

CLEANING UP

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DETAIL ADVANCEMENTS IN COAL PREPARATION EQUIPMENT.



Over the years, coal preparation plants have evolved from washing and screening plants into highly developed production processes. The plants are focused on the production of a clean coal product through the rejection of the ash and sulphur bearing rock. Accordingly, there have been new developments in process equipment focused on increasing the selective separation and recovery of coal, as well as providing and maintaining a high level of productivity.

Eriez has made several advances in coal preparation equipment, including the following:

- Suspended electromagnets to remove tramp iron and protect downstream equipment from damage and unscheduled maintenance.
- Metal detectors to discern non-ferrous tramp metal in the process stream.
- Wet drum magnetic separators for the continuous recovery of magnetite in the heavy media circuit.
- Hydraulic separators for the upgrading of fine coal in the -2 mm (-10 mesh) range.
- Column flotation cells for the recovery of fine coal -0.150 mm (-100 mesh).

Suspended magnetic separators for tramp metal removal

The most prevalent application of magnetic separation in a production plant is the removal of ferrous tramp from conveyor belts. This is a straightforward application that involves suspending an electromagnet over the conveyor belt. A typical example is illustrated in Figure 1. The magnet removes tramp metal that represents a potential hazard to downstream crushers, mills, pulverisers and grinders. The magnet can also be mounted over feeders or chutes.

There have been significant developments in the design and manufacture of suspended electromagnets. The 1220 – 1520 mm (48 – 60 in.) wide coal conveyor belts once considered large have evolved to 1830 – 2440 mm (72 – 96 in.) wide. Suspended magnets have increased in size and magnetic field strength accordingly.



Figure 1. Suspended magnet: the magnet is suspended over the conveyor belt to remove ferrous tramp from the coal before crushing. In this application the magnet is suspended over the material discharging the head pulley.

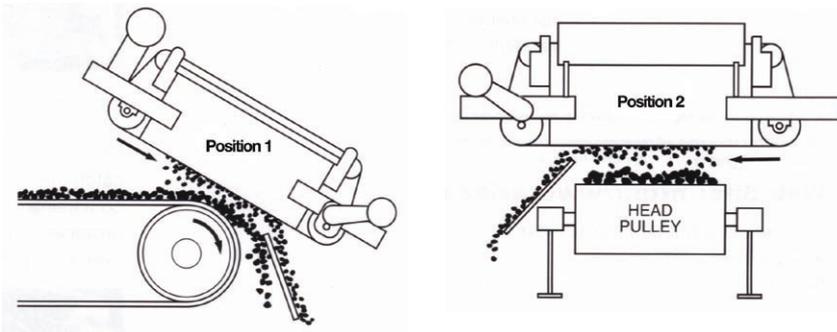


Figure 2. Positioning of suspended electromagnets. In-line position 1 is over the trajectory discharging the head pulley. Cross-belt position 2 is over the conveyor belt before the head pulley. Manual clean or self-cleaning magnets may be used. Pictured are self-cleaning magnets. These magnets use a cross belt to discharge collected ferrous tramp.



Figure 3. Eriez Model Metalarm metal detector. The conveyor belt runs between an embedded transmitter and a receiver coil.

Components

The electromagnet consists of an electromagnetic coil with a cylindrical steel core positioned in a steel housing. The coil magnetically induces the steel core, which in turn projects a magnetic field for the collection of tramp metal. The coil and core are submerged in transformer oil to dissipate heat. A power supply is used to energise the magnet: it converts the AC input to DC output to energise the coils.

Suspended magnet selection

The foremost factor in magnet selection is the burden depth of the material on the conveyor belt and the subsequent suspension height of the magnet (the distance between the face of the magnet and the surface of the conveyor belt). The suspension height of the magnet determines the effective magnetic field strength through the material burden.

Suspended electromagnets are mounted in one of two positions over a conveyor belt, as shown in Figure 2. In position 1, the magnet is mounted just over the stream of material leaving the head pulley. This position uses the full potential of the magnet as it reacts with the material in suspended trajectory. Tramp metal is easily pulled through the suspended burden. Further, the flow of material is directed toward the magnet face.

In position 2, the magnet is mounted over the conveyor belt before the head pulley. This position requires higher magnetic field strengths to attract the ferrous component, shift the direction of momentum and pull it through the bed of material.

Suspended electromagnets are available as a manual cleaning style or a self-cleaning style. Manual cleaning magnets are best suited where only small amounts or occasional pieces of tramp metal are encountered. The magnet must be periodically turned off in order to remove tramp iron accumulation from the magnet face. Self-cleaning magnets employ a cross-belt running around the magnet face to provide continuous removal of collected tramp iron.

Experience dictates that the operating magnetic field strength or the magnetic

field strength at the conveyor belt surface should generally be in the 500 – 600 gauss range for adequate ferrous collection.

High capacity conveyor belts

Very large electromagnets have been developed to accommodate the increasing conveyor belt widths and capacities. Suspended magnets ranging up to 3810 mm (150 in.) wide are appropriate for conveyor belt widths up to 3050 mm (120 in.), and are in operation. Electromagnets for high capacity conveyor belts require a thorough assessment of the specific application. These electromagnets are designed and engineered for continuous operation taking into account the required magnetic field configuration, as well as the thermodynamic properties.

Metal detectors

Metal detectors are used to detect non-ferrous tramp iron. The removal of this material will help protect downstream equipment from damage and unscheduled maintenance. Metal detectors are designed to provide a certain range of sensitivity to detect metals of a certain size and composition. The application of a metal detector in a mining application typically requires only a low sensitivity range corresponding to the relatively larger metal components that are a potential hazard to crushers.

Sizing and installation

In mining applications, the conveyor belt runs between an embedded transmitter and a receiver coil. Metal detectors are sized based on the specifications of the conveyor belt. The top coil must be high enough to clear the burden on the conveyor belt. The bottom coil is positioned just under the conveyor belt. The distance between the top and bottom coils is termed the aperture opening. An installed metal detector is shown in Figure 3.

Sensitivity

The sensitivity of the metal detector is measured in percentage of the aperture opening. The Eriez Eagle provides 2% sensitivity. The Eriez Hawk provides either 5 or 10% sensitivity. A metal detector operating on a 1800 mm wide



Figure 4. Eriez model counter-rotation self-levelling wet drum magnetic separator.

belt will typically have a 500 mm aperture opening to clear the conveyor belt idlers and the material burden. A 5% sensitivity will detect non-ferrous material corresponding to a minimum size of 25 mm (1 in.).

Operation

Metal detectors in mining applications have become very economical and reliable, providing a high level of insurance in protecting crushers. State-of-the-art metal detectors are easy to install and operate with minimal maintenance. They can be installed easily and can require little maintenance. The microprocessor electronics are highly resilient to electrical noise interference. The control system includes self diagnostics.

The sensitivity range is manually adjusted. When metal is detected, an electrical signal is provided to either stop the belt or activate another mechanism to remove the tramp metal.

Wet drum magnetic separators

Wet drum magnetic separators are employed in the preparation plant to recover the magnetite used in the heavy media separation circuit. Recent innovations in both magnetic circuit design and materials of construction have been applied to wet drum magnetic separators to maximise

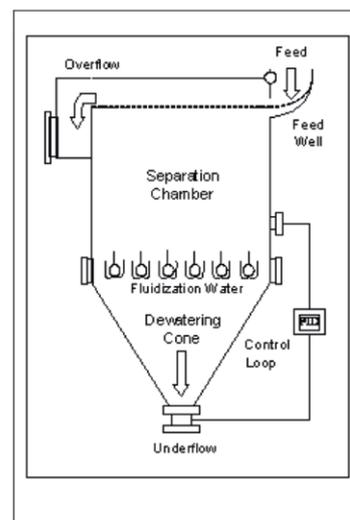


Figure 5. Schematic diagram of the CrossFlow separator.

magnetite recovery and minimise wear and maintenance.

Self-levelling style for heavy media applications

The magnetic element is the most important feature of a wet drum separator. In the design of a magnetic separator, the magnetic field intensity and the magnetic field gradient are two first order variables that affect separation response. Although there are several variables influencing magnetic separation, the magnetic field strength is indisputably the foremost variable for high levels of magnetite recovery.

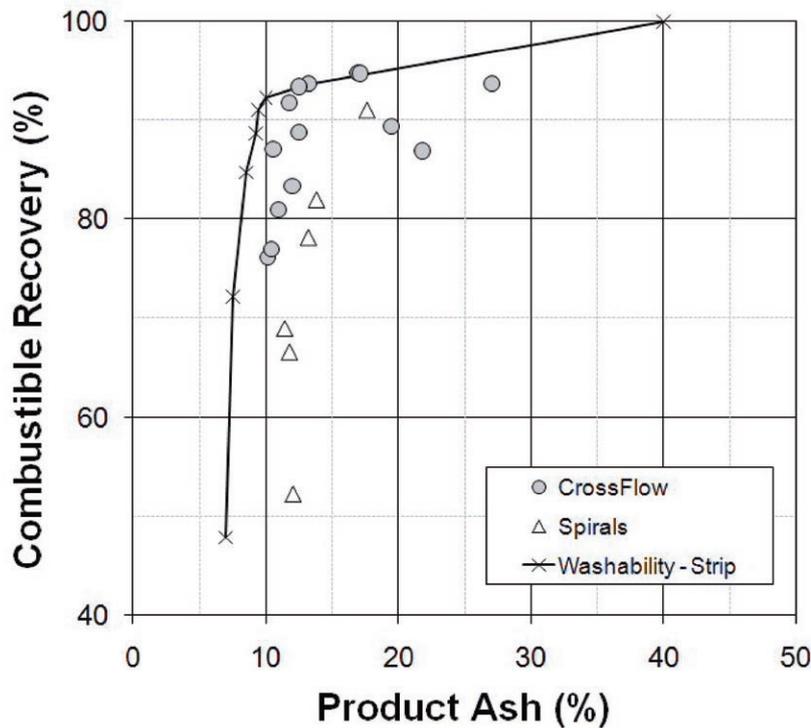


Figure 6. Pilot-scale results vs washability. Comparison of the CrossFlow separator to spiral concentrators.



Figure 7. Eriez CoalPro column flotation cells illustrating froth washing system.

There have been recent technological advancements in the design and modelling of magnetic circuits. Precise magnetic circuit modelling and optimisation is now carried out using multi-dimensional finite element analysis. The North American industry standard is the Eriez 950 gauss Interpole magnetic element. This magnetic element maximises the magnetic field strength and gradient resulting in high levels of magnetite recovery.

The counter-rotation wet drum tank style is preferred for heavy media applications. The drum rotates against

the slurry flow in the counter-rotation tank style. Any magnetite that is not immediately collected will pass through to a magnetic scavenging zone. The short path that the magnetic material must be conveyed between, the feed entry point and the magnetics discharge lip combined with the magnetic scavenging zone, results in high magnetite recoveries.

Essentially, all wet drum tanks used in heavy media applications have levelling spigots and a full width overflow that must be maintained during operation. A deviation in the overflow may result in inefficiencies in the performance and the loss of magnetite. A modification of the counter-rotation wet drum tank represents a recent development in technology for heavy media wet drum magnetic separators. The self-levelling tank has no discharge spigots to adjust or monitor and maintains a constant slurry level at any flow rate. A wet drum magnetic separator with a counter-rotation self-levelling tank is shown in Figure 4.

Performance

When a wet drum magnetic separator is properly applied, the magnetite loss will

be less than 0.25 g of magnetite/l of effluent. This generally equates to a magnetite recovery in the 99.8 – 99.9% range.

The slurry sizing parameters as well as the magnetic loading parameters for the 0.9 m and 1.2 m dia. wet drum magnetic separators are provided in Table 1.

Hydraulic separator

The Eriez CrossFlow separator has been developed as a new generation of teeter-bed or hydraulic separator to separate coal from rock.

The CrossFlow design uses an improved feed delivery system that gently introduces the feed slurry across the top of the separator. This transitional feed system delivers the flow to the full width of the separator so that the slurry velocity, and any associated turbulence, is minimised. This feed system also minimises the effect of feed variations and allows for a constant teeter-water velocity throughout the separator. A schematic diagram of the CrossFlow separator is provided in Figure 5.

The separation is based on the mass of the particle and is accomplished through the differential pressure in the tank. The pressure is maintained so that the lighter particles are conveyed over the top of the tank and the heavier particles move through the teeter bed and report the underflow valve.

Comparison testing

Central Appalachia strip coal

Test work was conducted using a pilot-scale CrossFlow separator to treat coal from a US strip operation. The material treated was relatively high in rock with a feed grade of approximately 40% ash. Operating in parallel to the CrossFlow was a single repulping test spiral. Feed was supplied to both units from an existing slurry distributor. Tests were conducted to create grade/recovery curves. The results of the test work are presented in Figure 6. As shown, the CrossFlow separator operates very close to the washability curve. At maximum separation efficiency, a product containing 12% ash was produced at a mass yield of 78% and a combustible recovery of 92%. In contrast, the spiral operated further

from the washability data, providing a significantly higher ash product for the same combustible recovery.

Parameters

CrossFlow separators are sized based on the feed solids rate. Capacity is generally rated as tph of feed/m² of cross-sectional area. Material in the

2 x 0.150 mm (10 x 100 mesh) size range provides excellent separation response. The typical capacity for coal cleaning is 20 – 30 tph feed/m² (2 - 3 tph/ft²) of cross-sectional area. CrossFlow separators have been manufactured up to 3.6 m x 3.6 m (11.8 ft x 11.8 ft), which can typically treat 180 – 270 tph of feed.

Column flotation

Recovering coal fines has typically been considered problematic due to high processing costs and poor flotation performance. However, the economical potential for fine coal recovery circuits continues to grow as the value of coal continues to climb.

Traditionally, fine coal flotation has been conducted using conventional mechanical cells. These cells typically have a low profile and are arranged in series as a “bank”. While conventional flotation cells are well-proven and are used extensively throughout the minerals industry, their primary drawback for coal recovery is the appearance of fine clay in the clean coal product. In contrast, column cells utilise an effective method of froth washing. This approach virtually eliminates the hydraulic entrainment of clays, resulting in high combustible recovery, while maintaining maximum product grades. A column flotation cell with a froth washing system is presented in Figure 7.

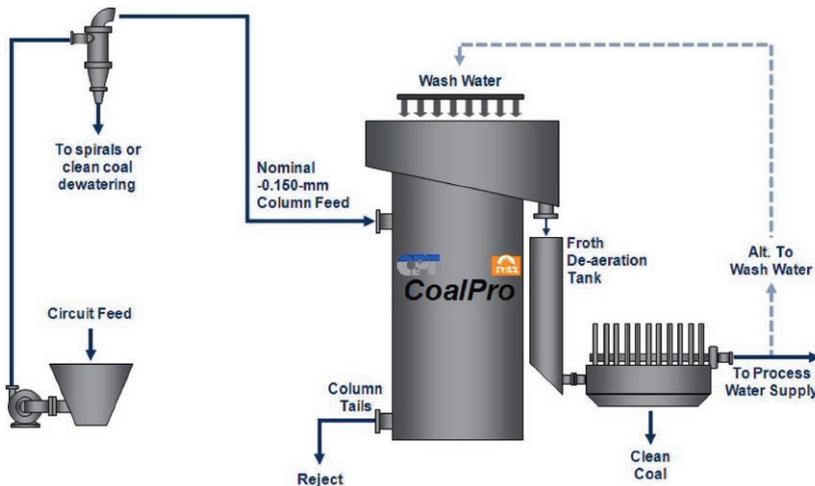


Figure 8. Traditional column flotation circuit treating by-zero coal.

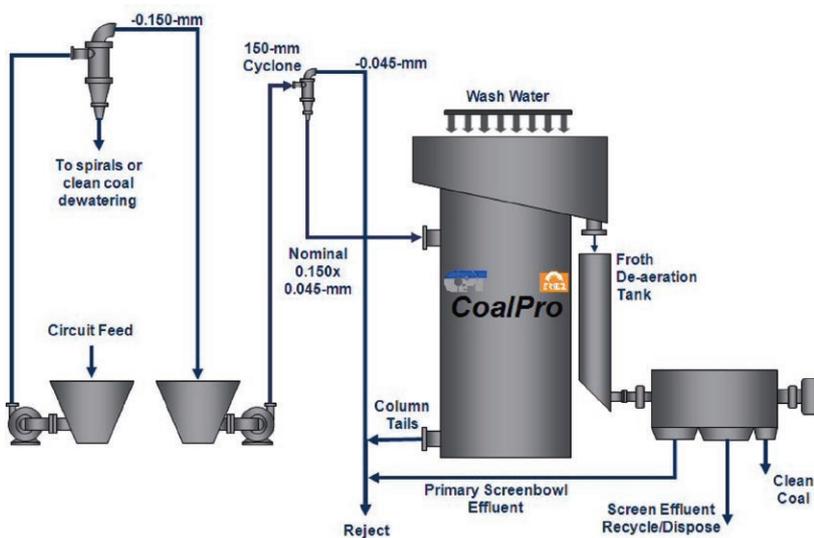


Figure 9. Deslime column flotation circuit with additional classification.

Circuit types

There are two circuits commonly used for fine coal flotation: the traditional by-zero circuit, treating -0.150 mm (-100 mesh) feed material and the deslime circuit, treating nominally 0.150 x 0.045 mm (100 x 325 mesh) feed material.

In the by-zero approach, -1 mm feed is sent to large diameter classifying cyclones. Typically, these cyclones are configured to make a cut-point of approximately 0.150 mm (100 mesh). This circuit is illustrated in Figure 8. The overflow stream of the cyclone is sent directly to flotation.

The second type of circuit, which has been gaining popularity, especially when producing coal for the steam market, is the deslime circuit. In this circuit, a secondary bank of 150 mm (6 in.) cyclones is used to further classify the flotation feed at approximately 0.045 mm (325 mesh) in an effort to reject a large portion of the ultra-fine clay and/or coal particles. This circuit is illustrated in Figure 9. This approach can be advantageous when the feed stock contains little combustible material in the finest size classes.

Table 1. Wet drum magnetic separator sizing parameters for heavy media application: counter-rotation style tank; heavy media sized (grade E) magnetite; feed slurry at less than 15% solids as magnetite

Drum dia.	Sizing parameter	
	Hydraulic	Magnetic loading
0.9 m (36 in.)	90 m ³ /hour/m drum (120 GPM/ft drum)	16 tph/m drum (5.5 tph/ft drum)
1.2 m (48 in.)	120 m ³ /hour/m drum (160 GPM/ft drum)	24 tph/m drum (8 tph/ft drum)

Each circuit has certain advantages. The by-zero circuit will always provide the maximum product, while the deslime circuit has continued to gain popularity due to its simplicity and ease of operation. In addition, the removal of the ultra-fine material results in a higher flotation capacity, reduces the number and/or size of columns required, and yields a product with lower moisture.

Air sparging technology

Two different air sparging systems are used in the Eriez CoalPro column flotation cells. One system is the Canadian Process Technologies SlamJet and the other is the cavitation tube.

The SlamJet sparger system uses a series of removable air-lances, including a large, single orifice located at the end of the sparger. High velocity air is injected into the column cell to create and disperse fine bubbles. This technology is best applied to coal that

has been deslimed at 0.045 mm (325 mesh).

The cavitation tube technology was conceived after research showed that the rate of flotation could be enhanced through the use of smaller air bubbles. Small (<0.8 mm) bubbles are generated by circulating slurry from the column through cavitation tubes into which compressed air is injected.

The cavitation tube technology has been best applied on by-zero or traditional fine coal recovery circuits. The primary reason is the ability to efficiently generate large amounts of very small bubbles for a given airflow.

Column flotation cell parameters

Column flotation cells are sized based on the carrying capacity of the froth. The carrying capacity is the amount of coal product that the froth removes and is measured as tph of product/m² of cell cross-sectional surface area. The

typical carrying capacity ranges from 1 – 3 tph/m² (0.1 – 0.3 tph/ft²) and is highly dependent on the product particle size distribution. Column flotation cells have been manufactured up to 4.9 m (16 ft) dia. and up to 16 m (52 ft) in height. Typically, a 4.6 m (15 ft) dia. column flotation cell can produce 18 – 50 tph of flotation concentrate.

Summary

Over the years, Eriez process equipment has evolved under the assessment of plant operation and performance. There have been new developments in process equipment resulting in an increase in coal recovery, as well as providing a high level of productivity. Major improvements continue in essentially all areas of the equipment either focused on the separation or the ease of operation and maintenance. 