INTRODUCTION TO SAMPLING FOR MINERAL PROCESSING

Part 7 in a series “Effects on Recovery and NSR”
SERIES CONTENTS

1 - Introduction to course and sampling
   - Course objectives
   - Course introduction
   - Objectives for sampling

2 - Sampling Basics
   - Some definitions
   - 3D/2D/1D Sampling
   - Delimitations / Extraction
   - Rebounding / Cutter Speed and geometry

3 - Sampling Errors
   - Delimitations / Extraction
   - Bridging / Cutter issues / Multiple cutters
   - Back pressure

4 - Metallurgical Samplers
   - Belt Samplers / Crushers
   - Linear Samplers and enclosures
   - Rotary Vezin / Arcual Samplers
   - Secondary / Tertiary Samplers

5 - Process Control Samplers
   - Launder / Pressure / Poppet sampler
   - Analyzers (XRF or particle)

6 - Effects on Mass Balancing
   - Some aspect of the AMIRA code
   - Detrimental effects and metallurgist responsibility
   - Sampling errors in launder / pressure sampler
   - Mass balance effects

7 - Effects on Recovery and NSR
   - OSA and sampler errors
   - Grade and Recovery targets
   - Recovery - Error propagation
   - Net Smelter Return - Error propagation (loss of revenues)
Detrimental effects to operations

The assays from samples are used for control and accounting purposes:

- **Planning**
  - Production targets
  - Plant need to make a certain amount of money to pay its bills and make a profit. This effects how much tonnage to push through a mill.

- **Plant control**
  - Grade / Recoveries
  - Target values for these are set and accurate, non-biased, assays are required to achieve this.

- **Metallurgical Accounting**
  - Unbalanced results (poor sampling, assaying or weighing of stream)
  - Unaccounted loss (lack of measurement accuracy)
How is sampling inaccurate

Problem with samplers which do not adhere to sampling theory:

- Launder and pressure samplers contain a bias, or errors, which can be constant (biased) or fluctuating (random). The ratio of fines:coarse, or light:heavy, particles entering the fixed cutter or nozzle will vary even without fluctuations in the process.
- Segregation by particle size, density, etc. is always present as there can be no guarantee that the slurry to be sampled is homogenous
- Segregation caused by pipe bends or intersections, etc.
- Unfortunately these errors change over time due to fluctuations in feed tonnages, particle size, densities, flow rates, pressure, etc. which can cause precision errors
OSA and Sampler Errors
(On-line Assays)

- On-Stream Analyzers (OSA) only analyze the samples it is presented
- Normal OSA accuracies, as 1-SD (depends on application)
  - Feed ~ 4-6% (Aver 5%), Conc ~ 2-4% (Aver 3%), Tails ~ 7-9% (Aver 8%)
- Measurement result error (1-SD):
  \[ s_{meas}^2 = s_{sampling}^2 + s_{analytical}^2 \]
  \[ s_{meas} = \sqrt{s_{sampling}^2 + s_{analytical}^2} \]
- If the sample feed to the OSA is biased, the results are biased
## Error Propagation - Recovery

### CASE 1

<table>
<thead>
<tr>
<th>Feed%</th>
<th>Conc%</th>
<th>Tail%</th>
<th>Rec%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>13.50</td>
<td>0.25</td>
<td>87.33</td>
</tr>
</tbody>
</table>

Errors % (1-SD) | Case 1 | OSA | ABSTotal |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>1.50</td>
<td>5</td>
<td>0.09135</td>
</tr>
<tr>
<td>Conc</td>
<td>1.50</td>
<td>3</td>
<td>0.45280</td>
</tr>
<tr>
<td>Tails</td>
<td>1.50</td>
<td>8</td>
<td>0.02035</td>
</tr>
</tbody>
</table>

Recovery error 1.2978

### CASE 2

<table>
<thead>
<tr>
<th>Feed%</th>
<th>Conc%</th>
<th>Tail%</th>
<th>Rec%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>13.50</td>
<td>0.25</td>
<td>87.33</td>
</tr>
</tbody>
</table>

Errors % (1-SD) | Case 2 | OSA | ABSTotal |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>1.00</td>
<td>5</td>
<td>0.08923</td>
</tr>
<tr>
<td>Conc</td>
<td>1.00</td>
<td>3</td>
<td>0.42691</td>
</tr>
<tr>
<td>Tails</td>
<td>1.00</td>
<td>8</td>
<td>0.02016</td>
</tr>
</tbody>
</table>

Recovery error 1.2794

Recovery Error Difference 0.0184 (1-SD)

http://www.paulnobrega.net/
• This statement can be found in the Will’s Mineral Processing Technology book:

“The aim (of a flotation control system) should be to improve the metallurgical efficiency, i.e. to produce the best possible grade-recovery curve, and to stabilize the process at the concentrate grade which will produce the most economic return from the throughput.”

• This statement has a few key points:
  – A concentrate grade is decided upon (could be by planner, metallurgist, control system or other and depends on feed grade)
  – Keep the process stable (upsets are not good)
  – Increase the recovery as close as possible, to the best grade-recovery curve, without de-stabilizing (upsetting) the circuit
  – Maximize recovery at a target grade
Assay errors and Grade/Recovery curve

Feed %1.75, Conc. %13.5 Tail %0.25, Rec. %87.33

<table>
<thead>
<tr>
<th>Case</th>
<th>Recovery error</th>
<th>Recovery Error Difference 0.0184 (1-SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>1.2978</td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td>1.2794</td>
<td></td>
</tr>
</tbody>
</table>

Uncertainty Ellipse Area

%Grade x %Rec  1.85  1.72

Control Area Improvement %  7.06

COMMENTS

• With the slightly better samplers in Case 2, the recovery target can be moved upwards the 0.0184% (or 0.0368% with 2-SD) error difference with the same probability of detecting an upset in the circuit as in Case 1
• As the target for grade / recovery changes, due to feed changes, the error difference changes only slightly (~10%).
Introduction to SPC

“All control starts with measurement and the quality of control can be no better than the quality of the measurement input.” (Connell [1988])

Rule 1: Any point falls beyond 3σ from the centerline (this is represented by the upper and lower control limits).

Rule 2: Two out of three consecutive points fall beyond 2σ on the same side of the centerline.

Rule 3: Four out of five consecutive points fall beyond 1σ on the same side of the centerline.

Rule 4: Nine or more consecutive points fall on the same side of the centerline.

https://controls.engin.umich.edu/wiki/index.php/SPC:_Basic_control_charts:_theory_and_construction,_sample_size,_x-bar,_r_charts,_s_charts
Introduction to SPC

- Control limits for grade / recovery depend upon the accuracy of the analyzer / samplers
- Example chart of recovery control, target shifted up 1-SD difference, 0.0184%

**Probability of error detection**
- **Case #1**: Probability of error detection over 2-SD UCL is still better than in Case #1
- **Case #2**: Probability of error detection over 1-SD UCL is the same in both cases

**Target moved up 1-SD difference (0.0184)**

**Tighter control limits** at 1-SD LCL and 2-SD LCL
Feed %1.75, Conc. %13.5 Tail %0.25

$NSR/t$ $149.78$

Case 1 (1.5%)
Case 2 (1.0%)

$NSR/t$ error 9.3848 9.1660

$NSR/t$ Error Difference 0.2188 (1-SD)

Estimating Assay Error Effects on NSR

Feed %1.75, Conc. %13.5 Tail %0.25, Rec. %87.33

Case 1 (1.5%)  Case 2 (1.0%)

$NSR/t error  9.3848  9.1660
$NSR/t Difference 0.2188 (1-SD)

Uncertainty Ellipse Area
%Grade x $NSR/t  13.35  12.29
Control Area Improvement %  7.92

COMMENTS

• With the slightly better samplers in Case 2, the $NSR/t can be moved upwards the $0.2188 (or $0.4376 with 2-SD) error difference with the same likelihood of detecting an upset circuit as in Case 1. This is done by the recovery control.

• At 2,102,400 t/year this is:
  – $459,786.00 @ 1-SD Error Diff
  – $919,572.00 @ 2-SD Error Diff
Estimating where your process operates

- The probability of process upset as a result of analysis errors at the UCL’s are, 1-SD is 16%, 2-SD is 2.25%, 3-SD is 0.15%. An upset occurs where your process crosses the grade / recovery curve.
- Your OSA has about 100 cycles a day, roughly a 15 minute cycle time (4/hr x 24hr ~ 100)
- How often a day does your process get upset?
  - At 8/shift (16/day) your SD is about 1
  - At 2-3/shift (5-6/day) your SD is somewhere around 1.5
  - At 1-2/shift (2-4/day) your SD is somewhere around 2
  - Once every several days, your SD is somewhere around 3
- This gives you an idea of how much you can increase your recovery / NSR target (x * 1-SDdiff)
• Low grade Cu mine with large tonnages (140,000t/day)
• Comparing 2% and 1% sampler errors
  • $0.045/t estimated improvement
  • $2.19M/yr estimated improvement
• Control improvements 15.06% and 16.93%
• Low grade Cu mine with large tonnages (140,000t/day)
• Comparing 3% and 1% sampler errors
• $0.115/t estimated improvement
• $5.60M/yr estimated improvement
• Control improvements 31.28% and 34.78%
For more information you can always contact us at:
www.heathandsherwood64.com