Hand Amputation in a Molten Metal Furnace

A particular factory production process required molten metal samples to be taken from the furnace for testing every two hours by employees. This was an aluminum holding furnace, operating at about 1,400°F. One employee lost a hand when the open furnace door through which he was sampling fell on his arm. The door fell because a turnbuckle was rotated in such a fashion as to unscrew one end and thus released the door.

Any non-locked turnbuckle, if acted upon so as to turn one of its eyebolts repeatedly in the same direction while holding the other stationary, will eventually cause one end to turn such that it screws into the center body to the end of its threads, and it unscrews the other end completely out of the center body, as shown in Figure 1.

Two main factors contributed to the accident: poor furnace design and poor operational practices.

Poor Furnace Design

The original furnace design allowed for molten metal samples to be taken from two horizontal covers, also known as clamshell doors, which were located at the end of the furnace, on a section that was approximately 4 feet above floor level. They each covered half of the furnace width, were approximately 4 x 4 feet, and each opened to opposite sides of the furnace. They were also used for loading the furnace. Sampling from that location did not require the worker to open the main door of the furnace. The clamshell doors were each opened and closed with a pneumatic cylinder, and each had a safety lock hook that secured the door when it was opened, and exposed only half of the furnace width when sampling was done through one of them. The clamshell door system included a direct cylinder rod connection to the doors, without any intermediate cables or turnbuckles.

The main door was a vertical door that lifted straight up the furnace to its full height of 8 feet, being pulled by a pneumatic cylinder through a system of cables and pulleys. It was set back from the end of the furnace behind the clamshell doors, thus about 4 feet from the end of the furnace. It was opened only for furnace cleaning. The door hoisting system on the original furnace included a safety latch, also known as a "gravity hook," that engaged when the door was fully opened. Also included was a lockout for the main door safety latch, whereby the operator would insert a lockout pin and place a lock or safety clip through a hole on the other side. When the door was fully opened and the lockout engaged on the original furnaces, it could be closed only by removing the lock or safety clip, then removing the lockout pin and then by moving a vertical bar to release the safety latch.

The factory owner became dissatisfied with the sealing and the refractory life of the original design and wanted to increase the heating capacity. A local fabricator was retained to design and build a completely new furnace and was provided with the stripped-down shell of the original furnace to use as the housing for the new design.

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

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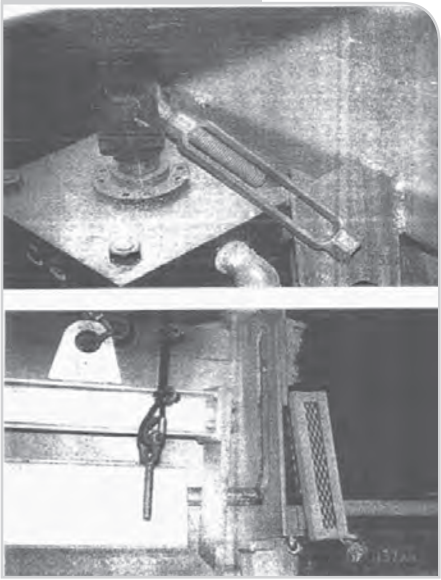
Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

Figure 1



Photos of the failed turnbuckle.

Figure 2

Rebuilt furnace and footed door.

The new design had a total of 15 electrical "glo-rod" heating elements, as opposed to the nine in the original design. To accommodate the additional heating elements, the upper section of the new design was longer than that of the original one. The top section extended almost to the end of the lower shell. There was no room for the clamshell or similar sampling doors (see Figure 2).

The new furnace was designed with a single "footed" door, which was placed at the end of the furnace. It replaced the original vertical lift door and the two clamshell doors. This door had both a vertical section and a horizontal section and weighed approximately 1,650 pounds (Figure 3).

The new footed door reused the same gravity hook and lockout system that was present on the main furnace door of the original furnace. This door was operated by a pneumatic cylinder through a hand air valve. The cylinder rod was connected to the door by means of a double cable arrangement — as can be seen in the right side of Figure 3 — that fed up over a double-grooved pulley to the lifting beam for the footed door. This cylinder was not of a "non-rotating" design, such that the internal piston and external operating rod could rotate about their axis (see Figures 3 and 4).

Note, from the twisted cables in Figure 4, that this cylinder has, during operation, rotated in a counterclockwise direction, when viewed from above. This photo was taken after the accident, and there now has been a set of locking devices installed on the turnbuckle. When the accident occurred, there were no locknuts, cotter pins, sealing wire or any other means installed to prevent either turnbuckle end's eyebolt from screwing into or out of the turnbuckle's center body.

Figure 3

New footed door and view of cylinder and turnbuckle to the right.

Figure 4

Twisted cables.

Poor Operational Practices

The revised design did not contain any sampling ports, and molten aluminum samples were taken through the new footed door. This caused too much heat loss, so a small sampling door was cut into the footed door. However, the size and location of the new sampling door made it difficult for the operators to see what they were doing as they reached in for a sample, and the tongs would catch on the side of the new small door. As a result, they reverted to opening the large footed door to take samples, which again caused a great deal of heat loss.

In order to reduce the loss of heat while sampling, the operators then started taking samples without fully opening the main door and thus not engaging the gravity safety hook on the main door mast. The accident occurred when the injured operator was taking a molten aluminum sample through the footed door of the furnace. He had not fully opened the footed door, and had not engaged the gravity hook. While he was reaching into the furnace, the turnbuckle became unscrewed and separated; thus allowing the door to fall on his forearm.

Accident Analysis

Both factors — poor furnace design and poor operational practices — had to have been present for this accident to happen:

1. The furnace design had three faults. The first two contributed to the release of the cabling system to allow the door to fall, and the third caused the operators to look for a convenient way to take the sample. These faults were:

    - The use of an air cylinder whose shaft could rotate.
    - The lack of locking devices on the two ends of the turnbuckle.
    - The lack of an adequate port for the sampling of the molten metal.

2. There were two distinct failures made by the plant personnel:

    - The operating practice of sampling through the door without engaging the safety gravity hook allowed the door to fall when the turnbuckle let loose. This hook assembly can be seen in the upper part of Figure 2. This is a definite breach of conduct for lockout/tagout procedures as required by U.S. Occupational Safety and Health Administration rule 29CFR1910.147, in that the potential energy of the hoisted door must be controlled. Proper employee education and operational monitoring would have prevented this occurrence.
    - Normal maintenance could have and should have revealed, during preventive maintenance operations, that the turnbuckle was slowly becoming unscrewed. This should have been acknowledged and the cause found and corrected. ✦