CHAPTER 4.4

Mechanical Classifiers

Robert C. Dunne

The principal use of mechanical classifiers was in closed-circuit wet grinding; however, this application has been replaced over the past few decades by the hydrocyclone. One mine still using large screw classifiers in the grinding circuit is the Boliden Aitik copper mine in Sweden (Lappi 2015). Other applications still appropriate for mechanical classifiers include desliming, dewatering, and washing operations. Sand–slime separation may be achieved using one or more stages of mechanical classifiers. Typical applications include washing and desliming of concrete aggregate or sand; glass sand; abrasives; oyster shells; phosphate rock; iron, nickel, and chromium ores; alumina; zeolites; solar salt; and precipitates from chemical processing. Again, some of these applications are being performed by hydraulic classifiers (see Chapter 4.3, "Fluidized-Bed Classifiers").

DESIGN AND OPERATING FEATURES

Mechanical classifiers consist of a settling tank with parallel sides and a sloping bottom equipped with a mechanism that continuously agitates the pulp and removes the settled solids. The functions served by mechanical classifiers include the following:

- Allow larger particles to settle in the tank and provide an overflow stream with a minimum of oversized particles.
- Produce an overflow or underflow product of sufficiently high solids content to meet the requirements of the subsequent processing steps.
- Agitate the pulp and allow separation of the entrapped undersize particles so they can report in the overflow product.
- Provide continuous mechanical removal of coarse settled particles.

The underflow product from the mechanical classifier can have a higher solids content and contain less entrapped/entrained undersize particles than the comparable product from the hydrocyclone. Consequently, it is able to operate at higher classification efficiency. The result is a reduced circulating load in closed-circuit grinding applications. The mechanical classifier requires less power and has lower maintenance costs than the hydrocyclone and ancillary feed pump.

The proper selection of mechanical classification equipment requires that the properties of the solids and liquid are adequately defined. The following descriptive information regarding the solids is desired: feed rate, physical composition, density, temperature, size analysis, and desired separation size. For the liquid used, the following data is needed: feed rate, density, viscosity, pH, and temperature.

Settling Area

The pool area required to permit a particle larger than the separation size to settle depends on the density and shape of the particle and on the density and viscosity of the pulp within the classifier pool. These criteria determine the settling rate, which, in turn, determines the settling area required. Determining the settling rate (terminal solids velocity) by the test method of measuring the cylinder batch can be used in calculating the settling area (refer to Chapter 1.6, "Laboratory Test Work and Equipment").

Usually, design information is provided in manufacturer literature. However, for those interested, the required pool area for dilute slurries in open-circuit desliming can be estimated from the following (Heiskanen 1993) equation:

$$A = W \times E = 2Q/V_T$$

where

A = pool area, m^2
W = length of the overflow weir, m
E = weir's mean distance from the feed entry, m
Q = volumetric weir overflow, m^3/s
V_T = terminal settling velocity, m/s

Overflow Weir

The hydraulic head, and therefore the velocity at which the overflow crests the overflow weir, is one of the factors controlling the particle size of classification. Consequently, the length of the overflow weir is designed to provide the overflow velocity that allows the particles larger than the required particle size of classification to settle in the working area of

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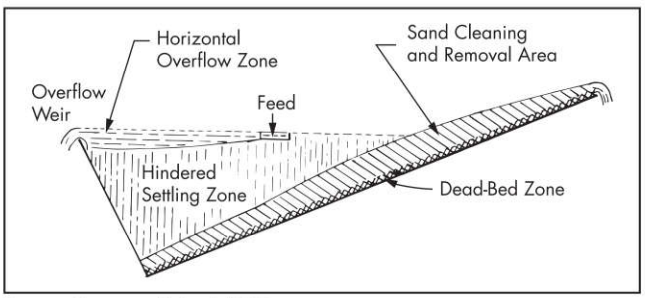
the pool. Obtaining the necessary weir length for a mechanical classifier of adequate sand-raking capacity may require

- Flaring of the classifier tank toward its overflow end,
- Wraparound overflow weirs, or
- Use of a bowl-rake classifier.

Settling Zones

The pool of a mechanical classifier contains many working zones, as shown in Figure 1. The horizontal overflow zone consists of free-flowing pulp. Essentially, it extends from the feed opening to the overflow weir where it approaches a depth of twice the hydraulic head cresting the weir. In this zone, velocity classification approaching free-settling conditions may be encountered with dilute feed, as in desliming operations. Below the horizontal overflow zone extends the hindered settling zone within which the size of the particles and density of the pulp increase from top to bottom. The less the turbulence and agitation and the lower the pulp density is at the top of this zone, the smaller will be the size of the settled particles. Therefore, the smaller the size of classification desired, the greater must be the depth of the gently agitated settling pool above the turbulence generated by the sand-raking mechanism. The particles settling through the hindered settling zone enter the sand cleaning and removal zone. There, the underflow solids are collected, agitated to remove entrapped water and fine particles, and removed from the pool by the sand-raking mechanism. At the bottom of the settling pool, below the reach of the sand-raking mechanism, is the dead-bed zone. The dead-bed zone serves to protect the tank bottom and has no further part in the classification process. The separation dynamics of solids in mechanical classifiers has been studied by many researchers (Roberts and Fitch 1956; Stewart and Restarick 1967; Reid 1971; Fitch 1973; Schubert and Neesse 1973; Fitch and Roberts 1985).



Source: Hitzrot and Meisel 1985
Figure 1 Mechanical classifier zones

Agitation

Agitation generated by the raking mechanism that removes the underflow sands liberates much of the entrapped water and undersize particles, permitting both to rise and report in the overflow product. Therefore, the sand product will contain only a small fraction of entrapped undersize particles, which constitutes a unique benefit from the use of mechanical classifiers. Increasing the speed of the raking mechanism increases agitation and increases the size of the particles reporting in the overflow. Raking speeds are specified by manufacturers of mechanical classifiers for the classification at various particle sizes.

Tank Slope

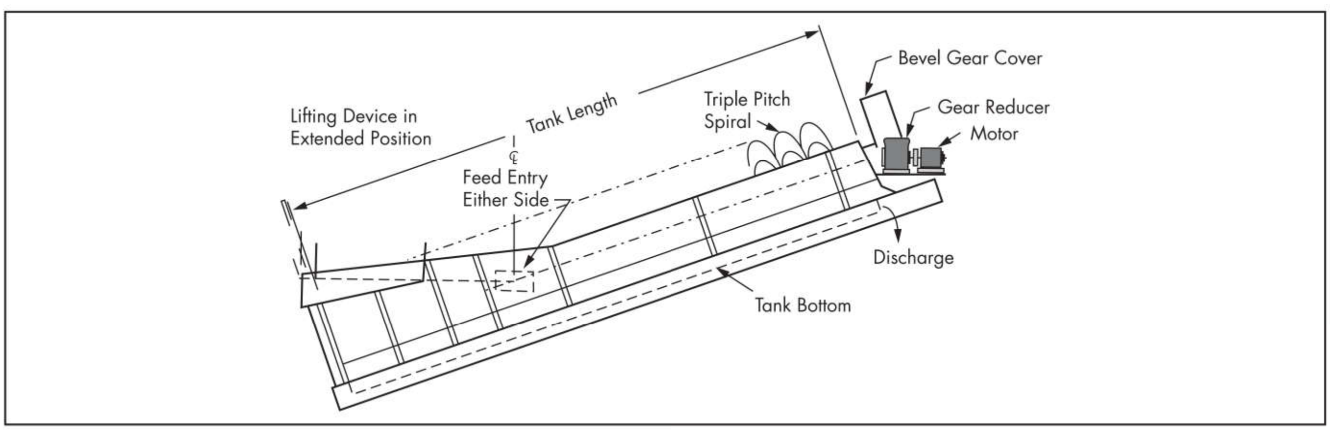
The speed of the raking mechanism of any given size classifier would have to be increased to maintain its raking capacity at an escalated tank slope. In turn, the increased raking speed compounds agitation and thus boosts the particle size of classification. Consequently, the drainage deck for a sand product of minimum entrapped water and undersize particles requires longer classifiers for classification at finer particle sizes. The slope of the tank bottom has a direct influence on pool area, sand-raking capacity, and sand drainage. It affects the separation size and moisture content of the sand discharge product.

Wash Water

Adequate removal of entrapped water and undersize particles from sand products frequently requires additional wash-water sprays on the drainage deck. However, the sprays wash back much of the solids, which has the net effect of reducing the sand-raking capacity in terms of the final sand product removed.

SPIRAL CLASSIFIER

A spiral classifier consists of an inclined tank in which one or two spirals, mounted parallel to the tank bottom, rotate without contacting the sides or bottom of the tank (Figure 2). The spiral structure provides the necessary pool agitation and



Courtesy of Wemco Division, Envirotech Corporation
Figure 2 Screw classifier

conveys the settled sand to the sand discharge lip. Feed is introduced at the pool level through one or both side walls. Pool level is maintained by adjusting the height of the overflow weir. The classifier overflow discharges from the overflow weir.

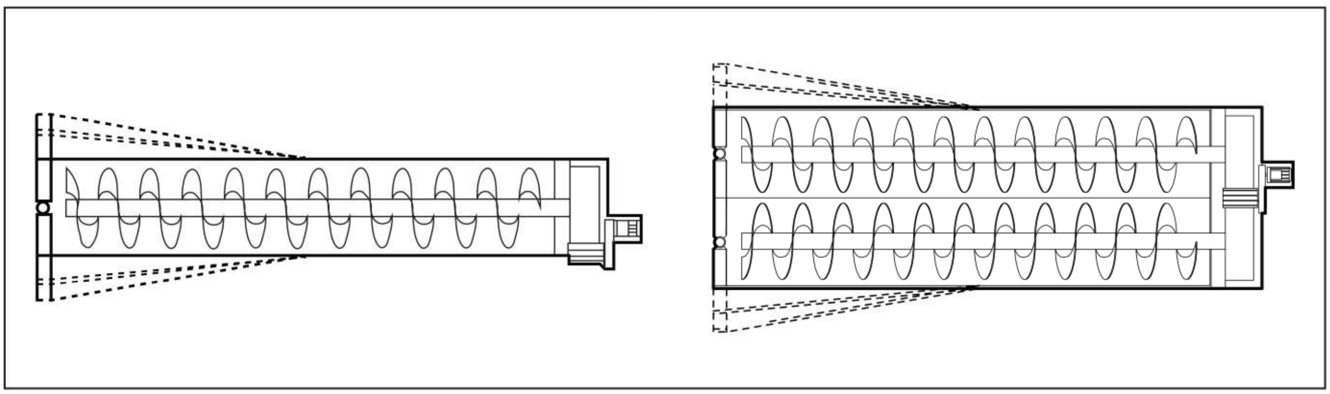
Spiral classifiers are built of simplex or duplex design, which defines the number of spiral mechanisms contained in the settling tank (Figure 3). The classifier mechanism is of single, double, or triple helix design, depending on the number of helices mounted on the rotating shaft, which extends through the length of the settling tank. The pitch of the helix varies among manufacturers (Figure 4).

Depending on the desired size of classification, the tank depth or submergence at the overflow weir end generally ranges from 90% to 150% of the diameter of the helix. For velocity classification in open circuit, attaining sufficient weir length and live pool area may require flaring of the weir end of the tank. Flaring of a simplex-classifier tank may increase its width at the overflow weir.

The spiral classifier is made in three different forms defined by the position of the spiral. The high-weir type is usually used in grinding circuits for classification sizes of 150 µm (100 mesh) or coarser. The submerged spiral type has the overflow weir high enough to submerge the lower end of the spiral. This increases the pool area and volume and provides higher capacity for fine separations. The lower end bearing of the spiral is above the pulp level in the low-weir type. This arrangement is typically used for dewatering sand or granular materials and for rough sand–slime separations.

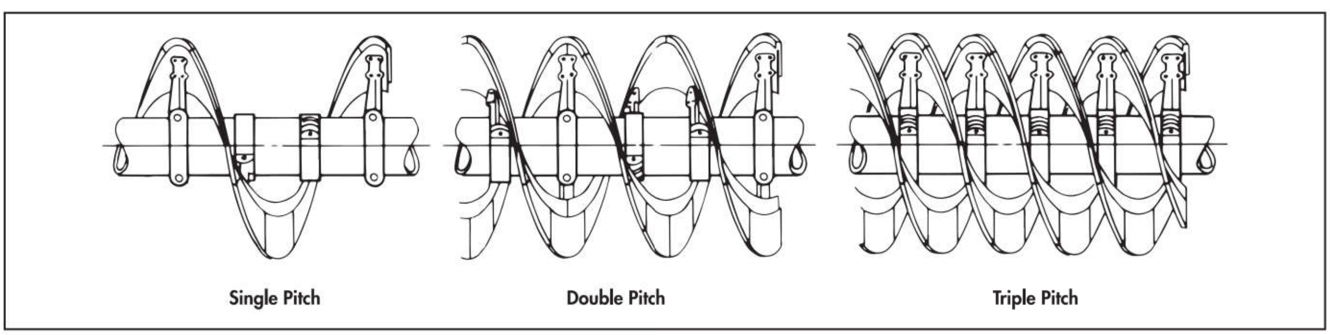
RAKE CLASSIFIER

When the spiral is replaced with a rake, the classifier is called a rake classifier. Rake classifiers are less common than spiral classifiers. The rakes consist of one or more parallel lines of steel plates that hang from a central shaft or shafts. The plates are hinged onto these shafts and have a reciprocating movement. The plates agitate the settling solids and drag the settled particles up the inclined base of the tank. At the end of the stroke, the plates rise sharply and then are lowered back into the tank after an eccentric movement to their original position. When repeating the operation, the settled matter is conveyed up the inclined slope and finally discharged into the sands launder. The overflow stream passes over a weir at the bottom end of the tank and is pumped to the next processing stage. The rake classifier consists of a tank, one or more rakes, and a mechanism for actuating the rakes. A gear case on the tank side near the sand discharge end and appropriate crankshafts and connecting rods move the rakes parallel to the tank bottom. The mechanism, in conjunction with the torque tube, gives the rakes a well-balanced operation at low power consumption. The torque tube is supported at the overflow end on a hydraulic cylinder that lifts the rear end of the rakes when oil is admitted under pressure. Depending on the service and width of the classifier, the tank may be equipped with one, two, or four rake mechanisms. Figure 5 shows a rake classifier.



Source: Metso 2006

Figure 3 Single and duplex spiral classifier

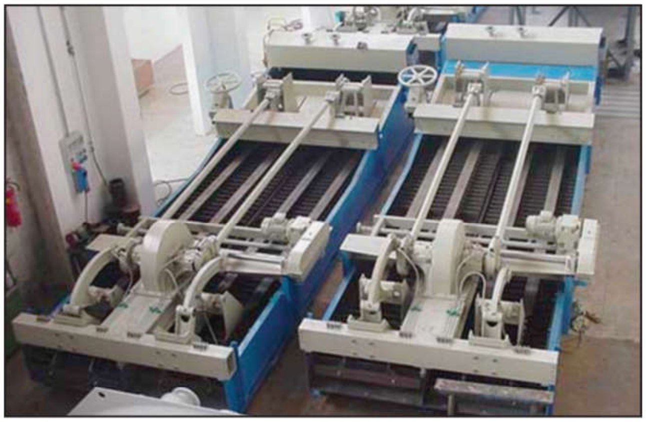


Courtesy of Denver Equipment Division, Joy Manufacturing Company

Figure 4 Different pitch designs

BOWL CLASSIFIER

The bowl classifier consists of a standard unit rake classifier at the pool end in a slightly sloping shallow bowl with a feed well at the center. Bowl diameters range from 3 to 10 m because of the limits on the width of rake classifiers and the limitation on the lower end of the reciprocating rake overhang. The heavy particles settle to the bottom of the bowl, which slopes toward the center of the tank. The settled particles are collected by the submerged rakes and guided to the discharge end by a conveyor and dispatched as the underflow fraction. Feed concentration is approximately 65% solids, and overflow and underflow percent solids can vary between 1%–15% and 70%–85%, respectively, depending on the application. The capacities range between 5 and 250 t/h depending on the diameter of the classifier. Figure 6 is a photograph of a bowl classifier.



Courtesy FLSmidth
Figure 5 Rake classifier

Courtesy of FLSmidth
Figure 6 Bowl classifier

EQUIPMENT MANUFACTURERS

Mechanical classifiers are produced by many suppliers. The following subsections detail the classifiers available from some of the more well-known manufacturers.

McLanahan Fine-Material Screw Washers

McLanahan (2018) produces fine-material screw washers (FMSWs), which are primarily used to dewater, classify, and wash sand and other fine materials (Figure 7). The selection of an FMSW is based on the type of material, feed size, desired product specification, capacity required, and water volume of a slurry feed. All of these factors must be taken into consideration for proper sizing. FMSW boxes are designed with longer weirs and a larger pool area behind the baffle plate to retain more 75-µm fines. The longer shafts allow for improved dewatering that results in a drier product. They are a low-cost, low-power sand processing solution that ensures retention of the optimal amount of fines. The washers are available in many sizes and configurations to accommodate the feed sand and water capacity. Wear shoes are available in multiple materials, including white iron, hardened metallic plate, and premium urethane to handle different types of feed. Specifications for the different spiral washers are provided in Table 1. The rake speed relationship to percent passing 300 µm in the overflow is provided in Table 2. A screw speed reduction will proportionately reduce rated capacity. For example, a 25% reduction in speed reduces rated capacity by 25%.

Eimco-KCP Spiral Classifiers

Eimco-KCP (2018) manufactures spiral classifiers. Spiral diameters of 0.3–2.25 m are available with single, double, and triple spiral pitches. Adjustable spiral speeds allow for peripheral speeds between 6 and 60 m/min. Replaceable wearing

Courtesy of McLanahan
Figure 7 Fine-material screw classifier

Table 1 Fine-material screw washer specifications

Screw Diameter × Length	Capacity, t/h	Maximum for Retaining Down to, m³/h			100% Screw, rpm	Power, kW
		150 µm	100 µm	75 µm		
Single-Screw Washer						
508 mm × 7.6 m	31	114	75	42	38	3.7
610 mm × 7.6 m	45	148	97	55	32	7.5
762 mm × 7.6 m	72	179	117	66	26	11
914 mm × 7.6 m	95	207	136	76	21	11
914 mm × 8.2 m	95	207	136	76	21	11
1,118 mm × 10.1 m	158	402	263	148	17	18.5
1,372 mm × 10.7 m	226	460	301	169	14	30
1,676 mm × 11.6 m	362	517	338	190	11	45
1,828 mm × 12.8 m	430	604	395	223	10	56
Double-Screw Washer						
914 mm × 7.6 m	190	312	204	115	21	2 × (11)
914 mm × 8.2 m	190	312	204	115	21	2 × (11)
1,118 mm × 10.1 m	317	597	391	220	17	2 × (18.5)
1,372 mm × 10.7 m	453	704	461	260	14	2 × (30)
1,676 mm × 11.6 m	725	780	511	287	11	2 × (45)
1,828 mm × 12.8 m	861	915	600	337	10	2 × (56)

Adapted from McLanahan 2018

Table 2 Screw speed impact on overflow particle size (relationship to % passing 300 µm)

%	% Speed
0–15	100
16–20	75
21–30	50
31–50	25
51–85	16

Adapted from McLanahan 2018

shoes come in different materials. The lifting device eliminates the necessity to drain the tank during shutdowns. The classifier can be quickly put in operation after shutdown even if the tank is fully sanded. Hydraulic-type lifters are standard on all units of 1.2-m diameter and larger. A handwheel-operated screw-type lifter is standard on units smaller than 1.05 m.

Application

Three classifier models are available (90, 125, and 150). For coarse separations down to 212 µm (65 mesh), series 90 units are used. Series 125 units are used for separations between 300 and 106 µm (48 and 150 mesh); and series 150 units are used for separations of 150 µm (100 mesh) and finer. Eimco-KCP also markets a high-volume classifier for treatment of industrial wastewater, which is designed to settle and dewater relatively coarse particles (~0.5 mm) from high-volume (19 m³/min), low-percent-solid streams. Flow surges up to 38 m³/min can be handled. The classifier trough is inclined and flared at the lower end to provide a quiescent settling pool (Figure 8) to prevent mixing of different size particles and carryover of coarse particles to the overflow.

Courtesy of Eimco-KCP

Figure 8 High-volume classifier

SAMM LSX Screw Sand Washing Machine

The SAMM (2017) LSX screw sand washing machine is designed for larger capacities and higher cleaning levels than traditional washing machines. It has three functions—washing, dewatering, and classifying. Consequently, the washer has a relatively small working footprint compared to separate units for comparable duties.

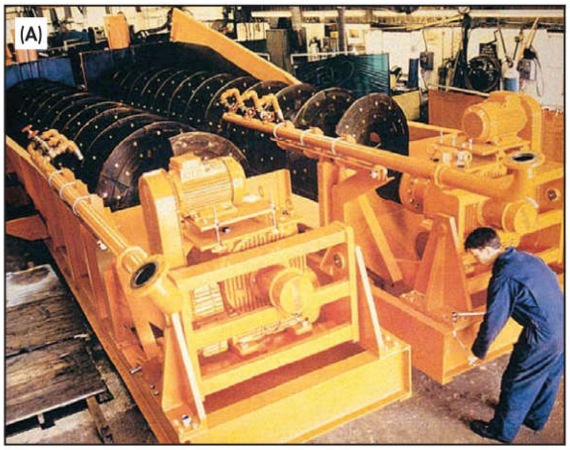
Applications

The LSX screw sand washing machine is used to remove the ultrafine particles in sand. It is widely used for cleaning duties in the following industries: quarry, minerals, building materials, transportation, chemical, and cement mixing stations. Details of the different models available are show in Table 3.

Table 3 Specifications of SAMM LSX models

Model	Spiral Diameter, mm	Tank Length, mm	Number of Spirals	Speed, rpm	Maximum Feed Size, mm	Capacity, t/h	Water Consumption, t/h	Power, kW
LSX920	920	7,585	1	21	≤10	100	9–80	11
2LSX920	920	7,580	2	21	≤10	200	20–160	11 × 2
LSX1120	1,120	9,750	1	17	≤10	175	20–150	18.5
2LSX1120	1,120	9,750	2	17	≤10	350	40–300	18.5 × 2

Adapted from SAMM 2017



Source: Metso 2006

Figure 9 (A) Single- and (B) double-spiral screw classifiers

Metso Spiral Classifier

Spiral classifiers are designed to provide effective pool area and overflow velocity requirements. By combining the appropriate submergence of the spiral with one of the tank designs, a choice of 63 combinations are available in straight, modified, or full flare tank designs from Metso (Jennings Alberts 2018). Polyurethane shoes are standard, and options of iron and Ni-hard are available. The wearing shoes are fastened to the flights with countersunk head bolts. The sealed, submerged bearings comprise two heavy-duty roller bearings mounted in a special housing and protected by spring-loaded grease seals plus a labyrinth seal. The bearing assembly is bolted to the lower end of the shaft. An automatic lubrication system is optional. The spiral assembly is raised and lowered by a simple, positive-action, handwheel-operated screw device for units up to 900 mm in diameter. Larger-diameter units are raised and lowered by an electric screw jack actuator. The adjustable weir overflow system of removable weir bars allows the spiral submergence and pool area to be altered. The classifier is driven by a shaft-mounted gear motor unit or reducer via V-belts and an electric motor. This innovative design allows the reducer bearing to act as the classifier.

Laboratory and pilot-plant spiral classifiers are available in 150-, 225-, 300-, and 400-mm diameter and include many features of the full-sized units. Models of the single- and double-spiral screw classifiers are shown in Figure 9. In addition to the standard-type screw classifier, Metso also supplies purpose-built dewatering and sand screw classifiers.

Spiral Dewaterer

The spiral dewaterer is for the treatment of coarse solids (Metso 2015). The typical application is scale removal in a steel mill. The feed is usually up to 2% solids w/w. The range of units can treat feed rates from 10 to 1,500 m^3/h. An oil skimmer is optional.

Sand Screw

The sand screw is a simpler version of the spiral dewaterer and mainly used for the treatment of natural sand. The objective is to remove the fine fraction, particles smaller than 10–50 µm, in the sand. The sedimentation pool is much smaller compared to that of the spiral dewaterer.

Triveni Spiral Classifier

The Triveni spiral classifier is similar in design features to that of the Metso screw classifier (Triveni, n.d.). Information on sizes and capacities for the Triveni screw classifiers are shown in Table 4.

Xinhai Screw Classifiers

Xinhai Mineral Processing (2017) manufactures two types of spiral classifiers:

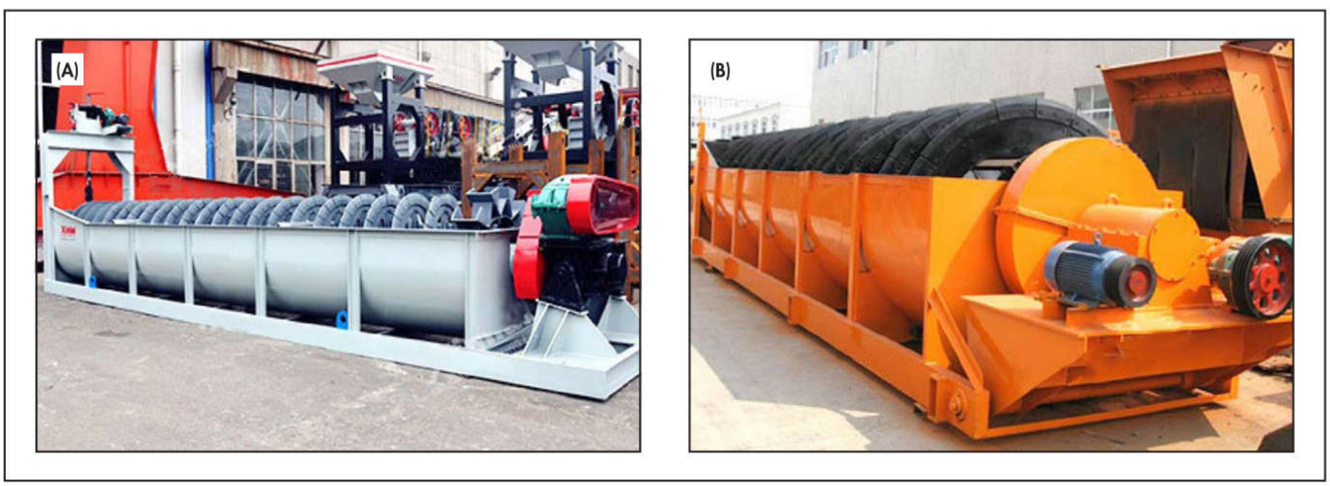
1. High weir spiral classifier with capacities from 50 to 1,785 t/d
2. Submerged spiral classifier with capacities from 50 to 1,410 t/d

Both models have automatic spiral-lifting systems. The two models are shown in Figure 10.

Table 4 Triveni screw classifier specifications

Size, mm	Tank Configuration	Overflow Pool Area, m² Model 100	Model 125	Model 150	Spiral Pitch	Raking Capacity per Spiral Revolution, t/h	Spiral, rpm	Motor, kW
610 Simplex	Straight	1.40	—	—	Single	0.5–1.0	6–16	1.1–2.2
	Modified flare	1.50	2.08	2.64	Double	1.0–2.0	—	—
	Full flare	—	2.41	3.19				
760 Simplex	Straight	2.12	—	—	Single	0.8–1.7	5–13	1.1–2.2
	Modified flare	2.09	3.21	—	Double	1.7–3.4	—	—
	Full flare	—	3.72	—				
914 Simplex	Straight	3.47	—	—	Single	1.7–3.5	4–11	1.5–3.7
	Modified flare	3.36	4.53	5.81	Double	3.5–7.0	—	—
	Full flare	—	5.30	7.06				
1,067 Simplex	Straight	4.12	—	—	Single	2.4–4.8	3.5–9	1.5–2.2
	Modified flare	4.61	6.17	—	Double	4.8–9.6	—	1.5–5.6
	Full flare	—	7.25	—				
1,219 Simplex	Straight	5.30	—	—	Single	4.3–8.7	3.2–8	2.2–5.6
	Modified flare	5.96	7.99	10.22	Double	8.7–17.4	—	3.7–7.5
	Full flare	—	9.38	12.45				
1,524 Simplex	Straight	8.23	—	—	Single	8.6–17.3	2.6–6.5	5.6–11.2
	Modified flare	9.25	12.45	15.89	Double	17.3–34.6	—	11.2–14.9
	Full flare	—	14.68	19.42				
1,676 Simplex	Straight	9.94	12.68	15.51	Single	10.2–20.4	2–6	7.5–11.2
	Modified flare	11.19	15.00	19.30	Double	20.4–40.8	—	11.2–14.9
	Full flare	12.63	17.69	23.69				
1,828 Simplex	Straight	11.80	14.96	18.12	Single	13.9–27.8	2–7	7.5–14.9
	Modified flare	13.29	17.74	22.58	Double	27.8–55.6	—	11.2–22.4
	Full flare	—	20.90	27.78				
1,981 Simplex	Straight	13.75	17.47	21.18	Single	15.6–31.5	2–6	7.5–14.9
	Modified flare	15.51	20.81	26.48	Double	31.5–63	—	11.2–22.4
	Full flare	—	24.62	32.61				
1,828 Duplex	Straight	22.58	26.11	29.26	Single	13.9–27.8	2–7	18.6–29.8
	Modified flare	25.64	30.47	35.21	Double	27.8–55.6	—	—
	Full flare	29.08	35.30	42.09				
1,981 Duplex	Straight	26.48	30.29	34.00	Single	15.6–31.5	2–6	22.4–37.3
	Modified flare	30.01	35.40	39.21	Double	31.5–63.0	—	—
	Full flare	34.10	42.09	49.24				

Adapted from Triveni Engineering and Industries 2007



Courtesy of Xinhai

Figure 10 (A) High weir and (B) submerged spiral classifiers

ACKNOWLEDGMENTS

This chapter draws heavily on the theory in the "Mechanical Classifiers" chapter written by H.W. Hitzrot and G.M. Meisel in the 1985 edition of the *SME Mineral Processing Handbook*. The author of this chapter updated the equipment data and information and revised selected material while leaving much of the theory in the chapter as originally written.

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