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Introduction to the Sampling World: technical and cost impacts…

Iteca Socadei in a few words…

- Iteca belonged to "*Les Ciments Lafarge*"
- More than 30 years of experience in the mineral industry
- Worldwide sales representative network
- More than 65 employees
- 3 divisions:
  - Cement division: *process control (from sampling to analysis), kiln seals, ball sorting machine, etc.*
  - Colour division: *on-line colour measurement*
  - Mine and Mineral Division:
    - ✓ Sampling solutions
    - ✓ Equipments production (Kiln / Calciner seals, ball sorting machine)
    - ✓ Instrumentation (level detection & measurement, rotation, etc.)
    - ✓ Truck / Train loading solutions

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Why sampling?

- **Process control**
  - *optimization of the process*
- **Reconciliation / Metal accounting**
  - *perfect knowledge of what is produced by each part of the plant (mine, crushing plant, beneficiation plant, etc…)*
- **Quality control**
  - *optimize the quality of final product*
  - *reduce the over-quality*
- **Commercial sampling**
  - *prevent the seller from any claims*
  - *prevent the buyer from any off-spec*

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« I have to control the quality of the product loaded in a 180 000 tons iron ore ship… »
For a 62% Fe iron ore concentrate:
✓ at 86$/dmt ≈ 15,48 M$
✓ at 100$/dmt ≈ 18,00 M$
✓ at 120$ /dmt ≈ 21,60 M$
« I don’t want to pay any penalty to my client!!!… »

What is the aim of sampling?

The aim of sampling is to get a ***representative*** quantity of product from a ***lot***…

<u>Lot</u>: Quantity of product (usually large) of which you want to estimate one or several characteristics

- ✓ hourly, shift or daily production,
- ✓ complete ship,
- ✓ etc…

<u>Representative:</u> A sample is representative when it is ***accurate*** (*When each particle of the flow has the same probability to be taken by the sampling device*) and ***reproducible***

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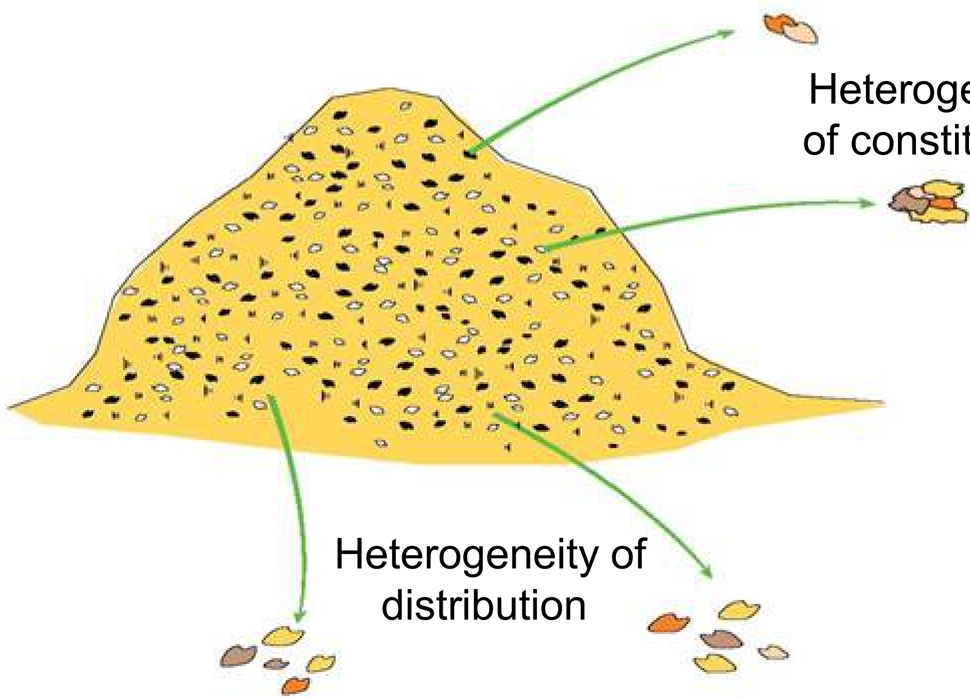
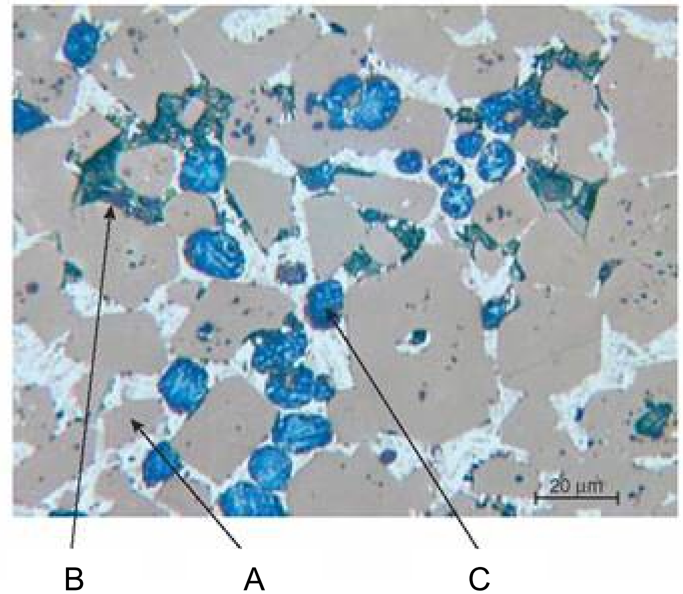
Why sampling is not that easy?

heterogeneity

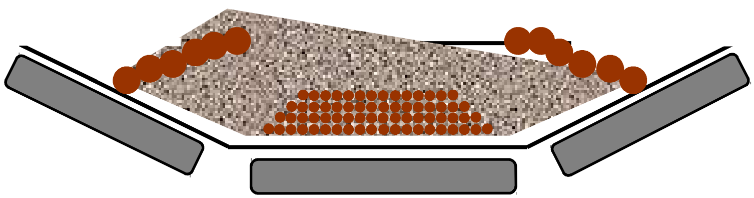




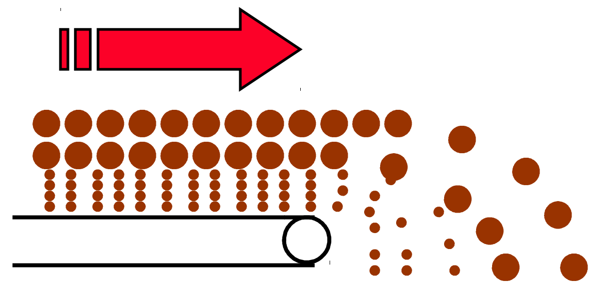
Heterogeneity of constitution	Heterogeneity of distribution
Depends on the composition of each particle	Depends on the distribution of the particles in the lot
The more different the particles are, the higher the heterogeneity of constitution will be	The higher the difference of composition between each particle or group of particle is, the higher the heterogeneity of distribution will be
A heterogeneity of constitution always implies a heterogeneity of distribution	

Segregation

- Front view -
Particle size distribution



- Cross section -
Particle size distribution



The kinetic energy creates segregation in the flow.

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Because of heterogeneities of constitution and distribution,

we have to consider that a product or a flow

can not be homogeneous.

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The theory of sampling of Pierre Gy

Pierre Gy's formula allows to predict the sampling precision for a probabilistic and bias free sample.

$$\sigma^2 = \frac{C \cdot d^3}{M}$$

With:
σ^2 = variance of the fundamental sampling error
C = mineral specific constant
d = maximum particle size (d95 can be used)
M = mass of the sample

A few rules to avoid bias

- The cutter must cut the entire stream of particles
- The cutter must move at constant speed through the stream and below 0,6 m/s
- The cutter blades must be straight and sharp to avoid any roll or slide of particles

[redacted] Extract of « Investigation of Sample Cutter Operations » (CSIRO, Australia) [redacted]

- The cutter must have sufficient capacity to hold the sample

[redacted] Extract of « Investigation of Sample Cutter Operations » (CSIRO, Australia) [redacted]

- Cutter aperture must be at least 3 times the nominal top size to avoid bridging of material over the cutter
- The cutter opening must be constant
- There must be no loss of material or contamination

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Sampling bias can be far greater than analysis ones.

« On the primary sampling, bias can be up to 1 000 % and up to 50 % on the secondary sampling whereas they never exceed 0,1 to 1 % in analysis. » (Pierre Gy)

Sampling can be far more important than analysis!

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Financial impacts are high!

Current price of iron ore concentrate at 62% Fe is around 95 $/t

Example of an iron ore mine producing 10 Mt per year:

- ✓ **1% bias on Fe** ⇒ **15,32 M$ / year !**
- ✓ **1% bias on moisture** ⇒ **9,50 M$ / year !**

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Example of iron ore sampling tower ISO 3082 compliant

Application:

- ✓ Product: Iron ore lumps with nominal top size of 31,5 mm
- ✓ Product Quality Variation *(acc. ISO 3082)*: Large
- ✓ Lot: 8 hours
- ✓ Flow rate: 3000 t/h

According to ISO 3082-2009 *(Iron ores - Sampling and sample preparation procedures)*:

- ✓ Cutter aperture of the sampler: 100 mm
- ✓ Cutter speed: 0,6 m/s
- *Mass of each primary cut: 140 Kg*
- ✓ Number of primary cuts: 120 (1 cut every 4 minutes)
- *Mass of sample collected = 120 x 140 Kg = 16,8 tons! Too large for the lab!*

It is necessary to carry out a fragmentation to decrease the mass of the sample without deteriorating its representativeness (i.e without decreasing its variance)

A Sampling process is often made of several stages of « collection of product » and « fragmentation »

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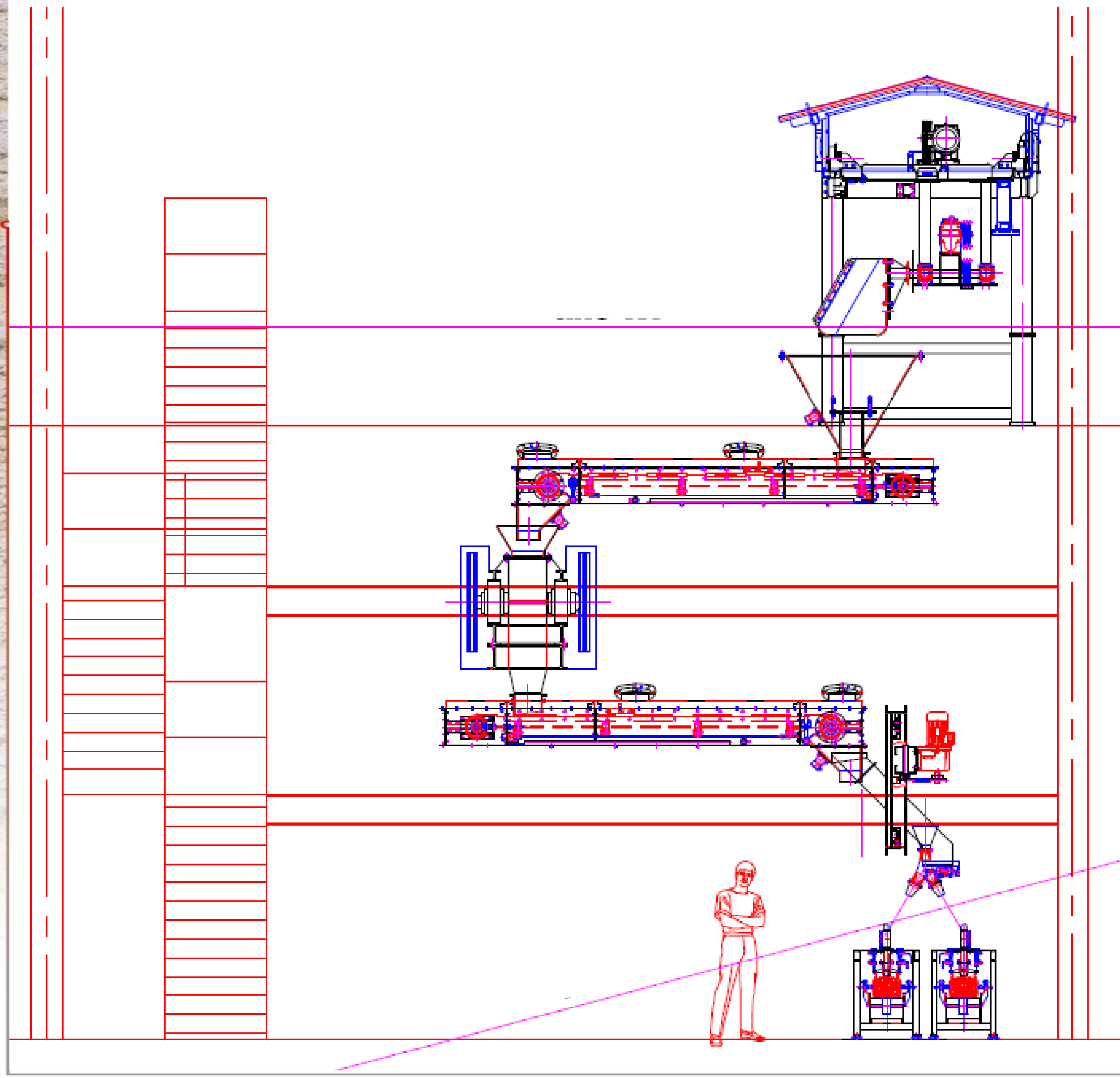
Example of iron ore sampling tower ISO 3082 compliant



Primary Sampler

- ✓ *Mass of 1 increment = 140 kg*
- ✓ *1 increment every 4 minutes*
- ✓ *120 increments*
- *16,8 t per 8 hours*

Jaw Crusher

- ✓ *Size in = 31,5 mm*
- ✓ *Size out = 8 mm*

Secondary Sampler

- ✓ *For dividing operation*
- ✓ *Final sample mass = 30 kg*
- ✓ *Frequency = every hour*

Reduction in the number of increments: consequences…

Reference sampling standard: ISO 3082
Product: Iron ore lumps (< 31,5 mm)
Lot = 8h (= 24 000 tons)
N1 = number of primary increments
Target overall precision given by ISO 3082: βSPM = 0,49
Measured Fe content for the lot: 62%

N1	β_{SPM}
120	0,49
60	0,67
30	0,92

βSPM = overall precision

βSPM = 2σSPM

$\sigma^2 SPM = \sigma^2 S + \sigma^2 P + \sigma^2 M$

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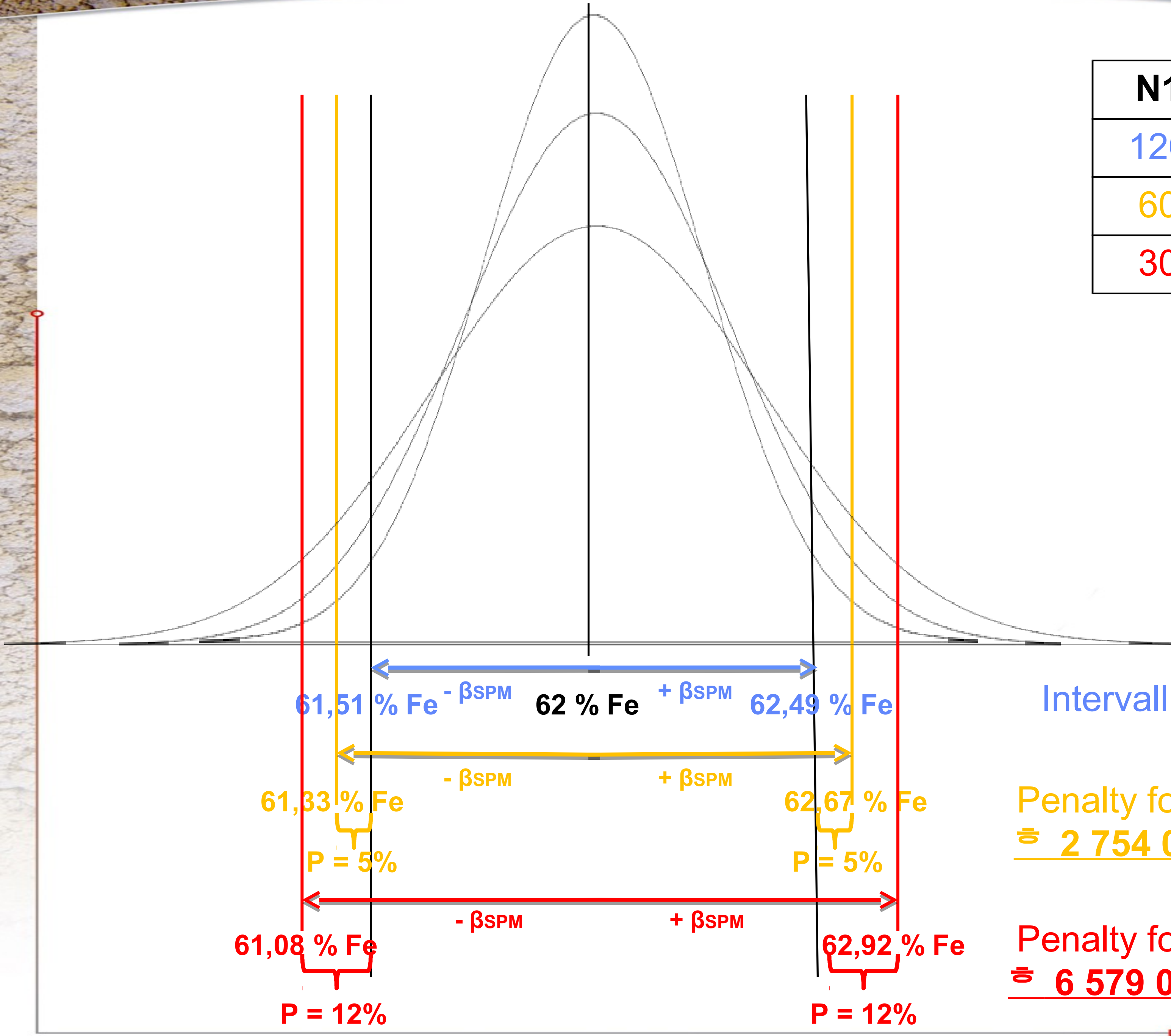
N1	βSPM
120	0,49
60	0,67
30	0,92



Intervall without penalty

Penalty for 10 % of the lot:
≈ **2 754 000 $ per year!...**

Penalty for 24 % of the lot:
≈ **6 579 000 $ per year!!...**

Example of bias and financial consequences

The iron grade of the large particles differs from the iron grade of the fine particles (for this example, let's say that the grade of the large particles is about 2% larger than the average for the entire stream of ore)

One single large particle wheighs about 74 g and each increment wheighs about 140 Kg

If 200 large particles (= 15 Kg) per primary cut (= 140 Kg) fail to be collected by the cutter then the bias on the grade is:

2% Fe x 200 x 74 / 140000 = <u>0,21% Fe</u>

Extract of « Investigation of sample Cutter operations » (CSIRO, Australia)

For an iron ore mine producing 10 Mt iron ore concentrate per year at 95 $/dmt:

0,21 % bias on Fe ≅ 3 217 742 $ / year !

Example of bias and financial consequences

For a iron ore mine producing 10 Mt/year:

- ✓ Number of increments not compliant: 6,58 M$ per year
- ✓ Wrong design of cutter: 3,22 M$ per year

Total penalties: 9,80 M$ per year!!!

« Why do I pay these huge penatlies???...

...because of the bad quality of my product???...

... or because my my sampling station creates bias?!?!... »

Terminology

- **Sample taker:** technical device for taking samples *(with or without representativeness)*

- **Sampler:** technical solution designed in order to obtain **representative** samples

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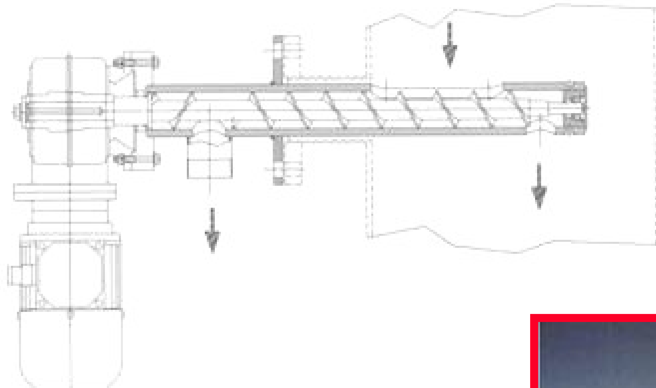
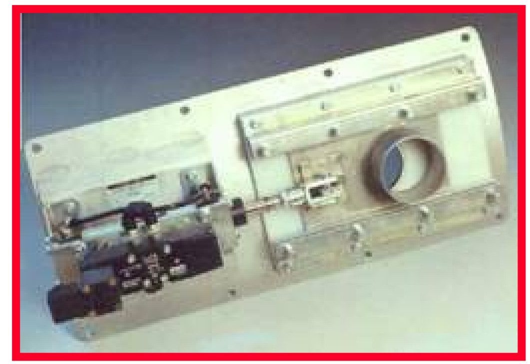
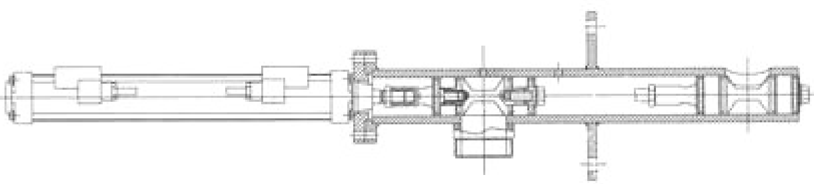
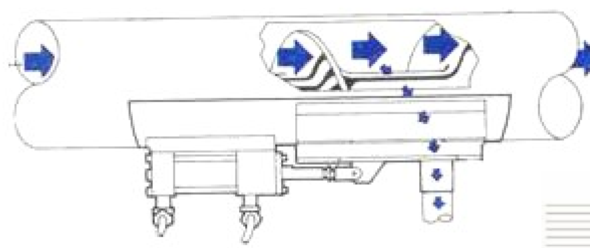
Examples of « sample takers »









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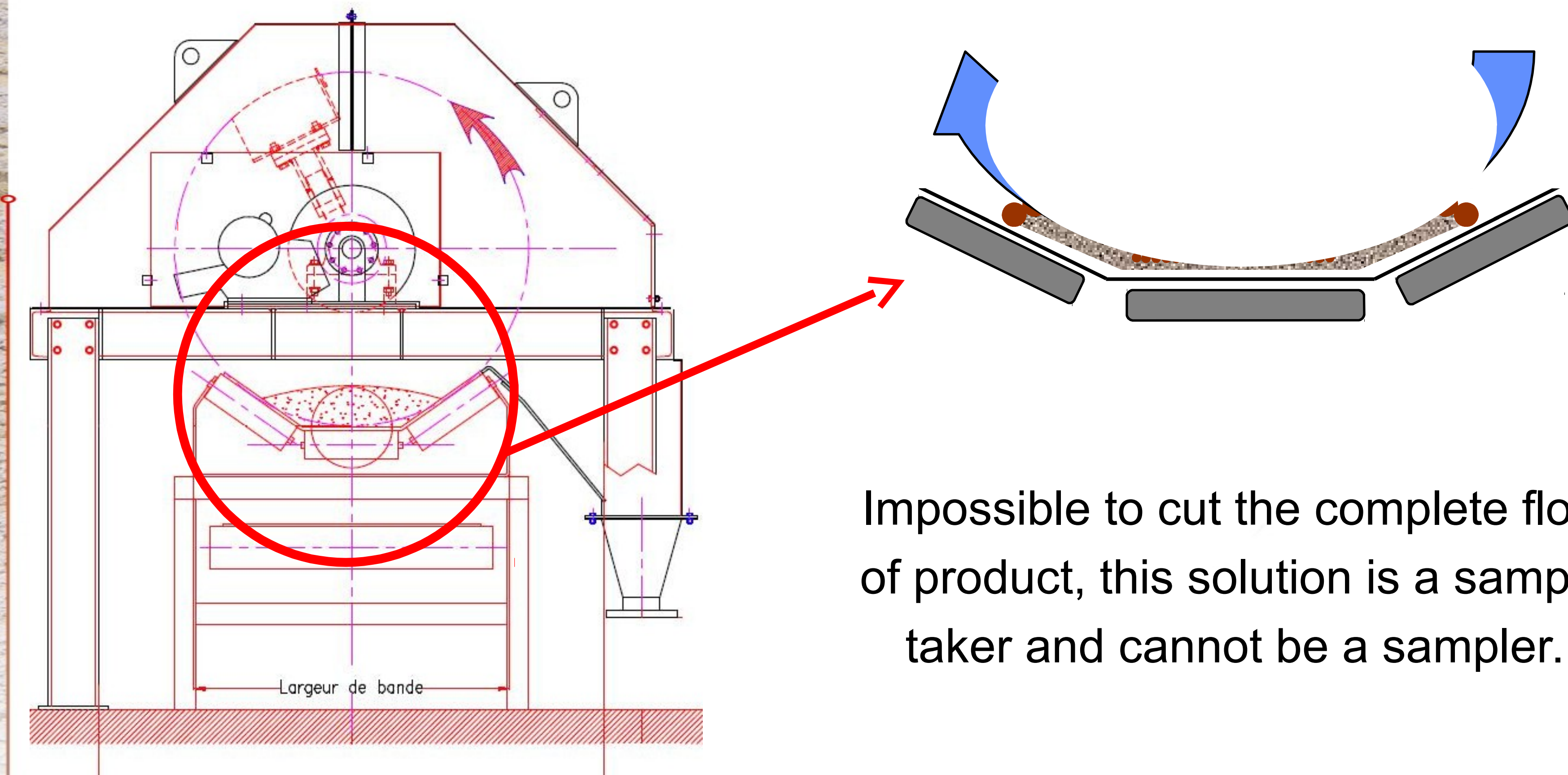
Cross-belt: a special case?



Impossible to cut the complete flow of product, this solution is a sample taker and cannot be a sampler.

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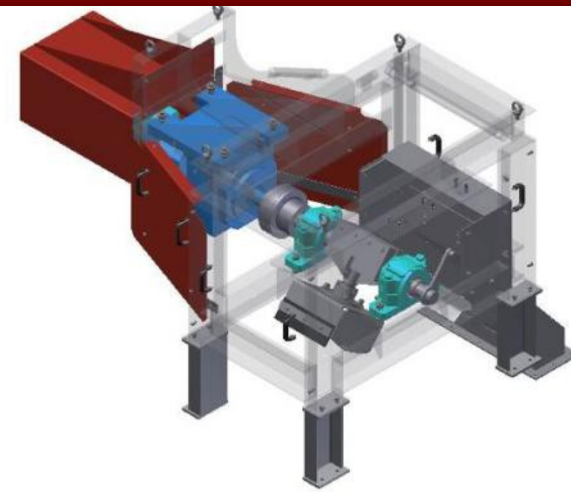
Cross-belt Sample-taker (on a conveyor belt) – PBA



- **<u>Does not</u> comply with Sampling Theory or International Sampling Standards**
- Sometimes could be better than nothing !
- Heavy duty construction (wear resistant steel)
- Design of the cutter is made according to the product to be sampled

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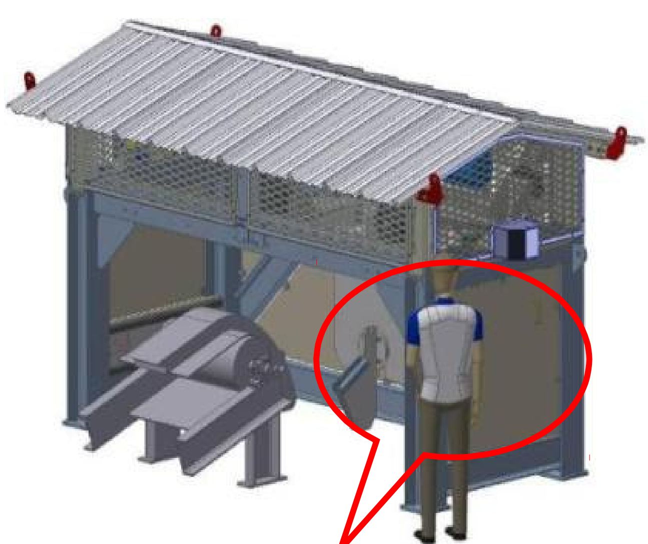
Sampler at conveyor belt discharge – EGTR



- **Fully compliant with Sampling Theory and International Sampling Standards**
- Very few place is needed thanks to the “Linear Rotary Bucket” principle *(patented solution)*
- Minimized increment mass *(collection during a single travel of the bucket)*
- Suitable for any type of mineral and solid bulk

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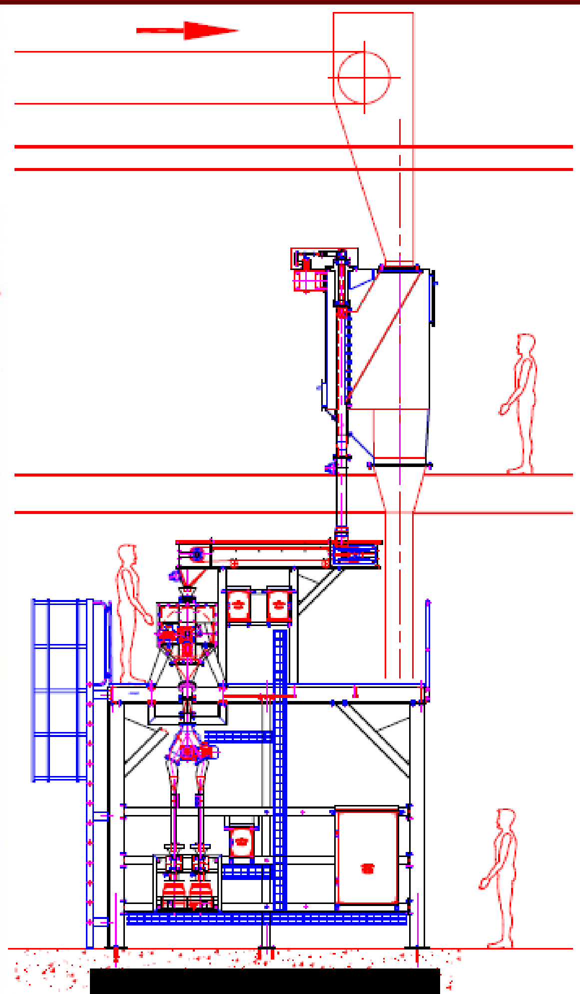
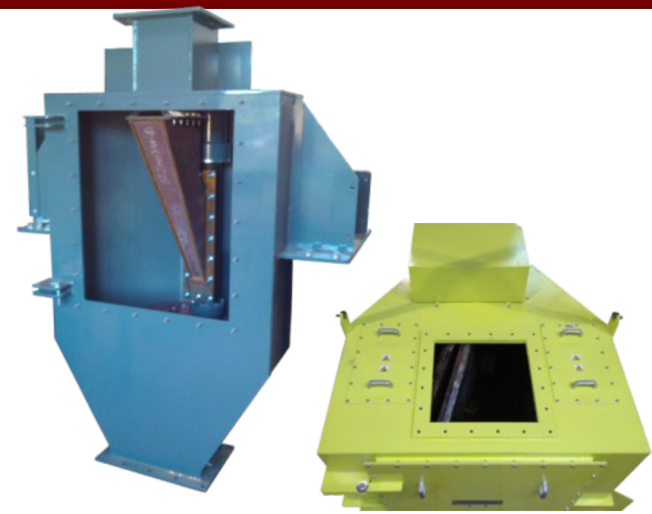
Sampler in a vertical chute - PGR





- **Fully compliant with Sampling Theory and International Sampling Standards**
- Design of the cutter is made according to the product to be sampled
- Angle of extraction according to characteristics of the product to be sampled
- Continuous or intermittent sampling operation
- Heavy duty construction

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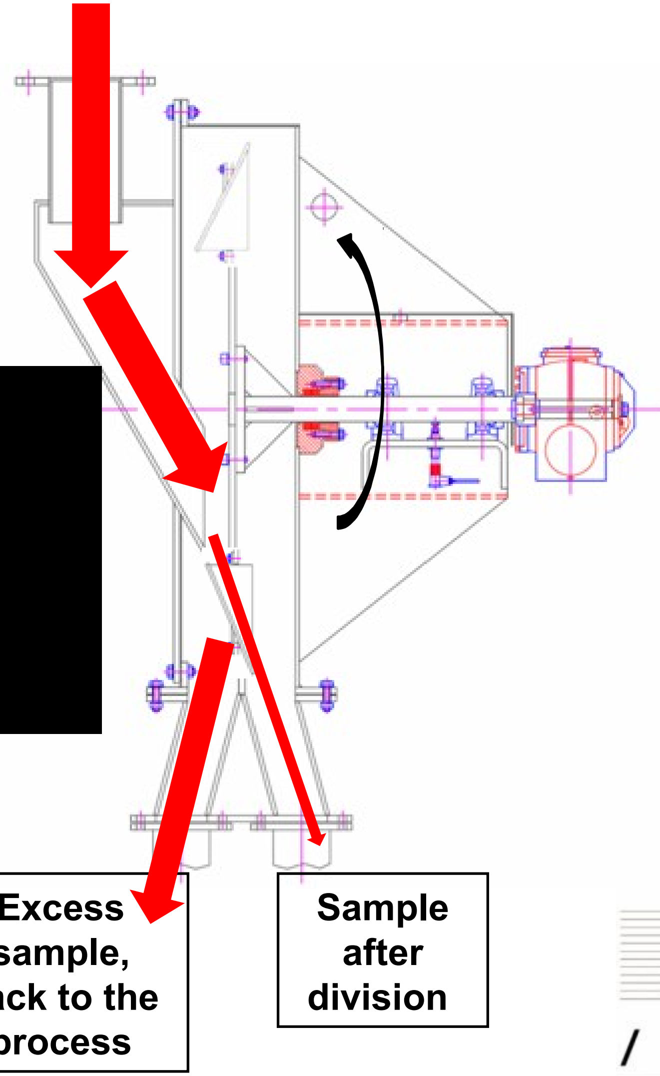
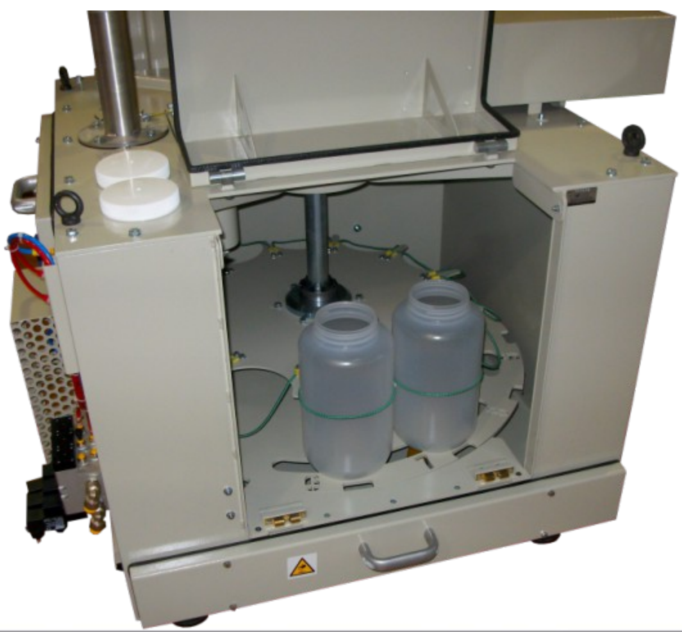
Rotary plate divider

[redacted]

[redacted]



Sample storage



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Sampling, Sample Preparation & Analysis

- Samplers
- Sampling tower
- Sample transport
- Sample preparation
- Automatic analysis
- Centralised laboratory

Sampler at the discharge of a conveyor belt

Vezin Sampler

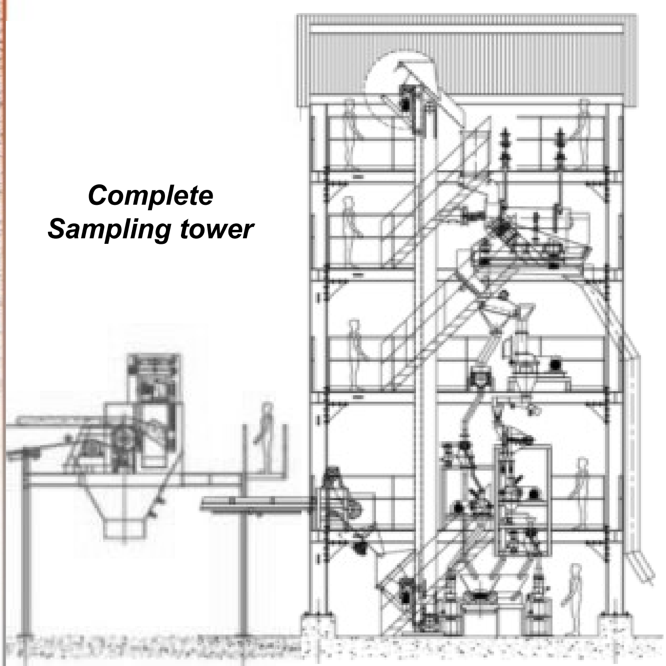
Cross-belt Sample taker

Divider

Sample storage

Semi-Automatic Mill & Press

Complete Sampling tower



Automatic Laboratory

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Bibliography and acknowledgments

- **ISO sampling standards** (ISO 3082:2009, ISO8656-1, ISO 4296-1, ISO 4296-2, ISO 8685, ISO 13909-2-2001, ISO 12743:2006, ...)

- **Pierre GY literature :**
  - (1979) Sampling of particulate materials, theory and practice
  - (1992) Sampling of Heterogeneous and Dynamic Material Systems: Theories of Heterogeneity, Sampling and Homogenizing
  - (1998) Sampling for Analytical Purposes

- **CSIRO – Division of Mineral and Process Engineering** (Sampling Bulk Commodities – Design and operation of sample cutters)

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Thank you
for your attention…

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