Underground Vehicle Design Standards, where can we advance?

Terry O'Beirne, ACIRL

Summary

This paper discusses a number of key issues and conclusions which have arisen from an ACARP funded project into underground vehicle design & the statutory implications.

Underground vehicles in Australian collieries are between 15% and 30% more expensive to purchase, and up to twice the cost to operate than their counterparts in metal mines. These premiums are largely due to a combination of the unique regulatory requirements and the few machines of any type that are built at any one time. The major opportunities for reduced costs are:

* Vehicles more closely matched to the applications and risks they need to deal with.
* Broadening the standards to allow established vehicles from non-mining or non-coal.
* Generally reduced regulatory constraints, eg Aluminium, gas emissions.

Colliery vehicles can be associated with a number of significant risks, including:

* their ability to ignite flammable gasses and other matter;
* loss of control, particularly on slopes;
* pinch, entrapment & sprain injuries from use or maintenance;
* injuries from unwanted release of stored electrical, pneumatic, hydraulic or spring energies.

Of these significant risks, only the ignition of flammable atmospheric gas or coal dust are unique to colliery vehicles. There are already extensive legislative and operational controls over the locations for potentially flammable gas in collieries, yet the controls applied to vehicles do not have any zoning attributes. The proposal therefore is that controls unique to flammable gas ignition, perhaps need only occur where there is some significant chance of flammable gas being present. This is not the current legislative position and is an opportunity for change and considerably reduced cost of ownership.

The existing legislation base is focused on the prevention of catastrophic accidents. Changes are needed to permit innovation, whilst still managing risk to acceptable levels. For example, limited pollution fuels like CNG and LPG are *effectively precluded because of the prohibition on spark* ignition. The raw gas emission limits coupled with ventilation controls result in atmospheric gas limits far less than the Australian community standards (viz Worksafe). These features, plus the controls on Aluminium, may soon thwart the introduction of new generation engines.

Introduction

This paper briefly discusses an ACARP funded project entitled "Underground vehicle design standards & statutory implication", and concludes with some comments on what the industry can do with the outcomes to provide themselves with better mine vehicles. The project was awarded to MineRisk Management Services, who utilised ACIRL as sub-contractors for some investigations.

Paraphrasing from the project application, its objectives were:

"To examine the risks of operating vehicles in underground coal mines, and study the effectiveness of engineering design and other controls over those risks. Possible alternate ways of managing the risks will be identified."

"The project outcome is to be a document to promote discussion on all possible ways to control the risks, with due consideration given to "Duty of Care" based legislation, and proposed new Regulations in Queensland, and the Industry's future needs across Australia."

For this project, vehicles were deemed to be any machine working or travelling underground, which had a design feature to carry a driver and passengers or load. It therefore encompassed Personnel carriers, Multi-purpose vehicles, Shuttle cars, Rail locos and so forth.

Study approach

The overall approach for this project was

IDENTIFY HISTORICAL CONTROLS OVER RISKS	**CONTRAST WITH**	**POSSIBLE CONTROLS OVER RISKS**	-- --	**DEFINE A STRATEGY TO MOVE FORWARD OR INSTIGATE CHANGE**

To undertake this study MineRisk assembled a team of highly experienced industry personnel, and created an approach to allow that team to provide the key input data on risks and controls. Specifically, the team had to:

1) Identify the risks associated with vehicles.
2) Rank and classify these risks.
3) Identify possible controls & contrast these with current situation.
4) Review and comment on the strategy prepared.

What are the risks in using vehicles?

Firstly, what vehicles are being considered?? Vehicles were not specifically "named", but rather categorised. The basic criteria was that a vehicle had the capacity to move its driver, and perhaps passengers within it, from one place to another, and it was specifically designed and used for such.

Risks were identified using a "classic" Energy out of control approach. This began by linking the energies present with various vehicle types, then considering what might go wrong if that energy got out of control. This produced a large table of risks and potential outcomes which is too lengthy to repeat in this paper. As an example though, when considering Electrical energy, one identified risk was an overheated light can lead to ignition of a fuel like dust.

In this study no criteria for acceptable or unacceptable risk was sought , nor was it obvious. Rather, all persons concerned continually tried to find ways to improve whatever risk management activities occur today, and ensure the controls generally were balanced against the magnitude of the risk. As with many other mining risk studies, there seems to be no sensible way to precisely define risk acceptance.

Systematically examining and contrasting all the current and possible controls covering all the risk areas led to a number of broad conclusions.

* Virtually every identified risk can be realised in any mine at any time. The notable exceptions being:
    - Out of control situations are most likely to occur when the vehicle is used on grades outside the acceptable mass/grade/speed relationship.
    - Gas ignition/explosion risks are not credible in every area of the mine and therefore should the controls be standardised?
* Fire risks have to be comprehensively managed in all mine areas at all times, as pollution from a vehicle fire could effect all persons inbye of it. The long term effectiveness of existing controls is of concern.

And, or a more detailed level, a number of conclusions & suggestions were forthcoming:

* Braking systems could be improved by providing complete redundancy and with some indication of park brake activation. Anti-lock braking systems could improve control under certain circumstances and should be researched. Non-contact brake systems & recycling brake energy into fuel cells may have a place in the future.
* Vehicles (and parts of them) will be inevitably used as work platforms. Design should either preclude or accept this, and not take an ambivalent middle ground position. Acceptance of this means they have to be made optimally safe for this use.
* High energy electrical systems should incorporate double insulation, and improved mechanical protection is desirable. Existing spark ignition systems probably still provide unacceptable risks of fire or ignition of surface dust.

* Pressure accumulators continue to provide unique risks. Some of these could be eliminated by using alternate technology to dispose of accumulators. Standards associated with accumulators should be upgraded to deal with all known hazards.

* Operator, passenger & maintenance locations must comply with community accepted ergonomic guidelines, and take due cognisance of the current accident/injury causes.

* The use of batteries in hazardous locations should be discouraged, but if used, their de-energisation under emergency conditions need further consideration. Some technical options are possible. Fire risks from batteries still need very effective management in "non-hazardous" locations.

Ownership costs VS risks

The risk study has been augmented by a technical study by ACIRL into the costs of buying and operating vehicles, and the impact of gas emission regulations on vehicle development. This ACIRL study identified that:

* A 30% cost penalty applies over the life of a vehicle because of using purpose built coal vehicles, made in very low numbers, and for a unique market.

* Capital cost penalties of between $50,000 and $100,000 (15% to 35% of capital) apply to coal specific vehicles when compared with ruggedised general industrial vehicles. The bulk of the penalty is attributed to these items (in decreasing priority).

    - the unique engine and exhaust package
    - the prohibition on Aluminium
    - the use of wet disc brakes
    - using FLP electrics
    - providing FOPS

* Maintenance costs on coal specific vehicles are 50% to 100% greater than similar ruggedised vehicles (used in metal mines). A majority of this is attributed to Statutory Inspections and servicing emission control devices.

* Several manufacturers are reticent to innovate because of the time, cost and complexity of meeting existing regulations.

Pollution constraints

Current vehicle design is significantly influenced by diesel engine emission regulations. These regulations, currently based on AS3584, ensure that every underground vehicle, no matter where it goes, or its duty requirements, will have an old generation, and highly inefficient diesel engine package, generally very low power to weight ratio, and need high levels of maintenance on its pollution and flame control systems.

Several issues are relevant to the pollution controls seen today:

Firstly, the recognised community standards (Worksafe) for pollutants are sometimes less than mining values. For example, the Mining community interprets its legislated gas limit values as MAC's (ie, the Maximum Allowable Concentration, which must never be exceeded). In reality, the underground limits set now, more closely reflect the community views for TWA (8 hour, Time Weighted Average). As an example, the Mining standard for atmospheric CO is 50PPM. The Worksafe (ie community accepted) level for atmospheric CO is a TWA of 50PPM (totally different result to MAC), and a massive 400PPM for STEL (15 minute, Short Term Exposure Level). Why are these pollutants more dangerous underground than any other workplace? This lack of understanding is contributing to over-regulation. In-mine measurements confirm atmospheric pollution, even under arduous conditions like on longwall take-offs, is but a fraction of the community accepted limits..

Next, restricting raw gas emissions from engines is precluding newer engines, and totally ignores the fact that ventilation plays the major role in the final pollution people are exposed to in mines. By regulating engines to produce limited NO_x, particulates and CO are raised, and performance is drastically reduced. The existing NSW limits on raw exhaust gas emissions and ventilation (m^3/sec/kW) can result in atmospheric levels far lower than those required to meet Worksafe standards. Modern, more efficient and high performance diesel engines, generally produce more raw NO_x than current limits. However, by being more efficient, they can be made to produce less volumetric pollutants per unit Kilowatt-hour than old engines, and therefore the overall result is less polluting. Legislation and Australian Standards changes are needed to deal with this. The optimum position would be that the pollution characteristics of every engine are known (including on an on-going basis), then air flows to dilute that to accepted atmospheric values have to be provided. This *may* provide some challenges for mines in certain situations like longwall take-offs or cleaning up falls , however, very low pollution engines could be used for that, whilst those with greater pollutants could be used in main air circuits.

Finally, there is increasing pressure to legislate for control of particulate emissions on the grounds they may be carcinogens. The only known Australian mining research (JCB) reveals no excess cancer risk for NSW coal miners in comparison with the community average. To be truly credible, any future legislation should concentrate on atmospheric values, however the challenge is to select the correct values, and not some artificially low values because of ill-informed pressure. Data from the JCB suggests that current levels DO NOT present an excess risk. The majority of overseas studies also support this view, however a few suggest there may be some increased risk, but it is not clearly defined by any means.

If atmospheric levels for particulates less than currently seen (as found by BHP research) are ever legislated, then two scenarios are possible. Firstly, newer engines with "unacceptable" NO_x will have to be used to reduce the raw particulate emissions, or engines will have to have external filters added. The latter scenario will clearly further greatly increase ownership costs. The former case is undoubtedly the best position, as it will encourage new generation engines as the "compromise".

However, one possible solution to particulates (and other pollutants to some extent) is to adopt "cleaner" diesel, or change to fuels like CNG or LPG. Some research in this area appears justified given the long term impact.

Are we alone with these problems?

Comparing the Australian legislation (pertaining to vehicles) to that from the USA, South Africa and the UK found Australia was generally similar in both thrust and detail to the UK and South Africa. However, some significant differences with the US are worth discussing, as they may help in finding a way forward with suggested changes. These differences fall into two main categories, emission control and explosion protection.

In relation to emission control, all engines used underground in the US must be tested for raw exhaust gas emissions and are then "certified" with a ventilation rate. This ventilation rate is that required to dilute the worst pollutant, *at the worst engine operating condition, down to the relevant atmospheric* limit (in PPM). The current atmospheric limits in the USA are; 50 ppm CO, 25 ppm NO, and 3 ppm NO_2. A raw exhaust limit also applies to CO (2500 ppm), but with no limit on NO_x. This allows a wide variety of engines underground, all with their own ventilation dilution requirement.

In relation to explosion protection, in areas in a US mines where IS electronics are required, engines must be explosion protected. The detailed requirements appear very similar to Australian explosion protected equipment. However the major difference is the use of "limited class" vehicles. These are basically road going vehicles with only minor modifications. They are only permitted in areas of the mine where non IS electric equipment is allowed, and this is managed by the operation. The use of Aluminium is currently unrestricted in US coal mines and this significantly cheapens their vehicles compared with Australia. Limited class vehicles have been used in the US for years. Contact with senior personnel in the US at the Mines Safety and Health Authority (MSHA), has indicated that no gas explosions have been attributed to the use of limited class diesel vehicles. Neither have any explosions been attributed to Aluminium and rusty steel causing a spark. As always, the differences in details of accident (statistics) reporting make other, more detailed comparisons, almost impossible.

Currently in the USA, changes to the 2 vehicle classes are being debated. These changes are detailed, and will not alter the class concept. One suggestion is for a third class of temperature controlled heavy vehicles, which may also involve added fire suppression systems.

Conclusions

Underground vehicles in Australian collieries are between 15% and 30% more expensive to purchase, and up to twice the cost to operate than their counterparts in metal mines. These premiums are largely due to a combination of the unique regulatory requirements and the few machines of any type that are built at any one time. The major opportunities for reduced costs are:

* Vehicles more closely matched to the applications and risks they need to deal with.
* Broadening the standards to allow established vehicles from non-mining or non-coal.
* Generally reduced regulatory constraints, eg Aluminium, gas emissions.

Little change will be possible however, until existing legislation is restructured to allow more flexibility in vehicle types. Some suggestions are offered:

* The current raw gas limits may be well in excess of that needed for occupational health management and therefore could be abandoned or severely restructured. Adopting sensible in-mine atmospheric values would allow more focus on the occupational health problem, and allow the issue to be managed at the enterprise, and potentially in a variety of ways. It would greatly improve the engine choices, dramatically reduce costs, and force operators to continually and pro-actively manage the environment.

* Current limits on ventilation (NSW Legislation) associated with diesel, assume all engines are equal polluters which is clearly incorrect. The ventilation limits, if any, need to reflect the individual engine pollution characteristics, and some credible duty cycle.

* Allowing a limited class of vehicle to operate where there are no gas ignition risks will dramatically reduce costs. These 'limited class' vehicles would need to still manage fire and out of control risks.

* Legislation may need to put more emphasis on day-to-day vehicle risk management. Issues like out-of-control, use as work platforms, operator ergonomics, braking systems and electronic control systems all need to be dealt with, but perhaps not by proscription.

Acknowledgments & Disclaimer

The views expressed in this paper are the authors and not necessarily those of ACIRL, MineRisk or any other Company, or any persons assisting with this project.

Thanks are due to the many individuals from Collieries in NSW and Queensland, Equipment Manufacturers, Unions & Mines Inspectorate, who freely gave their time for 3 rather arduous risk reviews, and latterly provided much information on the costs of building and operating vehicles.

References

The University of Newcastle
The New South Wales Coal Industry Cancer Surveillance Program (Inception Cohort)
Report to the Joint Coal Board, September 1994.

Standards Australia
Diesel Engine Systems for Underground Coal Mines, AS 3584-1991

US Department of Labor
Mine Safety and Health Administration
Approval, Exposure Monitoring, and Safety Requirements for the Use of Diesel-Powered Equipment in Underground Coal Mines
30 CFR Parts 7, 70, and 75 RIN 1219-AA27

O'Malley, Adrian
Design Restraints and Costs of Underground Coal Diesel Vehicles
ACIRL Report (SMT 3063-D)
June 1995