Exhibit #67

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Final Report

File No.: 00H-TL1067

Metallurgical Investigation of an Accident Involving a Reverberatory Furnace in the Copper Smelter (Hudson Bay Mining and Smelting Flin Flon, MB)

For

Manitoba Labor
Workplace Safety and Health Branch
Mines Inspection Branch
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ATTENTION: Ted Hewitt, P.Eng.
Director
Mine Inspector
Chief Investigator

September 29, 2000

PROVINCE OF MANITOBA
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REGISTERED PROFESSIONAL ENGINEER

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inches below the surface. Note the high volume fraction of the cubic shaped second phase material.

Sample #4-2 from Area #4 (2.5 inches below the surface)

The lower portions of the bath showed a vastly different microstructure in which the second phase is less distinctive (please see Figure F-9) indicative of slow cooling, more diffusion, ie: more mixing of the phases has occurred.

5.0 DISCUSSION

5.1 Molten Metal/Water Interactions in General

Molten metal/water interactions are a well-know hazard in the metal casting industry [1-6]. It is also well known that violent explosions occur when a thin layer of water is trapped under a layer of molten metal. It is now known that the triggering action is a minor explosion due to the sudden conversion to steam of a very thin layer of water trapped below the incoming metal. Long [1] found that the metal temperature and the depth of the water pool were found to be dependent of each other. As the water depth increased, progressively higher metal temperatures were required. With a 3 or 6 inch deep water pool, explosions occur at a temperature of 670°C (1240°F). When the water depth was increased to 10 inches, no explosion occurred at 670°C, but did at 750°C (1380°F).

Long [1] did make the observation which would be directly applicable to the situation under study – "No explosion of sufficient violence to break the water container were encountered in tests when the water depth was 2 inches or less. Instead, molten metal was blown out of the container, over a considerable area, and must be recognized as a serious hazard." [2]

5.2 Mechanism of Metal Explosions

Long [1] was one of the earliest researchers to undertake a systematic study of molten metal/water explosions using a total of 880 test. He found that water depth, temperature and composition must be proper for the rapid transfer of a large quantity of heat from the metal to the water.

Thermal Detonations

In the early 1990's workers [7] postulated that explosions resulting from the contact of molten material with coolant (ie: water in the case at hand) progresses through a number of distinctive phases [8].

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[2] P. 110 of Long [1]

"Initially, the melt and water mix on a relatively slow timescale (~1s). During this stage the melt and water zones have a characteristic dimension of the order of 10 mm. Because of the high temperature of the melt, a vapour blanket insulates the melt from the water and there is relatively little heat transfer. If this vapour blanket is collapsed in some small region of the mixture, high heat transfer rates result and there is a rapid rise in the pressure locally. In some circumstances this pressure pulse can cause further film collapse, so that it escalates and propagates through the mixture, causing coherent energy release. The propagating pressure pulse (which steepens to form a shock wave) has two main effects. Firstly, it collapses the vapour blanket, initiating rapid heat transfer. Secondly, it causes differential acceleration of the melt and water, which in turn leads to relative velocity breakup of the melt and a large increase in the melt surface area. As the energy of the melt is rapidly transferred to the water **high pressure steam is produced, which expands with the potential to cause damage to any surrounding structures**." [3]

Witte et al [3] reviewed a large number of explosive incidents involving extremely hot (perhaps molten) materials coming into contact with relatively cool liquids. The phenomena summarized as follows:

"Explosions occurring when hot molten materials contact cool liquids are frequently non-chemical: ie: the explosions are the result of extremely rapid vapour formation caused by heat transfer from the material to the liquid. The vapour explosion is controlled by the rate of energy transfer from the molten material to the liquid. In other words, the heat transfer rate from the molten mass controls the rate of vapour formation". [4]

5.3 Evidence of a Hydrogen Explosion

In an early paper by Long [1], studying the explosions created by molten aluminum and water he states there is no evidence of a hydrogen explosion.

Witte et al [3] citing an explosion in a Quebec foundry, in which one hundred pounds of molten steel feel into a shallow trough containing about 78 gallons of water states that a chemical analysis of the residue showed only a very small percentage of chemical reaction. Witte et al [3] note that some investigators theorize that hot molten metal reacts chemically with water to release free hydrogen which ignites in an explosive manner.

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[3] P. 2435 of Fletcher [7].

[4] P. 40 of Witte et al [3]

Author's Comment:

In all the papers reviewed there is no direct evidence of evolution and ignition of hydrogen playing a role in the explosions involving hot metal/water.

5.4 Steam Explosion Scenario at HBM&S, Flin Flon.

The situation with the reverbratory furnace on August 8, 2000 was slightly different than the usual molten metal/hot metal/ water explosion which involves hot metal coming inot contact with water.

On August 8 2000, water was draining into the bed from
fire hoses applying
17, 092 US gallons
for the period of 10:00 pm August 7, 2000 to 2:00 am August 8, 2000.

Certain localized areas of the bath such as under the spouts of the hoppers would have received a lot more water as a result of the hosing down of the interior of the large hoppers.

The timeline before the explosion was as follows:

22:45-22:55	Burners #2 and #3 are shut down.
22:55	Joe Klassen takes bath measurement. 12 inches overall, 6 to 8 inches slag and 4 to 6 inches matte, possibly 6 to 12 inches of matte below measurement.

Author's Comment:

We now know through the chemical analysis of the bath that there was no mat present. Only magnetite was present in the bath covered with 3 to 4 inches of slag. We also note that the magnetite (mistaken for matte) was molten, or at least, mushy.

NOTE: There is a large difference in temperature between the melting point of matte (approximately 1000°C) and the melting point of magnetite (1538°C) [10].

The bath, when the furnace was shut down, consisted of basically molten/mushy magnetite at a temperature in the range of 1538°C.

The large volume of water poured onto the hot bath, consisting of magnetite caused the slag to crack and then the magnetite to crack. The crack could be called quench cracking or thermal cracking. The cracking would propagate in length (across the width of the furnace) and in depth. Finally water would contact the molten, or near molten magnetite and this is when the popping began, evolving into a larger explosion.

However, fortunately this was not a fully developed steam explosion. Based on the author's experience of viewing and evaluating the damage caused by rapidly evolving steam in water/molten steel explosion at Algoma Steel in Sault Ste. Marie, in 1996, a fully developed steam explosion would have leveled the walls of the furnace.

The energy of the explosion in the reverbratory furnace on August 8, 2000 was one of a lower level, likely due in part to low depths of water (ie: 2 to 3 inches), encountering the molten/or near molten magnetite in the cracks. A situation never developed where a small amount of water was "trapped" under molten metal to create a colossal and much more violent molten metal/water steam explosion. In the HBM&S situation the water was merely "confined" in the crack while in intimate contact with the molten or near molten magnetite.

5.5 Temperature Monitoring of the Bath

One aspect of this investigation which really stood out was that there was never any mention of the temperature of the bath – such as the temperature of the bath when the burners were shut off and perhaps a temperature reading every half hour to determine the rate of cooling and indirectly the thickness of the crust solidifying on the upper surface of the bath.

Temperature is most important variable to monitor in order to determine whether the molten/solidifying material is safe to work nearby or overhead.

A capped pipe-type probe containing several thermocouples could have been pushed into the molten bath with a hydraulic ram to allow a continuous monitoring of the bath during the critical cooling down period after the burners were shut off.

6.0 CONCLUSIONS

1) The metallurgical analysis found that the bath at the time of the explosion consisted of: 2.75 to 4.75 inches of slag. The remainder was magnetite. There was no copper rich matte present.

2) An examination of the bath revealed the presence of an approximate 25-30 feet long crack which extended virtually across the complete width of the bath at the area of the jog. The crack was 1 to 2 inches wide over a length of 10 to 12 feet. The crack was 8 to 10 inches deep over the same length.

   This large crack is the probable location where water came into contact with molten or near molten magnetite, resulting in a low level steam explosion.

4) Water and molten metal are a dangerous combination. Water coming into contact with molten meal produces a threat to human life and property.

5) Water was being sued unnecessarily for several jobs where mechanical cleaning would be a reasonable and much safer solution.

7) Molten metal covered with a recently formed, thin layer of slag is an extremely unstable situation. The solidified layer of metal would be quite thin and unstable (subject to thermal cracking) after only 1 to 1.5 hours of cooling.

Conditions leading to the explosion during the August 08/00 shutdown were:

1) Inadequate cooling time between the time the burners were shutdown and water washing activities began. Consequently, there was ***inadequate time*** for a thick and protective layer of slag and partial solidification of the upper most layer of the liquid bath.

3) The protective layer of slag ***may*** have been much thinner as compared with previous campaigns.

4) The bath, composed of molten magnetite, instead of matte, was consequently approximately 500°C hotter than in previous shutdowns. Consequently, the time required for the solidification of a protective crust would have been substantially longer than in previous shutdowns.

7.0 RECOMMENDATIONS

1) Ideally, the use of water washing during the shutdown of the reverberatory furnace should be prohibited due to the danger to life when adequate control as to the volume of water used cannot be assured.

2) The bath should be cooled with forced air for a period of 8 to 12 hours ensure that a sufficiently thick crust has formed before water is used around the bath.

3) Water should be applied cautiously and sparingly.

4) **In future shutdowns, the temperature of the bath should be monitored on a regular basis once the burners are shut off to allow an estimate of the thickness of the crust which formed and as a general qualative measurement of the state or condition of the bath at any given time.**