Preventing Molten Metal Explosions in Smelters

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Abstract

Molten metal safety in many smelters is an afterthought. This mistake comes back to haunt them later when molten metal incidents occur in the potlines, casthouses, and rodshops. Not only are production stoppages commonplace but workers are being injured and killed. There is a gap in literature detailing molten iron and aluminium safety in a smelter. This paper will explain why explosions occur with aluminum as well as iron. This paper will review specific molten metal incidents and explain how they could have been prevented. Common reasons for molten metal explosions in smelters will be discussed. Failure to consider both molten iron and molten aluminium safety in smelter not only endangers workers but the smelter as a whole.

Keywords: Explosion, Molten metal safety, Molten aluminium, Molten iron.

1. Introduction

Explosions occur when molten metal reacts with water in either a physical reaction or a chemical reaction. Water can be present visually in its physical form (e.g., puddle of water) or invisible to the eye in a molecular form. Physical reactions are the most common type of molten metal explosions. A physical reaction results in a change in texture, shape, temperature, and state, without a change in the composition.

When molten metal covers water in a physical reaction, the water molecules expand as it turns from a liquid to a vapor. Water expands by a factor of 1 600 when it turns into steam [2]. “It expands because the bonds holding water molecules to each other are broken in the transition from water to steam, and the steam behaves like a gas -- it takes up much more space.” This rapid expansion results in the molten metal being propelled away in distances as great as 30 meters. A fire or injury or death can occur when the molten metal lands on a combustible material (e.g., cardboard, wood, etc.) or on a worker. In a physical reaction the mass of the metal remains unchanged after the explosion. For example, if 500 kg of molten metal explodes afterwards there is 500 kg of solidified metal spread around the workplace. Physical reactions are common with all types of metals, aluminium, iron, bronze, steel, etc.

Chemical reactions involving aluminum and water are our industry’s worst nightmare. These types of explosions can destroy a plant as well as injure and kill countless numbers of workers. They occur because aluminum is a very reactive chemical element that has a strong chemical attraction for oxygen with which it is almost always attached in nature (e.g., Al_2O_3). Just as aluminum requires a large amount of energy to break the aluminum-oxygen bonds and produce metallic aluminum in a reduction cell, that energy will be released if aluminum is able to recombine with oxygen. The energy released from one kilogram of aluminum that fully reacts with oxygen is equivalent to detonating 3 kilograms of trinitrotoluene (TNT) [14].

$$Al+3H_2O = Al_2O_3+3H_2 + Energy \quad (1)$$

These explosions can be very large destroying workplaces, injuring and killing workers. Shockwaves radiating out from the workplace can be detected by earthquake monitoring stations.

As stated before, in a physical reaction the mass of aluminium after an explosion does not change. But, in a chemical reaction the mass of the aluminium is turned into aluminium oxide and energy. The aluminium oxide in the form of powder commonly billows up in a mushroom like cloud from the workplaces is common in chemical reaction explosions.

Figure 1. Common physical reaction explosion involving a drain pan.

Figure 2. Aluminium oxide mushroom cloud from 2016 Noranda Aluminum chemical reaction explosion in the USA.

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