Application of MDL Reichert cone and spiral concentrators for the separation of heavy minerals

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Introduction

There has been a major evolution of mineral processing technology in the past decade. The evolution has been driven by recognition of broad environmental changes which have impacted various areas of the world. Numerous government regulations have required many mining and mineral processing organizations to introduce changes to reduce the undesirable effects on the environment; many mining companies have voluntarily introduced new technologies and practices which surpass the limits imposed by the regulations. Surprisingly, some of the 'new' technologies are modifications of concepts developed decades earlier. Gravity separation technology is in this category.

Mineral Deposits Limited, an Australian company, has been a world leader in the development of mining concepts, reclamation practices and equipment technology that is environmentally suited to today's requirements. This paper relates to equipment used for gravity concentration and electrostatic separation systems, including Reichert cones, spirals, and electrostatic separators. The basic devices and technologies were developed more than forty-five years ago, but use of the systems was quite limited until environmental and conservation practices were recognized and introduced. Spiral concentrators, for example, were patented in the mid-1940s by I.B. Humphreys in Denver, Colorado. The two types of spirals marketed (the Model 24A for minerals and the Model 24C for coal) remained essentially unchanged until expiration of the patents. During this early period most spirals were used in iron-ore wash plants on the Mesabi Range to recover fine iron which previously had been discarded. About the same time sand mining plants in Florida incorporated spirals to recover titanium minerals and zircon from low-grade beach sands. The Labrador Trough opened new opportunities for spirals when hard-rock iron-ore deposits were developed; approximately 10 000 Model 24A Humphreys spirals were installed between 1958 and 1966. About 5000 spirals of this model are still operating in the same capacity, in spite of the fact that extensive improvements have since been made in gravity separation technology.

Mineral Deposits Limited was conducting mineral sand mining operations in Eastern Australia in the 1960s, and they required new methods and equipment to improve metallurgical efficiency because of the decreasing grades of their deposits. Humphreys spirals were neither cost-effective nor efficient in the Australian environment, so MDL undertook to develop new concepts and equipment for high capacity gravity separation. Their program resulted in the development of the Reichert cone, a device that is now recognized and accepted worldwide as an efficient high-capacity gravity concentrator. In a parallel development program MDL constructed their own spiral concentrators, developing improved trough profiles and using new materials of construction. In the intervening years, MDL has continued development programs on spiral concentrators and now has more than thirty-five different models, types, and configurations which are used for various mineral and coal applications.

Keywords: Mineral processing, MDl Reichert cone, Concentrators.

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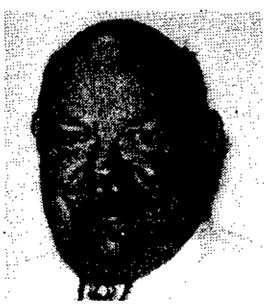

T.J. Ferree attended the University of Idaho where he received a B.S. in metallurgical engineering in 1955. He has worked continuously in mineral processing since 1955, exclusively in the fields of gravity concentration and electrostatic separation technology. He was involved with the original test work, design studies and commissioning of the iron ore concentrators at Gagnon and Mount Wright, Quebec, and the Wabush Mines and Iron Ore Company of Canada concentrators in Labrador, the Rio Algom Tin concentrator near Yarmouth, Nova Scotia, as well as numerous other plants across Canada, South America and Africa.

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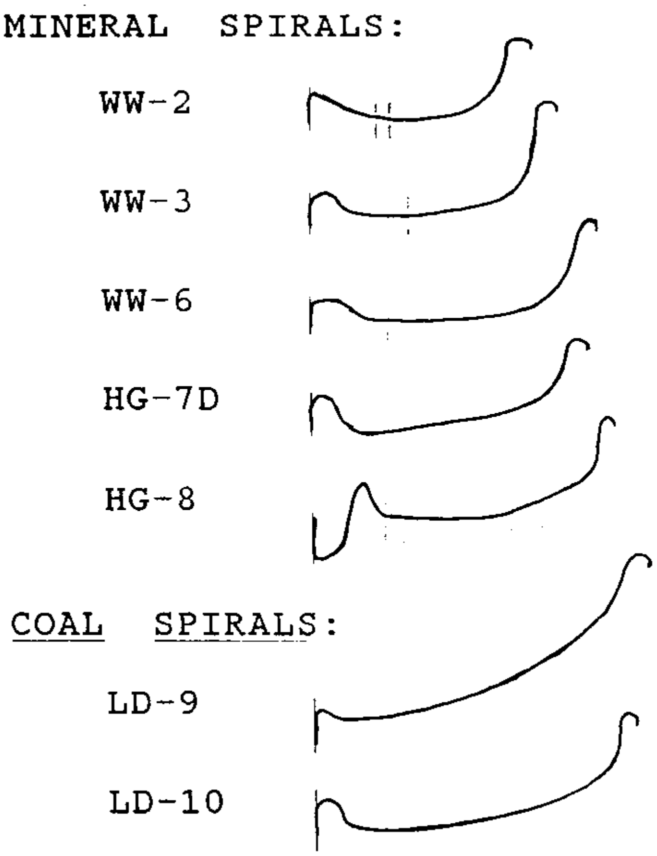
Reichert Cone Concentrators

Reichert cone concentrators are high-capacity separation systems suitable for processing material within the size ranges of 14 mesh to 325 mesh (1.2 mm to 0.044 mm) at throughputs up to about 400 metric tonnes per hour. Some separations are achieved for the size ranges finer than 325 mesh (.044 mm) but the efficiency of separations is dependent upon the characteristics of the mineral particles and the operating conditions maintained in the mill circuits. The cones, using the stratification principle of a pinched sluice, have no moving parts and depend upon gravity flow to transport the material through the cone assembly. A specific gravity difference of at least 1.0 (between minerals and gangue) is necessary in order to achieve efficient separations in the cone concentrators. Separation efficiencies are affected by particle shapes as well as specific gravity differences; flat (or 'platey' particles such as mica) tend to orient themselves in a manner that gives them an effective lower specific gravity in a flowing stream. This sometimes works to a metallurgist's advantage, as some minerals (such as mica) have essentially the same SG as the gangue from which it is to be separated. Size relationships of mineral particles vs gangue particles also affect the separation efficiencies. Feed materials containing coarse gangue and fine minerals separate more efficiently than feeds containing fine gangue and coarse minerals. Well classified feeds separate more efficiently in cone concentrators, but generally speaking the cost of classification ahead of the cones would not offset the increased recoveries achieved.

Reichert cone concentrators are being used successfully to recover iron minerals, titanium minerals, zircon, monazite, tin, tungsten, gold, and some uranium minerals. They are especially suited for use in primary concentration systems for rougher stage or scavenger stage service where high capacity and low operating costs are of primary importance. In typical applications a stage of cone con-



Profiles shown are NOT to scale. Several REICHERT spiral concentrators incorporate troughs wherein the profiles VARY in each turn. In others the trough PITCH (distance between turns) might vary. Some spirals have been designed for specific mineral applications.

FIGURE 1. Spiral trough profiles.

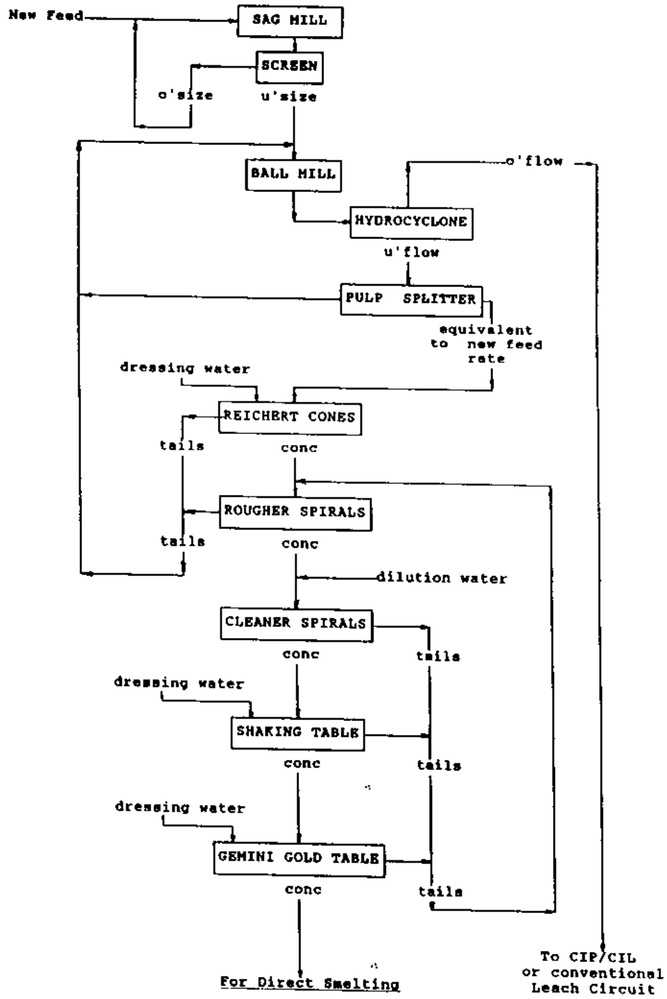


FIGURE 2. For plants with throughputs over 100 tph. Reichert cones and spiral concentrators adapted to grinding circuits to 'bleed off' free gold ahead of CIP/CIL and conventional leach circuits.

centrators produce upgrading ratios of about 3 to 1; in high tonnage installations two or three stages of cone concentration are often utilized, followed by further upgrading with spiral concentrators to produce a high grade heavy mineral concentrate product. The cones are manufactured in two basic sizes, 2.0 m diameter and 3.5 m diameter. The 2 m cones operate at tonnages between 50 tonnes to 90 tonnes per hour, and the 3.5 m cones operate at tonnages between 225 tonnes to 400 tonnes per hour, depending upon feed characteristics. Approximately 12 different internal component configurations are used to achieve maximum metallurgical performance in specific circuits; configurations used are usually selected by laboratory testing or computer modelling of the specific material being processed. Reichert cone concentrators and spiral concentrators are suited to the same size ranges of feed material, and their metallurgical efficiencies are very similar. Reichert cones are usually more cost-effective for circuits larger than 125 tons per hour; spiral circuits are more cost-effective for the circuits less than 125 tonnes per hour. However, economic evaluations should be undertaken to determine the most attractive system for any reasonable sized circuit.

A recent application of Reichert cones has been in gold recovery circuits to recover free gold in the grinding circuits ahead of flotation or leach systems. In many cases leach systems have been sized on the basis of time required to leach the largest size particle of free gold present, or flotation systems have required grinding to the size sufficient to achieve efficient flotation of the free gold particles. Use of a gravity recovery system to extract the free gold in the grinding circuit has resulted in substantially reducing the size and cost of the leach systems and the flotation circuits, while achieving increased over-all recovery of the gold. Experience has shown that often 30% to 60% of the gold values can be recovered in the gravity circuits of such installations, thus reducing the size and operating costs of the subsequent recovery systems.

Grinding circuits typically consist of SAG mills followed by ball mills, or rod mills followed by ball mills, and they inherently carry substantial circulating loads. Classification of the ball mill discharge is usually accomplished with hydrocyclones with the cyclone underflow being returned to the ball mill feed, and the cyclone overflow directed to the flotation or leach systems. Gravity recovery systems are usually installed to process the cyclone underflow fraction of the ball mill discharge product. If the gravity concentration systems were designed to handle the *total* grinding mill loads, the size and operating costs would be excessive. Accordingly, the gravity circuits are usually sized to process only a proportion of the ball mill discharge, equivalent to the new feed rate entering the grinding system. This has proven to be a very effective technique, both metallurgically and economically. Splitting the ball mill discharge can be accomplished using a pressure-type torespherical 4- or 5-way distributor. In this application, one distributor discharge line would be used to feed the gravity circuit, and the remaining lines would be returned to the ball mill feed. The tailing product from the gravity circuit would also be returned to the ball mill feed. Two flowsheets of this concept are included in this paper (Figs. 2 and 3). Figure

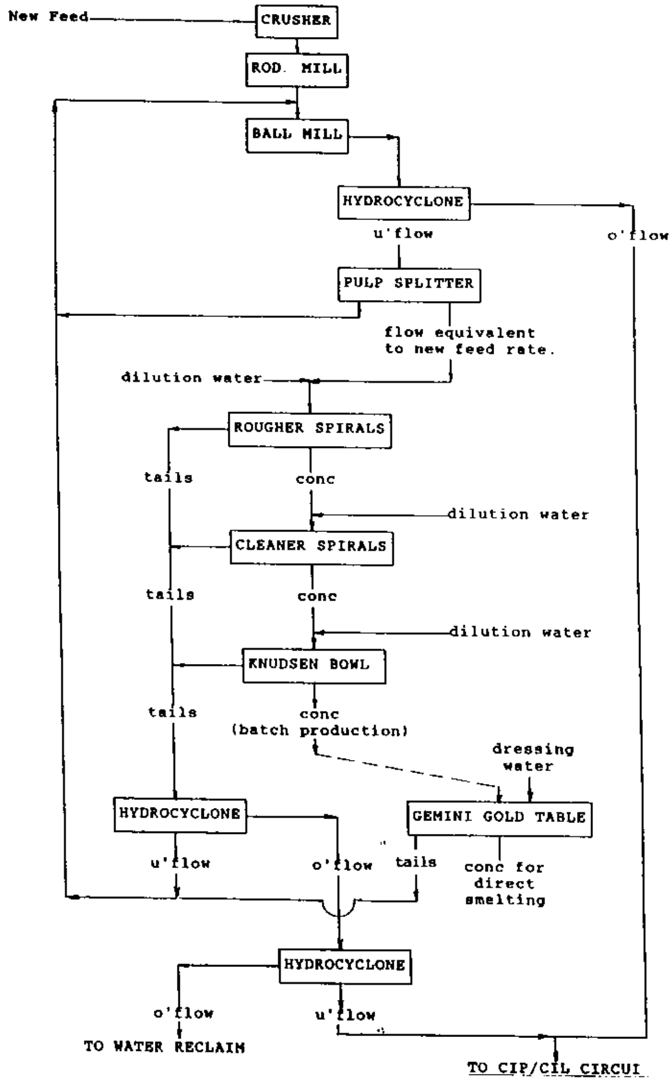


FIGURE 3. For plants with throughputs less than 100 tph. Spiral concentrators used in grinding circuits to 'bleed off' free gold ahead of CIP/CIL and conventional leach circuits.

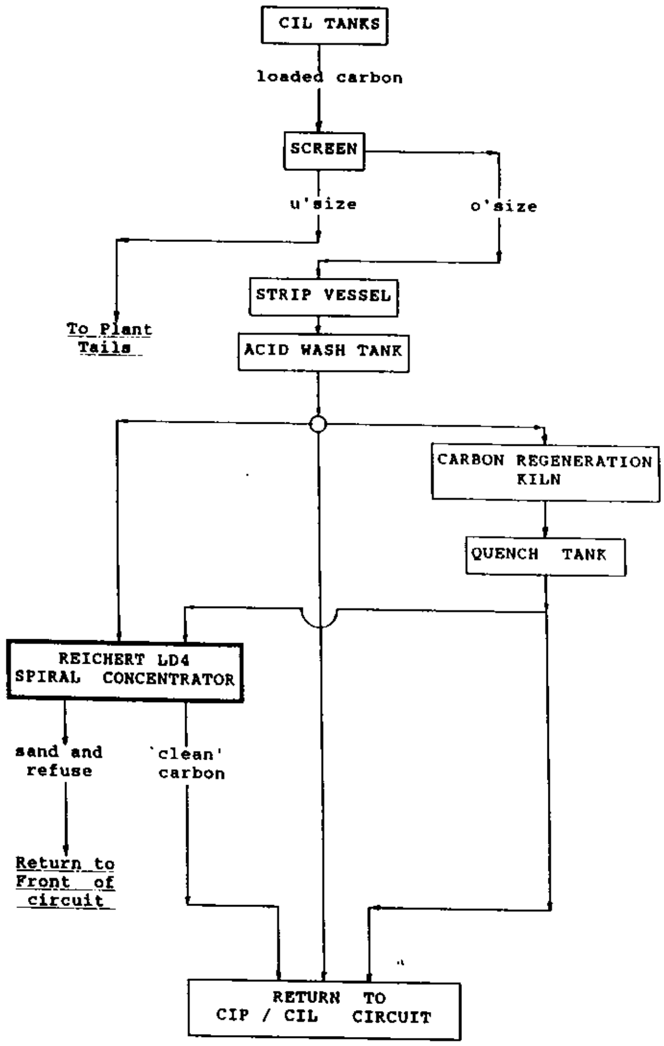


FIGURE 4. Using a Reichert spiral concentrator to remove sand and refuse from carbon in CIP and CIL circuits.

2 shows the concept for plant feeds greater than 100 tph and Figure 3 is for feeds less than 100 tph.

Reichert Spiral Concentrators

Mineral Deposits Limited is a world leader in the development and implementation of gravity separation technology. New concepts and designs of spiral concentrators which have evolved during the past decade have broadened the ability of processing plants to treat a wider size range of materials and to achieve higher recoveries of valuable products. This has been accomplished through the use of extensive modelling programs that have been developed through many laboratory and pilot plant data gathering exercises.

Spiral concentrators **are not** generic. Spirals manufactured by different suppliers **do** respond differently when treating the same materials. The MDL modelling programs have proven that spiral trough profiles and pitch distances (vertical displacement between trough turns) determine the separations characteristics which can be achieved on a particular material, and these parameters vary among the approximately thirty-five different types and models of MDL spirals. Certain minerals respond more favourably when using a specific trough profile; others respond more favourably when the pitch is changed between spiral turns. Figure 1 shows some of the trough profile differences between seven types of MDL spiral concentrators. Several models of MDL spirals exhibit profile changes between the top of the spiral column and the spiral discharge, and others exhibit pitch differences as the flow progresses through the length of the spiral trough. The combination of the variations developed through computer modelling has resulted in high performances of the spiral concentrators when used in various applications including the following:

- Recovering ilmenite, rutile, zircon, monazite, starolite, and others from the beach sand deposits in Northern Florida.
- Separation of alumina contaminate minerals from high-grade iron ore in Brazil.
- +85% recovery very fine FLAT free gold particles having a diameter-to-thickness ratio of 20 to 1. +50% of the −400 mesh gold (−0.037 mm) was recovered using a Reichert LG7 spiral.
- Removing ash, refuse, and pyrite from − ¼ in. (−5 mm) coal feed stocks.
- Separation of sand from carbon in Carbon-in-Leach and Carbon-in-Pulp gold extraction circuits (Fig. 4).
- Production of concentrates from iron ore operations, producing products with silica levels of 4.0% SiO_2.
- Retreatment of old mill tailings to recover various heavy mineral values including gold, silver, tungsten, tin, zircon, and various

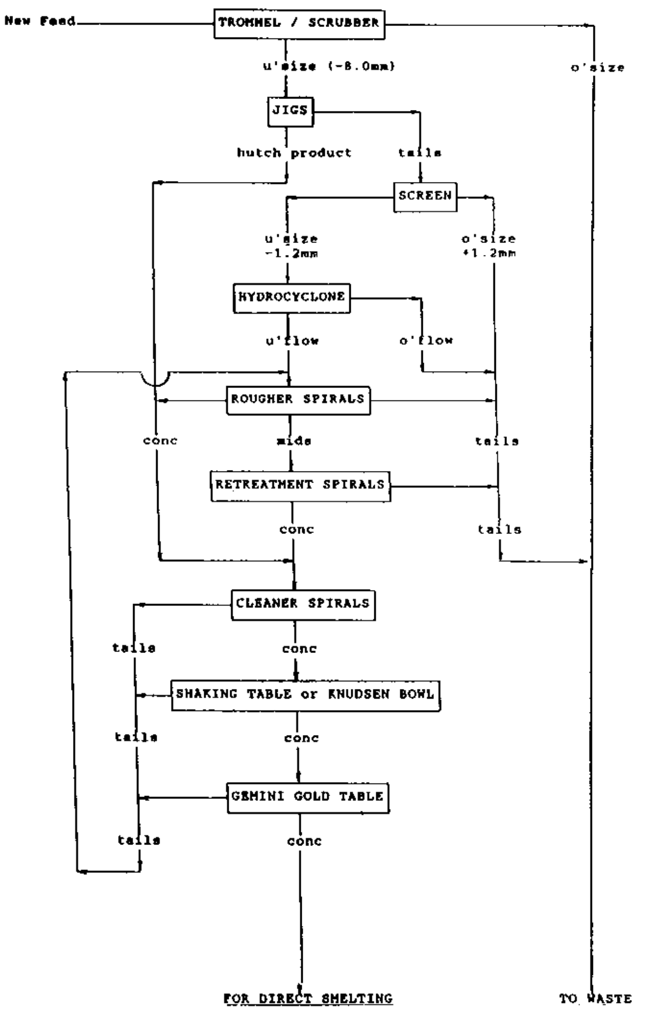


FIGURE 5. Gravity recovery circuit for placer deposits.

sulphide minerals. A suggested circuit for this concept is shown in Figure 5.

- The primary recovery system for the production of tin from alluvial deposits in Brazil, and from a hard-rock operation in Nova Scotia.
- The concentration of chromite, barite, copper oxide, lead oxide, manganese, phosphate, pumice, and titano magnetite in various operations throughout the world.

These illustrations of a wide variety of mineral separation applications show the wide acceptance of spiral concentration technology, and the broad applications which have been implemented in recent years. Mineral Deposits Limited is continuing design and development work on spiral concentrators to institute new innovations for expanding the range of materials that can be treated, the sizes of feeds that can be separated efficiently, and increased capacities of equipment to reduce capital, operating, and maintenance costs of future mineral processing plants.

The following list summarizes the identification and applications of the more commonly used Reichert gravity separation devices. There are many more configurations and types available; it is important to consider test programs on materials considered for gravity separation applications to confirm that the equipment selected is indeed the best for the particular application. Test programs can be conducted at various commercial mineral research facilities, or at the test facilities of Mineral Deposits Limited in Australia.

Nomenclature for Reichert Cones and Spiral Concentrators

Reichert Cones — Most Common Configurations

4DSV: Utilizes four stages of separation, including three stages of 'scavenging' and one stage of upgrading. Most often used for rougher stage or scavenger stage service.

3DSVSV: Utilizes three stages of separation, including two stages of 'scavenging' and two stages of upgrading. Most often used to recover free gold, as the rougher stage service in grinding circuits.

2DSVSV-DVS: Utilizes three stages of separation, including two stages of 'scavenging' and two stages of upgrading. The bottom stage of the cone produces a recirculating middling product.

3DSV: Utilizes three stages of separation, including two stages of scavenging and one stage of upgrading. This configuration is most often used with the application of the 3.5 m diameter cones.

Reichert Mineral Spirals — Most Common Models

(Wash-water Type Spirals)

WW2A: General purpose spiral most effective for processing high-grade zircon feed stocks, to produce roughly 50/50 splits of concentrate and tailing. Each trough carries a nominal 1.5 tph at a flow rate of about 20 to 22 USGPM.

WW6: Exceptionally forgiving spiral most useful for concentrating iron ore. Capable of carrying very high loads (±4 tph per trough) while giving excellent metallurgical performance. The nominal flow rate per trough is about 25 to 28 USGPM.

(Wash-waterless Type Spirals)

LG7D: Designed to treat low-grade feeds (containing less than 5% heavy minerals) and produce concentration ratios from 10 to 1 to about 30 to 1. Gives excellent performance for the recovery of free-gold and black sand from placer deposits. Each trough carries a nominal 1.75 tph to 2.5 tph at a flow rate of 18 to 20 USGPM.

MG4: Designed to treat medium-grade feeds (containing 5% to 35% heavy minerals) and produce concentration ratios from about 7 to 1 to about 15 to 1, with excellent metallurgical performance. Each trough carries a nominal 1.75 tph to 2.5 tph at a flow rate of about 22 USGPM.

HG7D: Designed to treat high-grade feeds (containing 35% to 75% heavy minerals) and to produce a very high-grade concentrate product. The HG7D spiral is usually used as a cleaner stage unit following the LG7D spirals. Each trough of the HG7D spirals carries a nominal 1.25 tph solids at a flow rate of 15 to 16 USGPM.

HG8: Designed to treat very high-grade feed stocks (containing 50% to 90% heavy minerals) while producing concentration ratios of 1.5 to 1 to 3 to 1. The spiral is normally used as a cleaner or finisher stage unit, operating at 1.5 tph to 2.0 tph at a flow of 22 to 25 USGPM.

LG6: Designed to perform the same duties as the LG7D spiral, but utilizing a differently designed product cutter system. The spiral is designed for feeds containing wood chips and blasting wire fragments; the product cutters are situated in the flowing free-fall stream of the products at the trough discharge. Trash and wood chips cannot get caught or build up on the product splitters.

Reichert Coal Spirals — Most Common Models

LD4E: Designed especially for coal washing circuits, to treat

−⅛ in. by 100 mesh (3.5 mm by 0.147 mm) material. The spirals typically accept feeds containing up to 40% ash and produce 80% to 90% BTU yields with refuse products having an ash analysis of 65% to 85% ash. Each spiral trough carries a nominal 3 tph solids at a flow rate of 38 to 40 USGPM. The LD4E has been in service about 5 years.

LD8: Designed to treat −¼ in. by 100 mesh (−5 mm by 0.147 mm) material. The spirals accept feeds containing up to 50% ash and produce 80% to 90% BTU yield, depending upon the characteristics of the feed. Each spiral trough carries 2 tph to 3 tph solids at a flow rate of about 30 USGPM. This spiral is designed to off-load dense-media cyclones by treating a substantial fraction of the material generally processed by the cyclones.

LD2: The LD2 coal spiral was one of the first developed specifically for removing ash from fine coal. The LD2 is somewhat smaller in size than the LD4E, and it can be retrofitted into some older plants not suited for the newer larger spirals. The capacity of the LD2 is about 1.5 tph to 2 tph of solids, at about 20 to 22 USGPM.