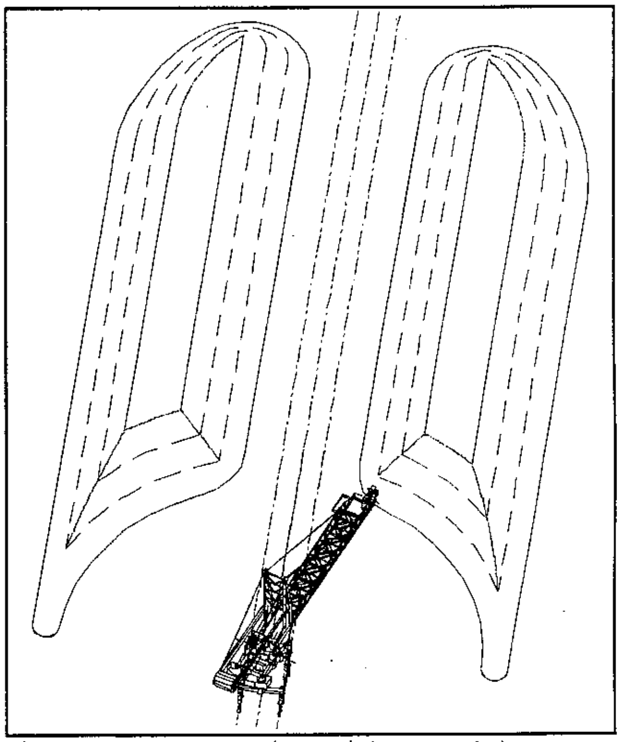
Performance of Bucket Wheel Reclaimers
(Method of Calculation in Principle)

by Wolfgang Knappe
MAN TAKRAF Fördertechnik GmbH

A: Introduction

The objective of the following is to consider bucket wheel reclaimers with a slewable boom moving on a rail track adjacent to or between stockpiles. (Picture 1)



Picture 1 Stockpiles with BW Reclaimer

The reclaiming capacity of the bucket wheel is a characteristic quantity for which a number of definitions are used. These will be explained further in this summary.
The most interesting factor for the owner of bucket wheel reclaimers is, however, the performance of the machine. If a power station has to be supplied with coal it is important to know how much coal will, for example, reach the coal fire silos in 4 hours. If a ship has to be loaded, how long will it take to load the ship? The term "nominal capacity" will not provide adequate information to satisfactorily reply to these questions.
The following is an introduction to the definitions of reclaiming quantities and to the interacting and influencing factors for determining the average reclaiming capacities to be expected with various shapes of stockpiles and reclaiming methods.

B: Definition of Reclaiming Capacities at the Bucket Wheel

1. General

The bucket wheel speed is assumed as a constant referred to a certain handled material with defined density.

The aim is to have constantly full buckets. The bucket filling is a product of the cutting height, the cutting depth and the cutting width.

Bucket volume $V_B = C_H \times C_D \times C_W$ (m^3)

The reclaiming capacity is the product of bucket volume and number of fills.

Reclaiming capacity $Q = V_B \times f \times N_D$ (m^3/h)

2. Theoretical or Design Capacity

The theoretical reclaiming capacity is the capacity for which the bucket wheel is sized, irrespective of the grain and viscosity of the handled material and the position (inclination) of the bucket wheel.

To determine the theoretical capacity the volume of the bucket with the corresponding proportion of the cell or of the annular space is calculated with the water cross-section, which signifies **the filling factor f = 1.**

3. Maximum Capacity

The maximum reclaiming capacity is of interest for the subsequent belt conveyors in order to avoid overfilling.

The maximum reclaiming capacity takes the most favourable conditions into account, but these are not necessarily always present.

The **filling factor f** may in this case be up to 1.2 and takes into account a filled annular space (cell) with additional overload on the buckets.

4. Nominal Capacity

The nominal capacity is the actual bucket wheel reclaiming amount to be expected. In this case, the available filling capacity of the buckets is examined which will vary depending on whether pellets, HBI or power station coal are to be filled. The grain size is also important as well as the inclination of the bucket wheel.
The filling factor is corrected here to the design capacity. The correction is carried out basing on the experience of the manufacturer in close agreement with the owners.

C: Performance of the Bucket Wheel Reclaimer

The performance of a bucket wheel reclaimer is determined not only by the nominal capacity but is also influenced by other factors, such as described hereunder.

Direct influences
Shape and size of the stockpile
Number of benches to be reclaimed
Prepared shape of stockpile for initial cut and end
Travel, slew and hoist speeds of the reclaimer
Accelerations of the movements
Reclaiming method

Indirect influences
Maximum reclaiming amount must be restricted for other reasons
Interruptions in operation
Starting and braking of the conveyor system
Weather influences
Enclosed particles in the material which have to be removed by manually
Caving in of stockpiles

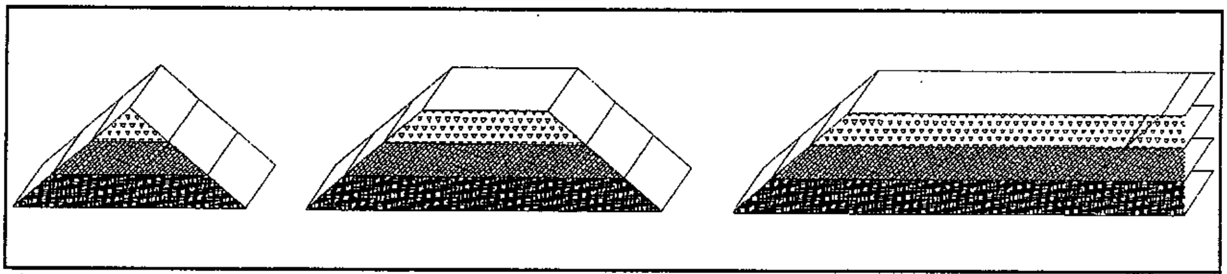
Intolerable stockpile construction deviations

From the above list it is apparent that only the direct influences can be accounted for when performing the calculation.

The indirect influences are dependent on the type and design of the whole conveyor system and on the consumer and cannot be further looked into at this stage.

D: Shape of stockpile and block heights

Bucket wheel reclaimers are familiar at triangular piles, trapezoidal piles and at trapezoidal piles with side banks. (Picture 2)



Picture 2 Stockpile shapes

The number of blocks are selected in accordance with the height of the stockpile and the diameter of the bucket wheel. The height of cut should not exceed **0.65 x bucket wheel diameter** as otherwise there is a risk of undercutting and of the stockpile caving in.

E: Speeds and accelerations

The slew speed (depth of cut) is already determined when selecting the bucket wheel.

The accelerations (decelerations) should not exceed **a = 0.1 m/s²** as otherwise a special stress analysis verification will be required.

The travelling speed is usually limited to 30 m/min and the hoisting/lowering speed is 8 m/min.

F: Control of the bucket wheel reclaimer

Diagram 1 shows the reclaiming capacity as a function of a constant slew speed.

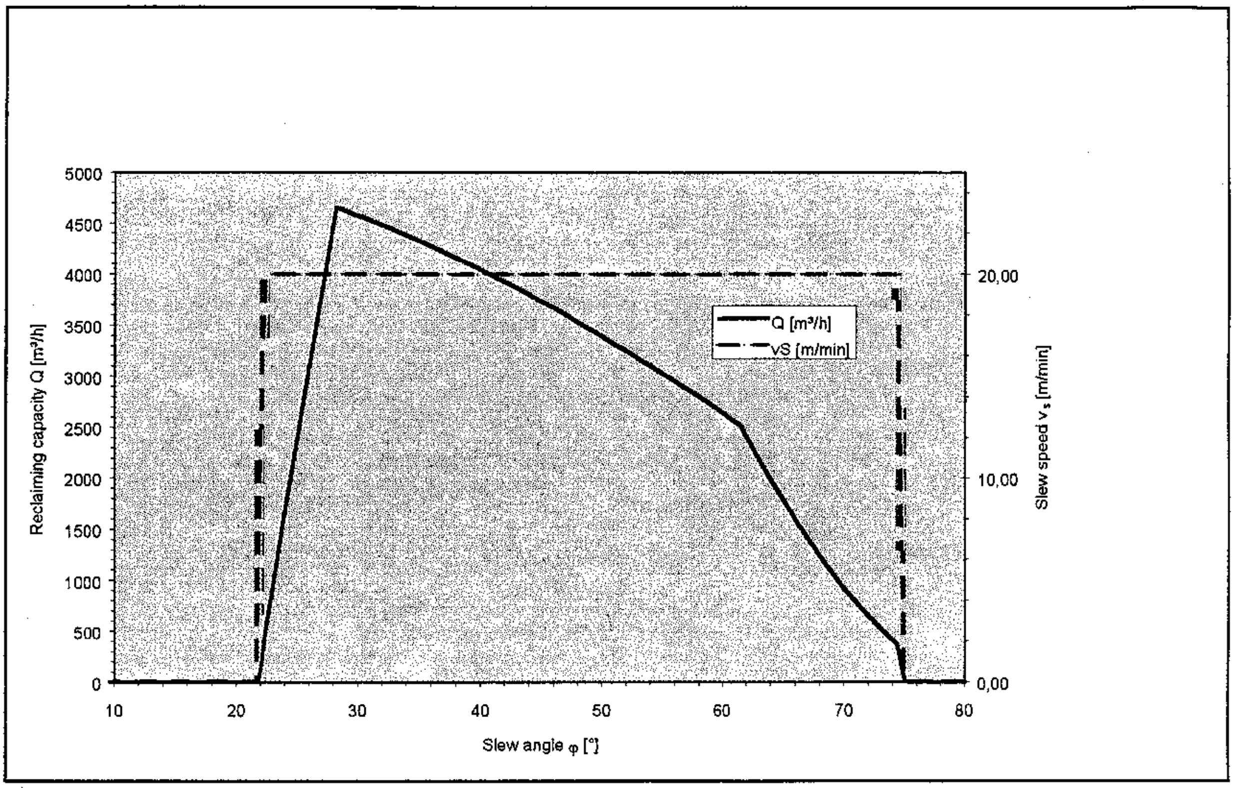


Diagram 1 Constant slew speed

The reclaiming capacity drops as the cutting depth is reduced during slewing. By increasing the cutting width the volume in the buckets can be compensated for. This is done by increasing the slew speed

With controlled slew speed, the diagram 2 is as follows:

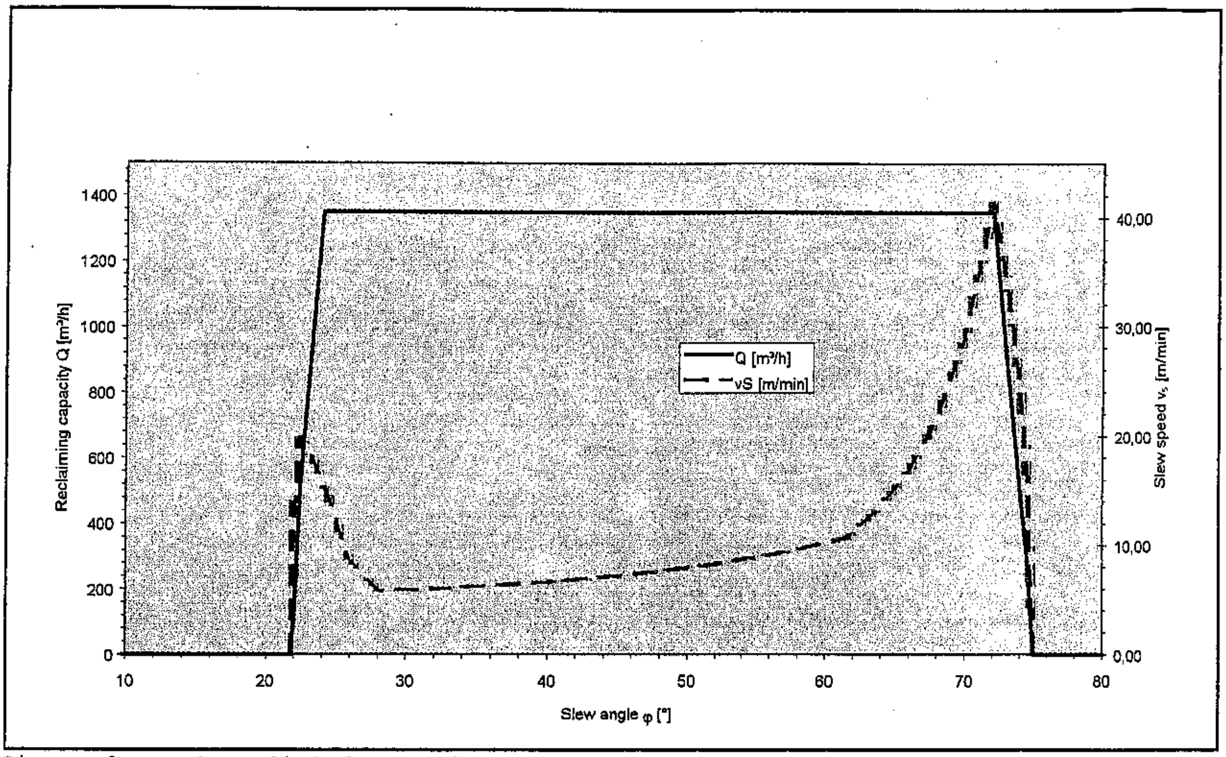


Diagram 2 Controlled slew speed

In order to achieve a constant volumetric flow, a belt scale can be used to measure the reclaiming amount. The belt scale can only be used in the boom conveyor. Due to it being positioned here, it will have an idle time of several seconds which is no longer permissible for the control system and is - on its own - thus unsuitable.

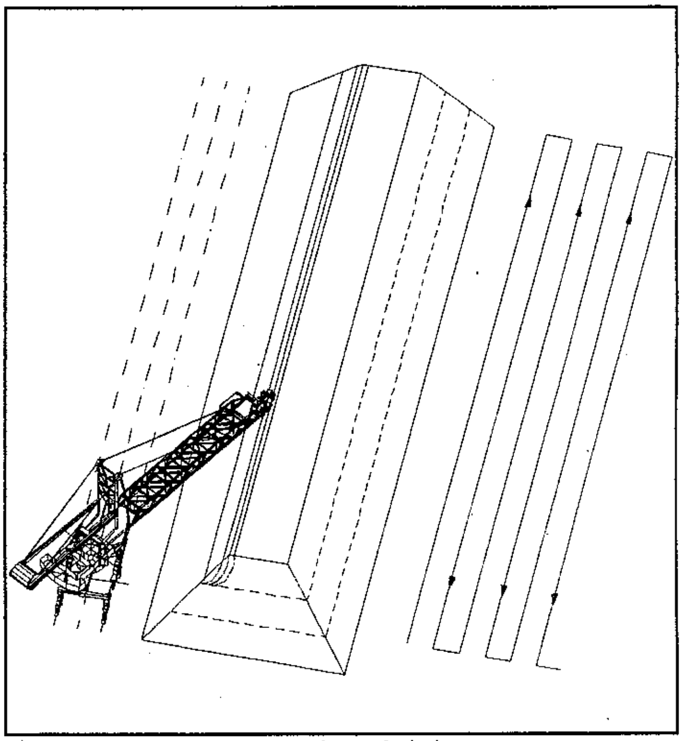
We can measure the direct influence of decreasing or increasing material flow on the bucket wheel. The motor power absorbed is our standard size.
The belt scale is, however, also necessary, but only corrects the nominal capacity as selected.

G: Reclaiming Systems

When making the following considerations, one proceeds as a rule on the assumption that in the area of automatic control 100% nominal capacity is also ensured. Lower capacities are performed when there is a need to accelerate or decelerate. Travelling and lifting/lowering of the boom must be considered separately.

1. Long Travel Reclaiming

In long travel operation, cutting is performed by travelling the whole reclaimer alongside the stockpile. The cutting depth is set after each travel movement by advancing the bucket wheel boom. Face operation is possible both with slewable reclaimers and with TRENCHER reclaimers.



Picture 3   Long Travel Reclaiming

Let us assume here that the machine moves with an average speed of 20 m/min and travels over a distance of abt. 200 m in one direction, then acceleration and braking must be additionally taken into account.

During acceleration/braking the full nominal capacity is no longer achieved which means that we must add in each case half the accleration times to the reclaiming time with full reclaiming quantity.

At an average travelling speed of 20 m/min, the acceleration/ decleration time is all of 3.3 seconds.

If we add in each case half of these times to the face reclaiming time, we arrive at a degree of operational efficiency of 99.5%.

If the travelling time is assumed at only 50 m equivalent to 2.5 minutes, the degree of efficiency is still 97.8%.

In the light of this high degree of efficiency of the reclaimer, it is not necessary to make an electronic calculation of the exact conditions. The control circuit tolerance of +/- 5% also has to be taken into account.

2. Slew Reclaiming

In slew operation, the pile is reclaimed in benches by slewing the boom. After completion of each individual slewing movement the machine is advanced for the new cutting depth.

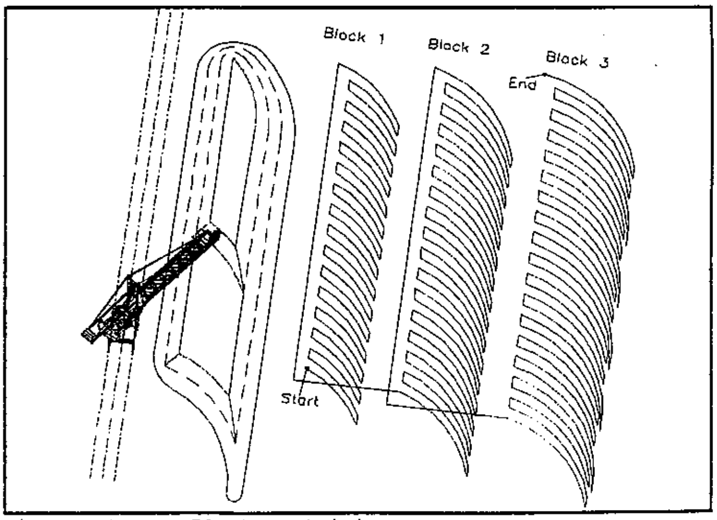
To illustrate this procedure we can observe the motion diagram - speed of the bucket wheel over slew angle - as an example for the middle bench.

The slewing process begins on the side near the runway by the acceleration of slewing. The acceleration ends at the point of intersection at the speed curve of the increasing height of cut. From this point of intersection, the control begins.

The control ends when the maximum slew speed has been reached or when deceleration commences.

2.1 Block Reclaiming

On block reclaiming, the stockpile is reclaimed in benches over a specified length. (Picture 4) The graph shows the development of the movements. After positioning the bucket wheel at the uppermost block, automatic operation will commence.



Picture 4 Block Reclaiming System

The travel advance is performed during the deceleration phase and does not occur as additional idle time.

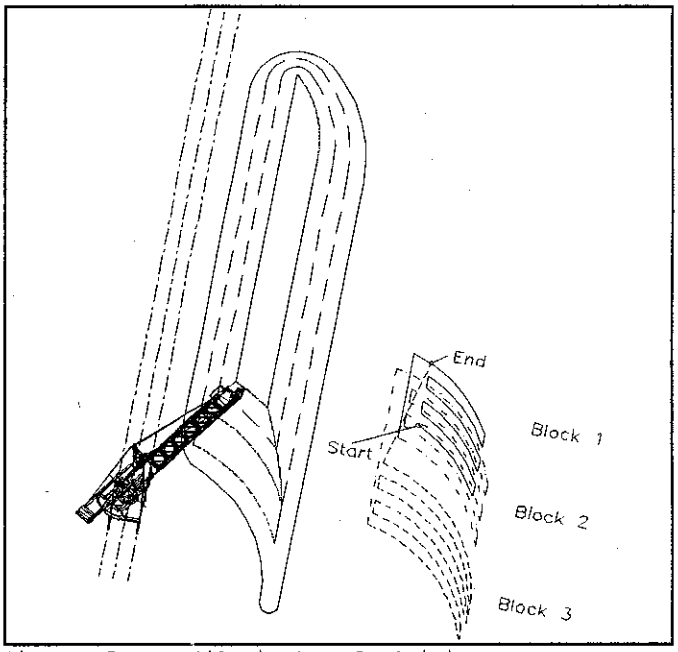
At the end of the pile the machine has to move back to the position of the next bench. Only the travelling time is taken into account. Lowering of the boom and slewing into the new starting position is overlapped by the travelling time.

The working cycle ends when the bucket wheel has reached the end of the pile in the lowest bench.

2.2 Pilgrim Step Reclaiming

The graph for pilgrim step reclaiming is in principle built up on block reclaiming.

However, in order to be able to reclaim the pile completely, a number of the travel advances have to be defined. The number of travel advances should be an even number in order to ensure that return travel takes place in a safe area of the pile.



Picture 5 Pilgrim Step Reclaiming

Slewing and lowering the boom into the next reclaiming position can take place during return travel and does not have to be especially taken into account.

After new positioning, reclaiming can be resumed at the lowest block height.

The working cycle ends in this case also when the bucket wheel has reached the end of the stockpile in the lowest bench.

H: Easy Calculation Method

The relations shown are normally calculated by a PC. The result is, however, relatively easy to calculate without a computer.

The control system is the basis as this ensures that 100% nominal capacity is always achieved where the control is effective.

If we take the cross section of a bench height and the reclaiming length, we arrive at the total reclaiming volume.

If we divide the reclaiming volume by the nominal capacity we arrive at the reclaiming time at 100% nominal capacity.

If we add the idle times indicated above to the reclaiming time we arrive at the degree of efficiency of the reclaimer by dividing the 100% reclaiming time by the reclaiming time with idle times.

The idle times are approximated as follows:

1. Acceleration/deceleration on slewing

On the runway side accelerate on an average up to a slew speed of 25 m/min or decelerate from a speed of 25 m/min. For the estimation 1/3 of the time will be considered.

At about 75° the bucket wheel achieves the maximum slew speed and thus leaves the control range.

The maximum slew speed is on average 40 m/min. The slewing time resulting with this slew speed up to deceleration shall be taken into account to an extent of 2/3. Likewise, 2/3 of the deceleration time following this shall be added on.

2. Travelling times

One travel advance occurs per slew movement. This shall not be taken into consideration as it is overlapped by deceleration.

At the end of the reclaiming path and in pilgrim step operation at the end of the specified steps, the bucket wheel must be positioned for the following height of cut. The full return travel time shall be taken into account as idle time.

3. Lowering and slewing for positioning the bucket wheel

Lowering and slewing times for positioning the bucket wheel are overlapped by the travelling time and do not, therefore, have to be additionally taken into account.

This method of calculation results in a maximum error of 2% against the computer calculation.

4. Results (guide values)

4.1 Long travel reclaiming

See above

4.2 Block reclaiming

	Trapezoidal pile	Triangular pile
- uppermost bench	abt. 70%	abt. 50%
- middle bench	abt. 85%	abt. 70%
- lowest bench	abt. 95%	abt. 85%
- on average	abt. 88%	abt. 75%

4.3 Pilgrim step reclaiming

- on averge abt. 80%

I: Improvements of the "average reclaiming rate"

1. Adapting the cutting depth

The maximum cutting depth is normally determined as the cutting depth possible in the lower bench.

The initial angle is larger in the upper benches and thus the cutting depth is smaller.

If one adjusts the cutting depth referred to the initial angle and thus the travel advance, this will result in less slew movements over the length of the pile and one is able to improve the degree of efficiency of the reclaimer by about 2%.

2. Longer boom

A longer boom automatically means a trapezoidal pile. However, even in the case of already calculated trapezoidal piles it is possible to achieve an improvement in the average reclaiming rate by extending the length of the boom, as the bucket wheel is longer in contact per slew movement.

3. Higher cutting height in the upper block

This measure will not bring about any improvement in the average reclaiming rate but it will increase the degree of efficiency in the upper bench.

4. Limiting the maximum slew angle

At a slew angle of about 70° the maximum slew speed is reached. The cutting depth then only amounts to about 1/3 of the initial angle.

If upon reaching the maximum slew speed, one starts deceleration, slews back and upon repeatedly reaching the max. slew speed then slews up to 90°, this will result in a saving of twice the idle time at max. slew angle. A saving of up to 3% can thus be achieved.

J: Conclusion

The movement procedures described here are based on automatic control which keeps the reclaiming capacity constant on average; which automatically performs travelling, slewing and lowering, once the individual starting positions have been entered into the on-board computer by the operator at the start of reclaiming operation. This mode is defined as "SEMI-AUTOMATIC OPERATION".

Basically, it is also possible to reclaim in fully-automatic mode.

Having stacked the material, we know how the stockpile is built up and we know the dimensions of the pile. What we do not know is the angle of repose and the tolerances of the stockpiling. Nor do we know the influences of weather on the particular pile.

Therefore, automatic control takes certain safety distances into account which lead to further idle times.