CANMET

Mining & Mineral Sciences Laboratories
Underground Coal Mining Safety Research Collaboration

Technical Information
Fact Sheet - Light Alloys
Revised February 2006

Fact Sheet on the Use of Light Metals & Their Alloys in Underground Coal Mines

Background

By 1998, Canada's underground coal industry had shrunk to 4 mines in 3 provinces across the country. By early 2006, this had further reduced to one mine in Alberta, one mine in BC and one mine in the planning stages in NS. In September 1998, in order to facilitate an ongoing safety research focus for the remaining mines, CANMET established the Underground Coal Mining Safety Research Collaboration (UCMSRC) to provide a research mechanism and technology forum for all industry stakeholders.

One of the first projects undertaken by UCMSRC was a review of the safety aspects of the use of light alloys in underground coal mines. It was concluded that, as most of the research on this had been done several decades ago, currently in the industry there were mixed levels of appreciation and awareness of on the potential hazard of light alloys and frictional ignition of flammable atmospheres. There was also a perceived lack of information on this hazard. As improved awareness is perhaps the most effective safeguard, it was therefore decided to produce a fact sheet, based on earlier research, to provide factual information on both the hazard of light metals and their alloys and provision of precautionary measures.

Hazards Associated with Light Metals

Light metals, most commonly aluminum, magnesium and titanium, and alloys containing them, are used in many industrial applications where lightness, hardness and ductility and resistance to corrosion are needed. They are widely considered to be near incapable of creating a frictional spark which is hot enough to ignite a flammable atmosphere. However, there are two exceptions to this where light metal alloys can be potential ignition sources in flammable atmospheres (e.g. methane): (a) thermite reaction, and (b) incendive chips (titanium) [1].

Potentially hazardous light alloys are those in which the total weight of aluminum, magnesium and titanium together exceeds 15%, and/or in which the content of magnesium and titanium together exceeds 6% by weight [2].

Thermite Reaction

Light metals and their alloys have an affinity for oxygen and when they are brought into close contact with oxygen bearing material, such as iron oxide (rust) in the presence of moderate heat, then a chemical reaction occurs, called a thermite reaction [1].

- This thermite reaction can generate temperatures over 2000˚C.
- The heat necessary to start the thermite reaction can be generated from frictional contact or from merely a glancing blow.
- A similar reaction can also be produced if either a smear of light metal is left on a rusty surface and is then struck with a glancing blow or where a rusty metal object strikes a surface coated with aluminum paint.
- Aluminum foils, widely used for cooking and wrapping candies and cigarettes will also produce a thermite reaction if laid over rusty metal and struck a glancing blow.
- Aluminum pop cans and lunch boxes can also potentially produce a thermite reaction if they come into contact with rusty steel.

Incendive Chips

Titanium and its alloys can produce highly incendive burning chips when they are struck or rubbed on various hard materials. These 'sparks' are easily capable of igniting a flammable atmosphere [1].

Experience with Light Metals & Their Alloys in U/G Coal Mines

Applications

In the 1940's and 1950's light metals and their alloys became widely used in the industry to take advantage of their lightness and resistance to corrosion. They were used primarily in roof support materials, but also in many other items of equipment and their components.

Incidents

Attention was drawn to the thermite reaction hazard in the UK in 1950, when a thermite flash caused a firedamp explosion, when a hand drill with a magnesium casing fell onto rusty steel. A mine explosion occurred at Glyncorrwg Mine in Wales in 1954 where 24 died and the ignition source was attributed to an impact of aluminum on rusty steel. Again, an explosion occurred at Hapton Valley Colliery in the UK in 1962 where 19 died. One possible cause for this ignition was a thermite reaction between aluminum wrapping foil and rusty steel rails [3]. In Canada, in 1973, a thermite flash ignited a small coal dust explosion which then started an underground fire with one fatality. This incident occurred when runaway aluminum rail cars struck rusty steel arches in No. 12 Colliery, Cape Breton Development Corporation [4].

Regulatory Issues

Following such fatal accidents around the world, various regulatory jurisdictions subsequently moved to address this hazard by formally restricting the use of light alloys in underground coal mines. These include United Kingdom, Germany, Australia, Alberta, British Columbia, etc. A notable exception to the severely restricted use of light metals and their alloys in underground coal mines is the USA. In Canada there are two jurisdictions (i.e. Federal and Nova Scotia) which have no formal restrictions, although industry practice has typically included restrictions on use of light metals and their alloys.

Other Issues

This disparity in restriction produces two groups of equipment available for use in Canadian underground coal mines - those available from the USA, which often have unprotected light alloy surfaces, or light alloy components; - and those which include precautionary measures (e.g. to replace or cover the offending material). These often make them heavier and more expensive. There is therefore understandable frustration by Canadian operators who want to use readily available purpose-designed US equipment in their underground coal mines but find in some cases that they do not meet regulatory light alloy requirements. Modifying US equipment costs money and delays implementation underground.

Industry's concern is increased by perceived anomalies in application of the light metal and alloy restrictions. For example, in some mines, use of light alloy lunch boxes, cans and foils is allowed, despite regulatory restrictions.

The thermite reaction between light alloys and rusty steel is a well researched hazard. Technical Literature is available outlining research undertaken in the United States, United Kingdom, Germany, Poland, Czechoslovakia, Australia, etc. The literature implies that their uncontrolled use still represents a safety hazard. CANMET, through UCMSRC, is working with industry stakeholders to rationalize practice and resolve such ambiguities.

Precautionary Measures

Risk Assessment

There are various industry approaches and techniques for assessment and management of risk to employee safety and health in use around the world. Essentially these methods allow safety management to achieve risk control. Applying the principles of 'practical risk assessment' requires the following to be considered for a given activity: identify the hazard (something with the potential to harm); determine the hazard effect (level of harm from the hazard - low, medium or high); estimate the risk (the likelihood or probability of hazard occurrence); estimate the severity or level of risk (product of hazard effect x probability); formulate preventive or protective measures to reduce the risk of the activity (prepare method statements or codes of practice, including appropriate restrictions and explanation of reasoning). In the case of light alloys, when applied on a specific case-by-case basis, as allowed in some jurisdictions in the industrialized world, safe use of some light alloys is possible at an acceptable and reasonable level of risk [5], [6].

Precautions to Address the Hazard

The final stages of risk assessment methods involve preparation of method statements or codes of practice which incorporate appropriate precautionary measures. Some of these for consideration in the use of light metals and their alloys follow.

Covering or Coating

- Prevent direct contact of the light alloy with rusty steel by covering or coating light alloy components with a non-incendiary material to protect them from impact.
- Keep the coatings completely intact and undamaged. However, this can be difficult as coatings often don't survive.
- Decrease light alloy percentage to safe levels, e.g. below established guideline levels
- Keep electrical components which are comprised of light alloys within a flameproof enclosure.

Removal or Separation from rust

- In most mines rust coatings on steel are unavoidable and covering or removing the rust would be impracticable.
- Precautions would have to prevent light alloys from coming into contact with rust by separating activity from likelihood of contact, for example, by keeping them in a non-steel/non-light metal container.

Removal or Separation from Heat

- The most common source of heat in underground coal mines would be from frictional contact, diesel and electrical equipment (such as motors).
- Remove the possibility of heat transfer from either prolonged contact or frictional impact by restricting use underground to circumstances where there is no possibility of such contact, friction or impact. This is often not very practical and can be difficult to do.

Removal or Separation from Potentially Explosive Atmospheres

- Restrict the use of light alloys from underground areas such as working faces, return airways, wastes, etc. where there could be exposure to potentially flammable atmospheres.
- Keep light alloy materials out of caving areas and gobs/goafs/wastes.
- If there is a reasonable probability of flammable gas or dust being present at the same time of a glancing blow between light alloy and rusty steel, then unless there are extensive benefits, the risks probably out-weigh the benefits of such an application; however, if there is none then the risk may be very low or negligible.

Examples of Safe Use

<u>USA</u>

The U.S. mining industry does not prohibit the use of light alloys; however it does restrict their use in some cases such as: aluminum alloy fan blades and external rotating parts shall not contain more than 0.5 and 0.6 percent magnesium respectively, aluminum and aluminum-alloys cannot be used in blasting materials and no ventilation controls installed after November 15, 1992, shall be constructed of aluminum. It defends its position of not outright prohibition by noting that their large underground coal industry has never had an accident where the thermite reaction was an issue. Regular use is made of mining equipment containing exposed surfaces of light metals or alloys. These include heavy equipment movers, hand-held bolting machines and hydraulic props, stone dusting machines, non flame-proof vehicles (some with exposed light metal gearbox casings).

Australia

Queensland, Australia regulations, as with the US regulations, allow the use of aluminum alloys with some restrictions, but in different ways. Industry spent over A$100,000 looking into the use of light alloys. It had been recommended that total prohibition is unjustified based on statistical risk (viz USA example) and a risk versus benefit approach was adopted. For example low risk/high benefit applications were to be immediately adopted [7].

In 1998/99 trials were successfully carried out of non-flameproof free-steered diesel vehicles. These were undertaken by ACIRL and overseen by a formal stakeholder committee (including potential users, Unions and Mines Inspectorate) necessary to break down long-held paradigms such as: use of uncoated light alloys, emission/temperature controls and non-flameproof/non-intrinsically safe electrics on mobile equipment.

The trials used specially modified Toyota HJ75 4WD’s to include control measures determined by a 'duty of care' approach and specific risk assessment studies. They were undertaken at the BHP Crinum Mine and Shell Moranbah North Mine, both longwall operations in Queensland's Bowen Basin in Australia. The vehicles are allowed to be used in specified zones only, essentially intake air zones, where a combination of training, signage and engineered electronic barriers are the primary barriers to prevent inadvertent entry to hazardous locations.

By April 1999 eight Troop-carriers and one utility vehicle had been used covering over 150,000km. By 2000, two more vehicles have been delivered to Shell Moranbah and another six were to be built for another customer. All the monitoring and control systems have evolved to a commercial level of reliability. The vehicle location system has proven it can prevent inadvertent entry into hazardous zones, the vehicles have low gas and particulate emissions, there has been only minor panel and trim damage and operator acceptance has been very high.

The trials demonstrate a recent application of risk assessment and the determination of both vehicle modifications and codes of practice for their use which together represent an acceptable and reasonable level of risk [7], [8].

Special Exemptions/Variances

Use of equipment containing light alloys in jurisdictions which restrict use of light metals and alloys, usually requires modification of the equipment, prior to use. This can include replacement of the offending components by acceptable ones, enclosing light components or by covering exposed light metal or alloy surfaces (although it is questionable whether such coatings will survive).

From time to time in the jurisdictions which require restriction, alternatives to the use of light metals or alloys are not feasible. In such cases, exemptions or variances may be issued, which usually include special conditions for use. For example, a video camera or geotechnical instrumentation, which have to be in the care of a responsible person all the time, cannot be left unattended underground and the use of which is only allowed after gas testing demonstrates a non-flammable atmosphere.

References

[1] Health & Safety Laboratories:Technical Information Sheet - Frictional Ignitions 2; HSE, London, UK (1980)

[2] NCB Spec No. 481, CENELEC 1977

[3] Hapton valley report

[4] CBDC No. 12 Colliery accident investigation report

[5] Practical Risk Assessment, W. Rowell, Mining Technology p184-188,Vol78,no899, July 1996

[6] Risk assessment for Busy Mine Managers BG Staley, Mining Technology p201-204, Vol 78 No 899, July 1996

[7] Correspondence with Terry O’Beirne, General Manager of Mining Services, ACIRL Ltd., Queensland, Australia

[8] Breaking Down the Barriers, T. O’Beirne et al, 2nd International Underground Coal Conference, 15-18 June 1999, Sydney, NSW, eds B.K. Hebblewhite et al, pp 145-148