Project ARGON: applying field collected stress data to develop a new generation of lighting

Urbain du Plessis

Centre of Excellence – Mining, Hella Australia Pty Ltd, Melbourne, Australia

"Project ARGON" is an ongoing global research program to collect and analyse the physical operating conditions of lighting equipment under actual operational conditions across a diverse range of mines and machinery. The findings of this program are applied directly to create new product design and test specifications to satisfy the extreme demands of mining.

Keywords*:* lighting; physical environment; test specifications, design specifications

urbain.du.plessis@ha.hella.com

A. Introduction

Hella® is a multinational group of companies founded in 1899 with it's head office still in the same German town of Lippstadt. The group is best known for producing lighting equipment for the automotive industry, but the production of mechatronics, electronic and thermo management equipment represent substantial sectors of the present company.

Hella also operate several specialist business units to service the needs of specific target-markets, one which the: "Centre of Excellence – Mining" was established in 2002 to focus on the needs of the mining industry. This unit is located at Hella Australia Pty Ltd in the metropolitan area of Melbourne, in the state of Victoria.

- The business unit started with no customers or products, but with a simple mission:
- Provide the customer with products that suit their requirements
- Distribute, market & guarantee these products to the global mining industry
- Make a profit in the process

This paper focuses on the first aspect of the mission, and specifically determining the physical operating environment of lighting equipment. The optical system design, production and verification process is not covered here but received equal levels of attention.

B. Project origin

The initial task appeared simple: obtain performance specifications from the leading mining machine manufacturers and select or design suitable equipment to fulfil the specifications.

The scope of work soon changed when it became clear that the mining equipment manufacturers[1] had more than enough work to design the mechanical and hydraulic aspects of their products to be bothered with detailed lighting specifications. It became clear that the only way to get the information we need would be to collect the raw data ourselves, analyse it and develop both performance and testing specifications. Project ARGON was born out of need.

C. Equipment

Our first and most obvious task lay in collecting data, based on the observed failure modes of our own[2] and competitor products used on mines it was clear that shock, vibration and temperature are the most important factors, with humidity, electrical / EMC and corrosion as significant secondary contributors[3].

[1] The names are omitted for obvious reasons
[2] Hella "automotive" specification products have been used on mines for decades
[3] Analysis of QA reports and warranty claims combined with end-user feedback

Thus our data collection equipment needed to focus on collecting physical environment data relating to the primary stressors. A sojourn into sensor and data-acquisition equipment catalogues made it obvious that bolting those magnificently accurate and complex devices onto a piece of mining machine would be to the sole benefit of the company selling the data-acquisition equipment.

Since our initial work made it clear that practically no knowledge exist of the physical stress environment we set out to investigate our strategy would be to collect a wide range of "low resolution" data to provide us with a baseline from where we could elect to focus in more detail if required.

This led us to the next decision: design and build data-acquisition equipment that meets the following key requirements:

- Survivability: ensure that the data collection task will occur under real operational conditions.
- Autonomous operation: data collection must not require any connection to the equipment systems. Anything else is simply not practical on mining equipment and raises significant safety and risk management issues.
- Rapid deployment: gaining access to equipment in use would be conditional on not affecting or interfering with production.
- Low cost: it was expected that some of the equipment would be destroyed during each collection exercise, so we need to have redundant systems that can be written off without halting the project.

Fortunately low cost autonomous data loggers were already used in specialised logistics services[4], we purchased some off-the shelf modules and modified these to suit our requirements.

Each module (Figure 1) consists of three primary elements:

- Sensor
- Recorder
- Power supply

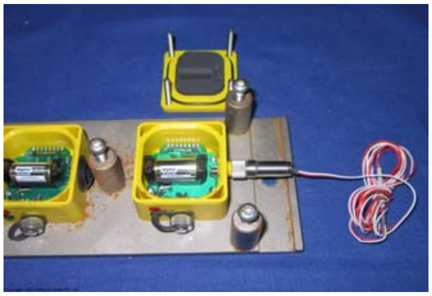

Fig 1

The standard sensors suffered two main drawbacks due to their original target market's cost restraints: insufficient dynamic range and fragility. Replacing the sensors with higher specification types calibrated was relatively simple. The recorder section also required upgrading to cope with higher acquisition rates and associated growth in data.

[4] Spoilable foodstuffs, pharmaceutical and military supply chains often require records of temperature etc to satisfy their QA requirements.

Fortunately the physical construction of the electronic modules was already of high quality and required minimal work to cope, and user-friendly data download and module configuration software made the operation simple.

The operation time of the modules at our preferred acquisition rate of one reading per second limited their operating window to about 12 hours from start[5]. A good supply of batteries became essential – and we noted large differences between brands.

Fixing a plethora of small fragile devices to working plant would be impractical and consume too much time – to overcome this problem we created a standard deployment module (Figure 2) that carries multiple independent data loggers and sensors, this deployment module is a heavy-duty milled steel skeleton that provides mechanical protection and allows attachment to the mining machine itself.

Fig 2

The deployment module is specified to be fragile enough so that it will not cause damage in case it falls off the machine under test and ends up in the rock crushing plant.

The payload of the deployment modules typically consists of a combination of temperature, humidity, shock and vibration sensors. The payloads can be customised. For some projects we recorded shock in 3 axis, for others we added acquisition modules to collect electrical system data, fluid temperature and more.

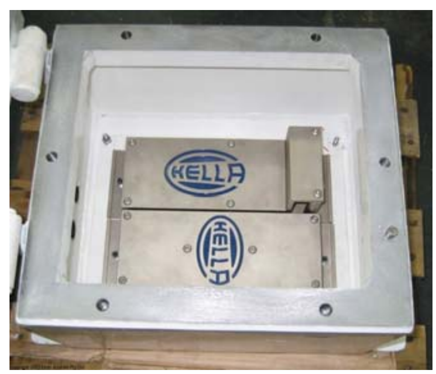

Fig 3

One area of particular interest for us was continuous miners and longwall systems in underground coalmines. For these hazardous areas[6] we built specially approved battery packs and fitted the units into a flameproof housing (Figure 3).

D. Data collection

Once we had the ARGON deployment modules we could set off on the real project to collect data in the field (Figures 4). Our objective was to establish base-line data for the following

Fig 4

[5] We found that this was not a practical issue since we typically had le
one machine, and we could program delayed starts where required.
[6] The presence of methane poses an explosion hazard in many underg

types of mining operation by looking at a few mines of each type:

- Underground hard rock mining
- Underground coal mining
- Open cut hard rock mining
- Open cut coal mining

In each of these operations a wide range of equipment is used and typical examples are:

- Excavation
- Hauling
- Drilling
- Personnel transport
- Service & maintenance
- Roof support and continuous mining in coal mines.
- Process plants & conveyor systems.

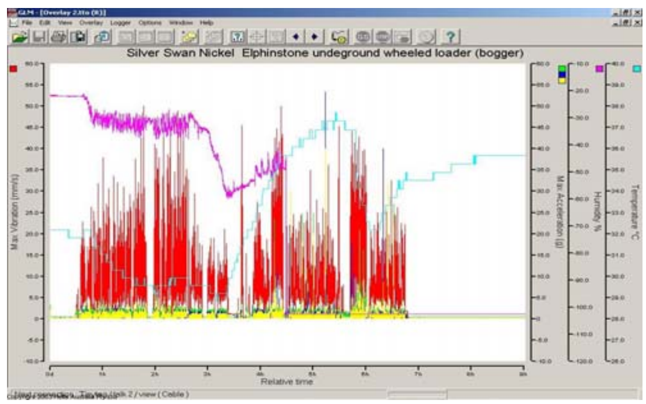

Fig 5

While we were gaining site access[7] we would also collect ground water and process materials for chemical analysis to add to the understanding of corrosive agents active in the different types of mining operation.

Even the most basic overview makes it clear that the project could keep several people busy for a lifetime, but since a significant objective of our venture involves making profits; we allowed one year for acquisition and analysis of baseline data.

We recruited candidates for our project by concentrating on visiting mines where some Hella equipment (from our automotive product portfolio) has failed. The management of these mine sites were glad to find somebody willing to visit them and willing to listen to their point of view – and their staff probably enjoyed the opportunity to work off a few of their frustrations by giving a novice from the city five or ten minutes during smoke break to fit or recover the equipment.

[7] A site visit would typically cover at least two consecutive shift changes to allow good access to mobile plant and provide ample time to interview maintenance staff that normally gets the task of escorting us.

At each mine we fitted the ARGON units to as many types of plant as possible, we typically deployed three to four modules (each with a suite of senor modules) at once to enable us to collect a large overview of data on a single site visit.

The downloaded data (Figure 5) quickly shows the severity of the application, and the comments of operators and managers were invaluable in understanding this data, allowing us to make far more informed analysis than what the raw data without context would allow.

E. Results

We expected to find that the environment would be hotter and mechanically more demanding than anything we have seen before, we did not expect to often exceed the calibrated measurement capabilities[8] of our sensors.

We also found the ground water salinity in central Australia to be more than ten times that of seawater, suddenly explaining why we were selling loads of marine grade products into a desert region.

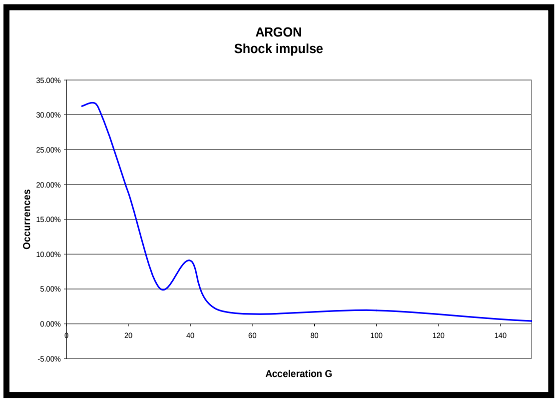

Fig 6a

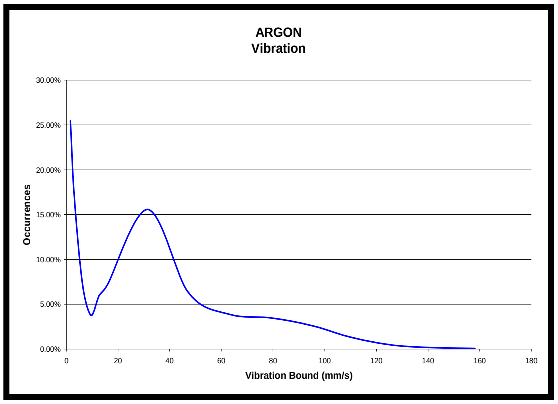

Fig 6b

The normalised data for shock (Figure 6a) and vibration (Figures 6b) shows that lights are exposed to large stress for significant periods. The data clearly indicated that we would need to create a new set of performance specifications[9] to design products that can reliably operate under these conditions, and some fairly specialised equipment would be called for to test and certify the same.

F. Test equipment

An example of the "Fit-for-Purpose" specification created by us as a result of our Project ARGON data for electronics is that all electronic modules or the complete light in the case of LED lights must be fully functional after a test routine of:

[8] Shock sensor 100G, Vibration sensor 50mm/sec
[9] The resultant Hella Norm for Mining products is a confidential document and not published here

- 10 000 cycles of 200G shock impulses.

Fig 7

Commercially available electrodynamic shock & vibration platforms[10] are excellent at producing high frequency vibration and impulses up to 15G, but not very well suited to this type of testing. The inspiration for a new type of test unit (Figure 7) came from the launch catapults used on aircraft carriers; we turned the slide catapult vertical, assisting gravity with pneumatics. Our impulse test unit is calibrated from 45G to 240G.

Each test cycle consists of the peak impulse and a series of aftershocks as the test unit recoils and the energy dissipates into a seismic block. This means we expose the test specimen to quite a broad spectrum of additional shocks in each of those 10 000 cycles[11]. Normally we alter the mounting position several times during the test to expose the components to stress in many axes.

Thermal shock and stress is another major factor, and here we could obtain some standard test equipment to cover our requirements of -40C to +150C combined with 0 to 110% humidity. As in so many aspects of this project we had to innovate here as well: to verify the functioning of vibration damping mountings at low and high ambient temperatures we have built a combined electrodynamic vibration testing rig with a thermal cycling unit.

The more extreme operating conditions found in Canada required us to build special equipment that could raise the temperature from -40C to 110C in less than 30 seconds. This thermal shock stresses adhesives and seals in assemblies using a mix of metal, glass and polymer components severely.

In addition to the specialized equipment we also use high-pressure water spay tanks, fogging chambers, dust penetration chambers and salt spray tanks. Our own chemical analysis lab that includes a gas chromatograph and infrared spectrometer tools backs up all of this.

G. Summary

Project ARGON was launched out of necessity to determine the basic operating conditions of lighting equipment in modern mining applications. The information did not exist because it was not important enough for the mining machine manufacturers. However the unpredictable failure of lighting equipment impacts

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[10] Widely used in automotive and aerospace product development and certification
[11] The catapult cycle is approximately 5 seconds – i.e. 14 hours for 10 000 cycles

significantly on the operational costs and safety of mines[12]. The enthusiasm and support of many mines[13] over the past few years to grant us access to their equipment and staff made this project possible.

Our investment in equipment and people is dwarfed by the value of information and knowledge gained in the process. While we can show millions of data points collected, this would remain just data without the many hours of interviews with operational staff at the mines. There is no substitute for their experience in fitting, repairing and using the equipment; at every mine we were told the following:

- Products must be easy to fit and maintain
- The long term availability of spare parts is essential
- Do not complicate the supply chain
- Systems solutions are essential
- Applications engineering support is essential
- Safety and reliability is more important than lighting performance.

Nothing in this list is revolutionary, the simple fact that these needs were not being effectively was a surprise to us, and confirmed our decision to invest in this market segment.

The knowledge gained with the help of the mines enables us to deliver engineering based solutions, application focussed products that come much closer to meeting their requirements. Very few things are as satisfying as returning to a test site with a new product built on their input.

We invite mines and manufacturers to participate in this project[14], every deployment adds to the understanding and more often than not delivers a surprise.

Urbain du Plessis was born and educated in South Africa in computer science, business and physics, settling in Australia in 1997 to work on the Sydney 2000 Olympics after a career designing lighting systems for projects ranging from safari camps to nuclear power plants in many different countries. He joined Hella in 2002 to create the *Hella Centre of Excellence – Mining*

[12] The economic impact of lighting equipment failure on mining operations is the subject of a separate Hella research project currently underway.
[13] Mines are not identified – anonymity was condition of participation for most mines.
[14] Participants are provided with copies of their own data – and share the normalised data resulting from Project ARGON – we have also run several workshops with end-users where we use this data to discuss their requirements of new products.

Urbain and his team at the *Hella Centre of Excellence – Mining* is responsible for the design, production, sales and marketing of application focused, engineering based lighting solutions to the global mining industry.

Urbain has received numerous lighting and design awards in South Africa, USA and Australia. The products designed by his team for the mining industry has been recognised with Australian Design Awards in 2004, 2005, SAE-A Engineering Excellence awards in 2004, 2005 & 2006