Light Metals 2014
Edited by: John Grandfield
TMS (The Minerals, Metals & Materials Society), 2014

PREVENTING EXPLOSIONS IN MAINTENANCE PITS UNDER FURNACES

Alex W. Lowery
Wise Chem LLC , P.O. Box 633 , New Albany , Ohio , 43054 , USA

Abstract

The maintenance pit under a furnace is a molten metal explosion hazard that has been overlooked in our industry for far too long. P. D. Hess and K. J. Brondyke's landmark study, "Causes of Molten Aluminum Water Explosions and Their Prevention" failed to address this issue. This paper addresses the issue of molten metal explosions originating in these areas with special attention on new industry best safety practices for mitigating this hazard. Specifically I will be looking at the use of a specific organic coating that has been proven to prevent molten metal explosions. I argue that numerous catastrophes in our industry where molten metal explosions occurred could have been prevented if a certain organic coating was applied to the pit walls and floor. Future injuries and fatalities can be prevented if the maintenance pit under a furnace is identified as a hazard where molten metal explosions can occur.

Introduction

Whenever two liquids with widely different temperatures come into contact, an explosion can result. This explosion is purely a physical phenomenon. With aluminium there is an additional concern. Because aluminium is a very reactive chemical element that has a strong chemical attraction for oxygen with which it is almost always attached with in nature. Just as aluminium requires a large amount of energy to break the aluminium-oxygen bonds and produce metallic aluminium in a reduction cell. That energy will be released if the aluminium is able to recombine with the oxygen from either water or air. The energy released of one half kilogram of aluminium fully reacts with oxygen is equivalent to detonating 1.4 kilograms of trinitrotoluene (TNT).

$$2Al+3H_2O = Al_2O_3+H_2 + Energy$$

There are three distinctly different types of explosions that can occur when molten aluminium comes in contact with water as defined by the Molten Metal Incident Reporting System. This program, administered by the Aluminium Association since 1985, is credited for bringing awareness to this hazard. In that system the different explosions are defined as Force 1, Force 2, and Force 3, which are characterized as follows:

Force 1 explosion, also referred to as "steam explosions" or "pops", occur when molten metal traps water which quickly turns to steam. These explosions are characterized by metal thrown a short distance, usually up to about 4.5 meters and often less than 4.5 kilograms, with minimal or no property damage.

Force 2 explosions are violent steam explosions. As with Force 1 explosion, water is trapped and turns to steam instantaneously. But in this case, the water is trapped by the molten metal and pressure builds up to the point that considerably more metal is thrown a great distance of 4.5 – 6 meters, often to the roof of the plant. There may be some accompanying equipment damage.

Force 3 explosions are the catastrophic events arising from reaction of molten metal with oxygen from water, air or both. They are characterized by considerable property damage and metal dispersed more than 15 meters away. Often the metal has disappeared and what remains is a white powder – aluminium oxide. An example of a Force 3 explosion is shown below in Picture 1.

Research on Root Causes and Prevention

Safety pit coatings have been used to prevent molten metal explosions for more than 30 years. Some of the earliest investigations in this field were performed by George Long of Aluminium Company of America (ALCOA) as part of his pioneering research into the violent reaction of molten aluminium with water and steam. Subsequent studies identified an organic coal tar-based coating, Tarset Standard as the most practical organic coating available at that time to prevent molten metal explosions.

Unfortunately overtime, Tarset Standard did not adhere well to the wet concrete walls of casting pits. Wise Chem E-212-F was introduced to the market because of its of adherence in these crucial applications and indeed, subsequent testing proved that the Wise Chem product delivered protection against molten metal explosions. Much of Long's research is still relevant today and forms the basis of current safety practices in aluminium plants to prevent molten metal explosions.

Tarset Standard was removed from the marketplace in 1994. Subsequent industry sponsored research identified three new coatings that could help prevent molten metal explosions. The goal of the research was not to find a replacement for Wise Chem E-212-F, but to identify additional coatings. The additional coatings needed to have low levels of volatile organic compounds (VOCs), because there were both environmental and industrial health concerns over the Tarset Standard product. Wise Chem E-115, a zero VOC, 100% solids coating passed. Further testing in 2000 by the United States Department of Energy's Oak Ridge National Laboratory found that upon contact with molten metal Wise Chem E-115 was able "to retain highest gas generation" among the new coatings tested. Wise Chem coatings have the unique attribute to produce non-condensable gas upon contact with molten metal. Research has shown that non-condensable gas prevents the trigger shock which results in an explosion.

Maintenance Pits

Maintenance pits were originally designed as a safety mechanism to contain any spilled molten metal from a stationary furnace. Pits were typically constructed out of concrete with dimensions varying depending on the capacity of the furnace. The pit was constructed to be large enough to contain all of the metal in the furnace in case of a lining failure. Possibly due to cost savings, the construction of maintenance pits under stationary furnaces was phased out. Nevertheless, there are numerous stationary furnaces operating in our industry. On January 2012 the lining in a stationary furnace in a foundry in the United States Midwest failed resulting in metal escaping. The metal entered the small maintenance pit under the furnace causing an explosion. Molten metal was thrown throughout the foundry generating small fires and igniting a natural gas line. In addition, thrown molten metal landed on a nearby fork lift igniting the propane tank. Luckily, the 35 employees who were working in the vicinity were uninjured and properly evacuated. The plant lost production for several days and the furnace was damaged.

Hydraulic tilt furnaces were first introduced into our industry as the need quickly load scrap and good access for cleaning and drossing grew. Extrusion scrap re-melters, in particular, do not want to saw up scrap. They want to put it straight into the furnace. Hence the trend is towards a front loaded furnace with an 8,000 mm wide door and a rail bound scrap charging machine. All hydraulic tilt furnaces have a maintenance pit constructed under them.

A number of years ago one of the hydraulic rams on a tilt furnace broke in a casthouse in Brasil. The furnace operator was unaware of damage and tilted the furnace. The furnace operator could not visually observe the molten metal pouring out of the furnace and directly into the pit. When the operator realized that something out of the ordinary had occurred it was too late. The molten metal in the pit exploded damaging the furnace, casting station and injuring several workers.

The most notable incident involving molten metal entering a furnace maintenance pit occurred in 2007 in China. An explosion occurred at the Binzhou Weiqiao Aluminium Company in China. Nine workers were killed and 64 injured. The report released by the Chinese Government stated a taphole in the furnace failed causing the large capacity furnace to empty its contents of over 50,000 tons of molten metal into the maintenance pit. The resulting explosion destroyed the facility (Photo 1).

Picture 1: Force 3 explosion on August 20, 2007 at Binzhou Weiqiao Aluminum Company, in China. 9 workers were killed, and 64 injured.

Conclusion

Molten aluminium water explosions have been with the aluminium industry from the beginning. Countless injuries and deaths have been caused by the molten aluminium water explosions. In addition, the explosions result in equipment and facilities being damaged and a loss in production. There have been countless companies who have gone out of business after a molten aluminium water explosion. Over the past 40 years, research spearheaded by individual companies, governments, and aluminium associations have resulted in a better understanding of the root cause of these deadly explosions. Our industry should be commended for recognizing the hazard and working collaboratively to research and identify methods of preventing molten metal water explosion.

The use of specific safety coatings like Wise Chem E-212-F, E-115, Intertuf 132HS have been proved to prevent such explosions. Their use has reduced the number of explosions but have not eliminated them entirely. Our industry must realize that explosions that occur when molten metal enters a maintenance pit under furnace can be prevented. Just as the casting pit and tooling are coated with products like Wise Chem to prevent molten metal explosions, Maintenance pit walls and floors need to be coated with Wise Chem to prevent molten metal explosions from occurring.

References

1. S. G Epstein, (1991) 'Causes and Prevention of Molten Aluminium Water Explosion," Light Metals 1991
2. G. Long (1957) 'Explosions of Molten Aluminium and Water – Cause and Prevention", 107-112 Metal Progress
3. R.P. Taleyarkhan, V. Georgevich, and L. Nelson, (1997) "Fundamental Experimentation and Theoretical Modelling for Prevention of Molten Metal Explosion in Casting Pits, Light Metal Age 1997
4. D.D. Leon, R.T. Richter, and T. L. Levendusky, (2001) "Investigation of Coatings Which Prevent Molten Aluminum/Water Explosions," Light Metals 2001
5. "Guidelines for Handling Molten Aluminium, Third Edition,"
6. Jone. D (2013, October 11). Email Interview
7. Sale, D. (2013, October 9). Email Interview
8. Emes, C. (2013, October 14). Email Interview