If you’re going to add a centrifuge to your operation anytime soon, you’re probably wondering how to select the right unit for your needs. You need to make the right decision because a centrifuge is costly and, what’s more, is often part of a process that includes further drying. Since dryers are generally sized to accommodate a specific tonnage of solids per hour containing a maximum percentage of moisture, the consistent performance of the centrifuge is critical to what type and size of dryer you select and how much it will cost.

So how can you make the right choice? And how do you know whether to trust what the centrifuge manufacturer’s sales rep is telling you? The answer is simple: testing. This article explains how you can run three simple tests on your feed slurry in your own lab to eliminate some centrifuge choices. By process of elimination, the tests can help you determine which type of centrifuge to select for a subsequent pilot plant test. The article also discusses how to run the pilot plant test and make your final centrifuge choice.

When a slurry is fed to a centrifuge, the goal is to have the machine separate the liquid from the solids to produce a high-quality end product at high capacity. The more consistent the feed slurry’s characteristics, the more consistent the end product. But variations in process conditions upstream from the centrifuge can change the feed slurry’s characteristics, such as its solids concentration, particle size, temperature, and viscosity, and significantly affect the centrifuge’s performance.

The best way to handle these variations is to select a centrifuge that can handle your feed slurry’s particular characteristics and any changes that can occur during the course of a production run. So before you make an equipment choice, you need to carefully characterize the feed slurry. This includes evaluating the slurry’s liquid and solid phases, first in the lab and then in a pilot plant test.

Before discussing the tests, let’s take a look at some centrifuge basics.

**Centrifuges 101**

A centrifuge, which has a rotating chamber, depends on the rotation to induce centrifugal force, which accelerates the separation of the liquid from the solids. Centrifugal force causes the solid phase to move through the liquid phase in a straight line and away from the center of rotation. Solid-phase characteristics such as particle density, size, shape, and consistency and the rotation speed for the chamber (a basket or bowl, depending on the centrifuge type) of a given diameter also influence how fast the solid phase moves away from the center of rotation. The higher the rotation speed, the higher the G force exerted on the solid phase and the faster the solids accumulate.
Two types of centrifuges are common: filtering and sedimentation. Both are available in batch and continuous models.

**Filtering centrifuges.** A filtering centrifuge is available in a range of configurations, including continuous units (fixed-angle, worm-screen, and pusher plate types) and batch units (vertical basket, horizontal peeler, and inverting bag types). Some examples are shown in Figure 1a. What they have in common is their primary component: a rotating perforated or slotted basket or bowl that’s covered with a filter media. The media, which can consist of paper or woven cloth sheets, metallic or synthetic woven mesh screens, perforated holes, laser-cut or pierced plates, or wedge-wire bars, must be properly selected for the application.

In operation, a feed slurry enters the inlet. Centrifugal force induced by the basket’s (or bowl’s) rotation moves the solids to collect on the filter media. The liquid passes through the solids, the filter media, and the basket and is discharged. (In some cases, the liquid is the desired end product and is collected after discharge.)

The collected solids form a cake on the media. The moisture content of this solids cake can vary widely, depending on the solids’ particle size, shape, and consistency.

The filter media provides a reasonable percentage of open area made up of holes of a certain size and shape. This enables the media to restrict passage of the solid phase while allowing the liquid phase to pass through freely, thus purifying and reducing the moisture content of the solids, cleaning and purifying the liquid, or both.

In operation, centrifugal force induced by the bowl’s rotation moves the solids to collect and compact on the bowl’s interior wall in the form of a moist cake.

Depending on the solids’ characteristics and the level of G forces at work, the amount of solids compaction can be low or high. In addition to compacting the solids to an acceptable degree of dryness, the sedimentation centrifuge can also clarify the liquid.

To determine which type of centrifuge will best handle your liquid-solids separation, you need to run lab and pilot plant tests on your feed slurry. The lab tests include simple procedures that will yield data on the solids purity and dryness, final liquid clarity, and other properties. You can use the data to determine whether to select a filtering or sedimentation centrifuge operating in batch or continuous mode for the pilot plant test.

**Running the lab tests**

The lab tests for characterizing your feed slurry include the static settling test, filtration rate test, and spin settling rate test. Before running these tests, you should also know some of the solids’ basic characteristics, including particle size distribution and particle shape.

**Static settling test.** The static settling test requires placing a representative sample of your feed slurry in a 1,000-mililiter beaker and allowing it to stand for 30 minutes. As the solids in the sample settle, density differences between the liquid and solid phases should be evident. Depending on the slurry, you can observe and record all or some of the following:

- Settled solids volume
- Floating solids volume (not always present)
- Liquid clarity (excellent, good, or poor)
- Number of phases (one, two, or three)
- Separation rate and quality (excellent, good, or fair)

If even the slightest separation of liquid and solid phases appears in the beaker, you’ve confirmed that the slurry’s liquid and solid phases have different densities and that a centrifuge and its centrifugal force can accelerate or enhance the separation. This indicates that you need to perform further tests.
Figure 1
Some common centrifuge types

a. Filtering

Fixed-angle (continuous)

Vertical basket (batch)

Pusher plate (continuous)

Worm-screen (continuous)

Horizontal peeler (batch)

b. Sedimentation

Decanter (continuous)

Disk ejection (continuous)

Vertical solid bowl (batch)

Tubular (batch)
**Filtration rate test.** The filtration rate test requires representative samples of both the feed slurry and its *mother liquor* (that is, the liquid used to form the slurry). The test will determine the permeability rate of the settled solid phase that accumulated in the static settling test. You can convert this permeability rate to gallons per minute per square foot, and the resulting number will indicate what type of centrifuge you should use in the pilot plant test.

To conduct the test, follow these steps:

1. Set up a 6-inch Buchner funnel and a 1,000-milliliter vacuum flask on a ring stand, as shown in Figure 2.

2. Place a 6-inch Whatman 1 fast filter disk in the funnel and seal the disk to the filter bottom by rinsing the disk surface with a small amount of the mother liquor.

3. Preset the aspirator on the vacuum flask (or the vacuum on your lab’s vacuum pump) at 4 to 5 inches vacuum, and begin to pour a thoroughly mixed sample of the feed slurry onto the filter disk’s surface. Allow the solids to build up to a 1- to 1.5-inch-deep cake, and make sure that this solids cake is distributed evenly. *Note:* During this step, check the solids cake as it’s dewatered so you can turn off the aspirator before it overdries the cake and causes cracking.

4. With the aspirator (or vacuum pump) turned off, place 500 milliliters of clean mother liquor in a 500-milliliter volumetric flask. Cover the flask’s mouth with a piece of cardboard or paper and invert the flask over the funnel’s center. Then remove the cardboard or paper so that the mother liquor flows out and forms an approximately 0.25- to 0.5-inch pool on top of the solids cake. As you do this, support the flask so the distance between the cake and the flask’s mouth is constant. By performing this step quickly and properly, you will keep the remaining mother liquor in the flask until you restart the vacuum (step 5).

5. Simultaneously turn on the aspirator (or vacuum pump) and start a stopwatch. The mother liquor should begin to drain out into the pool and through the solids cake as the vacuum draws the liquid through the cake’s capillaries and interparticle matrix and eventually into the vacuum flask. *Note:* If the mother liquor quickly drains through the solids cake before the aspirator is turned on, you can stop the test.

6. Record how long it takes (in seconds) for the mother liquor to vacate the volumetric flask, pass through the solids cake, and stop flowing freely into the vacuum flask.

7. Convert the filtration rate through the solids cake to gallons per minute per square foot. For the conversion, use approximately 0.20 square feet (28 square inches) for the 6-inch filter disk’s area and 0.13 gallons for the 500 milliliters of mother liquor.

So, for instance, if it took 10 seconds for the 0.13 gallons of mother liquor to pass through the 0.20 square feet of solids cake surface area and into the vacuum flask, the final filtration rate in gallons per minute per square foot (gal/min/ft²) would be:

- 1 square foot divided by 0.20 square foot equals a multiplier of 5.

- 0.13 gallons per 0.20 square feet times 5 equals 0.65 gallons.

- 60 seconds per minute divided by 10 seconds equals a multiplier of 6.

- 0.65 gallons times 6 equals 3.9 gal/min/ft².

8. Record the results and evaluate the solids’ permeability based on the filtration rate:

- 8 to 12 gal/min/ft²: outstanding permeability
6 to 10 gal/min/ft²: excellent permeability
4 to 8 gal/min/ft²: good permeability
2 to 6 gal/min/ft²: fair permeability
1 to 3 gal/min/ft²: marginal permeability
0.5 to 1 gal/min/ft²: poor permeability

If the filtration rate is between 2 to 6 gal/min/ft² or above, use a continuous filtering centrifuge for the pilot plant test.

If the filtration rate is 1 to 3 gal/min/ft² or below, use a batch filtering centrifuge for the pilot plant test.

If the filtration rate is less than 0.5 gal/min/ft², the solid phase probably consists of very fine, fluffy, or sticky particles that tend to compact and thus restrict drainage. Because a filtering centrifuge is impractical for separating these particles, you’ll need to use a sedimentation centrifuge for the pilot plant test.

To determine which sedimentation unit is best, run the following test.

**Spin settling rate test.** If the solid phase exhibits poor permeability, the spin settling rate test can determine what effect G forces and time have on the feed slurry’s ability to separate into distinct phases.

For the test, follow these steps:

1. Fill two test tubes with feed slurry samples and place the tubes in a bench-top test-tube spinner. (A spinner that can produce 1,000 Gs is typically used.)
2. Spin the tubes for 30 seconds and then stop the spinner.
3. Observe the liquid and solid phases in each tube for such properties as separation quality, liquid clarity, and solids cake compaction.
4. If necessary to achieve a satisfactory two-phase separation, repeat steps 2 and 3 up to three times, for a total of 90 seconds of spinning.

If the test achieves a satisfactory separation within 90 seconds, use a decanter sedimentation centrifuge for the pilot plant test of the feed slurry. This unit typically has a G force ranging from 2,000 to 3,000.

If the test doesn’t achieve a satisfactory separation in 90 seconds or the liquid phase is cloudy and not completely void of insoluble solids, use a disk sedimentation centrifuge for the pilot plant test. This unit can produce 4,000 to 5,000 Gs. The disk sedimentation centrifuge is often required to achieve a good three-phase liquid-liquid-solids separation, such as for a feed slurry containing oil and water.

If the test doesn’t achieve a satisfactory separation in 90 seconds and the solids’ particles are known to be less than 5 microns and have low density and low concentration, you can use a tubular sedimentation centrifuge for the pilot plant test. This machine can produce from 10,000 to 60,000 Gs.

Note: If none of the three lab tests produces a satisfactory liquid-solids separation, your feed slurry isn't suited to separation in a centrifuge. Instead, you need to consider using another type of liquid-solids separation equipment, such as a filter press or plate-and-frame filter.

**Selecting a centrifuge for the pilot plant test**

By the end of these lab tests, you'll have gathered both empirical and process data, such as the feed slurry’s percent solids concentration, other solids characteristics, and wash requirements (that is, requirements for adding a wash liquor that displaces the mother liquor to purify the solids during centrifuge operation). The data will help you narrow the choice of potential centrifuges to those units that can handle your application.

However, you can’t rely on the lab tests alone because they don’t reveal process changes that can affect the centrifuge’s operation. These changes include crystal agglomeration, particle size reduction, drops or increases in solids concentration, fluctuations in feedrates or wash rates, screen or basket blinding, and temperature or viscosity changes. Because of this variety of potential process upsets, you need to gather some long-term data and experience in a pilot plant test before making the final centrifuge choice for your application. The test requires running a representative sample of your feed slurry in a pilot-sized centrifuge for an extended period.

Before discussing how to run the pilot plant test, it’s helpful to know more about the types of available centrifuges and their limitations so you can select one for your pilot plant test. Again, a centrifuge can be continuous or batch, and either type is available in filtering and sedimentation models.

**Continuous centrifuges.** The filtering centrifuge accepts a continuous flow of feed slurry and simultaneously removes the mother liquor through the solids cake and screen as solids accumulate on the screen surface. The unit can continuously apply a wash liquor (metered in gallons
or liters per minute) to the solids if necessary, remove the wash liquor, reduce the solids' final moisture, and discharge the solids to a bin, container, or dryer. In a fixed-angle model, the solids discharge depends on the angle of the basket (typically 30 degrees, which is the angle of repose for most filterable solids). In a worm-screen model, the solids are conveyed out of the centrifuge by a scroll. In a pusher plate model, a pusher plate pushes the solids out of the centrifuge.

The sedimentation centrifuge accepts a continuous flow of feed slurry and simultaneously removes the mother liquor as the solids accumulate on the bowl wall. How the liquid and solids are discharged from the centrifuge depends on the centrifuge model:

- In a decanter unit, the mother liquor exits over an adjustable weir (dam) plate and the settled solids are mechanically conveyed by a scroll up an angled beach area for drying; the solids eventually exit through the unit's discharge port. If required, the decanter unit can apply a wash to the solids in the beach area.

- In a disk unit, the mother liquor exits via a center overflow or siphon tube, depending on whether one or two liquids are present. The settled solids are removed either continuously via fixed-orifice nozzles or intermittently via an ejection method.

**Batch centrifuges.** A filtering centrifuge, available in vertical basket, horizontal peeler, and inverting bag units, accepts a measured flow or volume of feed slurry. Once the slurry has been completely metered into the centrifuge, the feed is turned off and the centrifuge rotates and allows the mother liquor to drain through the accumulated solids, through the screen, and out through the basket's openings. Next, the unit applies a wash liquor to wash the solids, drains the liquor again, rotates to reduce the solids' final moisture, and discharges the solids to a bin, container, or dryer.

The sedimentation centrifuge, available in solids-retaining disk, vertical solid bowl, and tubular units, accepts a measured flow or volume of feed slurry. The centrifuge rotates, allowing the mother liquor and accumulated solids to separate into two, or possibly three, distinct phases. How the liquid and solids are removed depends on the centrifuge type:

- In a solids-retaining disk centrifuge, the mother liquor is removed by both an overflow discharge and skimming. When the solids-holding capacity is reached, the unit is turned off and the bowl is manually cleaned out.

- In a vertical solid bowl centrifuge, when the unit's solids-holding capacity has been reached (generally determined by timing or by observing a break point at which the overflow liquid being discharged is the same as the feed slurry going in), the feed is turned off and the mother liquor is removed via a skimmer at high speed to expose the solids cake. Then the unit is slowed down and cleaned out automatically, or the unit is stopped and cleaned out manually.

- In a tubular centrifuge, which has very little solids-holding capacity and is used primarily for polishing liquids by removing very small particles, the unit is run until the quality of the liquid leaving the overflow decreases as the solids build up on the walls. The unit is eventually shut down and cleaned out manually.

**Running the pilot plant test**

Knowing your feed slurry's characteristics, how the slurry performed during the lab tests, and the limitations of each centrifuge allows you to select a particular machine for your pilot plant test. This test's extended run of a representative feed slurry stream through a pilot centrifuge will provide the operating knowledge and data you need to make your final centrifuge selection.

The pilot plant test will answer these questions about a centrifuge's suitability for your application:

- Is it affordable?
- Is it repeatable?
- Is it reliable?
- Is it applicable?

**Before the test.** As soon as possible, determine whether it's economically feasible to use a particular centrifuge for your liquid-solids separation. This will prevent you from spending time and money on a lengthy pilot plant test of a centrifuge you can't afford to purchase.

**Running the test.** The centrifuge manufacturer will typically lease a pilot centrifuge to you for the test; the leasing cost can sometimes be applied toward your centrifuge purchase. An experienced factory service or process engineer from the centrifuge manufacturer should participate in your pilot plant test. This engineer can help you set up the centrifuge, which typically takes about 2 days, and establish the proper operating parameters for it.

For the test, monitor the pilot centrifuge's operation and record the data over several shifts for many days. You can expect the test, including setup time, to run from about 30 to 60 days total.
To get useful results, make sure that the operating parameters during the pilot plant test don’t exceed the production centrifuge’s mechanical limits — that is, don’t run the pilot centrifuge in a way you can’t duplicate in the production centrifuge.

If the filtration rate is 1 to 3 gal/min/ft² or below, use a batch filtering centrifuge for the pilot plant test.

Finally, consider these centrifuge design factors:

- Continuous or batch operation
- Filtering or sedimentation type
- Basket or bowl diameter
- Basket or bowl volumetric capacity
- Basket or bowl rotation speed (in revolutions per minute)
- G force
- Liquid loading sensitivity
- Solids loading sensitivity
- Screen type and size options

Making your final selection

To select the centrifuge, review the information you’ve discovered during the lab and pilot plant tests. The first set of data covers feed slurry characteristics and process parameters, including:

- Production rate (in pounds per hour or gallons per minute)
- Specific gravity
- Percent solids concentration by weight
- Percent solids concentration by volume
- Solids shape (crystalline, granular, or fibrous)
- Solids particle size (in microns or mesh)
- Viscosity
- Desired phase (liquid or solid)
- Desired clarity or purity of end product
- Temperature
- pH level
- Wash requirements
- Wash liquor type
- Final moisture content

Based on a careful review of this information and your lab and pilot plant test results, you’ll be able to select a centrifuge for your application with confidence.

References


2. The third phase can be another liquid, such as oil, that floats above the mother liquor.

Mike Vastola is technical manager of the centrifuge division at TEMA Systems, 7806 Redsky Drive, Cincinnati, OH 45249-1632; 513/489-7811, fax 513/489-4817 (mvastola@tema.net). He holds a BS in chemistry and biology from Miami University, Oxford, Ohio.