Dry Process Sampling
Representative sampling

As a customer, you can always trust that the essential requirement for representative sampling is in focus for any sampling solution delivered by FLSmidth.

Having completed hundreds of industrial process stream sampling projects, FLSmidth is a competent and experienced supplier of complete sampling solutions to the cement and mineral industries. We understand the basic theory of sampling (TOS), the rules of good, representative sampling practices as well as applicable industry specific international standards. Combining sampling with deep knowledge of relevant processes and industry specific experience, we have translated the theoretical specifications into practical, efficient and cost effective sampling solutions. The so-called sample variogram is an efficient way of evaluating an actual sampling installation. FLSmidth utilises variograms in our sampler design, and we recommend that our customers apply this method to document their sampling performance as well as to determine the optimal sampling frequency, which always depends on the plant specific process flow characteristics.

For the industries serviced by FLSmidth, we distinguish between sampling solutions for:

**Cement industry**
- Cement process sampling: Powder & granular material samplers

**Mineral industries**
- Ore sampling: Typically coarse, bulky, high capacity process flow sampling.
- Intermediate dry process sampling: Powder & granular material samplers.
- Slurry sampling: Feed, concentrate and tail slurry stream sampling systems.

**Homogeneity of sample process flows**

All material in a process flow must have an equal probability of being sampled. This is a basic principle in representative sampling, and should therefore always be seen as the ideal sampling concept. The ways in which this ideal sampling concept is translated into practical, cost effective sampling equipment solutions, differ from industry to industry and from one sampled material to another. It also depends greatly on the homogeneity of the sampled process flow, as these different case examples will show.

A run of mine/quarry ore stream – after primary/secondary crushing - on a conveyor belt will typically show high inhomogeneity in all 3 dimensions: along the length of the conveyor (L), across the conveyor (W) and in the depth of the material layer (D). In addition, particle size segregation may be distinct in the W and D dimensions. Needless to say, this puts high demands on the sampling, which is complex and will require multi-stage sampling towers with sample cutters, splitters, pulverizers and sometimes drying equipment. Following large grinding mills, a significant particle size reduction and homogenisation of the process flow has taken place. This simplifies the sampling scenario. The majority of the inhomogeneity is now in the L-dimension (or in the time domain), while the process stream ‘cross sectional’ inhomogeneity has been significantly reduced due to mixing in the grinding circuit.

When dealing with dry grinding, the powder product streams are transported by gravity in vertical chutes, or by ‘air suspension’ in horizontal covered airslides (Fluxoslides) or sometimes in open belt conveyors. As the ‘cross sectional’ inhomogeneity is greatly reduced – compared to the product flow before the grinding mill – practical experience in certain industries (and here cement production is a good example) has demonstrated that ‘one-dimensional’ sampling devices such as sampling screws (augers) for vertical chutes and sampling ‘tubes’ for horizontal air slides will deliver representative samples.

In other dry process flows, gravity caused segregation - e.g. originating from large differences in particle densities - calls for rotary cutter devices, where a two-dimensional cross cut of the process flow is taken. For wet grinding circuits and in flotation circuits, the slurry product is transported in vertical or horizontal pipes/launderas, which have different issues regarding representative sampling.

Turbulent flows are required in typical process streams to maintain the slurry in suspension. Better homogeneity is achieved if the solids in the slurry are finer and lighter. Gravity begins to have a significant impact when particles are above 100 µm in size; for very dense particles, e.g. precious metals, this may occur with a smaller sized particle. Turbulent, well mixed slurry flows enable the use of single stage samplers with a simple fixed cutter design for gravity flows and pressure pipe samplers for pumped slurry streams. Although this is not cross sectional sampling as the theory calls for, both concepts provide samples with adequate representation. None ideal mixing or broader particle size ranges call for linear or rotary cutters pending the characteristics of the sampling point.

Neither single fixed cutters nor pressure pipe samplers can produce a sample suitable for purposes such as metallurgical accounting, but may be adequate to serve an online analyser.

When online analysers – as often is the case - are associated with the sampling points, it is essential to keep the slurry flowing in the narrow feed hoses to the analyser as well as to clean effectively between different sample streams, when the analyser serves multiple sampling points.
Representative sampling, continued

Proper selection of sampling devices and their location is always of utmost importance to meet the overall objective of sampling, analysis and related process optimisation. There are no methods of analysis that can compensate for errors/bias in the sampling stages. Therefore, it is crucial to always ask yourself if the sampling method is adequate when investing in sophisticated analysis technology.

For metallurgical accounting of the main feed, concentrate and tail streams, the typical picture is to have multi-stage (typically 2 or 3) sampling installations. Cross cut samplers (linear or rotary sample cutters) as well as samplers with multiple parallel fixed cutters are typically used. Such sampling installations can be used for both metallurgical accounting and online analysis.

Sampling standards/ Sampling solutions
In some industries, e.g. iron ore, the samplings are carried out in accordance with comprehensive international ISO standards, where the described sampling methodology leaves only little room for variations in the applied sampling components. In other industries, a combination of focus on practical, cost effective sampling solutions and acquired experience has meant that implemented sampling concepts may not fully meet the ideal theory.

So, while understanding the sampling theory in every aspect, both suppliers and users of sampling equipment will also take into consideration the cost of a given sampler product and the ‘cost vs performance’ equation. Will you pay a high price for a marginal, barely measurable improvement? For example, look at the above described sampling practices for the cement production process. According to theory, a ‘one dimensional’ sampling screw should be replaced in a rotary cutter, so that each spot in the 2-dimensional cross section is sampled. However, this will mean a significant cost increase not only for the sampling installation, but also related to the process design around the sampler. Is this justifiable if the difference in documented sampling performance is only marginal? If the implemented sampling is found adequate, should it be rejected just because it may not meet the ideal theory?

In FLSmidth, we have a pragmatic approach to sampler design and we deliver well performing state-of-the-art sampling solutions for a range of different process applications. We do this with competent sampling theory combined with solid practical experience from different industries. Our sampling solutions are often the fundament for added services, such as fully automatic sample preparation & analysis as well as software solutions for process optimisation, both regarding to quality and operation.

Proper selection of sampling devices and their location is always of utmost importance to meet the overall objective of sampling, analysis and related process optimisation. Other important factors to consider are correct installation and ease of access for maintenance and inspection.

FLSmith offers a complete product program for sampling dry products for all types of process sampling in a cement plant from quarry to bagged cement. For other minerals industries, our product program comprises sampling stations for ore sampling as well as in-process dry (granular/ powder) or slurry sampling solutions.

This brochure describes our sampling products for the cement industry as well as including our automatic sample transport product program, which complements our samplers to provide a fully automatic sample collection from process to a central laboratory facility and/or to online analysers.

Gy’s relation between particle size and minimum sample mass

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<tr>
<td>5mm</td>
<td>1kg</td>
</tr>
<tr>
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Derived from the work of the ‘father’ of the Theory of Sampling (TOS), Pierre Gy; these figures show the theoretical correct minimum sample mass in one cut of a solids material stream as a function of the largest particle in the sampled material.

Material mass flow from process to analysis

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The table illustrates the masses involved in sampling and X-ray analysis of a typical dry powder process stream, and demonstrates the importance of homogeneity and sample representation.

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Sampling in the cement industry

Sampling takes place throughout the cement plant for checking chemical processes, process optimisation and checking silo homogenisation as well as for documentation of product quality at various product stages. Typical analyses (but not all) conducted on the sampled material comprise:

- Elemental analysis (by XRF)
- Mineral composition (by XRD)
- Finess, e.g. particle size distribution, Blaine, sieve residue etc.

Two types of sampling programs exist:

A) A routine sampling program is conducted at frequent intervals (every ½, 1, 2, 4, 8 hours or longer intervals) during normal operation. These samplers are permanently installed at designated locations and usually operate fully or semi-automatically. Most samplers collect composite samples in the time intervals between sample collection, but spot sampling is regularly used at a few locations. Samples are collected on a defined time schedule and brought to the laboratory manually or automatically; in the latter case by means of automatic tube transport systems.

B) For initial commissioning of process equipment and for trouble shooting purposes, the samplers mentioned under A) will naturally be used, but they may not be sufficient to provide all the necessary details. Therefore, it is required to have a number of inspection sampling access points, where manual spot sampling devices can be inserted to extract random samples.

Using FLSmidth terminology we distinguish between:

- Inspection samplers: Manually operated, which are simple, movable mechanical devices for spot sampling and performing activities listed under B) above.
- Manual samplers: Permanently installed, which are automatically operating samplers for routine sampling with manual sample collection.
- Automatic Samplers: Permanently installed, which are automatically operating samplers for routine sampling with automatic sample collection via tube transport system.

The following pages outline the off-the-shelf cement industry sampling solutions – manual or automatic - we apply in FLSmidth for new cement plant projects as well as for projects with delivery of sampling equipment to existing plants. In our experience, well over 90% of all sampling requirements can be solved by selecting one of the preengineered standard solutions. In the remaining few cases, a customised project solution may be built from a wide range of standard components available.

Many of the listed sampling solutions are built around two key sampling components: the PSM chute sampler and the PS-AS air slide sampler. Let us take a closer look at these in terms of how the composite sampling is arranged and how the sample delivery/collection takes place manually or automatically.

Backed by over 125 years as a supplier of process machinery, FLSmidth has a comprehensive cement plant sampling product program covering basically every occurring process activity from boreholes, exploration/quarry blasts to delivery/dispatch of cement.

Use of pre-engineered off-the-shelf standard solutions means:

- Short delivery time
- Cost effective solutions
- Consistently high sampling quality
- Reliable equipment operation
- A safe choice

A sampling tube with a thin slot is placed with the slot located opposite the direction of the material flow. With intervals of a few minutes, the tube is rotated 180 degrees, so that the slot is focused on the material flow and a small sample portion (=sample increment) is collected and routed to the mixing tank. The mixing tank has internal lifters rotating with the mixer motor, which means that the sample material in the tank at all times is a homogeneous mix. The variable frequency motor can be adjusted, so that the time it takes to fill the mixing tank is within ½ to 2 hour, with ½, 1 or 2 hours as the typical sampling intervals.

A sampling screw (auger) rotates slowly (a few rpm's) and continuously extracts powder material from the sample process stream in a vertical or close to vertical chute section. A mixing tank – on the same axis as the screw – collects the material for a composite sample. The mixing tank has internal lifters rotating with the auger, which means that the sample material in the tank at all times is a homogeneous mix. The variable frequency motor can be adjusted, so that the time it takes to fill the mixing tank is within ½ to 2 hour, with ½, 1 or 2 hours as the typical sampling intervals.

Chute sampler

Air slide sampler
Sampling in the cement industry

A high degree of automation in sampling means that all samples are taken:
• at the right time
• at the right place
• consistently

Further important benefits of automated sampling from an experienced professional supplier such as FLSmidth include:
• representative sampling
• minimum sample to sample cross contamination
• fail-safe sample identification
• correct time stamp
• automatic product assignment

The below diagram outlines a typical selection of samplers employed for a modern cement plant from FLSmidth: 5-7 sampling locations have automatic transport integrated with the automatic samplers. Another 4-8 sampling locations are equipped with samplers with manual sample collection. Manually collected samples may enter the automatic transport system via manually operated sending stations, servicing a number of nearby manual sampling locations.

1. Raw meal
2. Filter dust
3. Kiln feed
4. Hot meal
5. Coal meal
6. Clinker
7. Cement mills
8. Cement silos & cement dispatch

Manual sample collection.
Automatic sample collection via tube transport system. Alternative sampling location.
This page outlines the greater part of available off-the-shelf solutions for manual samplers, which in our terminology means automatically operating sampling devices, where activation of the sample delivery and sample collection is manual.

A local control box is an available option for all samplers with manual sample collection. If not included within A.ESmith's supply range, the customer must supply the sampler control either from the central control system or a local control box.

**Typical key specifications for most powder samplers**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Minimum/Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature range</td>
<td>-10 ~ +40 [°C]</td>
</tr>
<tr>
<td>Extended temperature range</td>
<td>-20 ~ +55 [°C]</td>
</tr>
<tr>
<td>Maximum temperature of sampled material</td>
<td>120 [°C]</td>
</tr>
<tr>
<td>Maximum particle size of sampled material</td>
<td>2 mm</td>
</tr>
<tr>
<td>Compressed air supply</td>
<td>Dry, oil free, 6-10 bar</td>
</tr>
<tr>
<td>Electrical power supply</td>
<td>3 phase; 460-480 V</td>
</tr>
<tr>
<td>Protection class</td>
<td>IP 34 (dust IP54)</td>
</tr>
</tbody>
</table>

Required pneumatic control components are always included in the scope of supply and are delivered in separate pneumatic control boxes.
Automatic sampling solutions

PSM composite sampling station with gravity return of excess sample material.

PSM composite sampling station with excess sample material return blower.

Dual PSM composite sampling station with gravity return of excess sample material (Two sampling points served by one shared sample transport sending station).

PSM composite & screw spot sampling station with gravity return of excess sample material.

Screw+mixer composite sampling station with excess sample material return blower (Two sampling points served by one shared sample transport sending station).

Dual screw+mixer composite sampling station with excess sample material return blower (Two sampling points served by one shared sample transport sending station).

Air slide sampler+mixer composite & air slide spot sampling station with excess sample material return blower.

Dual air slide+mixer composite sampling station with excess sample material return blower (Two sampling points served by one shared sample transport sending station).

Air slide sampler+mixer composite & air slide spot sampling station with excess sample material return blower (Two sampling points served by one shared sample transport sending station).

Hot meal spot sampling station including water cooling device for fast cooling of sample.

Screw sampler integrated with in-line particle sizing (granulometric laser).

Clinker sampling concept delivering a fine ground sample to a sample transport sending station (Concept is intended for analysis at a central lab facility).

A)

B)

Fully representative clinker sampling tower & sending station concepts capable of delivering both spot and composite samples: A) clinker sampler located above processing tower; B) "low“ located clinker sampler with sample skip hoist to lift sample portion to the top of the processing tower.

Clinker sampling concept delivering a fine ground sample to a sample transport sending station (Concept is intended for analysis at a central lab facility).
Automatic sample transport

Automatic sample transport complements automatic sampling and creates fully automated sampling procedures:
- Fast turnaround time from sampling to analysis
- Improved product quality and related operational savings
- Optimised overall sample taking schedule
- High system availability
- Easy connectivity to automatic sample preparation systems
- Worldwide service & support

A typical project scope may comprise:
- Automatic sampling equipment
- Process send/receive stations
- Laboratory send/receive stations
- Transport tube & tube diverters
- Transport air blowers
- Project specific control hw & sw
- Optional sample ID entry terminals
- QCX/AutoSampling supervisory software
- Project engineering services
- Factory Acceptance Testing
- Installation supervision and commissioning services

Samples are transported in sample cartridges (or carriers or shuttles). For dry powder/granulates, typically 200-500 cc material is sent to the laboratory. For steel/metal samples ("lollipops" or similar), a special cartridge with a clamping device is employed.

One or more rotary blowers integrated in the tube network generates an over- or under-pressure, which allows the cartridges to move at transport speeds between 8 and 20 metres per second. Send/receive stations – in the process area or in the laboratory – may be manually serviced or fully automated, which at the process end means full automation of the entire sampling & sample transport process. At the lab end, full automation implies that powder/granulate sample portions are automatically dosed into one or more sample cups for further preparation and analysis, while steel/metal type samples are returned from the clamping device and transferred to the relevant piece of preparation equipment.

The applied advanced logic control programming techniques ("QCXSYS") ensures cost effective engineering for the specific project as well as providing a very high quality and consistency in both overall and device control. Directly from the PC screen, mimic diagrams (so-called 'face-plates') provide easy accessible operational and diagnostic details from the device control level.

Samples are sent from the process stations to receive/send stations in the laboratory in accordance with individual sample priorities and wait list status. Sample entities like sampling location, product type, sampling time etc. are automatically passed on to the next handling stage, whether manual or automatic. The integrated automation concept includes advanced priority handling schemes: in case an equipment error leads to reduced capacity in the automated preparation system it is possible to automatically scale down the automatic sampling & sample transport activity, so that lower priority samples are skipped or called for less frequently.

Process stations:
1. Cement
2. Clinker
3. Coal meal
4. Kiln feed
5. Hot meal
6. Raw meal

Laboratory stations:
7. Automatic receiving station integrated with automated laboratory
8. Manual receiving station