusual stress levels.

From a risk management perspective, it could provide for real-time data capturing, with visual footage that will result in accelerated risk warning measures and controls. It could also provide data for post-incident analysis and assist in more informed decisions for future design and planning.

The intention of DOHEMS is to provide consolidated and consistent monitoring of all the necessary physiological and environmental information that will support a healthier and safer working environment. ◆