How to conduct a ball mill audit

Introduction

- The aim of the ball mill audit is to make a full evaluation of the operation and condition of the shop in order to identify areas for improvement
- This thorough "***full audit***" should be done routinely at least every 3 years on a mill, but could also be triggered by:
  - Change of product type
  - Change of feed materials
  - Rapid deterioration in performance
  - Low annual PIFM as reported to CKHC
- The audit is normally made by competent plant process engineers and technicians. Assistance of Technical Centre engineers for transferring experience can also be beneficial.
- A "***mini–audit***" can also be performed for a faster evaluation of the shop for trouble-shooting and should be conducted at least annually by the plant. The audit is essentially the same as the full audit, except that it can exclude the following:
  - Grindability test – when grindability is already known or not a factor
  - Heat Balance – when drying or cooling are not a factor
  - Ball grading – when the grading is already known
  - Full material axial sampling – only sampling at chamber inlet and outlet is performed

Objectives

- To make a full evaluation of the operation and condition of the shop
- Identify the weak points of the shop
- Set an improvement action plan

Safety aspects

- Conducting this procedure involves exposure to many hazards regarding:
  - Moving machinery
  - High noise level
  - Heat stress exposure and burning risk from hot material
  - Tripping hazards inside the mill
  - Dust as a potential risk of eye injury and respiratory damage, even explosion (coal mill)
  - Confined spaces with specific risks of heat stress, asphyxia, burns and engulfment due to mill feed.
  - Working at height
  - Falling objects
- It is imperative that all members of the audit team fully understand the risks, conduct a risk assessment and apply the necessary safety procedures and personal protective equipment.
- Goggles shall be used for eye protection. Gloves against burns and safety boots covered by the trousers to avoid entrance of hot material.
- For any work At Height (including sampling and measuring points out of reach from a standard platform), the correspondent FHRA shall be reviewed and a permit issued before starting the task. The rescue plan must be explained and rescue equipment available, if possible close to the area.
- Special attention to climbing on vertical ladders: always 3 supports, hands free, additional fall protection

for ladders above 30 feet (depends on local regulations).

- Before entering the mill, it is necessary to review the task-specific Confined Space risk assessment. A permit shall be signed by a competent person based on the requirements specified in the risk assessment (gas measurement, surveillance, etc.). The rescue plan shall be explained and rescue equipment shall be pre-mounted for an eventual extraction.
- For lighting or hand tools, all power sources to be used inside the mill shall be protected with differential circuit breakers unless only 24V safety lighting and tools are used.
- Prior to entering the mill, energy isolation of the mill and associated equipment must be ensured and all persons entering must have their own personal lock out and tag out, in accordance with the plant Hazardous Energy Risk Assessment and Hazardous Energy Control Procedures and under the supervision of a competent EI responsible person.
- Special PPE may be required for sampling hot material in accordance with the local risk assessment and procedure (gloves, facial protection for air slides).
- All required documents described above shall be pre-requisite when planning any mission.
- For coal mill audits, a strict adherence to chapter 11 of the Technical Agenda on "Safety in coal grinding shops" is required before any intervention.
- The mill fan is to be restarted and set on a low damper position to aid cooling. A safe procedure must be in place to prevent anyone from entering the mill until the fan and damper have been adjusted and the damper physically isolated.

Prerequisites

- Start to prepare the audit plan about one month in advance, consider the following points:
  - Any planned major changes to the mill shop, feed or products
  - Mill availability
  - Measurements to be made
  - Samples to be taken
  - Required Resources
  - Calibration and availability of Process testing and sampling equipment
  - Availability of special safety equipment – e.g. harnesses for mills without platforms
- Collect data for all equipment in the shop, mill (dimensions, internals, gearbox, motor, speed, etc), separator, fans, filters, elevators, conveyors, etc

  Grinding > Job aids > Mill shop datasheet
- Study shop control and instrumentation including Lucie (if applied)
- Study shop flow-sheet
- Check suitability of measuring / sampling points (check cross sectional area for gas-flow measuring points)
- Arrange calibration check of mill feed and rejects weighers
- Arrange for check of the accuracy of power monitoring (particularly mill drive and total shop metering) devices installed in the shop
- Analyse mill performance for each product from recent and historical mill operating data (including feed and product characteristics), noting any trends or changes to the performance
- Analyse mill reliability factor and incident stoppages
- Check CKHC PIFM for finish mills

  PIFM definition available on BRS database > Indicators
- Check quality control procedures and sampling points

- To help speed up the process, notify laboratory that feed materials will be to be sent for chemical analysis, grindability testing and feed size distribution. Feed materials to be taken on the day of the audit.

Time frame

The time from starting the preparation audit preparation to producing the audit report can be around 1-2 months depending upon the preparation and the laboratory turn around time.

- Preparation – 2- 4 weeks
- Plant Operation, Testing & Inspections 3-5 days
  - Observation of mill operation, including quality control and process control loops
  - Measurements & sampling during mill operation – 4-6 hours
  - Crash stop & cooling – 2-4 hours
  - Mill inspection and sampling – 4 – 6 hours
- Laboratory Tests (need to allow additional time for laboratory workload and transport to laboratory) 1-2 weeks
  - Grindability testing 1 week
  - Material size analysis – 1 week
  - Results Calculation & Reporting – 1-2 weeks

Tools

- Plant testing equipment for airflow, temperature and pressure
- Sample containers for circuit samples and mill axial samples
- Special pointed spade / scoop for digging into media for sampling
- Sample scoop and coarse sieve for material samples
- Camera for recording condition of mill internals, separator internals and all findings from the audit.
- Measuring tape and measuring scale for mill internal measurements

- Templates & calculation spreadsheets available in:

  Grinding > Job aids

In this procedure you may find references to other information (tools, other "How to" procedures, knowledge documents, etc) which are available from their respective domain of the Web Cement Portal (e.g. Grinding, Pyroprocessing..) or from the BRS database (indicators).

- Examples:

  Grinding > Job aids > …

  means you should go to Cement Portal > Grinding domain > Job aids Section

  Pyroprocessing > Standards & procedures

  means you should go to Cement Portal > Pyroprocessing domain > Standards & Procedures Section

Access the Web Cement Portal via L.O Group Portal:

http://lo.lafarge.com > Access to all intranet sites > Division sites > Cement

Action Steps

1. Plant in Operation

Observe plant operation, check for

- Steady operation
- Quality control procedures - Appropriate, well defined and correctly applied
- Effective and well tuned control loops
- Consistency of mill feeders, especially moist or sticky materials
- Observe mill feed size
- Check for signs of false air that could affect mill airflow and separator airflow

Measure

- mill motor power,
- total shop power
- and other individual equipment according to the available power monitoring devices.

Take samples to check separator performance

- ***How to check the separator efficiency***

Measure the mill airflow

in at least one location and temperature & pressure at:

- mill inlet, mill outlet,
- dust cyclone inlet, dust cyclone outlet,
- filter inlet, filter outlet,
- fan damper inlet, fan damper outlet,
- fan inlet and fan outlet.
    - ***How to check airflows through a mill***
    - ***How to measure airflow by Pitot tube***
    - ***How to measure airflow by anemometer***

Measure the separator airflow

in at least one location and temperature & pressure at:

- all separator inlets, separator outlet,
- dust cyclone inlet, dust cyclone outlet,
- filter inlet, filter outlet,
- fan damper inlet, fan damper outlet,
- fan inlet and fan outlet.

- ***Note*** any excessive pressure losses.
- ***Check*** measured values against control room indication.

Action Steps

- ***Compare*** measured fan performances against performance curves & note any significant differences
  - *How to measure fan efficiency of the main fans (Pyroprocessing)*
- ***Also check*** if mill airflow and separator airflow meet the standard Lafarge values
- ***Measure mill feed temperature***, if appropriate
  - e.g. clinker for a cement mill
- ***In the case of mills and separators*** vented by kiln exhaust or hot gas generator exhaust gases - conduct false air survey using portable oxygen monitor
  - *How to measure false air (Pyroprocessing)*

2. Mill System Crash Stop

- ***Crash stop mill circuit completely***
- ***Arrange for the mill and all circuit equipment to be locked off*** (see local safety procedures) except for the mill fan in the case of an independent ball mill for raw meal or cement where it may be possible to use the fan for some cooling of the mill.
- ***If the fan is to be restarted***, once the mill doors have been removed, restart the mill fan and set on a low damper setting (typically up to 5-10%) to provide slight draft through the mill.
- ***Then lock off the fan damper*** to avoid any further adjustment. This should be covered in the safety procedures for the mill shop.
- ***Conduct mill feed belt weigh off***, either by manually taking material off the belt or running the material into a truck, if the facility exists.
  - *How to measure material flow-rates*
- ***Once the mill is safe to enter***, conduct the mill inspection, liners, water injection, diaphragms, media contamination, height of material relative to charge, etc.
  - *How to do a mill crash stop inspection*
- ***Conduct material sampling along*** to check the grinding progress along the mill length
- ***Check the height above charge***
  - *How to manage ball charge level*
- ***Take samples*** of grinding media along the mill axis to check the ball charge grading and classification.

3. Mill System Inspections

- Conduct separator inspection
- Conduct mill cyclone, mill filter and mill fan inspection if deemed necessary from airflow tests
- Conduct separator filter and separator fan inspection if deemed necessary from airflow tests
- Inspect main transport equipment of circuit – bucket elevators and air-slides
- Inspect condition of internal flaps – mill discharge, cyclone flaps, separator flaps and filter flaps

4. Mill System Run Out Stop

- After completing part 3 above of the procedure arrange for the mill to be 'boxed up' and all locks removed.
- Restart the mill system without feed and run for 10-15 minutes to grind out the residual cement, avoid running too long as this could risk damage to the mill liners
- Once the mill is empty then stop the mill system again, and apply the same safety precautions as for mill crash stop
- Re-measure the height above the charge in both chambers to be able to determine the true media volume and the extent of oversized particles, particularly for the first chamber.

5. Sample Testing

- Arrange for chemical analysis, particle size distribution and grindability of mill feed materials
- Arrange for chemical analysis and particle size distribution of circuit samples
- Arrange for physical and chemical testing of mill product

6. Evaluation of the Results

The key points to mention are:

- Feed grindability, any change from previous results
- Feed size, any coarse particles +30mm (residue < 5% & >25mm for cement mills)
- Changes in feed moisture
- Mill and shop power consumption – comparison with grindability test prediction
- Power consumption for each chamber, use the Slegden formula - ensure 8-10 kWh/t for the main product for chamber 1
- Calculate volume loading for each chamber
- Check charge expansion by difference between volume load for crash stop and run out stop
  - Typical values: Raw mill chamber 1: 3-5%
    Cement mill chamber 1: 2-3%
  - Higher values indicate a build up coarse particles (nibs) in the chamber
- Separator efficiency, circulating load, cage loading, airflow through the separator, Rosin-Rammler slope and Tromp curve
- Ball classification – any signs of reverse classification
- Ball grading – contamination, too coarse, too fine (consider along with material filling level)
- Mill liner condition – wear / coating, prediction of remaining lifetime
- Mill diaphragm condition – blockage, excessive gaps, wear, scoops or other flow adjustment, prediction of remaining lifetime, etc
- Material axial grinding curve – any signs of nibs build up in compartments or at the diaphragms? does the mill achieve the target size at the intermediate diaphragm? Max 5% +2,5mm. Is there a general progression of the grinding through the mill?

- Mill ventilation
  - Velocity 1,5 to 2 m/s above mill charge, lower for finer grinding
  - Sources of leaks
- Product particle size grading, slope RR curve
- Mill system heat balance to check drying capacity (mills with wet additives) and cooling capacity for low cement temperature

7. Reporting

- Reporting using standard report format, first part to be a simple action plan with priorities and target improvements

  Grinding > Job aids > Mill Audit Report template

Revisions

Version	Date	Update
2.0	April 2010	"Safety aspects" updated further to the review by Health & Safety Dept
1.0	March 2008	First issue.