How industrial plants benefit from apron feeder magnetic separators

by Timothy G. Shuttleworth and Carlos Stipicic

In the late1970s, mineral processing plants producing copper sulfide concentrates and oxide leaching feedstocks went online with operating tonnages that exceeded traditional installations. This created a need for larger capacity belt conveyors and apron feeders.

Apron feeders are slow moving, heavily loaded conveyors that feed a deep bed of ore from a bulk holding location (a bunker) as a controlled stream, often into a large capacity crusher. Apron feeders use sprockets and caterpillars, while belt feeders use rubber belts with motorized head pulleys to convey the material. The damaging of belts and clogging of transfer points from tramp iron required larger magnetic separators and the removal of tramp metal cannot prevent these serious problems. Corrective action at this location is important for two reasons:

- Removing tramp iron early in the ore stream protects downstream equipment from potential costly damage.
- Installing apron feeder magnets before the primary large capacity crusher means that secondary and tertiary crushing steps (made up of multiple parallel units) operate more efficiently, since tramp metal is removed at the onset.

Using belt or apron feeders with suspended electromagnets

Belt and apron feeders have been successfully protected by suspended electromagnets in many industrial applications. The use of sprockets and caterpillars for apron feeders must be nonmagnetic, preferably made of iron with a high manganese content. The nonmagnetic caterpillars should come from the same manufacturer as the apron feeder, according to the requirements of the customer. When using a conveyor belt, it is recommended (but not mandatory) that the shell of the head pulley be nonmagnetic stainless steel. When feeding pebbles, the head pulley should also ideally be nonmagnetic.

For the primary crushing applications, where the ore is normally sized 15.2- to 20.3-cm (6- to 8-in.), the main purpose of the suspended electromagnet is to protect the belts and to avoid the clogging of the chutes. Tramp iron measuring less than 10 cm (4 in.) is not typically harmful to the belts or chutes, so electromagnets are set to capture only the larger pieces of tramp iron.

Eriez separators installed at Cerro Verde.

For copper sulfides processed in semiautogenous grinding (SAG) mills, no downstream suspended magnets are required after the belt or apron feeder magnets, because there are no secondary and tertiary cone crushers. For oxide leaching plants, manual or self-cleaning standard magnets are used on belt conveyors to remove tramp metal after the primary crushers, but before the cone crushers and the leaching piles.

To remove tramp iron smaller than 10 cm (4 in.), a nonmagnetic shell pulley is required, especially for pebble applications. In the pebble crushing plants of the Chile's Codelco Chuquicamata, Pelambres, Esperanza mines and Antamina in Perú, the shell of the pulleys are nonmagnetic.

Belt feeders are used more often at the discharge end of suspended electromagnets because apron feeders are historically more expensive and have limited application (mainly for minerals larger than those found on belt feeders). For the apron feeders in current use, the customer or supplier is not always willing to change the existing magnetic caterpillars for ones that are nonmagnetic.

Therefore, protection of earlier crushers by an apron feeder magnet can provide significant return-on-investment through less plant

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Table 1

Some Eriez electromagnets installed during the past 30 years.

Kennecott Copper Mine	
Bingham Canyon Utah, USA	
SER 700	315 cm x 168 cm (124 in. x 66 in.)
Installed:	1988
Material:	Copper ore
Capacity:	91. kt/h(10,000 stph)
Belt feeder width	305 cm (120 in.)
While this magnet does not look particularly large today, at the time of its construction it was the largest.	
Codelco Chuquicamata Division	
Chile	
SER 700	275 cm x 178 cm (108 in. x 70 in.)
Cerro Verde	
SER 700	229 cm x 229 cm (90 in. x 90 in.)
Material:	Copper ore
Capacity:	5.2 kt/h (5,800 stph) each
Material size:	7.6 to 10 cm (3 to 4 in.)
Belt feeder width:	213 cm (84 in.)
Burden depth:	38 cm (15 in.)
Antamina	
SER 700	254 cm x 238 cm (100 in. x 94 in.)
Material:	Copper ore
Capacity:	5.7 kt/h (6,300 stph)
Material size:	2.5 to 31 cm (1 to 12 in.)
Apron feeder width:	198 cm (78 in.)
Burden depth:	63.5 to 76.2 cm (25 to 30 in.)

downtime and maintenance expense.

In the early 1980s, the first suspended electromagnets were installed at the discharge of belt conveyors in the Codelco Chuquicamata, Chile operation. These were the first large electromagnets with rectangular cores installed anywhere in the world. Eriez has installed many of these during the past 30 years (Table 1). However, before reviewing these applications, consider the technical designs needed for these huge magnet installations.

Apron magnets differ from usual magnetic separation in mineral processing conveyor applications in the following ways.

Magnet orientation. Suspended magnets over conveyors or head pulleys are nearer to horizontal than to vertical. In contrast, apron and belt feeder suspension is nearer vertical than horizontal (Fig. 2). This requires different internal and external construction, both of the magnet structure and the internal electrical coil assembly.

Operating gap. As these magnets are often positioned before large capacity crushers — sometimes even primary crushers — large lumps of ore must be allowed to pass. This leads to a larger operating gap than is seen in conveyor applications. A large gap, between the face of the magnet and the location of the tramp iron to be separated, means a much stronger magnet is required to pull the iron across that large gap to the magnet face. Stronger magnets, besides being more costly, sometimes also need other facilities, such as force cooling (see ancillary equipment).

Space constraints. These magnets (and the ancillary equipment) are often installed after plant construction and must be retrofitted into existing space, because relocating the bulk ore bunker or the large downstream crusher is impractical.

Manual cleaning. Apron feeder magnets have manual cleaning capabilities for several reasons:

- Large pieces of tramp metal are rejected from the face of the magnet without operator assistance.
- The tramp metal is discharged in a safe manner, minimizing risk to personnel or nearby equipment.
- The flow of ore past the magnet creates a significant amount of dust. Manual cleaning apron magnets are sealed to the chute work and contain the dust.

Housing and surrounding structure. The usual suspended, manual cleaning magnets have an open gap between the magnet face and the passing ore, which can be easily observed and monitored by plant staff. When ferrous tramp iron has accumulated, an operator can move the magnet aside and discharge the iron. Excess iron on the magnet face can lead to ore sweeping iron off the magnet or cause ore spillage. Because the accumulated iron on the apron magnet cannot be observed inside the sealed chute work, a magnet load monitor is fitted to the magnet.

Ancillary equipment. Apron magnets require:

- Transformer-rectifier power supplies (standard for all electromagnet applications).

- Monorail or trolleys to move the magnet back for cleaning (standard for all manual cleaning). These monorail or trolleys can be overlooked, but they perform an important role in the entire system and their design and engineering is essential.
- Manual cleaning electromagnets at the discharge end of the feeders now use trolleys that move the magnets between working, cleaning and maintenance positions. There are several reasons why magnets should be moved away from the conveyor in line rather than to the side, such as less time being needed for a cleaning cycle because the distance to the cleaning point is shorter and tramp iron being stuck to the face of the electromagnet can hit the housing of the feeder or nearby structure and fall off.
- Auxiliary cooling systems in some applications of force-cooled magnets.
- Tramp iron carts or baskets to safely remove the iron from the cleaning station and the processing plant.
- Magnet load monitor, an electronic product installed on the outside surface of the manual cleaning magnet. (This device tracks the amount of steel on the face of the magnet by a sensitive "hall effect" element and control unit located off the magnet. Once steel has accumulated on the magnet, an audible and visual alarm alerts the plant operators when it is time to move the magnet aside and clean off the accumulated tramp iron.)
- Apron magnet applications are on another scale both technically and financially. Project costs exceeding $1 million are not uncommon.

These characteristics of belt and apron feeders make them ideal for the suspension of electromagnets at the discharge end.

Burden depth of the material over the belt or the caterpillars. Regardless of belt speed — which varies from 0 to 0.5 m/s (0 to 100 fpm) — the burden depth on the belt or caterpillars remains constant. The height is determined by the gap of the transfer chute of the material to the moving surface. When the speed increases, capacity increases without varying the burden depth. The electromagnet at the discharge end remains stationary to maintain an adequate suspension height over the feeder.

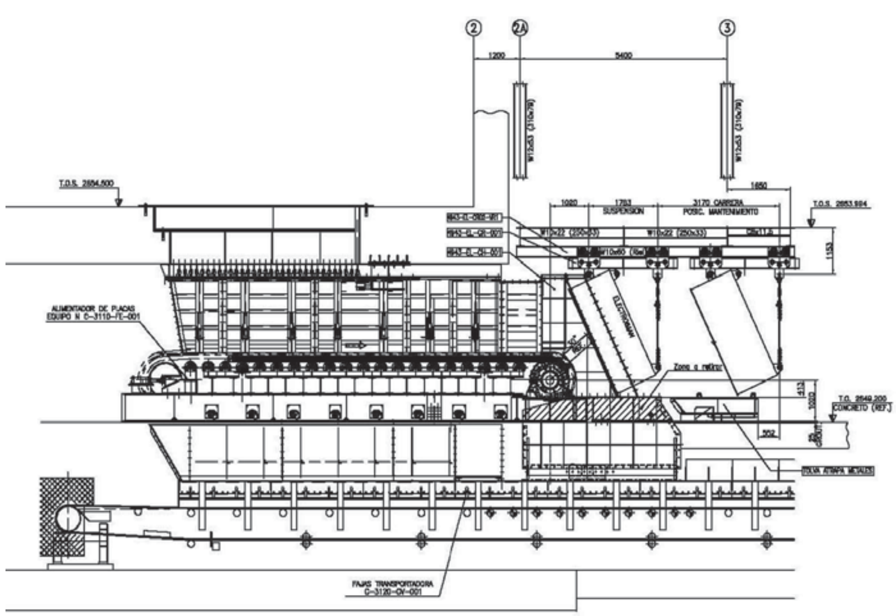
Table 2

Eriez suspended electromagnets installed at 60° to 65° inclines.

Installation	Number of magnets installed
Collahuasi	4
Cerro Colorado	1
Quebrada Blanca	1
Codelco Radomiro Tomic	6
Zaldivar	8
Lomas Bayas	1
Escondida Sulfuros	1
Escondida Oxidos	1
Spence	3
Gaby	5
Pelambres	5
Codelco Andina	2
SurAndes	2
Codelco El Teniente	4 (2 apron, 2 belt feeder)
Esperanza	4

Slow speed. Since maximum speeds of belt and apron feeders are relatively slow at less than 0.5 m/s (100 fpm), material is not thrown out from the conveyor in a long, flat trajectory as it is at higher speeds. In these feeders, the material falls off the end of the feeder or conveyor. When the burden falls, it sloughs to about one-half the previous depth on the conveyor or feeder.

Because of the slow speed, the suspended electromagnets at the discharge end can be positioned much closer to the feeders, resulting in



Eriez magnetic separators diagram.

An installed Eriez magnetic separator.

higher separation efficiency. Tramp iron is efficiently captured by the suspended electromagnet while the material falls from the feeder.

The slow speed of these feeders requires that the electromagnets be manually cleaned and installed at steep angles, inclined as much as 60° to 65°. This angle positions the magnetic field where the material has the least possible depth. At inclines this steep, using a self-cleaning electromagnet, both tramp iron and product would be discharged in nearly the same direction, making separation of the two almost impossible.

Self-cleaning electromagnets are not easily enclosed to dust. Manual cleaning electromagnets allow flexible booting to seal between the discharge chute and the magnet.

Flat belts or caterpillars. Most belt feeders have maximum idler angles of 20°, although many are flat. This causes a humped configuration to the burden, with the center depth being the steepest. Apron feeders are completely flat. Burden depth is distributed evenly across the feeder and with a lower overall burden depth, increasing magnet efficiency.

When the feeders have a width greater than 1.2 m (48 in.), the electromagnet must have a rectangular coil and core. This generates a homogeneous magnetic field, both at its center and sides, covering the entire burden depth. Standard suspended electromagnets have circular cores and coils that generate stronger magnetic fields in the center and weaker ones at the sides.

Quick cleaning cycle. Removing captured tramp iron from the surface of the electromagnet can be handled in a few minutes. Since the electromagnets are inclined between 60° to 65°, it is not necessary to move them great distances. The horizontal projection of the magnetic face is never greater than the length of the electromagnet. This characteristic allows the electromagnet to be cleaned quickly with a few steps:

- Stop the feeder.
- Move the electromagnet back to its cleaning position.
- Turn off the electromagnet.
- Detach the tramp iron into a non-magnetic container.
- Move the electromagnet back to its work position.
- Turn on the electromagnet.
- Turn on the feeder.

The tramp iron should be placed inside a non-magnetic container made of stainless steel, plastic or even wood, then transported to discharge chutes. This is because residual magnetism from the collected tramp metal could adhere to mild steel chute work.

Automating the operation of the electromagnet and the cleaning cycle. Apron and belt feeders can be operated manually or automatically, locally or remotely. The electromagnets and their trolleys have the same possibility. To automate this equipment, Eriez developed the magnet load monitor, which detects tramp iron on the magnetic face of the manual cleaning electromagnet.

The magnet load monitor is installed near the electromagnet with a probe on the magnetic face. The probe is pre-set to send a signal when a specified amount of tramp iron accumulates on the magnet face, triggering the need for a cleaning cycle. This signal of 4 to 20 milliamps can be used to warn or automatically initiate the cleaning cycle.

Eriez has many installations of suspended electromagnets at 60° to 65° inclines at the discharge of belt ad apron feeders (Table 2). ■