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Review of Raw Material Stacking and Reclamation Methods

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Überblick über das Absetzen und Wiederaufnehmen von Schüttgütern
Revue des méthodes d'empilage et de récupération des matières premières
Revista de los métodos de ensacado y reclamación de materias primas
原料段積み及びリクレーム法の検討
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Summary

A comprehensive review of the processing equipment utilised within the minerals processing industry for stockpile raw material stacking, blending and reclaiming is presented. The benefits and shortcomings of each based on their as observed operational performance are given and relative comparisons are made on the basis of desired material homogenisation and blending efficiency.

The concept of the raw material stockpile as a bulk solids mixing device is amplified and the basic intrinsic process parameters, variables and operational constraints which influence performance are highlighted.

This paper is the first of two concerned with the optimal design of raw material stockpile homogenisers.

1. Introduction

Raw material stockpiles are utilised for storage and blending purposes in most sections of the processing industry, being an integral part of the raw material preparation and processing stage of, for example, iron and steel manufacture, coke plants and coal washeries and in cement manufacture.

A common feature and basic requirement of the raw material stockpile is to even out and reduce the variation or variability in some inherent or intrinsic raw material physical or chemical quality. In this respect, the stockpile has a dual role within the overall preparation system, being a storage unit in addition to its capacity and capability for blending and homogenisation. As an intermediate buffer storage device, production activities in the quarry and in subsequent processing stages need not be related and a constant supply of raw materials to the process is ensured.

Good overall input/output raw material variability reduction can be achieved if correct layout or stacking is employed and hence raw materials from poorer deposits with large scale heterogeneity can be utilised.

Raw materials arriving from the quarry or mine typically have certain unwanted characteristic variations or fluctuations in their chemical composition which in most cases must be filtered out if a consistent good quality product is to be achieved and increasingly high consumer demands for improved product quality met.

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With regard to blending and homogenisation, the way in which the stockpile functions is exceedingly simple in principle when correctly designed and therefore very suitable for the extreme environmental conditions that are usually encountered. Fig. 1 illustrates the CHEVRON method of stacking where theoretically the homogenisation effect is achieved as follows:

- As a result of layer by layer stacking the input raw material flow is divided into small quantities ΔR, where ΔR is the mass of each layer.
- Because of this the characteristic quality variations which occur in the raw material are also divided into equal intervals of ΔR and due to the layered build up of the stockpile the variations within the sub-pile quantities are superimposed.
- On considering cross-sections through the stockpile taken at right angles to the direction of layering, it can be seen that because of the superimposition effect there occur altered characteristic variations from one cross-section to the next.
- Mixed slice by mixed slice reclaiming of the layered material in quantities ΔK will reduce only the variations within the cross-section whereas variations between the mean qualities of cross-sections are predetermined by ΔR, ΔK, and the number of layers used in the construction of the stockpile.

Correct stockpile design consists essentially in selecting the optimum values for the parameters ΔR, ΔK and the number of layers N together with the stockpile physical dimensions so that the variations between and within the stockpile cross-section are reduced to a minimum; and that the change in the mean quality level between the piles is also minimised subject to a certain critical sampling quantity.

Increasing the number of layers in consequence reduces the quantity of material per layer; in general this enhances the homogenisation effect of the stockpile because the variations between the cross-sections are subsequently reduced. Depending upon the type of slicewise reclamation employed, the variations within the individual slices reclaimed will be evened out to a greater or lesser degree.

The CHEVRON method involves layering the stockpile along a fixed axis by means of a conveyor and stacker, the boom of which is usually adjustable in height to minimise the amount of dust created and the height of free fall of the material during the stacking-out operation.

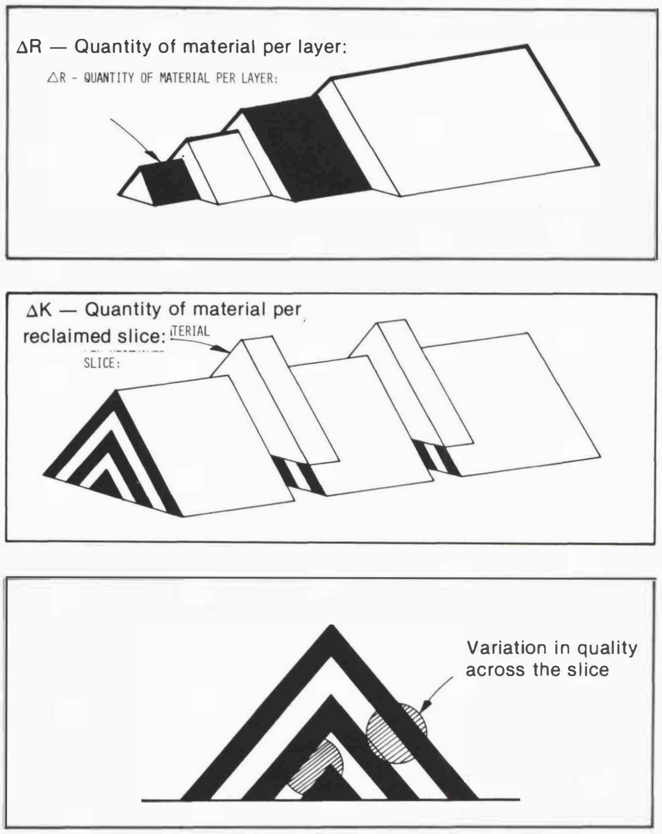


Fig. 1: Representation of stacking and reclaiming in the stockpile pre-homogeniser

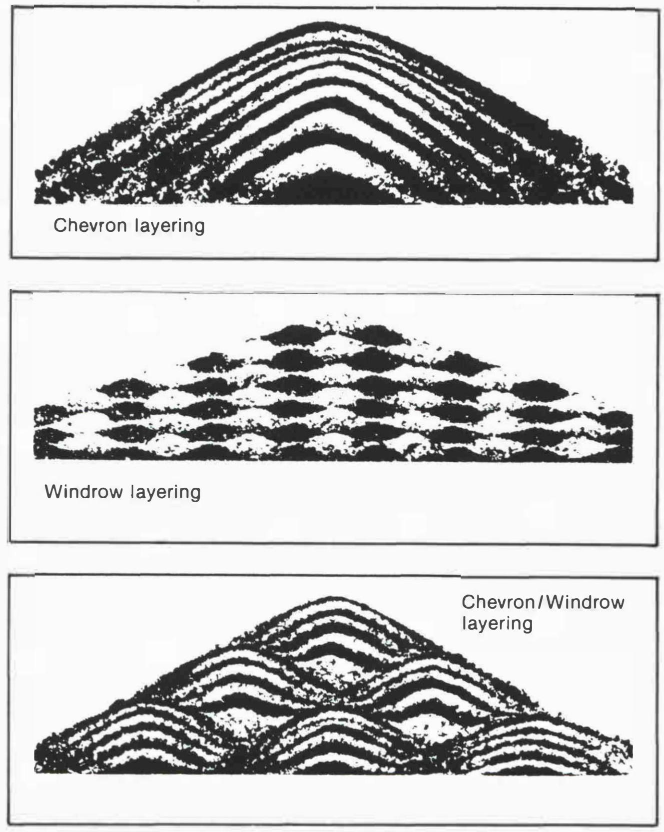


Fig. 2: Typical stacking methods showing a cross-section through the stockpile

Segregation of the larger particle sizes within the raw material towards the base of the stockpile is a natural consequence of the use of this method of stacking, but as long as the stockpile is reclaimed by a device which works from the end of the pile the variations in output composition so generated will be of a short relative time-scale.

Where it is necessary to minimise variations in the quality of the reclaimed material caused by the inherent mechanism of particle size segregation other types of stacking methods should be considered; for example, WINDROW or WINDROW/CHEVRON layering (Fig. 2).

In addition to rectangular prism stockpiles, a wide variety of geometrical forms are possible, for example, conical heaps, circular, prisms, semicircular prisms etc., and they can be sited either under cover or in the open according to climatic, environmental or material considerations.

Except for the purposes of storage, the conical heap should be discounted because of the extent to which particle size segregation occurs and because of its basic ability to generate variations during the material reclamation process rather than achieve any homogenisation effect.

The choice between the other variants of stockpile shape is made according to available space; quantity to be stored, geographical interrelationship between the mine or quarry and the works site, stacking and reclaim throughput rates and types of equipment employed.

The latter choice is dictated by the scale of operations, the degree of raw material homogenisation to be achieved and by the physical nature of the materials to be handled.

In the initial instance, the designer has to choose how the stockpile is to be constructed and subsequently reclaimed. This is dictated by the degree of variability in the feed materials, their size-range, their nature, e.g., sticky, friable etc., and whether there is an association between chemical composition and particle size.

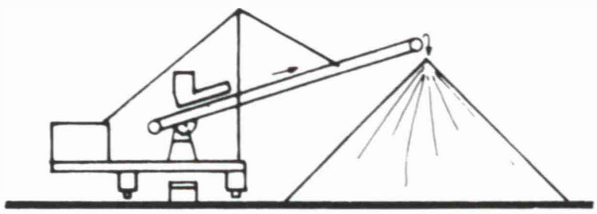
Many different equipment types and stacking configurations are employed within the industry for material layering and reclamation. The main criteria affecting the choice of such equipment and layering configurations, is a function of the desired stockpile input-output material quality variability reduction, the inherent material physical properties and the space and capital expenditure available.

2. Stackers

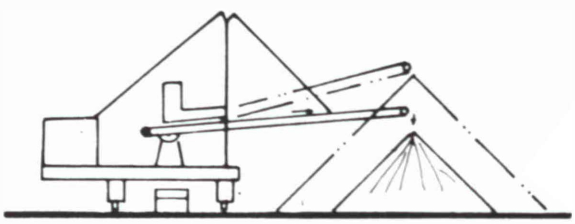
Several variations of stacker exist for use in the construction of rectangular prismatic stockpiles and a selection is illustrated in Fig. 3.

The use of the fixed boom stacker should be restricted to situations where non-dusty materials are being handled and its chief attraction is, of course, low capital cost. When dusty materials are to be handled the stacker with a boom which can be lifted and lowered, is to be preferred (Figs. 4 and 5).

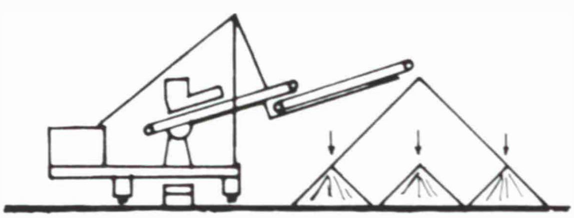
Construction of WINDROW stockpiles with non-dusty materials requires the use of a machine with at least a rigid boom and a retractable belt, one that can be lifted and lowered, should be used where the feed is dusty. The provision of the facility for swivelling the stacker permits the charging of two parallel stockpiles and use of the windrow technique; in both



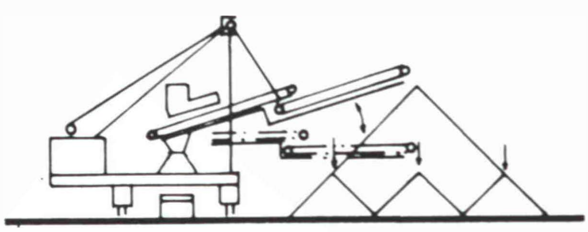
Stacker with rigid boom



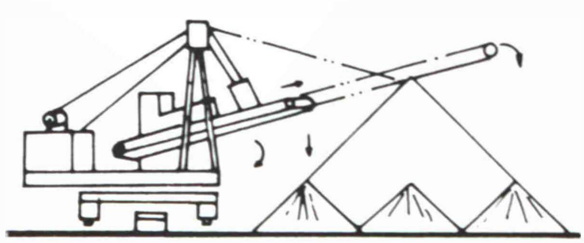
Stacker with boom that can be lifted and lowered



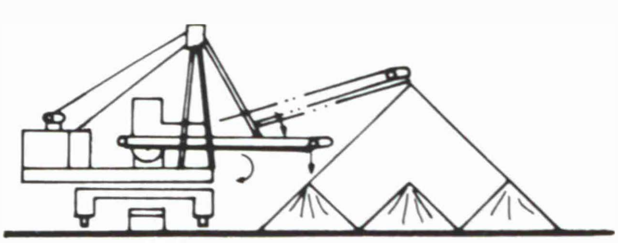
Stacker with rigid and retractable belt



Stacker with rigid and retractable belt that can be lifted and lowered



Stacker with swivel boom



Stacker with swivel boom that can be lifted and lowered

Fig. 3: Alternative raw material stockpile stacking equipment

cases for non-dusty materials. The most versatile machine is one where the stacker can be swivelled and the boom can be raised and lowered thus permitting the construction of stockpiles according to a wide range of strategies but it would only be chosen in preference to the above if it had been decided to lay out the heaps in parallel arrangement, on account of its high capital cost.

Under certain circumstances of terrain it may be appropriate to arrange the feed belt above the pile where the reclamation is effected by paddle wheel extractors. Alternatively, where covered storage has been deemed necessary, a feed belt with tripper can be suspended from the roof trusses: such a choice would be made (in the case of non-dusty materials) after a cost comparison with the most simple rigid boom stacker.

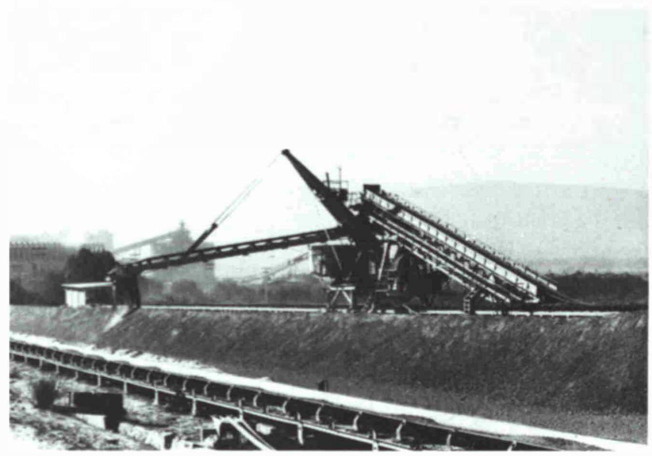


Fig. 4: Stacker with a boom that can be lifted and lowered

Fig. 5: Height of free-fall minimised to prevent undue dust loss

3. Reclaimers

The reclaimer must be considered as a integral part of the homogenisation equipment if the maximum potential of the system for blending is to be realised.

There are available a whole variety of different reclaimers which can be loosely categorised under the following headings:

1. Reclaiming scrapers
2. Bucket chain conveyor reclaimers
3. Bucket wheel reclaimers

4. Barrel reclaimers
5. Disc reclaimers
6. Mobile shovels, bull dozers etc.
7. Under-pile reclaim methods using either paddle wheel or plough reclaimers.

For maximum blending efficiency within the pre-homogeniser it is necessary to reclaim the stockpile from the front in a cross-sectional slicewise manner, with the ideal concept that each reclaimed slice has an average quality close to that of the stockpile average quality.

Underground extraction techniques using paddle wheel or plough reclaimers are not to be recommended basically because of the lack of flexibility afforded by such a system; in particular the low percentage live capacity and lack of accurate and dependable homogenisation make their use extremely unattractive. Use of mobile shovels and/or bull dozers as stockpile material reclaimers has obvious economic advantages and offers a realistic alternative to expensive inflexible purpose designed reclaimers in cases where the stockpile is likely to be a temporary measure or where the homogenisation requirements are not too critical.

However, if economies have to be made in the initial installation it is better to use a temporary reclaim method short of the ultimate, e.g., a bull-dozer rather than to skimp on the stacking equipment. Later expenditure on improved reclamation equipment can then be justified on the basis of giving a further reduction in variability.

In an integrated designed system it is necessary to have a purpose designed material reclamation system which is capable of giving a constant rated output and which ideally mixes the entire cross-sectional slice during the reclamation process. The following sections detail those reclaimers which were designed with this concept in mind; and as we shall see some are more efficient than others.

3.1 Scraper Reclaimer

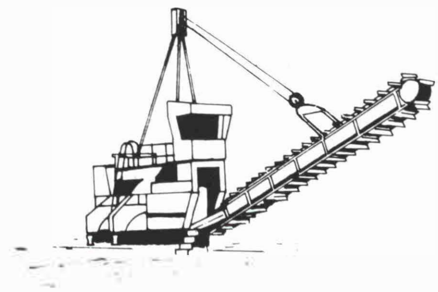
The reclaiming scraper (Figs. 6 & 7) consists of a boom with a circulating chain to which scrapers are attached. Its construction allows for lifting and lowering movements and in some designs a slewing capability is incorporated. It can either reclaim the stockpiled material from the front end in a progressive lateral manner or from the side by travelling along and adjacent to the longitudinal axis of the stockpile.

Although all scrapers work on the same principle there are, however, several types available. The type of scraper influences the design of the stockpile form and the subsequent handling procedures.

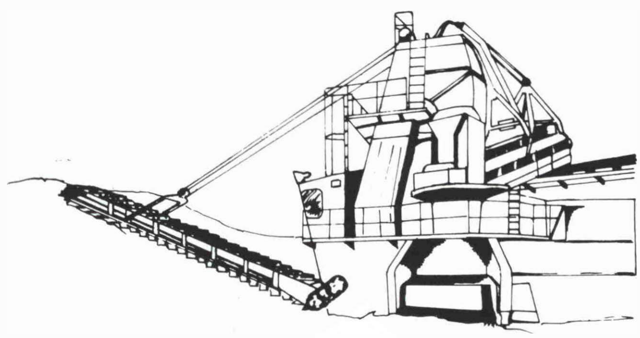
Full Portal Scrapers reclaim the stockpile usually in a longitudinal direction (down the full length of the pile) from one side of the pile only, onto one conveyor belt. The span of the portal scraper reaches over the full width of the building with the machine running on tracks on the ground.

In many designs there are two reclaiming chains, a main chain which reclaims 80 % to 90 % of the storage volume and an auxilliary chain which feeds the remaining material to the main chain; both are attached to the portal base by means of articulations. The use of two chains results in a 25 % energy economy with regard to the total time required to excavate the stockpile.

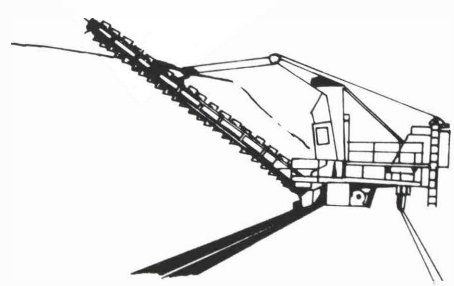
The scraper reclaims while it is continuously travelling back and forth in the longitudinal direction. At the end of each



Two-rail scraper



Two-rail scraper with bucket elevator and boom



Two-rail scraper
that cannot be swivelled

Crawler-mounted scraper for reclaiming material from small stockpiles

Fig. 6: Selection of raw material scraper reclaimers

pass the scraper chain is lowered through a winch system, by the cutting depth of its blade, and by reversing the direction of travel a new reclaiming cycle is initiated.

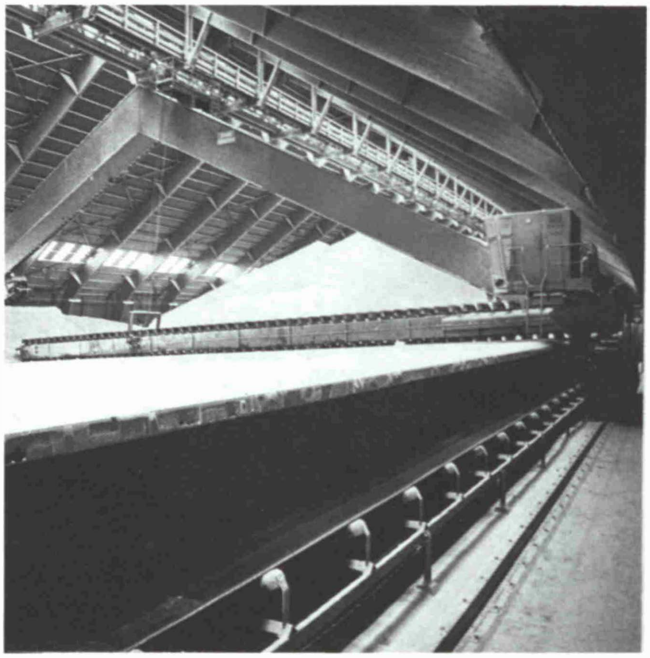


Fig. 7: Full portal scraper reclaimer

The semi-portal scrapers which are a light variation design usually operate in pairs, one on each side of the pile discharging material onto two conveyor belts. Operation is similar to that of the full portal scraper.

Because of the longitudinal reclamation action the travelling scrapers described above limit the homogenisation or variability reduction obtainable unless a strict and very complicated material layering scheme is implemented.

Slicewise Reclamation: The side acting (Fig. 8), front-acting and bridge-type scrapers are used in cases where one wishes to reclaim in a slice-by-slice manner from the end of the stockpile as would be appropriate where CHEVRON and WINDROW stacking methods had been employed. After each slice has been completed the scraper or bridge moves forward by an adjustable depth of cut and a further slice or cut through the pile is initiated. The working methods of the side-acting and bridge scrapers differ by the fact that the side-acting scraper spans the pile and reclaims the material by a sweeping arc motion from one side of the pile whereas the bridge scraper approaches the front end of the pile cross-section, dislodges the material in the face by means of a raking device and reclaims the loosened material via a scraper chain which then conveys the material onto a longitudinally arranged conveyor belt.

The face raking device of the bridge scraper ensures that reclamation takes place approximately over the whole front face so that theroretically all the layers are reclaimed together. So that material does not cascade from the top of the pile, the side-acting reclaimer must traverse longitudinally down the stockpile at the same time as the boom is being lowered across the pile; thus making a sectional cut at an angle equal to or less than the natural angle of repose of the material (Fig. 8).

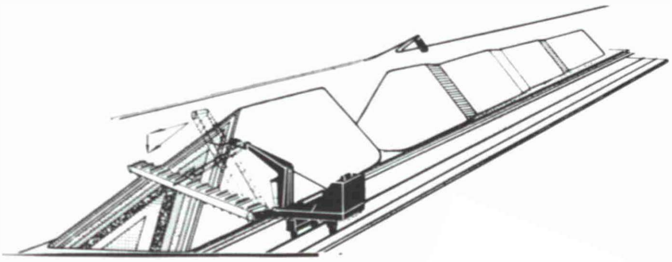


Fig. 8: Side acting scraper reclaimer

The front-acting reclaimer is mounted on a bridge which straddles the base of the stockpile. The scraper is traversed laterally across the triangular section of the pile pulling material into a cross belt mounted on the bridge which in turn discharges to the longitudinal reclaim belt. The boom carrying the scraper is set at the natural angle of repose of the material being reclaimed.

A basic variation to the front-acting scraper reclaimer is the bridge mounted bucket chain conveyor reclaimer which is designed primarily for operation in pits or rectangular storage piles.

The scrapers described above which operate in a slicewise manner are clearly superior to those which reclaim material in a longitudinal manner because such machines cut across the pile layers and impart a substantial mixing facility during reclamation.

3.2 Bucket Chain Conveyor Reclaimer

Fig. 9 shows a special design bucket chain conveyor reclaimer. The plant illustrated consists of a deep pit which is filled by a feeding belt carried on a bridge straddling the pit. The reclaimer consists of a chain conveyor with buckets attached. It travels laterally across the pit on its own bridge which is able to move longitudinally up the pile after each traverse of the chain conveyor. The relatively high expenditure for the erection of the building is compensated to a certain extent by the full utilisation of the interior space.

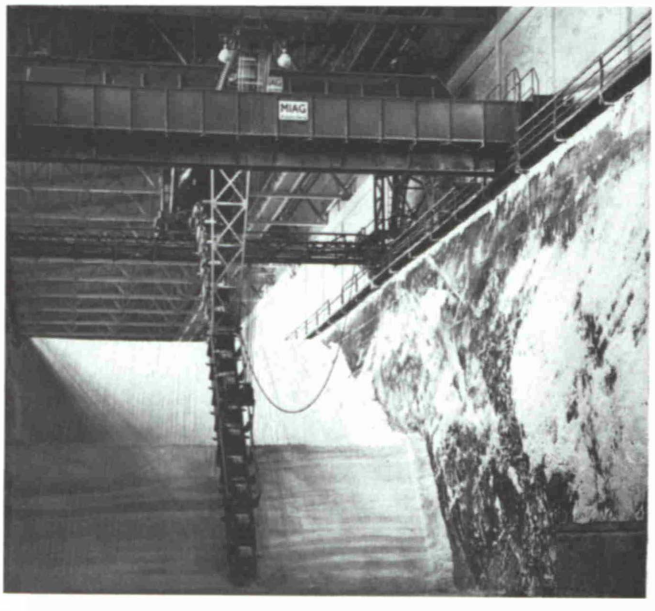


Fig. 9: Bucket chain conveyor reclaimer: bridge-mounted

The basic advantages of this type of homogenisation system and material layering configuration are:

— Particle size segregation within the stockpile is almost non-existent due to the method of lateral horizontal material stacking. Hence, difficult materials can be effectively handled and homogenised.
— Any section of the stockpile face is representative of the whole face or cross-section and because the reclaimer at all times cuts across all the layers within slice variation is almost non-existent.
— The bucket chain reclaimer can handle even the most sticky of raw materials.
— The quantity of material that can be homogenised in the rectangular pit type stockpile is in no way dependent upon the angle of repose of the material as is the case of the longitudinal/linear stockpile homogeniser.

Hence, in comparison with other stockpile forms the area of land utilised per tonne of material stored is small and the maximum nett stock is limited only by the height of the retaining walls.

3.3 Bucket Wheel Reclaimer

The bucket wheel reclaimer (Fig. 10) finds considerable application in the cement and iron and steel industries for reclaiming material from stockpiles where homogenisation is the primary requirement and where non-sticky materials make up the pile.

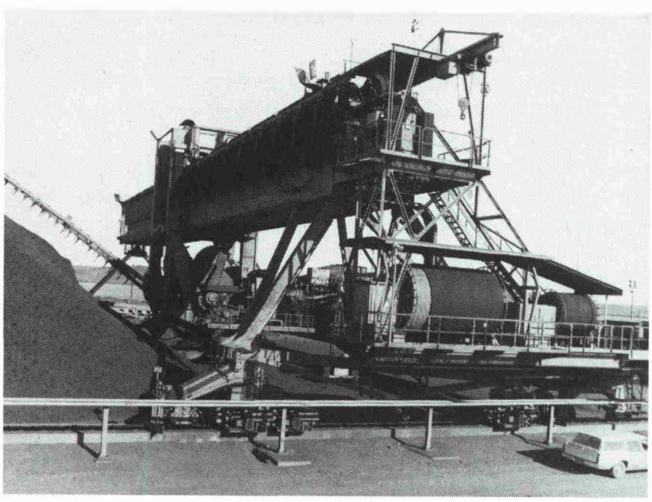


Fig. 10: Bridge-mounted bucket wheel reclaimer

Fig. 10 illustrates a bridge-mounted version which traverses the stockpile end face. The bridge advances by an adjustable increment after each traverse of the bucket wheel, which for a stockpile base width of 20 m would be typically after about every two minutes.

The harrows are designed to promote the flow of material to the base of the pile where the buckets lift the material up and discharge it onto a cross conveyor which passes through the axis of the wheel. The harrow undertakes the following functions (Fig. 11):

— Loosens the material particles in the pile front.
— Guarantees a constant flow of material to the base of the pile.
— Controls the pile front to prevent cascading when the bucket wheel is undercutting the pile during its digging operation.

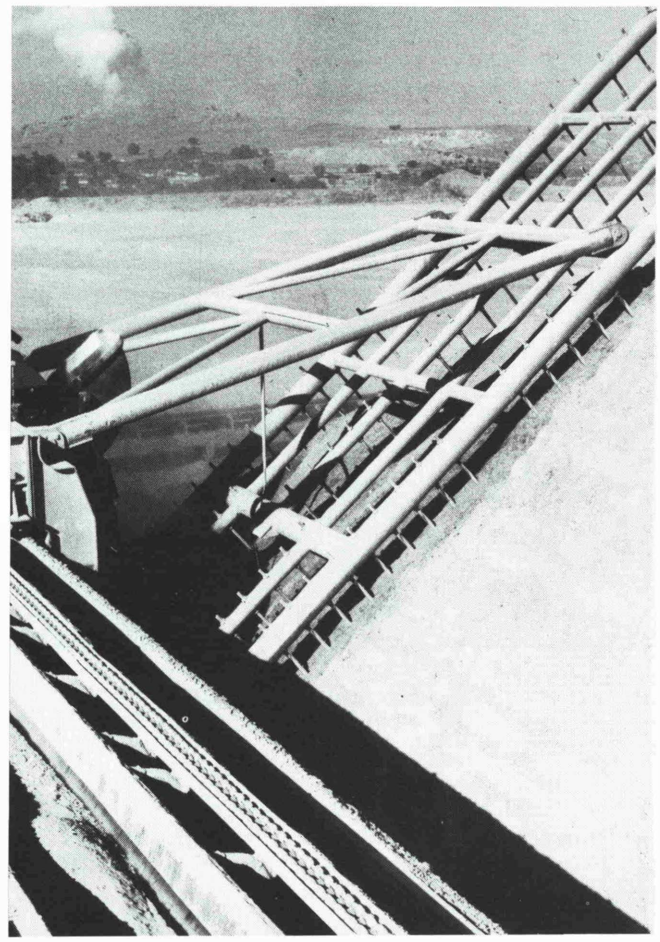


Fig. 11: Harrow arrangement on the bridge-mounted bucket wheel reclaimer

As is the case with any slicewise stockpile end reclamation device, the bridge-mounted bucket wheel must fulfil certain operational requirements to guarantee a reliable and approximately homogeneous product. These are:

— The reclaimer must remove from the stockpile thin slices which are square to the longitudinal axis of the pile.
— The output capacity of the reclaimer must be as constant as possible.
— At a certain required capacity the reclaimed slices have to be of an equal thickness.
— The output material must retain its mixed quality after reclamation.
— Low maintenance and operational costs.

The use of this machine for the handling of very sticky materials is precluded by build-up on the harrows and by bridging in the buckets.

As with the front-acting scraper there is one basic disadvantage with the bridge-mounted bucket wheel in that as the reclaimer traverses from one side of the triangular cross-section to the other (in the case of the linear stockpile), it reclaims material fluctuating both in physical and chemical quality. This observation is particularly relevant to a linear stockpile which has been constructed by the CHEVRON method where the larger particles within the raw material tend to segregate from the fines and concentrate at the bottom of the outside edges of the cross-section with the fines concentrated in the centre of the pile. Hence, reclamation will be cyclic, that is, as the bucket wheel moves across the pile coarse particles will be reclaimed first, followed by the fines, followed by coarse and so on. This effect, however, can be minimised by either altering the stacking procedure or by reducing the thickness of the slice.

In addition to the above, boom-mounted bucket wheels can be used and these may be rail or crawler-mounted. Because the recovery of material from the full height of the face is achieved by elevation and lowering of the boom and does not rely on the effectiveness of harrows, one can tolerate somewhat more sticky materials and modifications can be made to the buckets (such as the fitting of chain bottoms) to overcome bridging.

3.4 Barrel Reclaimer

Essentially the barrel reclaimer (Fig. 12) is an extension to the bucket wheel principle and comprises of a rotating barrel fitted with a large number of reclaiming buckets arranged along its length, into which material is uniformly fed by the harrow. Collected material is discharged from the buckets onto a belt conveyor contained within the barrel. Advancement of the machine along the axis of the pile is automatic and speed variation can be incorporated to provide a range of reclaim rates.

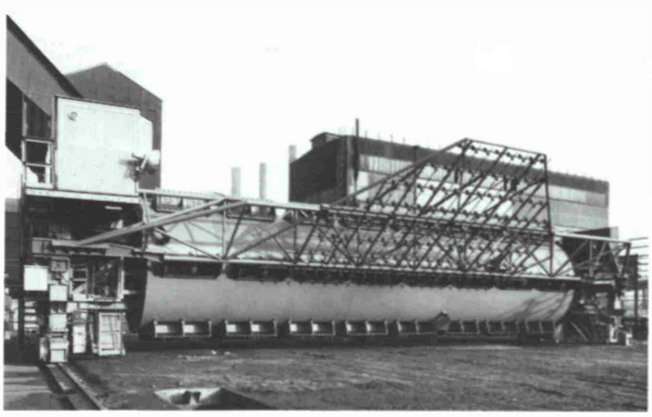


Fig. 12: Barrel reclaimer

The barrel reclaimer is exceptionally robust in design and construction and combines a minimum of working parts. The barrel is supported on heavy self aligning rollers and is rotated by a simple robust drive isolated from material contact and contamination.

The barrel reclaimer is essentially a very large capacity machine and has been used extensively by the British iron and steel industries who employ large stockpile homogenisers (e.g., 120,000 tonnes) with reclaim rates up to 3,000 t/h. The experience of the UK steel industry in the main shows that such reclaimers have minimal maintenance requirements and downtime is negligible.

3.5 Comparison between the Bucket Wheel and Barrel Reclaimer

- Reclaiming material from a linear longitudinal stockpile using a bridge mounted bucket wheel reclaimer having only one bucket will give a belt loading which exhibits a similar form to that of the stockpile cross-section regardless of belt speed and side travel of the bucket wheel. Because it spans the width of the pile the barrel reclaimer does not introduce any apparent periodicities in either the quality/grade of the output or in the belt loading.
- Because of its basic lateral traverse action the bucket wheel is not able to alter or affect any substantial mixing during the reclamation process and therefore the variability across the face is transferred to the discharge belt in an unchanged form; whereas the barrel reclaimer, because of the systematic superimposition of several bucket fillings from various face sections with different total volumes and different grades, brings about enforced mixing and balancing of the belt load.

Where the requirement is for a high output machine and where the high capital cost can be justified the barrel reclaimer is worthy of consideration as its mode of operation closely approaches the ideal concept of complete within slice mixing, and with regard to its reclaimed slice mixing efficiency comes a close second to the Disc Reclaimer which is detailed below.

3.6 Disc Reclaimer

The disc reclaimer, originally designed by International Handling but now owned by F.L. Smidth (Figs. 13 & 14), is the first reclaimer that can truly justify the claim of producing a batchless product with material relaimed in a continuous manner from the entire cross-section of the stockpile.

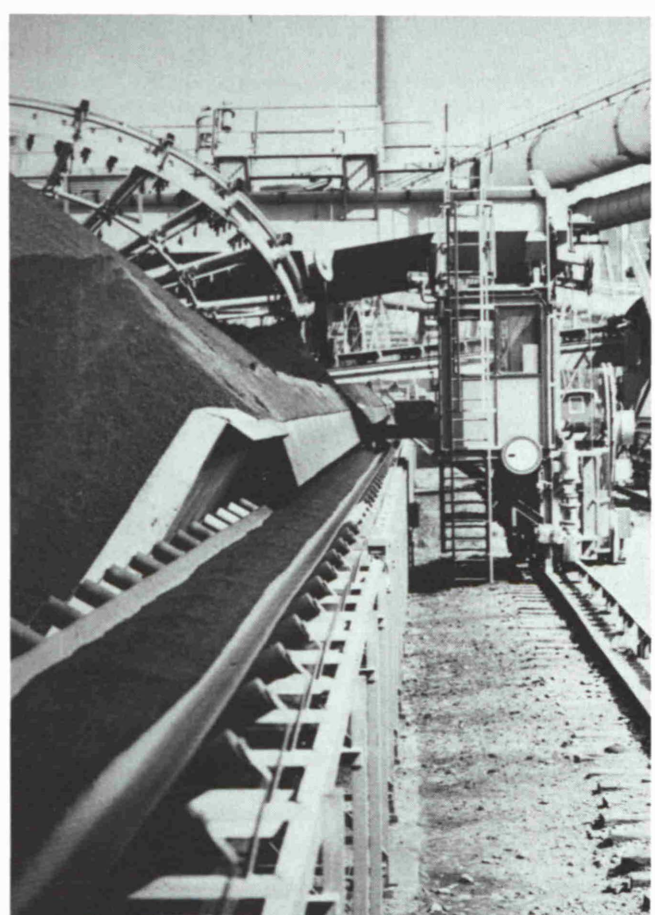


Fig. 13: The Disc Reclaimer

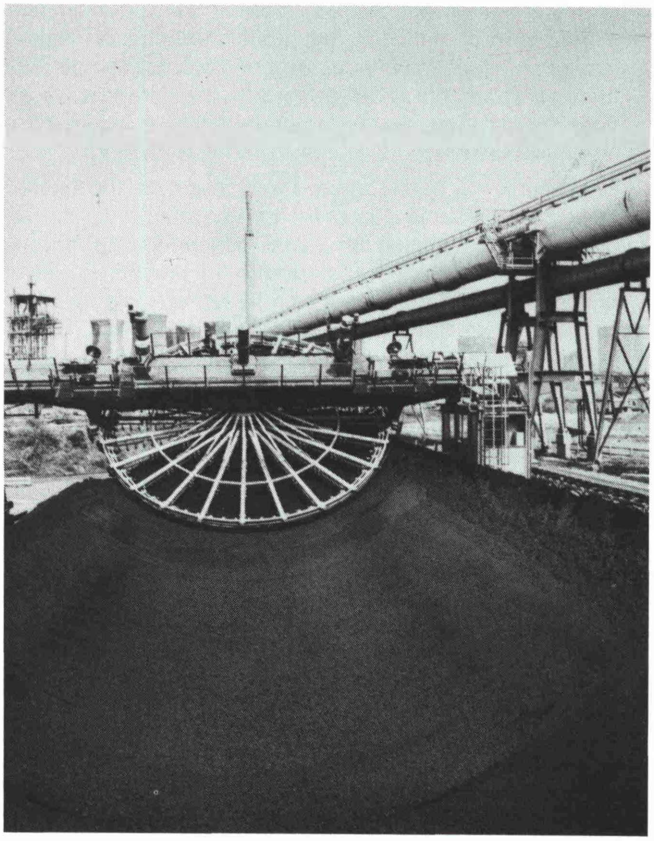


Fig. 14: Material discharging from the Disc Reclaimer

The disc reclaimer was designed so that it could be easily produced and manufactured with the minimum of sophisticated equipment virtually on site and with the minimum of important component parts, thus overcoming any likely import restrictions.

The disc reclaimer consists of a rotating disc structure supported by a bridge spanning the width of the stockpile and supporting structures at each end of the bridge allowing the machine to travel in the longitudinal direction.

The bridge/disc assembly is hinge connected to the end frames. The tilting action coincides with the axis of gravity of the assembly so that tilting requires a minimum of power. The angle of the disc in relation to the horizontal can be adjusted from 50° in one direction through 0° to 50° in the other direction. In addition, the disc can be rotated in both directions. These features make it possible to reclaim in two travel directions.

The action of the disc is threefold:

— Agitating the particles in the pile face. This is performed by teeth connected to the spokes of the disc. During the rotation motion of the disc, the adhesion of the particles in the pile face is disturbed by the teeth causing these particles to roll and slide downward in a controlled manner.
— Collecting the reclaimed material. This is performed by the rim of the disc.
— Transporting the reclaimed material. This is performed by the rim itself and the carriers along the rim. At the point where the rim passes the side slope of the pile, the material flows out of the rim by gravity to a collecting conveyor.

The machine advances forward at a constant speed. This speed may of course be adjusted in order to regulate the reclaimer output.

If direct comparisons are drawn between the Disc Reclaimer and all the other major types of reclaimers currently available, the following operational advantages are evident:

1. The agitating function within the pile face, material collection and transportation functions, which on other reclaimers are performed by two or three mechanical units, are accommodated by one element — the disc, which has only one movement, that is, rotation at a constant speed.
2. The disc covers the complete stockpile and therefore the material reclaimed and discharged onto the collection conveyor contains particles from the entire pile face, fully mixed and in the correct proportions.
3. Produces a batchless product where the reclaimed slice to slice mean quality variance is essentially negligible.
4. Space requirements in terms of additional stockpile width to accommodate the reclaimer assembly are very much reduced, resulting in a saving in the total plan area.
5. Because of the potential for mixing during reclamation, it dispenses with, to a certain extent, the problems associated with reclamation of the stockpile end cones.
6. The output capacity of the Disc Reclaimer is potentially as good if not better than any other reclaimer.
7. All delicate parts such as the main bearing, disc drive and tilting mechanism etc., operate under clean environmental conditions and require little maintenance.