XL Risk Consulting

Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.17.13.0

ALUMINUM INDUSTRY ABSTRACT

INTRODUCTION

Aluminum is a lightweight, nonmagnetic metal used in aircraft, building materials, consumer products and industrial equipment. Refined aluminum is soft and malleable and is often alloyed with other metals to increase its strength. Depending on the processes used, aluminum is produced in many forms, including powder, ingots, billets, slabs, sheets, foil, rod, wire and tubing.

Raw materials for aluminum production include bauxite (aluminum ore), caustic, petroleum coke, pitch, cryolite and aluminum fluoride. Large quantities of electric power are required for alumina reduction.

Reduction furnaces (commonly called smelters or pots) and rolling mills represent large loss potentials in the aluminum industry. The pots present the hazards of large electrical power supplies and of molten material handling. The hazards of rolling mills include those associated with large motors and gear drives and with combustible oil-based cooling, lubricating and hydraulic systems. As a combustible metal, aluminum presents fire and explosion hazards when finely divided or when molten. Other loss potentials in the aluminum industry stem from large mobile equipment, pressure vessels, fuel-fired rotary kilns, extrusion presses and electrical power generation equipment.

Most equipment in the aluminum industry is very expensive and can take a long time to replace, so both the property and business interruption portions of a loss can be very large. For this reason, it is important that an aluminum processing facility install proper protection for all hazards and implement excellent management programs for loss prevention and control.

PROCESSES AND HAZARDS

Aluminum processing involves four major steps: mining; refining; reduction; and fabrication. Mining is usually done at a separate location while other operations may be combined or separate. Mini mills, which recycle aluminum by melting and rolling scrap, involve primarily fabrication operations.

Figure 1 shows a simplified process flow for making aluminum products.

Mining

Bauxite is collected by open pit mining. This mining method involves large and unique mobile equipment, such as drilling equipment, power shovels, drag lines, loaders and hauling vehicles. It can also involve nonmobile equipment, such as conveyors, crushers and kilns, and buildings for maintenance and storage.

100 Constitution Plaza, Hartford, Connecticut 06103

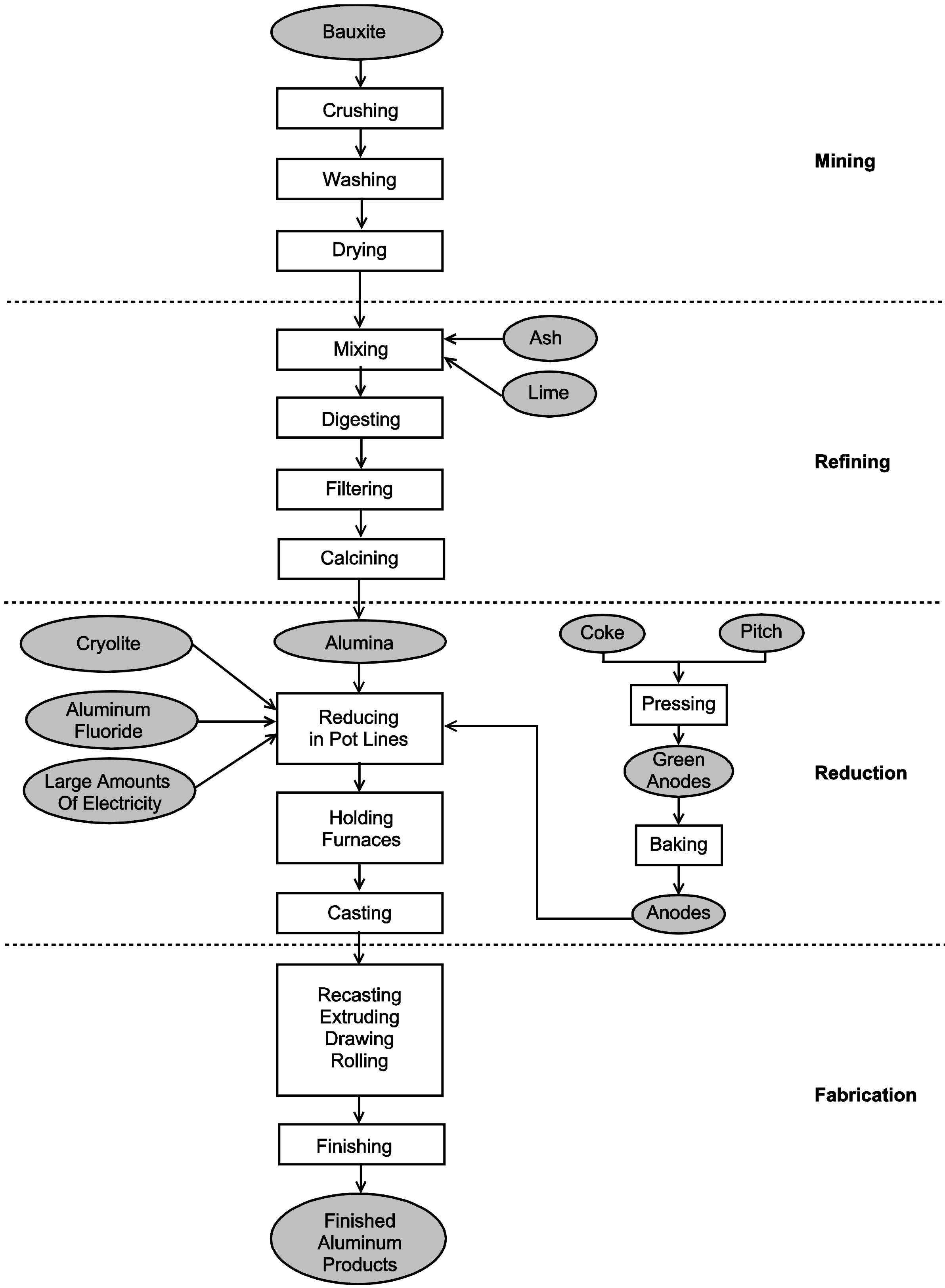

Figure 1. Simplified Process Flow From Aluminum Ore To Finished Aluminum Products.

Mining operations often include waste water treatment facilities. Larger mining operations may also have their own power generation equipment.

Drills make holes for the charges that blast the bauxite loose. Shovels and drag lines move the rock, and loaders put it onto vehicles or conveyors. The shovels and drag lines are vital to production. Before ore leaves the mining area, it is usually crushed in ball mills and calcined (dried and heated) to remove organic matter and reduce water content. These operations reduce the ore's shipping weight and make handling easier.

Loss exposure in mining operations includes machinery breakdown and fire in mobile equipment. Hydraulic oil and diesel fuel fires are common types of losses, as is electrical breakdown in motors. Conveyor belt fires can damage conveyor structural supports. Breakdown of conveyors, crushers, rotary kilns and drive motors can result in long downtime. Such incidents can disrupt material flow and curtail operations at the refiner.

Refining

Refining of some metals, such as copper, involves an electrolytic process. This is not true with aluminum. However, alumina reduction does use an electrolytic process (see Reduction).

Refining of aluminum ore converts the bauxite to aluminum oxide. Aluminum oxide, or alumina, is a white powder with chemical formula Al_2O_3. The most common refining process, the Bayer process, reacts bauxite with sodium hydroxide to form sodium aluminate, which is then filtered, precipitated and calcined to produce alumina.

In the Bayer process, the bauxite is finely ground in a ball mill and mixed with sodium hydroxide (or other sodium-based caustic) and lime. The mixture is heated under high pressure for 2 to 8 h in steam-heated steel tanks called digesters. When digesting is complete and the mixture settles, the solution containing sodium aluminate is removed. The insoluble residue, called red mud, consists of the oxides of metal impurities (iron, silicon, titanium and others) from the ore.

The sodium aluminate solution is filtered in a filter press and sent to a precipitator where the solution is stirred, seeded with aluminum trihydrate crystals, and cooled to precipitate aluminum hydroxide. The aluminum hydroxide is then calcined in a fuel fired rotary kiln to yield alumina. The solid produced by the Bayer process is 99% or more alumina. Figure 2 shows a filter room for filtering sodium aluminate solution.

Exposure to loss in refining operations includes rupture of pressure vessels, mechanical breakdown of crushers and mills, heat damage to kilns, electrical breakdown of large motors, and fire or breakdown in conveyor systems. Some refiners receive raw materials by ship, so loss of the pier or wharf and ship unloading equipment also presents a major loss exposure.

Reduction

Unlike most other metal smelting processes, alumina reduction includes electrolysis. Because reducing alumina to aluminum consumes such great quantities of electric power, it is more cost effective to build alumina reduction plants near inexpensive sources of electric power and ship the alumina to the plants. An estimated 17.5 kWh (63 MJ) delivered at currents of up to 250,000 amp dc are needed to make 1 lb (0.45 kg) of aluminum. Large rectifier-transformers are needed to convert incoming power to dc. Many reduction plants generate some of their own power.

Figure 2. Filter Room Showing Two Filters Closed (Left Background) And One Open (Right).

The reduction process forms aluminum through electrolysis. In electrolysis, current flows from the anode (positive terminal) to the cathode (negative terminal) through an electrolyte (bath) contained in a vessel. The vessels in which alumina reduction takes place are called smelters, pots or cells. The cathode of a pot is the lining, which is a baked carbon mixture. In the Söderberg process, the anode is a paste being continually added to the pot. With pre-bake technology, the anodes are bars made by baking appropriate mixtures of petroleum coke and coal tar pitch. The bars are lowered into the pots as they are consumed.

In alumina reduction the electrolyte is alumina dissolved in molten cryolite (Na_3AlF_6, or sodium aluminum fluoride). To maintain proper bath composition, aluminum fluoride and smaller amounts of calcium fluoride and sodium carbonate are added. During electrolysis, aluminum collects at the cathode while CO_2 is produced at the anode. Molten aluminum is tapped off the pots; collected in large brick-lined crucibles; sent to holding furnaces; poured (cast) into ingots, billets or slabs; and sent to fabrication processes.

Weights of ingots, billets or slabs can range from 10 lb – 30,000 lb (4.5 kg – 13,500 kg) or more. Direct chill casting is the most common method of casting large pieces. In this method, aluminum is poured into a mold, then water is sprayed directly onto the mold as it descends into a casting pit. Water collects at the bottom of the pit but does not reach the mold. Figure 3 shows aluminum ingot casting and Figure 4 shows finished aluminum ingots.

Continuous casting is now becoming common. A continuous caster is a combination casting machine and rolling mill. Molten aluminum is fed to the machine and emerges as re-draw rod for a rod mill or as re-roll stock for a sheet mill.

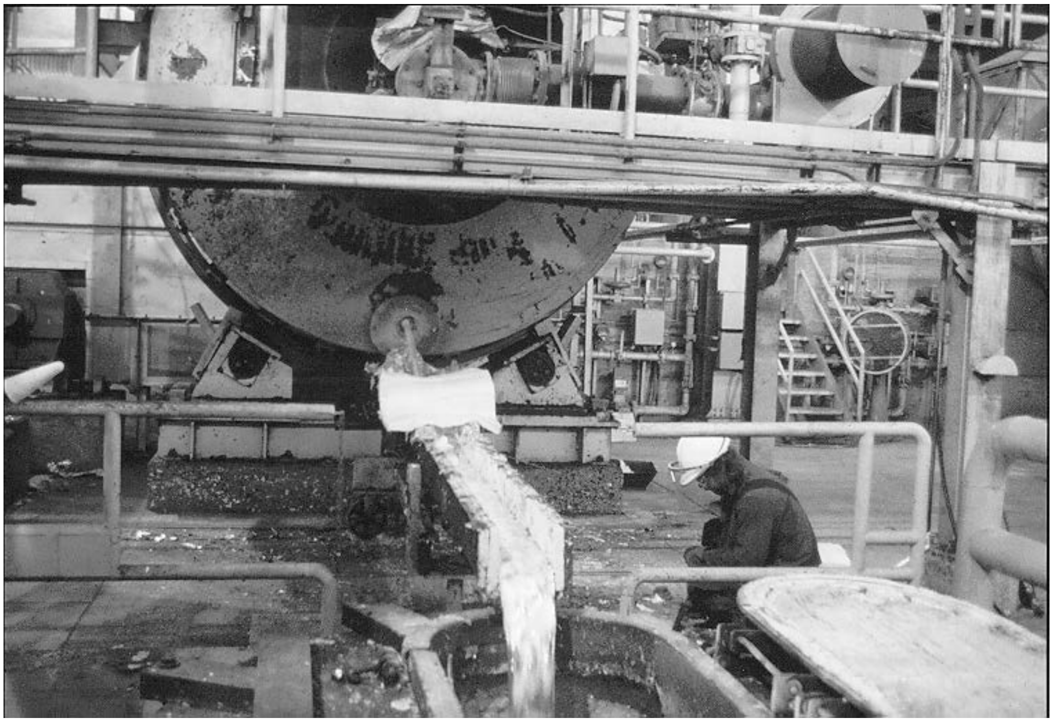

Figure 3. Aluminum Ingot Casting.

Figure 4. Finished Aluminum Ingots.

Figure 5. An Aluminum Pot Line.

The major loss exposure at a reduction plant is electric power loss. On some pot lines, loss of power for as few as 3 h – 4 h can cause the electrolyte to cool to the point where its electrical resistance is too great to restart the line when power is restored. On other pot lines this may be 7 h – 8 h. It is expensive and time consuming to restart a frozen pot line, because the solidified aluminum and electrolyte must be physically broken out of the pot. Complete restoration of a pot line can take several months, after which the expected life of the pot is reduced approximately 50%. Figure 5 shows a pot line.

Another loss exposure is a molten aluminum spill. Molten aluminum can spill in or near casting pits, or can break out of holding vessels or filters for continuous casters. Molten aluminum can cause a steam explosion and is reactive enough to explode upon chemical reaction with water. It can also explode when it contacts rust on steel surfaces.

The hazards involved in anode production are steam or hot oil-heated mixing vessels, the anode-baking “ring furnace,” and the anode press, which is subject to cracking. Plants that generate power are also subject to the hazards of power generation equipment.

Other loss exposures in the reduction plant are hydraulic systems for tilt furnaces and furnace doors. Leaks in these systems will ignite and result in a hot torch fire.

Reduction operations require pollution control equipment, primarily scrubbers and precipitators. Scrubbers often contain parts made of plastic or other combustible material. Either may build up a combustible residue.

Fabrication

Fabrication involves casting, extruding, drawing or rolling.

Casting

Casting as a fabrication process is actually recasting. It involves remelting ingots or scraps in furnaces and recasting them into molds. Engine blocks are made by recasting.

The hazards associated with recasting are the same as those for casting from the pot lines, except the holding furnaces are usually much smaller. An additional hazard of recasting is the exposure to radioactive contamination. Any facility purchasing scrap for casting could unknowingly obtain contaminated scrap. Using such scrap would render the finished product useless.

Extruding

A cylindrical aluminum billet heated to approximately 800°F (426°C) is extruded into a continuous length of uniform cross-section by forcing the billet through a steel die under high pressure. The extrusion process can produce bars, tubes, L-brackets, U-shaped rods and many products with unusually shaped cross-sections, including tapered cross-sections. Figure 6 shows an aluminum extrusion press. The major loss exposure is the high pressure hydraulic systems using combustible hydraulic fluid. The fire or explosion potential is ignition of the oil mist from a leak. Cracking or breaking columns, cylinders or crossheads is the primary boiler/machinery loss potential.

Drawing

The drawing process involves pulling a cold aluminum bar or tube through a steel die to form the desired final shape. Sometimes, aluminum bar or tube is drawn while still hot from extruding. Several stages of drawing gradually reduce the size of the product to form wire, bars, rodding and tubes of varying sizes.

Figure 6. An Aluminum Extrusion Press.

The loss exposure of the drawing process is similar to that for extruding, except aluminum processing temperatures may not be as high.

Rolling

Rolling turns cast aluminum into plate, sheet or foil. Aluminum rolling mills are large, critical pieces of equipment that generate a lot of heat and use combustible coolants, lubricants and hydraulic oils. These mills present very large property damage and business interruption loss potentials. Loss exposures include machinery breakdown, cracking and combustible fluid fires. Figure 7 shows an aluminum rolling mill.

For a more detailed description of aluminum rolling mills, the hazards associated with them, and their protection, see PRC.17.13.1.

Finishing

Finishing operations for fabricated aluminum products include cutting, trimming, cleaning and coating with various solutions. Figure 8 shows a coating line for aluminum sheet wound into coils.

LOSS PREVENTION AND CONTROL

Mining

Use noncombustible construction for buildings. Cut off boiler and electric generating areas with 3 h rated fire barrier walls and 3 h rated automatic closing fire doors. Cut off office and switchgear areas with 2 h rated fire walls and 1½ h rated automatic closing fire doors.

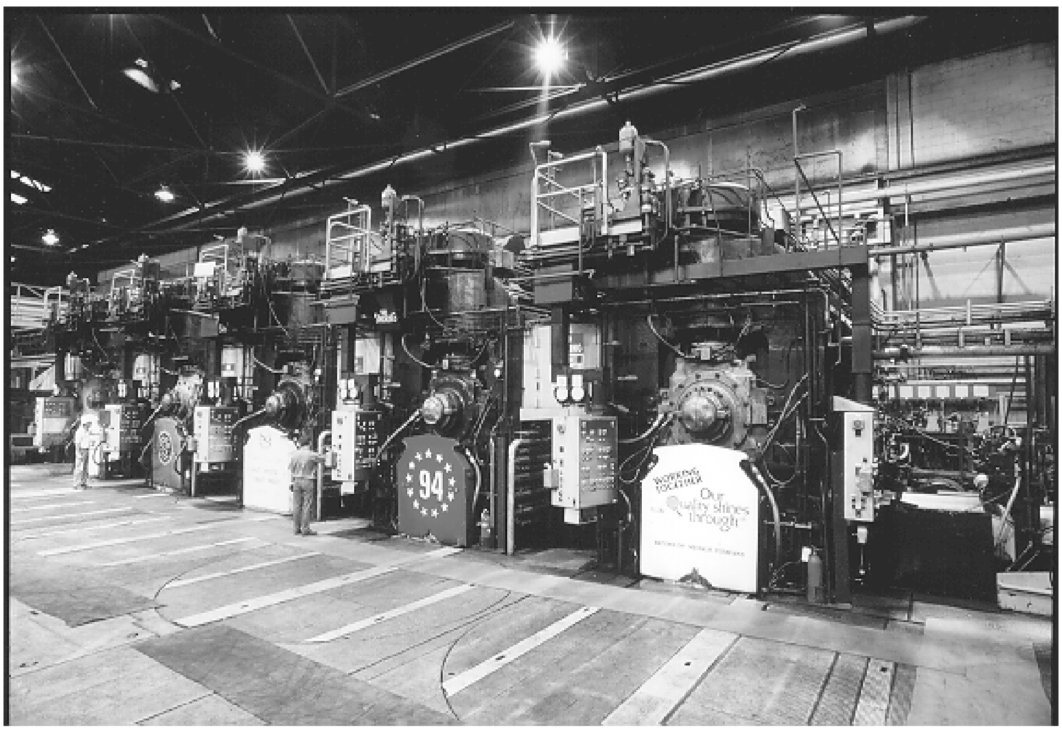

Figure 7. A 5-Stand Aluminum Cold Rolling Mill.

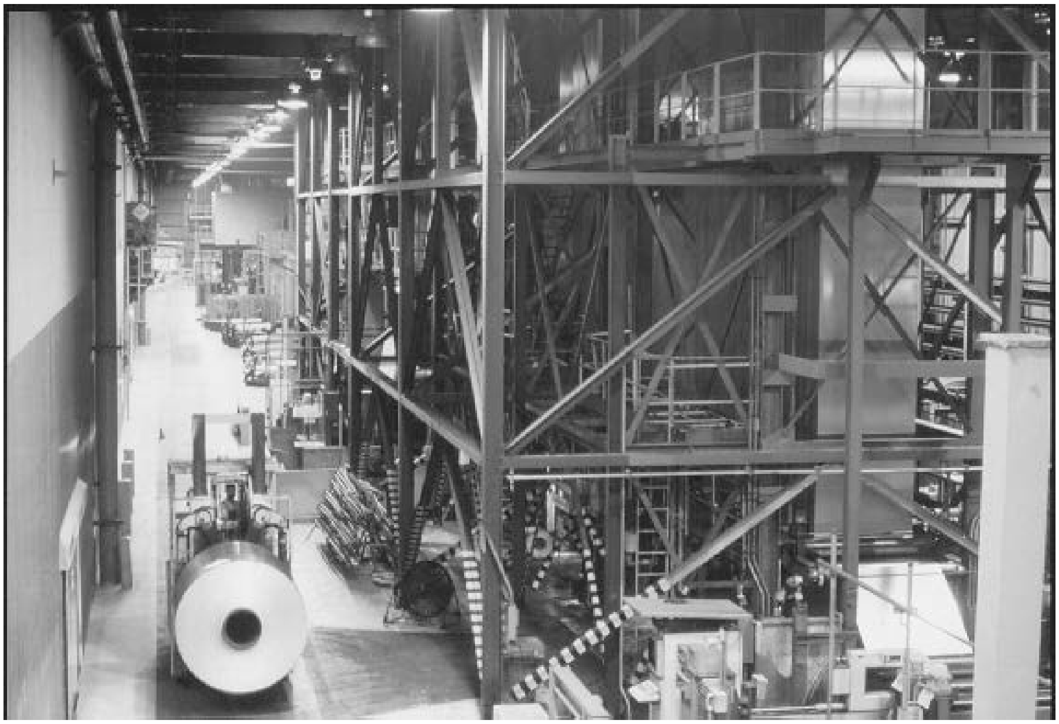

Figure 8. An Aluminum Coil Coating Line.

Reserve an adequate portion of the mine water supply for fire protection. See PRC.14.1.1.0 for information on the amount of water that should be reserved. Provide a separate system of looped underground fire protection mains in accordance with NFPA 24 and PRC.14.5.0.1 to supply hydrants and sprinkler systems. Space hydrants at 250 ft (76.3 m) intervals.

Provide automatic wet or dry pipe sprinkler systems in building areas with combustible occupancies in accordance with NFPA 13 and PRC.12.1.1.0. Such buildings commonly found in mining operations include maintenance, water treatment, office and storage buildings.

Provide automatic sprinkler, water spray or foam-water protection for hydraulic and lube oil reservoirs for crushers, kilns and conveyors in accordance with NFPA 13, NFPA 15 or NFPA 16 and with PRC.12.1.1.0 or PRC.12.3.1.1, as appropriate. Design water-only systems for 0.25 gpm/ft^2 (10.2 L/min/m^2). Use 0.16 gpm/ft^2 (6.5 L/min/m^2) for foam systems. Dike, drain and trap oil reservoirs. Protect hydraulic systems in accordance with PRC.9.2.4.

Arrange and protect fossil fired and hydroelectric generating electric generating equipment in accordance with NFPA 850 and PRC.17.12.1. Monitor turbine-generators for excessive vibration. Protect power transformers in accordance with PRC.5.9.2.

In mining, boilers may be used to heat buildings or generate electrical power. Install combustion safeguards for these boilers in accordance with NFPA 85 and PRC.4.0.1.

Monitor rotary kilns for excessive vibration. Provide backup diesel drives or independently powered motors and run them weekly. Protect motor enclosures for rotary kilns with double-shot carbon dioxide systems. Install combustion safeguards for rotary kilns in accordance with NFPA 86 and PRC.4.0.1.

Store and handle explosives in accordance with the Bureau of Mines regulations and NFPA 495. Protect bulk storage of flammable and combustible liquids in accordance with NFPA 30 and PRC.8.1.0. Handle these liquids in safety containers and keep only one day’s supply outside the bulk storage facilities.

Protect belt conveyors in accordance with PRC.9.3.1. Locate hydrants or hose connections to permit hose streams to reach all parts of the conveyor gallery.

Provide portable dry chemical or CO_2 extinguishers on mobile mining equipment. Choose the appropriate size, type and location of extinguishers for the equipment power supplies, oil systems and mechanical operations. Consider providing fixed protection for large, important mobile equipment.

Provide and store spare rotating elements for turbine-generators, crushers, kilns and conveyors.

Conduct preventive maintenance on equipment at the mine.

Refining

Provide automatic sprinkler, water spray or foam-water protection for hydraulic and lube oil reservoirs for mills, kilns and conveyors in accordance with NFPA 13, NFPA 15 or NFPA 16 and with PRC.12.1.1.0 or PRC.12.3.1.1, as appropriate. Design water-only systems for 0.25 gpm/ft^2 (10.2 L/min/m^2). Use 0.16 gpm/ft^2 (6.5 L/min/m^2) for foam systems. Dike, drain and trap oil reservoirs.

Install combustion safeguards for boilers in accordance with NFPA 85 and PRC.4.0.1.

Design digesters in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code. Monitor steam pressure and temperature in the digester heat exchange system. Arrange the control system to alarm and subsequently shut down when excessive pressures or temperatures are detected. Provide overpressure protection for digesters.

Monitor rotary kilns for excessive vibration. Provide backup diesel drives or independently powered motors and run them weekly. Protect motor enclosures for rotary kilns with double-shot carbon dioxide systems. Install combustion safeguards for rotary kilns in accordance with NFPA 86 and PRC.4.0.1.

Protect belt conveyors in accordance with PRC.9.3.1. Locate hydrants or hose connections to permit hose streams to reach all parts of the conveyor gallery.

Provide and store spare rotating elements for mills, kilns and conveyors.

Reduction

Use noncombustible construction for buildings. Cut off boiler and electric generating areas with 3 h rated fire barrier walls and 3 h rated automatic closing fire doors. Cut off office and switchgear areas with 2 h rated walls and 1½ h rated automatic closing fire doors.

Provide automatic wet or dry pipe sprinkler systems in building areas with combustible occupancies in accordance with NFPA 13 and PRC.12.1.1.0.

Provide automatic sprinkler, water spray or foam-water protection for hydraulic and lube oil reservoirs for turbine-generators and kilns in accordance with NFPA 13, NFPA 15 or NFPA 16 and with PRC.12.1.1.0 or PRC.12.3.1.1, as appropriate. Design water-only systems for 0.25 gpm/ft^2 (10.2 L/min/m^2). Use 0.16 gpm/ft^2 (6.5 L/min/m^2) for foam systems. Dike, drain and trap oil reservoirs. Protect hydraulic fluid systems in accordance with PRC.9.2.4.

In reduction operations, boilers may be used to heat buildings or generate electrical power. Install combustion safeguards for these boilers in accordance with NFPA 85 and PRC.4.0.1. Install combustion safeguards for holding furnaces in accordance with NFPA 86 and PRC.4.0.1.

Protect hydraulic fluid systems in accordance with PRC.9.2.4.

Protect all structural members exposed to molten aluminum spills with appropriate heat-resistant masonry materials. Coat all exposed areas to a height of at least 6 ft (1.8 m) above the floor. There are no materials listed specifically for this purpose; however, materials meeting UL 1709 criteria for 1½ h and ASTM E119 criteria for 3 h may be suitable.

Coat casting pits with organic coatings such as those made by Tarset, Wisechem, Bitumastic and Rustoleum. Maintain at least 6 ft (1.8 m) of water in casting pits. Monitor the water level and send an alarm to a constantly attended location when the level drops to 4 ft (1.2 m) above the bottom of the pit. Equip cooling water systems with low pressure and low flow alarms.

Provide deluge water spray systems for scrubbers and precipitators. Design the systems in accordance with PRC.17.12.1.

Arrange and protect fossil fired electric generating equipment in accordance with NFPA 850 and PRC.17.12.1. Arrange and protect hydroelectric generating equipment in accordance with NFPA 851. Monitor turbine-generators for excessive vibration.

Protect power and rectifier-transformers in accordance with PRC.5.9.2. Provide at least one spare power transformer and one spare rectifier-transformer. If transformers in the plant vary and are not interchangeable, more spares may be warranted.

Protect cable tunnels and cable spreading rooms in accordance with NFPA 850 and PRC.17.12.1.

Provide automatic sprinkler protection for anode production areas where liquid pitch is handled or where hot oil heat exchange systems are used. Design sprinklers for 0.25 gpm/ft^2 (10.2 L/min/m^2) for the entire area and at least 20 ft (0.61 m) beyond. Arrange hot oil heat exchange systems in accordance with PRC.7.1.5.

Provide combustion safeguards for ring furnaces in accordance with NFPA 86 and PRC.4.0.1. Install sprinklers inside ring furnace exhaust ducts and filters.

When possible, include provisions for emptying molten aluminum from pots if the power fails long enough to risk solidifying the pots. Establish criteria to determine when the pots will be emptied and train employees when and how to empty them. Alternatively, develop a pot line recovery program to permit starting 10 to15 pots per day. This may require emergency generators large enough to operate anode drive motors.

Protect building structural members from molten aluminum spills to at least 6 ft (1.8 m) above the floor. Coat all areas exposed to spills with an appropriate heat resistant material. Materials meeting UL 1709 criteria for 1½ h or ASTM E119 criteria for 3 h may be suitable.

Fabrication

Casting

Follow the recommendations for holding furnaces, hydraulic systems, and molten material exposures for reduction operations.

Provide secure gates to control all materials coming into the site. Monitor scrap for radioactive contamination before it enters the facility.

Extruding and Drawing

Protect hydraulic fluid systems in accordance with PRC.9.2.4.

Conduct regular nondestructive testing on equipment subject to high forces, particularly columns, cylinders and crossheads.

Rolling

Rolling presents the highest loss exposure of aluminum fabrication methods and requires specialized protection. Refer to PRC.17.13.1 for a complete treatment of the loss prevention and control measures needed for these operations.

PHOTOGRAPHS

Courtesy of Reynolds Metals Company; Richmond, VA.