Design for sampling—preliminary exploration

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Synopsis

A modern mineral processing plant represents a substantial investment. During the design process, there is often a period when costs (or overruns) must be compensated for by cuts in capital expenditure. In many cases, sampling and measurement equipment provides a soft target for such 'savings'.

This process is almost analogous to reducing the capital investment in a corner store by not including a cash register. The consequences will be quite similar—a serious lack of sound performance data and plenty of opportunities for theft— deliberate or inadvertent.

This paper makes the case that investment in sampling and measurement equipment is more cost-effective during the design phase. Further, a strong measurement culture will have many benefits including the ability to take advantage of small gains. In almost any business, there are many more opportunities to make small gains than to make large, step changes.

In short, if a project cannot justify the cost of accurate and reliable measurement of its performance, it probably should not be a project at all.

Introduction

The observations presented in this paper are based on the authors' experience—mostly negative and difficult—of sampling mineral processing plants at several hundred sites over a few decades and across a number of continents.

A modern mineral processing plant represents a substantial investment. During the design process, there is often a period when costs (or overruns) must be compensated for by cuts in capital expenditure. In many cases, sampling and measurement equipment provides a soft target for such 'savings'.

If we do make these 'savings', how can we accurately measure the plant performance for optimization?

This paper considers why making this 'saving' is a very poor strategy and outlines some ideas that are simple to include at design but difficult and expensive to retrofit.

More accurate measurement simplifies and enables sensible and correct decision making.

For example:

Consider a 1000 t/h processing plant which achieves a 0.5% improvement in throughput at grind at target size. This is an additional 5 t/h for 360*24*0.9 or 38 880 t over a year at 90% combined availability and utilization.

A plant which nets less than USD10-20 per ton processed (after mining costs) will not be a good long-term prospect. Hence, each 0.5% improvement which can be measured and verified is worth 0.4–0.8 million US dollars on the bottom line.

As there are potentially many more 0.5% improvements than 1% improvements, let alone 5% improvements, the perception that sampling is an 'optional extra', which may be omitted to 'save money', has a very poor business case indeed. Omitting sampling and measurement will 'save' profit as well as encouraging poor asset management and sacrificing future benefits.

Sampling objectives

The objectives of sampling can be broadly categorized as: measurement of production, metallurgical accounting/corporate governance, trouble-shooting, and optimization surveys. These are expanded upon in Table I.

Generalized objectives for each part of a circuit for a full survey are given in Table I. The listed data apply to each piece of equipment around the circuit. Additionally, equipment dimensions, power, pressure, etc are required.

Comminution circuits

- Feed rate
- Feed moisture

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Table I

Sampling objectives

Objective	Size samples	Assay samples	Benefits	Limitations
Measurement of Production	Final product—cyclone overflow, tails, mill discharge densities	Flotation concentrates, tails	General indication of the health of the plant and if grind and recovery are deteriorating	Generally doesn't indicate the cause of changes in recovery
Metallurgical accounting/ corporate governance		Feed, product, tailings	Measure of overall plant recovery and losses.	No information on where or how losses occur
Trouble-shooting	Production samples and mill products, cyclone products.	Production samples and intermediate tails in a float bank or between banks	Better indication of source of the problem	Incomplete data of circuit, extra samples often biased
Modelling and optimization surveys	RoM feed, feed and product streams of all equipment, flow rates of water and small streams—e.g. screen oversizes	Final grind product, concentrates by float bank, intermediate tails,tails and, final concentratea number of flow rates.	Full circuit mass balance—by size density and flow, model of circuit, quantifiable simulation outputs of the influence of circuit changes	Manpower intensive, difficult to do well, costly sample processing, simulations only as good as the models

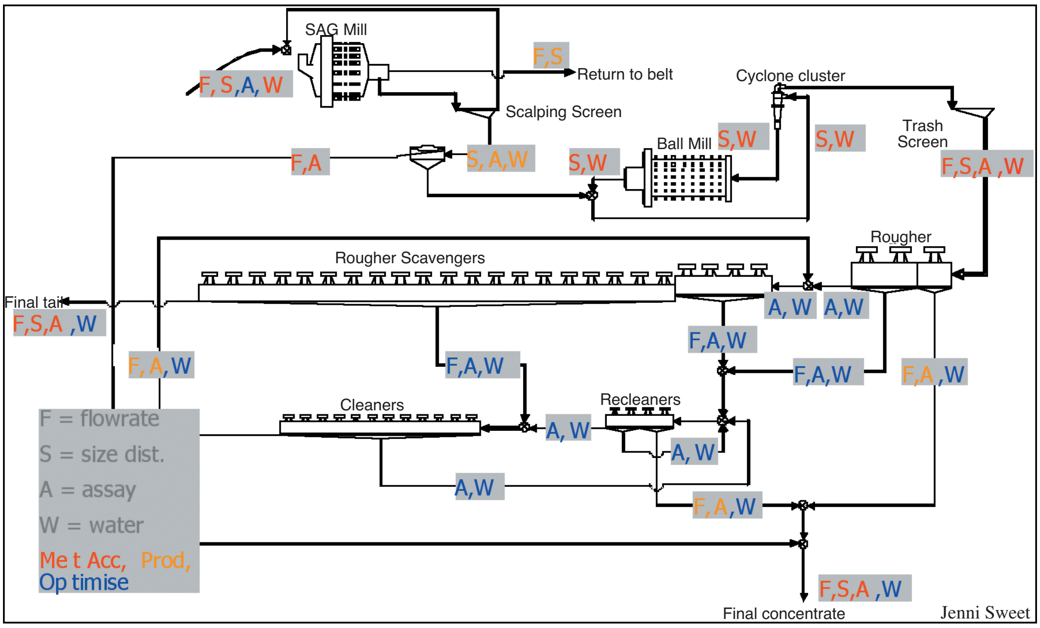


Figure 1—Example circuit illustrating desired sampling points

- ➤ Feed sizing
- ➤ Product sizing/rate
- ➤ Circulating load sizing
- ➤ Circulating load rate
- ➤ Mill filling—balls and ore independently
- ➤ SAG mill load sizing (usually an estimate).

Flotation circuits

- ➤ Feed rates
- ➤ Feed grades
- ➤ Froth flows
- ➤ Froth grades
- ➤ Percent solids.

An example of a typical flotation circuit, with the sampling points labelled according to type of sample required, and priority of sample, is illustrated in Figure 1.

The bulk of this paper considers the sampling requirements for each stream in some detail, as a basis for assessing the sampling requirements of any plant during the design phase.

Plant run-of-mine feed

An accurate measurement of 'true' dry feed rate, size distribution and composition is essential for performance assessment—not to mention providing a reference point for mine production and mine model composition. A representative sample for size distribution is 'easy' to achieve for fine particles and challenging for coarse particles. This is due to the numbers of particles issue, with there being too few large particles to give a representative sample for a manageable sample size.

For AG/SAG feed, good access to 10–20 m of the feed conveyor is essential. Dust covers should be designed to be easily removable for sampling. Ideally, this section of conveyor should provide vehicle access, which will allow a belt sample to be quickly shovelled into drums on the vehicle. The drums can then be sealed to preserve the moisture content. Suitable sampling strategies are detailed in Chapter 5 of Napier-Munn *et al.*[1].

At least a 5 m section should be well lit to allow digital photos to be taken to monitor feed size variation during testing. For new plant design it is strongly recommended that a camera imaging system is installed to give an online sample of feed size— especially for AG/SAG mills.

As both valuable minerals and moisture tend to be concentrated into finer size fractions, it is useful to measure assays and moisture by size fraction to allow errors due to size sampling to be estimated. This is sometimes impractical for moisture. However, in many cases, the coarser fractions are 'dry' for all practical purposes and the percentage finer than a few millimetres will be a more accurate estimator of moisture content than any direct measurement.

The wet feed rate to the mill usually does justify an 'accurate' weightometer. A suitable unit should use four idlers and be provided with a roller chain for quick and accurate calibration and checking. Reliable performance also requires accurate alignment of conveyor belt and weigh frame. An area that often receives insufficient attention is belt speed measurement. This is of serious concern as an error in this measurement is almost always a bias.

For toll treatment, the feed material should be trucked over a certified weigh bridge and the empty truck tared on the way out.

Toll treatment is given special mention as it is becoming more common to treat ores that come from many sources with different owners or business units. It therefore becomes imperative to measure mass and grade delivered from these sources.

The mining division of an organization may not accept in-circuit sampling—especially if there are concentration devices within the grinding circuit. Hence primary ore feed sampling will sometime be a necessity.

A favourite retrofit has been the hammer sampler, and an example is illustrated in Figure 2. With constant attention and high quality maintenance, hammer samplers do work but do not generate enthusiasm among their users. An issue with any belt sample is that the vibrating and shaking motion of the belt causes the fines to segregate to the bottom of the belt. As a consequence, if there is any loss of sample through imperfect cleaning of the belt, the sample will be strongly biased. The grade is invariably strongly biased to the fines, so any loss of fines results in a biased feed grade measurement.

When incorporating primary sampling at the design stage, a quite different strategy might be used. In essence a little more height would be added to the feed system. Added height is expensive but would allow for much simpler sampling. A conventional sample cutter would need to be enormous. A more interesting approach would be to use a sliding screen (at a conveyor discharge point) to remove a defined top size and direct it to a primary jaw crusher. The concept is illustrated in Figure 3.

The primary screen undersize is directed to a matching cone crusher There are some small 'waisted' cone crushers available from Wescones (www.wescone.com.au). These crushers have excellent top size control. For those familiar with the JKMRC crusher model[1], K1 and K2 are just about the same for these crushers. Therefore, their product should be ideal for sub-sampling.

If the mass of -50 mm material is excessive, for sufficient plus 50 mm material, then this stream can be sub-sampled. The jaw crusher product would then be split down by the same ratio, so as to maintain the correct ratios. The usual area of failure of primary samplers is over-coarse feed, but this one would measure the coarse fraction at the same time, thus resolving this issue.

A more traditional approach is to use a sampling tower for lump (30 x 6 mm) iron ore. These are expensive, mechanical and maintenance nightmares and the need for something simpler and much more reliable should be obvious. The Wescone type crushers are potentially part of a much simpler solution.

Mill product

In most cases, an assay sample of the comminution circuit product will be more accurate than any practical feed sample—because particle size has been reduced and in-circuit mixing will reduce short-term variation. This sample overcomes the issues of obtaining a representative sample from the run-of-mine feed or primary crusher product.

A well-designed proportional sampler may also provide an independent estimate of the mass of feed.

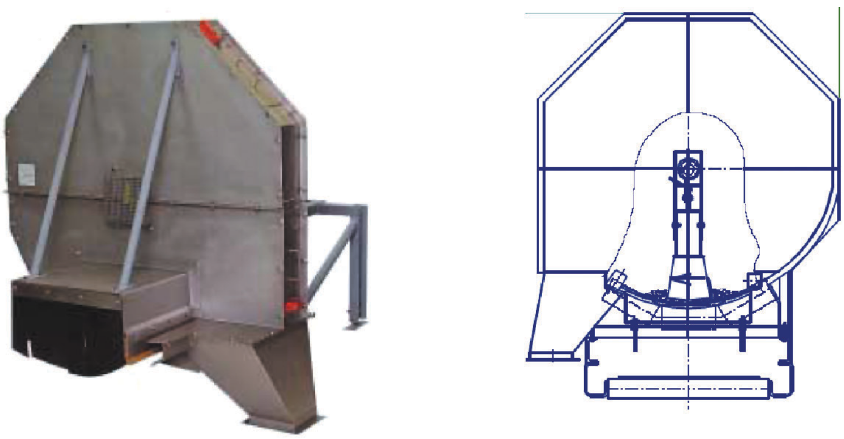


Figure 2—Hammer sampler (M&W Jawo Handling) http://www.tema.net/products/sampling.html

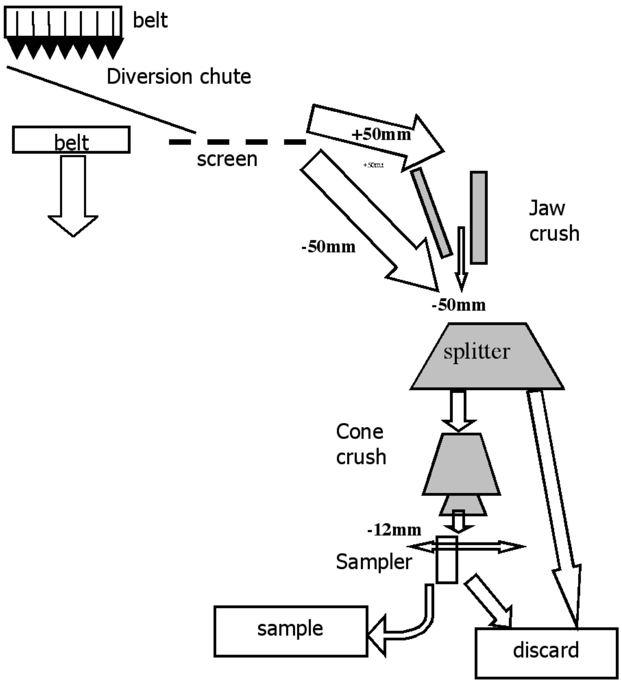


Figure 3—Run-of-mine feed sampling

The increased degree of liberation of particles of different specific gravity can bring its own problems with segregation. This needs to be considered in launder and cutter selection. Liberated gold causes special problems because it can easily accumulate behind ball mill liners and in pump sump dead zones. Therefore a sample of AG/SAG ground product may be less prone to in-mill accumulation. The traditional strategy of 'rattling the mill' at the start/end of each accounting period is some times helpful as is a pre-concentrator treating all or part of the circulating load.

To know when each of a different range of feeds is being processed, the following strategy is proposed. As each ore from a new source is delivered, a radio tracer is dropped onto the feed belt. Passive transducers with radio frequency identification (RFID) are becoming readily and cheaply available. They can be viewed as consumables. If there are a number of primary mills then this ore is fed into a dedicated silo—which is deliberately run down to a low level in preparation for the next feed lot to arrive. A transponder located at the head of the mill feed belt triggers the start of the new feed. After about three mill residence times (to clear out the previous ore) the mill product (which can be cyclone overflow or screen undersize) is automatically sampled at 20 minute intervals over a two-hour period. This provides a sample of few kilograms which is representative of 5 000 t rather than a snap feed belt sample of 50 kg, upon which to base this important accounting sample. Additionally, the performance of the mill will be well characterized for that particular ore, which will assist in mill optimization strategies.

In-stream concentrators

Concentration devices (such as flash flotation or a gravity circuit) within the grinding circuit may remove a concentrate before the comminution product can be sampled. Therefore, it is essential that product streams from these circuits be accurately sampled and assayed and concentrate flow rates well measured.

For batch gravity concentrators (such as a Knelson concentrator), the concentrates can usually be dried, weighed and sampled in a well-controlled environment. For flash flotation devices, an opportunity should be provided to divert the complete concentrate flow rate into a container such as a 200 ℓ drum for a precisely timed period. A pneumatically actuated diverter controlled by a precise timer is recommended. Such a system is simple to include at design time and often very difficult to retrofit. As around half of total circuit production is often contained in this stream, it should be straight forward to justify accurate flow measurement and sampling. Because of the difficulty of obtaining a good coarse feed assay to close the balance around a flash flotation cell, a measure of flow rate is always useful. The flow rate and assay samples are independent, with the flow rate sample being returned to the circuit product after it has been weighed.

Mill discharge

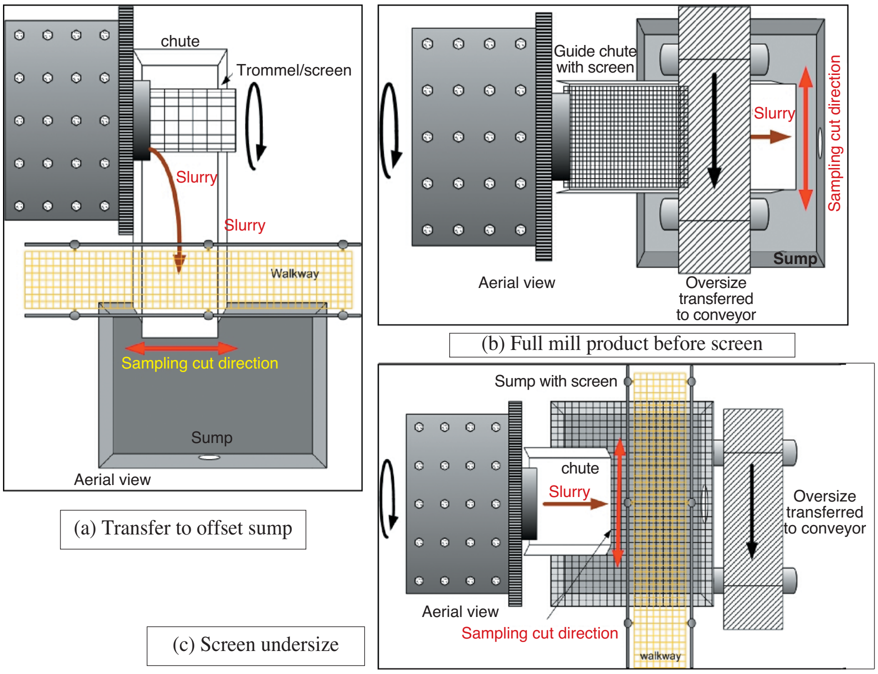
The design of many milling circuits make mill discharge streams almost impossible to sample. Typically, trommel and screen deck mill discharge set-ups are a serious impediment to accurate sampling of the undersize product—although they usually provide a good sampling and flow measurement (via recycle) for oversize—provided good, safe access is included at the design stage.

A transfer chute from the mill to the sump is easily implemented at design stage by offsetting the sump from the mill. For a SAG and ball mill sharing a sump this arrangement is standard. This allows the lip of the chute to be sampled, Figure 4a. This can be applied to a trommel or screen discharge.

For a screen discharge it is often not desired to change direction, in which case the sump can be moved slightly away from the mill, and a transfer chute installed, Figure 4b. For discharge onto a screen, it is easiest to shift the screen forward, away from the mill, so that a short transfer chute can be installed, Figure 4c. This allows the full mill product to be sampled off a good launder. This has the added process benefit of supplying a better distributed feed to the screen. It has been observed that generally less than half the length of vibrating screens serving SAG/AG mill discharges is utilized, so the transfer chute can extend over the sump without loss of screening capacity.

For a SAG/AG mill with pebble ports it is inconvenient and difficult to sample the full mill product, as an outsize sample cutter is required. In this case it is preferable to sample the screen undersize. If it is not desired to offset the sump, as in Figure 4a, then a chute can be placed under the screen and the lip allowed to overflow near the far end of the sump, ensuring that the stream, which has a low velocity, does not impact on the side of the chute, Figure 4c. Safe access over the side of the sump should provide an excellent stream within easy reach of a manual sample.

For all of these options, a non-corroding walkway should be provided over or along the edge of the sump to allow for safe manual sampling as the pulp flows over the lip of the

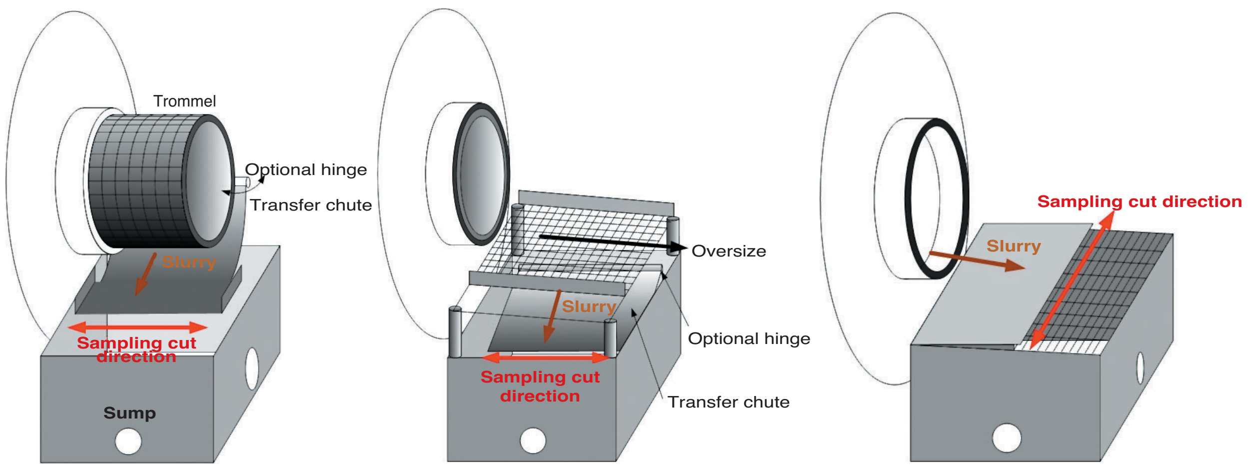


(a) Transfer to offset sump

(b) Full mill product before screen

(c) Screen undersize

Figure 4—Mill discharge sampling



(a) Trommel side chute (b) Screen side chute (c) Step on screen

Figure 5—Mill discharge retrofit sample points

chute into the sump. Plastic or rubber non-corroding walkway panels should be used so as to avoid corrosion, which is a safety risk. Alternatively, a fully removable structure can be used that is placed over the sump for sampling only. These solutions are easily implemented at the design stage and often impossible to retrofit.

Retrofits

If a retrofit is required then the following are suggested for the above scenarios.

For a mill with a chute that cannot be accessed where it enters the sump, a relatively simple design solution is a stepped launder en route to the mill discharge sump. With a reasonably wide step (up to 1.2 m wide and a drop of 150–200 mm), a flow rate of 1 000 t/h can be accurately sampled by hand—for particles up to a few millimetres top size. If need be, this can be a rubber covered steel plate, which is only fitted for the sampling campaign.

For screen or trommel undersize, a transverse chute can be provided for the first metre or so, which is the zone in which all the fines pass through the screen, this can be checked through visual inspection. At least 300 to 500 mm of clear access should be provided between the end of the chute and the wall of the sump to allow an accurate manual sample to be taken. More clearance will reduce splashing. A heavily rubber lined chute will last a long time in such a flow if the slope is adjusted to keep the velocity as low as is practical. The chute can also be designed to be hinged out the way when not in use. These ideas are illustrated in Figure 5 a and b.

For a screen, where the sump is already too narrow for any sort of access, a blank horizontal section can sometimes be fitted to the first 300–500 mm of screen to provide a 100 mm 'step' with a lip at which a representative manual cut can be taken, Figure 5c. This system can be employed when the screen area is underutilized, which is usually the case for these mill discharge scalping screens.

Samplers

Once access has been provided, most of the streams can be manually sampled. However, larger flows require an actuated primary sampler feeding into a launder, which can then be manually sampled. A pneumatically driven, flow-through, primary cutter is usually the most practical for this task. Such a cutter does not require additional headroom or need to withstand high inertial forces. Most commercial cutters reverse the flow. A flow-through cutter experiences reduced driving force and requires less restraining force. The collection launder can be placed well clear of the primary flow.

Despite the higher up-front cost, commercial drive mechanisms will usually provide a lower total cost solution than in-house construction. There are many ways for such devices to be poorly designed so ongoing modifications and breakdowns result in an overall higher cost and, more importantly, in non-availability or non-optimal (biased) samples. The lesson is that a reputable and experienced sample manufacturer or supplier must be used.

Cyclone feed

A cyclone feed distributor provides a well-mixed zone, well suited to representative sampling. If at least one (and preferably two) blank cyclone feed distributor outlets are provided, one can be used to mount a probe type sampler. The probe diameter should be at least 3 times the diameter of the largest particle. The probe is inserted into the turbulent region of the distributor. A length of hose is used to provide enough back pressure to match the pressure in the cyclones, to reduce the sample flow to something manageable, and to provide an easy sample point.

Blanking off the overflow of a standby cyclone, and opening the feed to it for a brief period, provides a feed sample at the underflow. This works well, but has the disadvantage of disturbing the circuit. This technique can be used to check the validity of the probe sampler, and the depth of insertion of the probe adjusted if required.

Density and flow measurement on the vertical line to the distributor should of course be standard practice. One trap to be aware of is that high density minerals (such as sulphides and magnetite) will concentrate in the circulating load and the solids s.g. from the cyclone sample (not the mill feed) should be used for the circulating load flow rate. If the grade varies widely, a grade model correction may be necessary for accurate calibration of the density gauge.

Cyclone underflow

For a cluster of cyclones discharging into a launder, the outlet from the launder can have a 300 mm step built into it. This step will provide an ideal sampling point for the combined underflows. Access is provided via a hatch above the discharge outlet.

For neatness and to contain splashing, the underflows are often sealed into a covered launder box. If this is the case, then the lift-off covers must provide sufficient space for sampler access, Figure 7a. There needs to be sufficient space on either side of the spigot for a sample cutter to pass through the whole stream into a clear area on either side. There also needs to be sufficient vertical space, at least

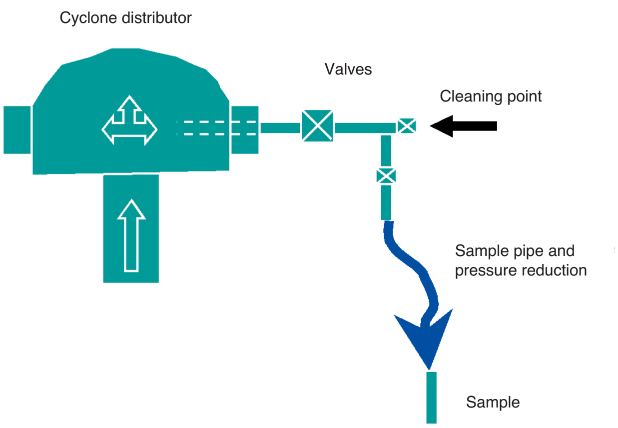


Figure 6—Cyclone feed probe sampler

(a) Cover plate removed, revealing a roping cyclone (b) Good operator view and access

Figure 7—Cyclone underflow access

300 mm, below the spigot so that a cutter can fit under the cyclone. It should be noted that a large cutter width is required to receive the coarse cyclone underflow, and this stream has a high velocity, thus a large volume is collected, typically 5 to 10 ℓ. Many plants operate successfully, and cleanly, with open underflow troughs, Figure 7b. These are favoured by the authors as they not only provide easy sample access, but also, and more importantly, provide an excellent visual measure of cyclone operation—as the flare angle of the underflow is sensitive to cyclone performance. The consequence of a hidden underflow is illustrated in Figure 7a, where a cyclone in a cluster is roping.

Cyclone overflow

This is usually provided with an auto-cutter, as it is an important metallurgical accounting sample. If this is not the case then the overflows must not be directed straight into a pipe and on to a sump. It should be ensured that the combined overflows pass through a suitable launder, with easy access for manual sampling.

Screen oversize

The recycle stream in a milling or crushing circuit provides a rapid and strong indication of changes in ore type. The screen oversize provides an ideal stream for online measurement of flow rate, and an easily sampled stream for measuring the recycle size distribution.

Access to screen oversize is easy to design in; good and poor access is illustrated in Figure 8. The lip of the screen should be within easy reach, no more than 500 mm from the edge of the discharge box. There should be a safe walkway and rail (usually the side of the discharge box) to provide access. Walking along the screen with a cutter provides an excellent sample. The flow rate can be measured by progressively sampling each section of the screen for a fixed period. For online flow rate measurement an impact weigher (www.isa.org ‘Applying Impact Flowmeters’) can be used, or it can discharge onto a short transfer belt that has a weightometer.

Screen undersize

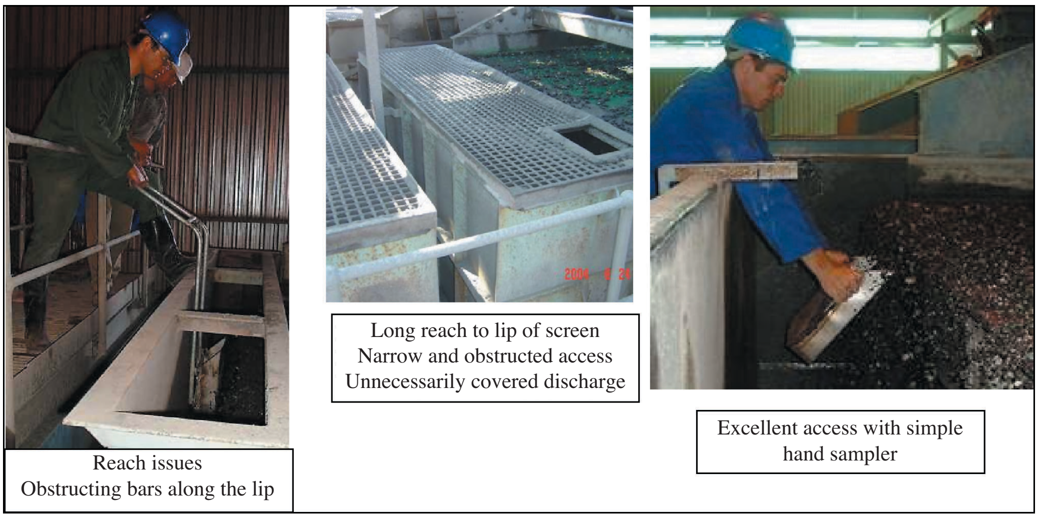
Usually the screen undersize discharges directly into a sump—which is clearly a good engineering solution, but prevents sampling access. Any sample taken by waving a sample cutter under the screen is dramatically non-representative. All too often the undersize is sealed into a discharge box that discharges vertically down a pipe into a sump, and is totally inaccessible. The screen undersize stream is moving at a low velocity and for wet operations it flows easily. It is therefore an ideal stream to direct towards a discharge chute that presents an ideal sampling lip. This flow can then discharge into the sump of transfer pipe.

Pumped streams

Where a pumped stream changes direction from vertical (or near to it) to 45 degrees or horizontal, an in-pipe sampler can be inserted, provided that the flow straightening length of the vertical section is greater than 10 times the pipe diameter. The key to accurate sampling for these devices is to use three or more turbulence rods one to two pipe diameters ahead of the sample point. One of the authors has tested this type of sampler against a well-designed, ‘classical’ three-stage, cross-launder sampler. The in-pipe sampler with a pneumatically actuated switching secondary sampler provided ‘identical’ results at a fraction of the capital and operating cost. However, pipe bends are excellent classifiers and poor attention to mixing will certainly produce biased results, as has been measured on a number of sites. As emphasized earlier, only reputable, proven sampling equipment should be used; one is illustrated in Figure 9. The accuracy of the sample should be verified once it is installed, and thereafter it can be used with confidence.

Gravity flow streams

Where streams flow under gravity, usually towards a sump, it is best to interrupt this relatively low pressure and velocity stream for sampling than have to cope with a high pressure pumped stream. Under gravitational flow streams become



Reach issues
Obstructing bars along the lip

Long reach to lip of screen
Narrow and obstructed access
Unnecessarily covered discharge

Excellent access with simple hand sampler

Figure 8—Screen oversize sampling

strongly segregated, so sampling should be conducted with care. There are excellent samplers on the market. Two stage rotary cutters have been applied for many years, but present operation and maintenance issues. Static flow-through splitters, have much to recommend them in large flow rate applications because of their lack of moving parts and minimal head losses. The ANSTAT samplers developed by AMDEL (now ThermoGamma Metrics) are an example, Figure 10. Their size means inclusion at design is strongly recommended. It is not recommended to allow a change in direction, such as the application illustrated in Figure 10, as this causes mixing and sanding issues that can negate the advantage of this simple cutter.

Figure 9—In-pipe sampler (Heath and Sherwood)

Dry streams

Good access should be provided for belt cuts of pebble and crushed rock streams transported on conveyor belts. Access at transfer points allow for online sampling, which can be most useful for performance analysis, as it is not necessary to stop the belt, and associated comminution equipment, to take a sample.

Flotation pulps

Drop boxes between flotation banks often provide a relatively well- mixed zone, which can be sampled using a probe sampler. Beware of sampling accumulated froth on the top of a drop box. A small vertical shaft pump with integrated sump can be used to return excess sample to the flotation bank—or shared by several samples where circuit flows are large.

Flotation froths

Measurement of froth flows and accurate samples are required to provide key performance information. However, launders are often carefully designed to prevent spillage—and any sort of measurement access. It should be noted that flow rate is a key issue that is usually overlooked in design (and sampling) but is critical to performance assessment.

Ideally, similar products are directed into short launders, which can be safely and accurately sampled over a receiving sump. Unfortunately, a more common approach is a ‘rat’s nest’ of pipes with minimal access. Applying rigorous discipline to launder design will have benefits in maintenance and measurement.

Where mining hose is used, it should be set up to allow diversion to a catch container. If sufficient head is available, placing a catch container above each sump will greatly simplify flow measurement. A relatively small container can be used to measure quite large flows. For example, 200ℓ over 10 seconds is equivalent to 700 m^3/h—which is more than adequate for almost all concentrate flow rates. A simple overflow box, of a known volume to the lip, can be utilized. The measurement starts with the valve closed, and this is

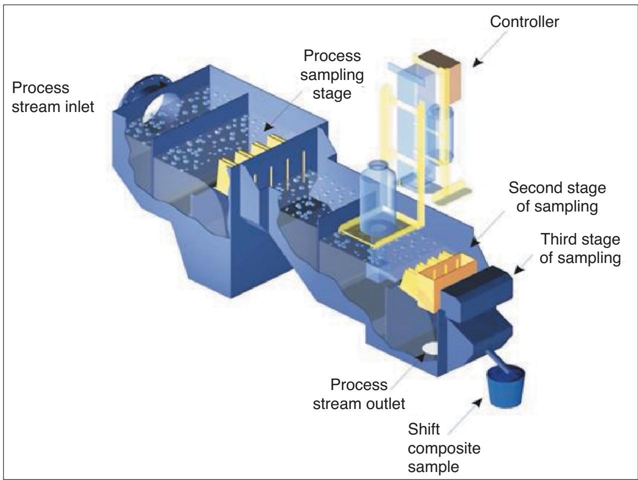


Figure 10—ANSTAT sampler

opened to drain the box once the measurement is complete. For streams that require regular flow rate measurements, the whole system can be automated with ball float switches and a pneumatically operated discharge valve.

If the concentrates are pumped, the pumped stream samplers discussed earlier can be used. However, air entrainment makes nuclear density and most instrument flow measurements quite difficult. If the froth is being pumped over a substantial distance (or pressure head) then it should be measured at the highest pressure point where the entrained bubbles will be most compressed. Without de-aeration, the flows will be least subject to error in this region. For corporate governance the final concentrate taken as 20 minute incremental samples, plus an accurate measure of flow rate, provides an accurate measure of final grade and total production. This is excellent in the short-term, and will be better in the short and long-term than a spear sample from a truck or wagon. However, a well-designed feed system for truck, wagon or container will provide an opportunity for concentrate to flow past a single point where it can be sampled representatively and be related to the contents of each container.

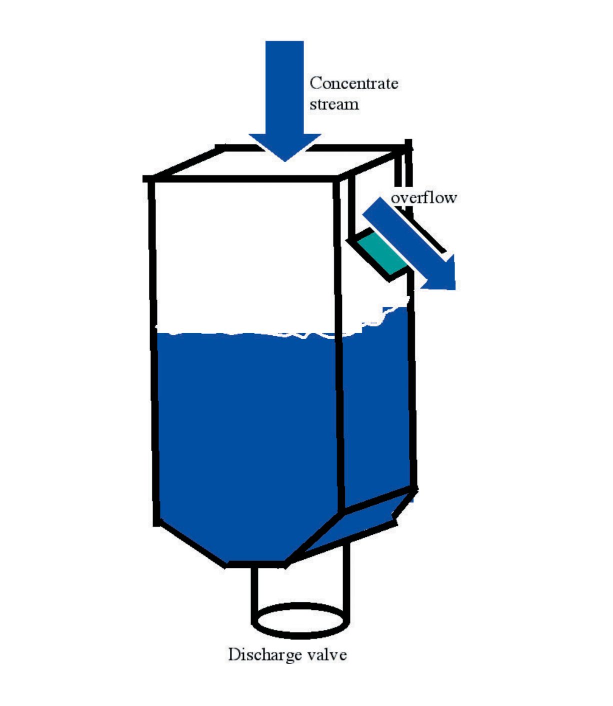


Figure 11—Concentrate flow rate box

Samplers

Once access has been provided most of the streams can be manually sampled. The basic guideline of the cutter width being at least three times the diameter of the largest particle should be adhered to—this is an amazingly common error with sampling of coarser streams, such as cyclone underflows. The cutter must not overflow, so it requires spare volume, usually about 50% spare is recommended. The cutter must cut the full width of the stream, and pass through at a constant velocity. It is common to see standard production samples as well as campaign samples taken from an accessible portion of a stream—this is always biased. The cutter should pass through perpendicular to the stream and the sampling slot should be parallel to the stream flow. These simple and obvious guidelines can be applied at design stage to ensure that all streams are amenable to accurate sampling.

Most streams around a circuit can be manually sampled; however, larger flows require an actuated primary sampler feeding into a launder, which can then be manually sampled Figure 12. A pneumatically driven, flow-through, primary cutter is usually the most practical for this task. Such a cutter does not require additional headroom or need to withstand high inertial forces. Most commercial cutters reverse the flow. A flow-through cutter experiences reduced driving force and requires less restraining force. The collection launder can be placed well clear of the primary flow. Such a system is ideal for mill discharge streams.

Despite the higher up-front cost, commercial drive mechanisms will usually provide a lower total cost solution than in-house construction. There are many ways for such devices to be poorly designed so ongoing modifications and breakdowns result in an overall higher cost and, more importantly, in non-availability or non-optimal (biased) samples. It is the practical experience of the authors that home-made samplers often produce biased samples, due to issues such as non-optimal mixing. The lesson is that a reputable and experienced sample manufacturer or supplier must be used.

Areas to be addressed

When relating the ideas and discussion in this paper to what is commonly encountered on plants, a number of areas that can be addressed at the design stage are highlighted.

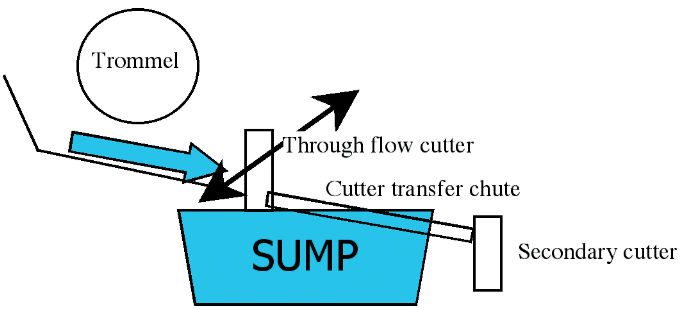


Figure 12—Flow through cutter for large stream flows

Metallurgical accounting

- Ore source tracking
- Feed moisture
- Feed grade at circuit product
- Concentrate grade and flowrate
  - in-circuit concentrators (flash float, gravity)
  - intermediate concentrates (roughers)
  - final stream

Production and control

- Mill product stream access
  - few plants know their actual mill densities
- Cyclone underflow
  - sample access on combined stream
- Screen oversize
  - sample access
  - flow rate via small transfer conveyor and weightometer
- Intermediate concentrate and flow rates (roughers)

Circuit optimization

- All gravity flow streams should have a stepped sample point
  - access to good manual sample
  - can install auto-cutter if desired
  - launder with rectangular lip and access at sump entry
- Cyclone feed
  - take-off from spare point on distributor
  - pressure and flow reducing pipe
- Screen oversize
  - accessible for easy manual sample
- Flotation bank tails
- Build in sample access points
- Flotation concentrates
  - give access
  - allow for flow rate measurement

Conclusions

For those who are designing a plant, beware of cost cutters. They are usually profit cutters in disguise. It is always worth considering whether there may be a more cost-effective way to achieve an objective. Omission (or supposed delay) of sampling and mass measurement equipment is not worth considering as organizational functionality is sacrificed. This equipment is an essential part of any plant.

Sampling and mass measurement are much more cost-effective if designed into the plant. Most of the suggestions for sample access that are presented in this paper can be included at almost no additional cost. In addition, suitable and safe access for operations and maintenance can be included at the same time.

It is usually not cost-(or time) effective to design your own samplers. Well-designed samplers and measurement instruments are certainly not cheap to purchase—but they are exorbitantly expensive to develop in an operating plant. Levering off the expertise and experience of established suppliers is strongly recommended. (Ask their existing customers.)

Lastly, good, safe access to flows allows operators to 'see' problems and to take samples when necessary.

Do

1. Try to develop a strong measurement culture at a new operation. This culture is very difficult to retrofit
2. Provide access to each new stream.
3. Provide flow rate measurement for key concentrate and recycle streams. For slurries a simple timed cutter and weighed sample, linked in with a metallurgical sample that is used for percent solids determination, is adequate
4. Shift equipment alignment to allow the insertion of sampling points, there is no need to be locked into symmetry
5. Allow streams to pass over launders, for accurate sampling
6. Make streams that give a visual cue to plant operation visible, such as cyclone underflow and screen oversize
7. Firmly justify the need for sampling as an integral part of plant design, and ensure that the samplers are part of the engineering solution.

Don't

1. Direct pipes down into sumps leave the flow accessible
2. Use home-made samplers; save in the long-term by purchasing well-proven samplers
3. Sample and assay coarse samples where alternatives are feasible
4. Be bulldozed by cost cutters—they are mostly profit cutters
5. Let engineering design for convenience override metallurgical requirements.

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Some useful websites:

http://www.heathandsherwood64.com/mineral.html

www.wescone.com.au

www.isa.org

http://www.tema.net/products/sampling.html ◆