Bulk Raw Materials Storage Selection

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INTRODUCTION

The processing of mineral ores to useable minerals in their commercial forms are produced in stages which differ in method and duration of processes. In order to perform these various stages economically and within strategic operational safety margins, these stages need to operate independently from one another. This is achieved by storing material after and/or before each stage.

The selection of the correct size and type of storage of material is important from a strategic and economical point of view. Too large a size of storage of material is a high capital expenditure and a high work in progress cost. Too small storage size may cause discontinuity of processes both upstream and downstream of the storage facility with resultant production losses, penalties, losses in economics of scale and losses in the advantages of continuous processing for certain processes. In this presentation guidelines are given for the selection of a storage facility.

SIZE SELECTION

The storage size selection is a function of the balance between the process differences of the material supply and material receiving side. Using a systems approach to balancing the equation the following is noted as part of these criteria (annexure A)

- The rate at which the material is delivered to the storage facility.
- The frequency at which the material is delivered.
- How many sources of input material there are.
- Whether material needs to be homogenized or blended. (The required or preferred properties of material for the next process.
- The rate at which material needs to be withdrawn from the storage facility.
- The frequency at which material needs to be withdrawn.
- The transportation method and distance between storage facility and next process, (risk, additional storage)
- The strategic size of the buffer capacity.

A practical example (annexure B) of the above is: An opencast mine producing five days a week, twenty hours per day, needs to feed a processing plant that operates twenty four hours per day, seven days a week. The strategic buffer may be required to be one week's feed to the processing plant (inclement weather, breakdowns etc.). The additional capacity is determined as a mass flow balance between the total average weekly production from the mine and feeding the plant at a continuous rate for seven days a week. The example above is a simple situation that can be determined by hand calculations. There are various computer simulation techniques available to calculate complex situations.

The required material properties to the plant may also have an influence (the effect of blending and homogenizing is discussed later) on the overall size selection. The distance between the mine and process plant will also have an influence. If the plant is far away the storage may only be sized for disruption in the transportation process. A long overland conveyer can in itself provide storage. Belt conveyors generally have a small storage capacity, but long overland systems may have an influence on buffer capacity and resultant storage selection. A 20km overland conveyor system has approximately 3000m^3 storage capacity. If production history shows that no more than 6 000m^3 buffer capacity is required to reduce downstream stoppages, a storage of only 3000m^3 will be required, provided that enough storage is available to ensure downstream operation if the conveyor is out of operation.
Once the size of storage is determined, the type of storage can be determined.

STORAGE TYPE SELECTION

Storage type selection [1] is determined by:

- The size of the required storage facility.
- The capital and operating costs of the facility.
- The required throughput rate.
- The required material properties (degradation and blending / homogenization).
- The reliability of the system (strategic importance).
- Environmental influences on material (moisture, oxidation).
- Pollution hazards (wind, rainwater wash away).
- Environmental influences on equipment (wind and rain influences on stability and safety of operation).

The following storage facilities for bulk handling systems (with continuous reclaiming abilities) are commonly used:

- Conical stockpiles
- Longitudinal stockpiles with bottom withdrawal.
- Earth and concrete bunkers.
- Silos
- Longitudinal stockpiles (with a combination of various types of reclaiming equipment).
- Circular stockpiles.

For a summary comparison please refer to annexure C

Conical stockpiles:

This is a simple and low cost means of storing material by forming a cone on the surface from a single discharge point. Reclaiming is normally done via vibrating feeders feeding out onto a reclaim conveyer in a tunnel under the stockpile. The live storage capacity is very low (± 30 – 40%of the total volume) and the "dead" material needs to be reclaimed with labour intensive equipment. Where material can be stored for prolonged periods of time without jeopardizing quality or running risks such as spontaneous combustion, this may prove to be a good economical solution. Typical storage capacities are up to 10 000m^3 total storage.

Longitudinal stockpiles with bottom withdrawal:

This is a variation of the conical stockpile with the only difference that the feed is not fixed and it is typically a travelling tripper car. Withdrawal is via a series of feeders (typically vibrating). The spacing of withdrawal points is a cost trade off as the civil work required for each point is a great cost contributor. The live storage capacity is in the region of 35 – 45% depending on the number and type of withdrawal points. This type of system is economical in areas with good competent ground conditions with little or no ground water. Typical storage (live) capacities are 10 000 – 15 000 m^3. At longer lengths / higher storage sizes other methods of storage become more economical. The exact crossover depends on the area's specific ground condition. Optimisation of this system lies in the reclaiming method used. The following options are available: Vibrating feeder ; Radial gate / gravity feeder ; Belt feeder / Apron feeder ; Plough feeder. The specific application for each of these are a subject of its own but basically comes down to the economics of the solution, optimisation of utilised live capacity, flowability of material and accuracy of reclaimed volumetric flow.

As the operation of this type of storage depends on gravity to feed the extraction point/s, these systems are limited in the reclaim flow rate for up to a maximum of approximately 2000 m^3/h. Higher flow rates can be achieved for short periods of time by extracting from more than one point. The flow rate is also very dependant on material flowability and variation thereof (e.g. changes in moisture and clay content).

Earth and concrete bunkers:

These are a variation of the longitudinal stockpile with bottom withdrawal tunnel. The major difference is that the dead material storage is eliminated by the geometrical shape of the bunker. This is more expensive than the previous type but may be a specific requirement for materials that pose a safety threat or lose quality when stored for prolonged periods of time. A life cycle total cost model approach may also render such a system more viable when the cost to rework dead material is brought into the cost of operations. Another advantage of this system is that it covers less area (in plan) for the same quantity of live material stored and can thus be covered at a lower cost, or alternatively be installed in a more confined space.

Typical storage (live) capacities and reclaim flow rates are the same as for those of the longitudinal stockpile with bottom withdrawal tunnel, as for larger storage requirements other systems become more economically viable.

Silos:

Silos have a space advantage over earth and concrete bunkers and storage capacities are typically up to 4 000 m^3 live. In the cement industry storage sizes are up to 10 $000m^3$. The costs are relatively high and maximum storage capacity is limited by physical design limitation and logistics. Typical applications are in confined spaces in existing plants and storage above (or at) processes that require centralised extraction available immediately (e.g. Rapid train load out stations).

Longitudinal stockpiles with total extraction:

These storage systems are normally formed by placing material longitudinally along a length of ground via a travelling stacker. The specific storage requirements and environmental issues determine whether the stacker is fixed, has a luffing boom or is of the luffing and slewing type.

Storage capacities are typically above 15 000 m^3 and the reclaiming system depends on the specific application. Longitudinal stockpiles are basically determined by length and width. A narrow stockpile width results in either smaller storage facility or long systems with associated civil, feed and reclaim conveyer costs, and the costs of services such as power and water reticulation. A wide stockpile width may have the advantages of shorter systems but the machine costs to stack and reclaim increases considerably. Other general considerations required with doing width and length selection are the stack and reclaim flow rates (throughput). A machine with a very high reclaim rate for instance may be such that design limitations require certain minimum physical sizes and therefore a narrow machine may not be feasible and/or economical. This also implies that in such a case, depending on the required storage capacity, the storage selection may go to one of the other type of systems. These storage systems normally use positive reclaim methods that "force" material into the withdrawal system.

The following types of reclaimers are used and each has their specific application:

Side scraper reclaimers are the smallest machines and reclaim rates are typically $400m^3/h$ with boom lengths up to 20m. The largest side scraper reclaimers have reclaim rates of 1 $000m^3/h$ with a 25m long boom, but these were applied in specific existing plants where the layout limited the use of a portal scraper reclaimer. Apart from the layout and lighter design, side scraper reclaimers have the same application as portal scraper reclaimers.

When the size and mass of the boom increases past a certain point, a design that utilises a portal, which spans over the stockpile, becomes more economical. Portal scraper reclaimers are normally used as non-blending machines (either very early in production or on final products) where it is important that the machine can cross over various storage piles to reclaim from a specific stockpile. When selecting a portal scraper reclaimer it is important to note the way of operation and that there is a vast difference between the average rate of reclaiming and the maximum rate of reclaiming. The maximum rate of reclaiming is determined by the physical size of the machine and it's reclaim buckets. The average reclaim rate is a function of the stockpile length, the position of the boom in the stockpile, dressing time and whether the stockpile was fully stacked or not prior to commencement of reclaiming. A further consideration is that there are also instantaneous fluctuations in that each "bucket" discharges onto the receiving conveyer. When designing downstream systems for these reclaimers it is important to design for these fluctuations otherwise the system would not be able to achieve the required flow rate. Maximum reclaim rates of 2 200m^3/h are possible for single boom portal scraper reclaimers and up to 4400m^3/h for double boom scraper reclaimers. Average reclaim rates can go as low as 75% of maximum depending on the specific plant layout. Stockpile base widths of up to 60m are possible but economical sizes are in the region of 25m to 45m.

Where blending is required, bridge scraper reclaimers are normally used. These machines cannot cross over stacked stockpiles and the system design needs to take that into consideration. Maximum reclaim rates are in the region of 1 800^3/h with stockpile widths up to 60m. Economical stockpile widths are in the region of 25m to 45m. The machine's reclaim capacity only fluctuates with the discharge of the "buckets" onto the conveyer, as the complete face of the stockpile is covered by a rake that causes the material to 'avalanche' down to the reclaim scrapers.

Where higher reclaim rates are required or where the material is very abrasive, bridge bucketwheel reclaimers are used. Drum reclaimers are a further development of bridge bucketwheel reclaimers where the "bucketwheel" spans the complete stockpile base to achieve a better blending effect. Drum reclaimers can reclaim up to 4 500m^3/h for light materials (and a uni-directional machine) and up to 6 000tph for heavy materials, with stockpile widths up to 50m. Reclaim capacity is very constant and wear and tear on the machine very low. The machine is also a low generator of material degradation.

Very high reclaim rates require the use of bucketwheel reclaimers, which can reclaim up to a maximum of 9 000m^3/h for light materials and 10 000tph for heavy materials. These machines are normally used to move products, which normally does not require blending, very quickly between processes (e.g. onto trains or ships) where time delay can cause penalties due to limitations in resources. These machines also have a further advantage that reclamation can be done on the parallel stockpiles from one machine. Average reclaim capacity is affected by the stockpile cross sectional geometry and the size of the bucketwheel diameter in relation to the stockpile length and can go as low as 80% of the maximum reclaim rate. Instantaneous fluctuation due to buckets discharging on a conveyor also occurs and need to be considered in the volumetric design of downstream systems.

Circular stockpiles are used where the storage area is confined, the stacking and reclaiming rates are relatively low and/or where covering of the stockpile is required. The selection of a circular stockpile are in most cases an economical choice, since for a set of design parameters, a circular stockpile would be more cost effective than a longitudinal system with all its conveyors. This is typically in the range of 25 000m^3– 60 000m^3. Circular stockpiles are normally combined with bridge scraper reclaimers but in certain cases portals/side scrapers are also used. Blending can be achieved by using the chevcon stacking method. This does imply that a certain portion of the stockpile is not live in the sense that it is used for stacking the chevcon tail. A further advantage of this type of storage system is that the storage bed is "endless" and the reclaimer does not need to be relocated. Circular Stockpiles can be covered more cost effectively than longitudinal stockpiles since the area to volume ratio is much smaller for circular stockpiles. Typical storage volumes are up to 85 000m^3 and 120 m in diameter. Reclaiming rates are limited to 1 800m^3/h.

BLENDING/HOMOGENIZATION

There are various publications that explain the mechanisms for blending or homogenisation[2]. The purpose here is to explain the effect that homogenisation or blending has on the storage size and machine type selection. The blending/homogenisation effect for a chevron stacking method is a function of the square root of the number of layers on the stockpile. The stockpile cross area, again is the function of the number of layers, the stacking rate and the stacker travel rate. For a given homogenisation/ blending effect and stacking rate there are thus a fixed set of parameters for the stockpile cross section and the stacker travel speed (assuming constant stacking rate). The length of the stockpile is now determined by the total number of production tons that needs to be homogenized/blended (typically it may be required that one week's production be blended/homogenized). A good guideline, though, is that the length of the stockpile needs to be a least four times the width. This will ensure that the effect of the end cones are minimised and it is also less likely that consecutive layers are identical or repetitive.

In general bridge scraper reclaimers and drum reclaimers are used together with chevron stacking to obtain a good blending ratio. Circular stockpiles with a chevcon stacking method and bridge scraper reclaimer produces similar results. Lesser blending ratios can be achieved by combining a portal scraper reclaimer with strata stacking and also by combining windrow stacking with a bucketwheel reclaimer.

CONCLUSION

Storage system selection is not only determined as a wish, but can be scientifically calculated and modelled. Various factors play a roll and one must ensure that the system is balanced when selecting and sizing a storage system. A system that is cost effective for one set of parameters, may not necessarily be so for a different set of parameters. The size of the storage system is not only dependant on strategic values, but also operational issues such as mass balance differences and the need to blend/homogenize. Other external factors that have a selection influence are the need to cover the storage system (either due to product contamination or environment contamination) and the physical space available.

References

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   Bucket Wheel Reclaimers
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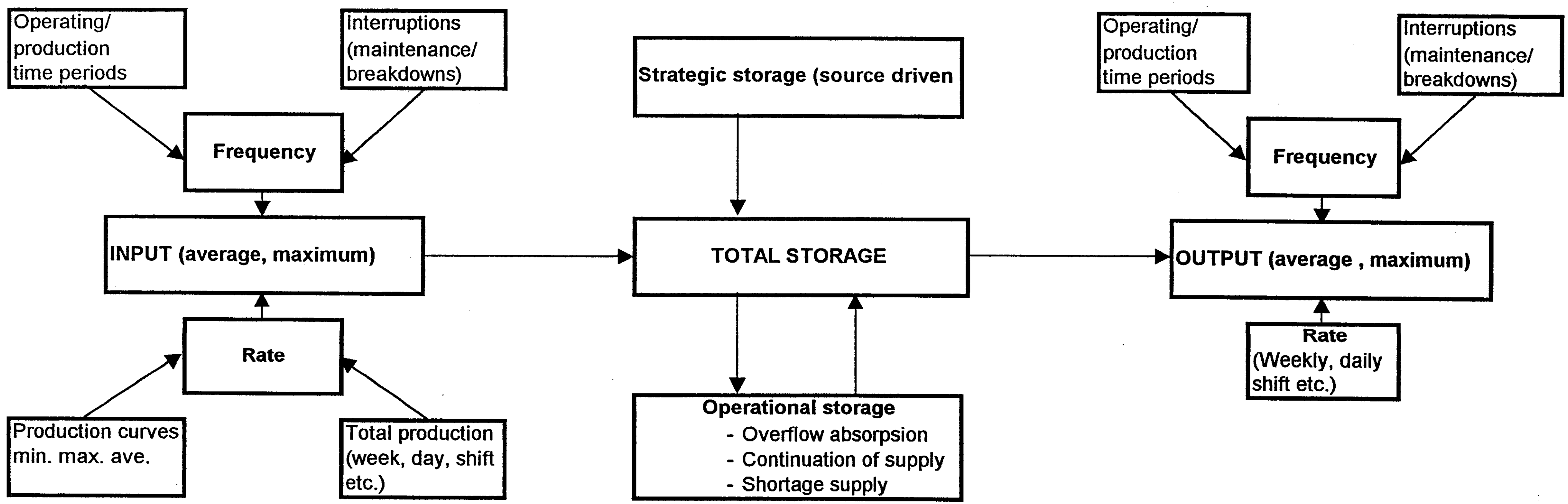
ANNEXURE A

MATERIALS STORAGE SELECTION

SYSTEMS APPROACH TO SIZE SELECTION



MATERIALS STORAGE SELECTION

ANNEXURE B

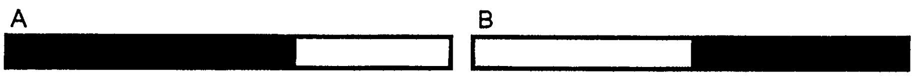
EXAMPLE OF STORAGE PHILOSOPHY / SIZE SELECTION

Weekly Production : 50 400 t, 5 days , 24h/day (average : 420 tph)
Strategic Storage : 20 000 t
Reclaim Rate/Plant feed rate : 50 400 t , 7 days , 24 h/day (average : 300 tph)
Operational Storage : 14 400 t
Assumption : Reclaim and stack can take place on same stockpile

1) Beginning of the Week

Stockpile A (20 000t) is full - start reclaiming from A and stacking on B

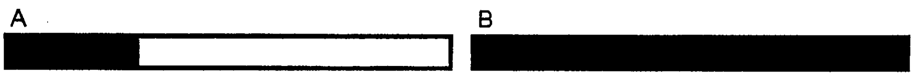
2) End day 1



Material Reclaimed 7,200
Material Stacked 10,080

3) End day 2

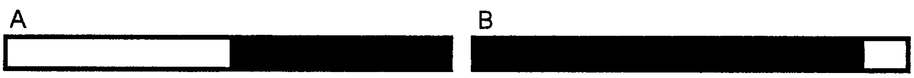
Stacking on B , Reclaiming on A



Material Reclaimed 14,400
Material Stacked 20,160

4) End day 3

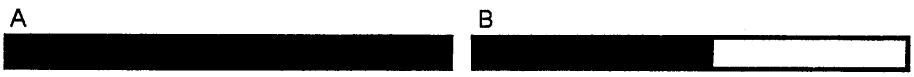
Stacking on A , Reclaiming on A and B



Material Reclaimed 21,600
Material Stacked 30,240

5) End day 4

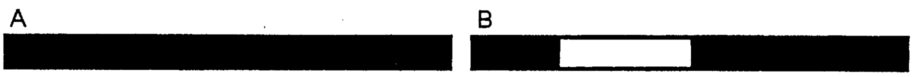
Stacking on A , Reclaiming on B



Material Reclaimed 28,800
Material Stacked 40,320

6) End day 5

Stacking on B , Reclaiming on B



Material Reclaimed 36,000
Material Stacked 50,400

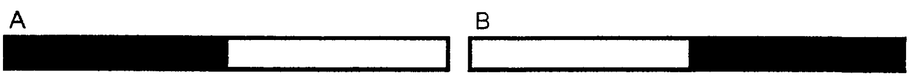
7) End day 6

Reclaiming on A and B

Material Reclaimed 43,200
Material Stacked 50,400

8) End day 7

Reclaiming on A



Material Reclaimed 50,400
Material Stacked 50,400

ANNEXURE C

MATERIALS STORAGE SELECTION

TYPE SELECTION

Longitudinal reclaim machines	Typical Stockpile Width	Maximum Reclaim Rates	Average Reclaim Rates	Comments
Side Scraper Reclaimer	10 m - 25 m	1 000 m^3/h	As low as 75% of maximum	High cyclical peaks superimposed by immediate fluctuations of "buckets" discharging
Single Boom Portal Scraper Reclaimer	15 m - 60 m	2 200 m^3/h	As low as 75% of maximum	High cyclical peaks superimposed by immediate fluctuations of "buckets" discharging
Double Boom Portal Scraper Reclaimer	15 m - 60 m	4 400 m^3/h	As low as 75% of maximum	High cyclical peaks superimposed by immediate fluctuations of "buckets" discharging
Bridge Scraper Reclaimer	15 m - 60 m	1 800 m^3/h	Approximately 95% of maximum	Constant reclaim rate with immediate fluctuations of "buckets" discharging
Drum Reclaimer	20m - 50 m	4 500 m^3/h	Approximately 95% of maximum	Constant reclaim rate : Maximum is 6 000 tph for heavy materials
Bucketwheel Reclaimer	30 m - 60 m	9 000 m^3/h	As low as 75% of maximum	High cyclical peaks superimposed by immediate fluctuations of buckets discharging : Maximum is 10 000 tph for heavy materials

ANNEXURE C

MATERIALS STORAGE SELECTION

TYPE SELECTION

Type	Typical Total Storage Size	Typical Live Storage Size	Typical Reclaim Rates	Maximum Reclaim Rates	Comments
Silos	4 000 m^3	4 000 m^3	1 000 m^3/h	2 000 m^3/h	Storage sizes of up to 10 000m3 are used in the cement industry
Conical	10 000 m^3	4 000 m^3	1 000 m^3/h	2 000 m^3/h	
Longitudinal with bottom withdrawal	20 000 m^3 to 30 000 m^3	10 000 m^3 to 15 000 m^3	1 000 m^3/h	2 000 m^3/h	Higher reclaim rates can be maintained for short periods by withdrawing from multiple points
Earth and Concrete bunkers	10 000 m^3 to 15 000 m^3	10 000 m^3 to 15 000 m^3	1 000 m^3/h	2 000 m^3/h	The design allows for 100% live capacity
Longitudinal with reclaim machine	+ 15 000 m^3	+ 15 000 m^3	200 m^3/h to 4 000 m^3/h	9 000 m^3/h	Maximum reclaim rate limited to 10 000 tph for heavy materials
Circular	25 000 m^3 to 85 000 m^3	15 000 m^3 to 65 000 m^3	200 m^3/h to 1 800 m^3/h	1 800 m^3/h	