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Evaluating Screening Performance

Screening (separating dry material based on particle size) is a complex task that requires sophisticated machinery. An optimized screener needs to be designed with consideration of countless variables, including:

- Motion: how a screen moves, whether vibrating, gyratory, linear or stationary
- Loading mechanics: feed rate/unit area, etc.
- Material characteristics: particle size distribution, particle shape, bulk density, moisture, friability and static charge

Designing a screening machine with the right mix of variables can have a significant impact on the quality and quantity of product output — both of which affect profitability. Given the many factors that go into screener design, how does a company find the right balance? More importantly, what are the best practices for evaluating screening performance?

An optimized screener needs to be designed with consideration of countless variables, including:

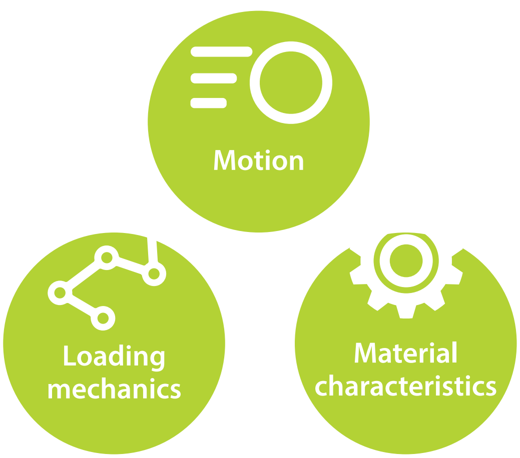
Where to Start

Evaluating screening performance begins with identifying an operation objective. This is often the production of a single product through the removal of oversize, fines or both, though sometimes it can be the production of several products through grading with a multiple-deck screener.

Once the objective is known, two more factors must be considered:

1. **Final product quality**
   Does the screener deliver an acceptable product overall?

2. **Efficiency**
   How much of the screened final recovered product in the feed can be considered good?



Product quality

Product quality can be expressed in many ways; most are focused on the measurement of particle size.

Sieve analysis is the standard for evaluating screens of dry granular or powder-like materials in the range of 40 microns to 10 millimeters. The process introduces a small sample to a stack of progressively finer test sieves, which sit above a collection pan. Each sieve consists of a precisely woven wire screen with a standard opening. The sieves are identified by a number (based on opening size per inch) and a standard, such as #10 U.S. or #35 Tyler (Table 1). The larger the sieve number, the smaller the opening.

Once the sample is introduced, a mechanical sieve shaker moves the sieve stack in a circular motion. This motion is combined with a separate tapping motion from above, causing the material to segregate through the sieves.

After a set time, the stack is disassembled and the amount of material retained on each sieve and in the pan is weighed. Those weights retained on sieve trays are expressed as a percentage of the total.

The determined product quality is usually expressed by a product size specification that identifies the nominal particle size range (in terms of sieve number), along with acceptable tolerances at the limits of the range.

For example

A grade of citric acid crystals with a nominal particle size range of -16/+30 U.S. (finer than a #16 U.S. test sieve) might have a specification that could be expressed in any of the following ways:

- -16/+30 U.S., <5 percent oversize, <10 percent fines
- 5 percent maximum +16, 10 percent maximum -30
- 95 percent minimum through #16 U.S., 90 percent minimum on #30 U.S.

Table 1 — Test Sieve Opening

		Openings	
U.S. Sieve #	Tyler Sieve #	In.	Microns
3.5	3.5	.2230	5,600
4	4	.1870	4,750
5	5	.1570	4,000
6	6	.1320	3,350
7	7	.1100	2,800
8	8	.0937	2,360
10	9	.0787	2,000
12	10	.0661	1,700
14	12	.0555	1,400
16	14	.0469	1,180
18	16	.0394	1,000
20	20	.0331	850
25	24	.0280	710
30	28	.0236	600
35	32	.0197	500
40	35	.0167	425
45	42	.0140	355
50	48	.0118	300
60	60	.0098	250
70	65	.0083	212
80	80	.0071	180
100	100	.0059	150
120	115	.0049	125
140	150	.0042	106
170	170	.0035	90
200	200	.0030	75
230	250	.0025	63
270	270	.0021	53
325	325	.0017	45
400	400	.0015	38

Quality Tolerance

Setting a predetermined quality tolerance is necessary because absolute separation with a production screener is impractical. This includes the coarse end (top side), where a zero percent specification would typically lead to excessive carryover of good product to the "overs" fraction and the fine end (bottom side), where no screener can remove 100 percent of fines.

Sometimes multiple sieves are used to better define the desired particle size distribution. For example, the S.A.E. specification for S230 steel shot is: zero percent retained on #16 U.S. sieve, 5 percent maximum retained on #20 U.S., 85 percent minimum retained on #30 U.S., and 97 percent minimum retained on #35 U.S.

Specifying nominal size and tolerance limits is by far the most common method of representing product quality, but other methods have been developed, usually for specific industries.

Screening Efficiency

Efficiency is not the same as product quality. Screening efficiency or, more specifically, product recover efficiency, is the ratio of on-size product separated by a screener divided by the amount of on-size material present in the feed. Screening efficiency determines process yield, which in turn determines production rates. The yield is the amount of material separated as product, which is expressed as a percentage of the rate of material fed to the screener (See Figure 1).

Efficiency is most often calculated as follows:
Efficiency (product recovery): % on-size I product x % product yield / % on-size available in feed

When analyzing a laboratory screening test, be cautious that the feed distribution may be determined by material balance. Take the sieve analyses for each fraction, multiply the percentage found on each sieve by the yield for that particular fraction, and add the products for each sieve (Table 2). This minimizes the effect of sampling error and prevents calculations of efficiencies actually greater than 100 percent.

Table 2 — Material Balance Calculation

A Fraction: Yield:	B Fines 15.0%	C Product 56.2%	Overs 28.8%	15.0% xA	+	56.2% xB	+	28.8% xC	=	Feed by Material Balance
6	0.0	0.4	83.4	0.0	+	0.22	+	24.02	=	24.2
7	0.0	25.1	16.5	0.0	+	14.11	+	4.75	=	18.9
8	0.0	40.2	0.1	0.0	+	22.59	+	0.03	=	22.6
10	20.5	33.0	0.0	3.08	+	18.55	+	0.00	=	21.6
12	49.9	1.2	0.0	7.49	+	0.67	+	0.00	=	8.2
14	21.8	0.1	0.0	3.27	+	0.06	+	0.00	=	3.3
PAN	7.8	0.0	0.0	1.17	+	0.00	+	0.00	=	1.2
	100.0	100.0	100.0	15%		56.2%		28.8%		100.0

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Determining the variables in these equations is relatively easy in a laboratory setting. In the field, it is sometimes difficult to measure mass flow rates of the reject fractions, but sampling of the various fractions is usually possible.

Armed with these, an approximation of efficiency for a single-deck separation can be calculated:

Efficiency (undersize recovery) = % undersize in feed - % undersize in overs) / [% undersize in feed x (100% - % undersize in overs)]

Screening efficiency is typically inversely proportional to the amount of near-size present in the feed. For simple scalping applications where little near-size is present, 100 percent screening efficiencies are achievable.

For extremely difficult grading applications, efficiencies as low as 50 percent might be considered good. Generally, screening efficiencies of 80 percent to 100 percent are common in chemical processing.

As with product quality, screening efficiency must never be used as the sole measure of screening performance. Any screener could achieve 100 percent efficiency by removing the screen from the top deck and putting a blank plate on the bottom deck, but product quality would be suspect.

In addition to product recovery efficiency, other measures of efficiency are sometimes employed. Some applications lend themselves to analysis of over-removal efficiency or fines-removal efficiency. The calculation is essentially the same.

• Efficiency (overs removal) = % oversize in over x % overs yield / % oversize available in feed

• Efficiency (fines removal) = % undersize in fines x % fines yield / % undersize available in feed

In reality, these efficiencies are another measure of product quality. For example, a screener operating with 100 percent overs removal efficiency is, by definition, producing a product that contains zero percent oversize.

Capacity and Efficiency

Laboratory testing makes it possible for manufacturers to predict the product quality and screening efficiency of a screening machine in most applications, but it's important to acknowledge these predictions are only valid within a specific capacity range. Exceeding the stated capacity can lead to flooding the screen deck, which results in good product tailing over the screen and a reduction in product quality.

A screener's capacity can be expressed as an absolute: a feed rate to the size of the machine. Sometimes, this will be expressed as an allowable screen loading, stated in terms of feed rate/unit screen area. The data shown in Figure 1 was obtained at a screen loading of 1,000 pph/square foot of screen area. The capacity of a 50-square foot screener in this application is:

Capacity = loading x screen area

If the desired feed rate is known, the amount of required screen area can be calculated:

• Required screen area = feed rate/loading

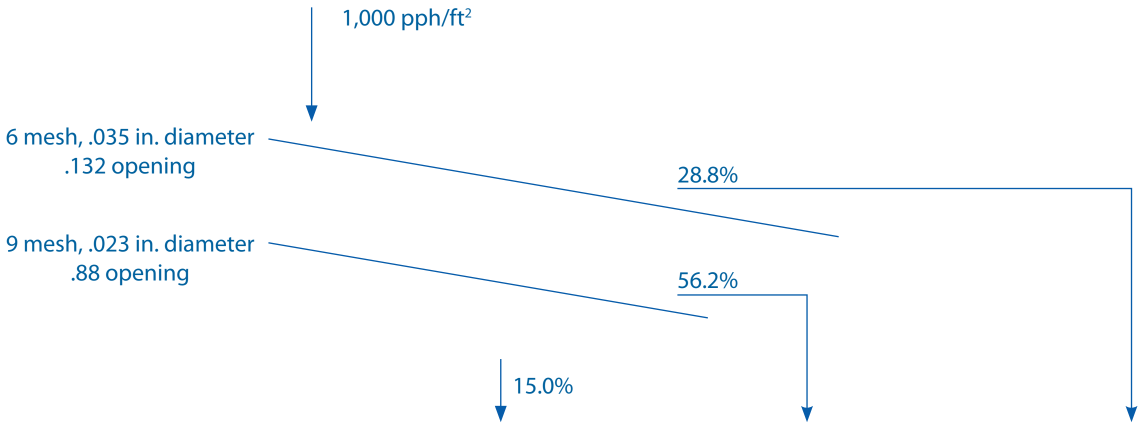
Figure 1 — Laboratory Test data

Feed Distribution

U.S. Sieve	Opening In.	Opening mm	Percent retained Test	Percent retained Mat'l bal.
6	.132	3.35	24.0	24.2
7	.110	2.80	20.3	18.9
8	.0937	2.36	22.5	22.6
10	.0787	2.00	21.5	21.6
12	.0661	1.70	7.2	8.2
14	.0555	1.40	3.3	3.3
Pan	---	---	1.2	1.2
			100.00	100.00

Product specifications:

1% Max. +6 U.S.
3% Max. -10 U.S.
80% Min. efficiency



-10 Fines

U.S.	% Ret.
6	0.0
7	20.5
8	
10	
12	49.9
14	21.8
Pan	7.8
	100.00

-6/+10 Product

U.S.	% Ret.
6	0.4
7	25.1
8	40.2
10	33.0
12	1.2
14	0.1
Pan	0.0
	100.00

+6 Overs

U.S.	% Ret.
6	83.4
7	16.6
8	
10	
12	0.0
14	0.0
Pan	0.0
	100.00

Production Rates

The rate capacity of a screening machine always refers to the feed rate, not the product output rate. Production rates will be a function of the particle size distribution of the feed and the screening efficiency, both of which can vary in a production environment. Production rates can also be predicted through laboratory testing. For example, in the application represented in Figure 1, a feed rate of 50,000 pph is assumed. The mass flow rates of the various output streams are calculated as follows:

• Product rate: 50,000 pph x 56.2% = 28,100 pph

• Fines stream: 50,000 pph x 15.0% = 7,500 pph

• Overs stream: 50,000 pph x 28.8% = 14,400 pph

In situations where efficiency is relatively low, it is important to determine why and where product is being lost. This is done by examining sieve analyses of the reject fractions.

In the example in Figure 1, 16.6 percent of the overs fraction is actually good product and 20.5 percent of the fines is good product. How much actual product loss these percentages represent is determined as follows:

• Product loss to overs fraction = % product in overs x % overs yield x feed rate

The effects of this product loss must be considered when comparing screeners of varying efficiencies. A less-efficient screener will require a higher feed rate to produce the same amount of product. It will also result in higher costs due to the additional amount of reject material that must be either reprocessed, sold as off-spec product or scrapped and thrown away.

Conclusion

Proper evaluation of the screening process is a multifaceted process with countless variables. To have the most impact, any screening test or process must include measurements of both product quality and screening efficiency. Such an analysis will not only help manufacturers to determine the optimum balance of product quality and yield, it will also help them optimize screeners for maximum efficiency and increased profitability.