6 COAL BENEFICIATION

As discussed in chapter 3, the gasifiers in the Gas Production section of the Sasol Synfuels complex require coarse coal. Chapter 4 shows that many of the treatment options prior to the use of the coal – biotreatment, leaching, chemical changes – require size reduction of the coal. Coal beneficiation based on surface activity differences also require the coal to be small to be able to present sufficient surface for the chemicals to work. The very fine coal particle sizes required for these processes make the resulting cleaner coal unsuitable for the SasolLurgi gasifiers. Hence, methods need to be evaluated which can beneficiate the coarser fractions of the coal, without reduction to fine sizes (smaller than 5 mm).

6.1 Coal Beneficiation Technology Options

For the beneficiation of coarse coal (larger than 5-6 mm), there are basically two wet routes: with dense medium based technologies, or with water-only technologies. Flotation and agglomeration principles will not work since the particles are too large and will sink, irrespective of the quality (save maybe the very lightest of density fractions). Spirals will be ruled out for the same reason; the smallest size of the particles acceptable to the gasifiers (approximately 5 mm) is at the top end of the range that can be tolerated for spiral-based beneficiation.

On the other end of the size scale is the top size of 75 to 100 mm. For design purposes, one has to cater for the largest particles possible in the system, and that would be the 100 mm particles. It must be said that the Coal Preparation plant in the Sasol Synfuels complex does pass through some particles larger than 100 mm, but this is should not be the norm. The design philosophy for the Coal Preparation plant includes a 100 by 100 mm grizzly screen on the overflow of the coarse screens, that must block the oversize material from reaching the Gas Production units. Some oversize material (larger in one dimension, so called “fish”) will however be able to slip diagonally through the grizzlies.

Dry coal beneficiation is more frequently discussed at present, following work done at the University of Kentucky on dry coal cleaning with the FGX separator and energetic marketing by the equipment manufacturer. This separator is a re-designed version of the shaking table concentrators developed in the late 19th century, originally in wet application for the separation of ores, but later also in dry applications including being used for coal “beneficiation”. Wet applications of shaking tables are still abundant, particularly in heavy mineral sands separation.
application [Moore (92)]. The current FGX version for dry beneficiation of coal was
developed in China by prof Y Y Song, and has reportedly many commercial applications
in China [Honaker (93)(94)]

![Diagram of FGX dry coal separator](image)

**Figure 6.1** FGX dry coal separator [Honaker (95)]

The coal on which this technology has been applied is Laurasian coal, with low near
density material and relatively easy separation of mineral matter (contamination,
adventitious mineral matter) from the product coal. In South Africa, the CoalTech
organisation and Exxaro have expressed interest in this technology and wish to evaluate
the FGX separator under South African conditions with South African (Gondwana-land)
coal. Specific focus will be on separating efficiency in destoning operations, as concerns
have been raised about carbon / energy losses due to misplacement at the lower
densities cut points where the amount of near density material is high.
Until these evaluations show positive potential for the South African applications, the
technology will not be considered as commercially proven and is not included in this
research.

This leaves only a few coal beneficiation technologies:

- Dense medium separation using volume and time, Baths: Wemco drum, Teska,
  Drewboy, Norwalt, etc.
- Dense medium separation using centrifugal force: D.S.M. cyclones, Large
diameter cyclones, Dynawhirlpool, Vorsyl, LARCODEMS, etc.
- Water-only technology: jigs.
6.2 Dense Medium Separation Using Baths

The principle of dense medium separation of coal with baths is relatively simple: supply a vessel containing a large enough volume of medium (usually a mixture of water and finely ground magnetite), ensure that the correct density of the medium is maintained, introduce the unwashed but de-slimed coal (to remove the very fine particles which could interfere with the viscosity of the medium and hence separation efficiency) into the bath, and wait a while. The material of a density lower than the medium density will float; that which is denser will sink. Collect the sinks separately from the floats and the separation has been done.

Over the years, various types of machinery have been developed to mechanize this process and to allow for ever increasing throughput, and sometimes better separation efficiency.

6.2.1 Wemco drum separator

The Wemco drum separator is shown in figure 6.2, and is the simplest example of a dense medium bath. Raw coal enters in the one end, into the magnetite/water mixture. Separation starts taking place immediately, with the heavier material sinking to the bottom, and the lighter material floating on the medium surface.

Figure 6.2 Wemco dense medium drum separator [DTI (96)]
The drum rotates, and internal scrolls move the discards to a removal point in the middle of the drum, where they are removed with lifters into a removal chute.

The product, the “floats”, moves with the medium out on the other end of the drum, over a drain screen to remove correct-density medium and over a rinse screen to remove the remainder of the medium. Medium is recovered, and returned to the bath. The discard material is also rinsed to recover more medium. If needed, the product and discards are further dewatered (separately) on dewatering screens before they are stacked for disposal (discards) or transported to the client (product).

The maximum size of coal that can be handled in the Wemco drum depends on the size of the inlet, outlet and lifters. Material with top size of 300 to 500 mm is not unusual if liberation of mineral matter from the coal is not a requirement. The Wemco drum can handle as much as 400 ton per hour feed, approximately 20-25 ton per hour per m² pool area, with very good separation efficiencies [Osborne (97)]. High separation efficiency can be maintained through manipulation of the residence time in the vessel, either by supplying a large enough pool surface, or reducing the throughput of the raw coal. Epm (Ecart probable moyenne, an indication of the sharpness of separation) values of 0.03 or better can be achieved [Leonard (98), Osborne (97)].

6.2.2 TESKA separator

A different version of a bath type separator is the TESKA separator, of KHD Humboldt Wedag.

Figure 6.3 TESKA dense medium separator [Horsfall (99)]
Operation of the TESKA separator is shown in figure 6.3. This separator has a more compact bath than the Wemco drum, and has a refuse discharge wheel perpendicular to the direction of coal flow that removes the sinks from the bath. Again, separation efficiency is controlled by residence time, or pool surface, and throughput.

**6.2.3 Drewboy separator**

This French design separator is very similar to the TESKA in operating principles. The discards removal wheel is parallel to the direction of coal flow, and at an angle to the bath to facilitate the removal of large size discard material. A version with the discard wheel vertical is also available, and more often used in the beneficiation of smaller coal.

![Drewboy dense medium separator](Horsfall [99])

All three bath-type separators have similar performance characteristics; with the Drewboy having a preference for somewhat smaller sized material than the other two (due to the discard removal arrangements).
Table 6.1 Characteristic performance data for baths [Osborne (97), Horsfall (100)]

<table>
<thead>
<tr>
<th></th>
<th>Wemco</th>
<th>TESKA</th>
<th>Drewboy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size range, mm</td>
<td>150 x 6; larger top sizes depending on discard removal system</td>
<td>250 x 5; larger top sizes depending on discard removal syst.</td>
<td>800 x 6</td>
</tr>
<tr>
<td>Tonnage, t/h</td>
<td>&gt;400</td>
<td>&gt;750, clean coal</td>
<td>&gt;1000, feed</td>
</tr>
<tr>
<td>Epm</td>
<td>0.025 to 0.08, depending on separating density 0.006 to 0.023 for same density range, 38x12 mm coal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.2.4 Norwalt separator

This process is a South African development. The feed to this separator is introduced in the middle, and forced into the medium bath via a rotating curtain type wall to which stirrer arms are attached. This ensures that there is good mixing of the coal with the medium. Material lighter than the medium will float to the surface on the other side of the curtain-wall, and is moved by the stirrers towards the edge and discharges over a weir.

![Norwalt separator diagram](image)

Figure 6.5 Norwalt separator

The discard material sinks to the bottom and is moved with scrapers to a discharge point at the bottom of the separator, and removed with a wheel or bucket type elevator.

Separation efficiencies are of the same order as the other baths.
6.3 Dense Medium Separation Using Centrifugal Force

Whereas the static baths described in section 6.2 only use the density differences in a gravitational field between the particles and the dense medium in the bath, centrifugal separators add centrifugal force to separate the particles of different densities from each other.

Pressure energy in the fluid (the mixture of medium and coal particles) is converted into a centrifugal force in a rotational motion that causes the particles to separate from each other. The rotational motion is created through the tangential injection of the fluid into the vessel. At the entry point of the fluid, the vessel is cylindrical. Depending on the technology employed, the vessel can stay cylindrical in shape (like the Larcodems or Dynawhirlpool) or may become conical (like the cyclones). The smaller the radius of the cylinder or cyclone, the higher the centrifugal forces acting on the particle will be. The centrifugal forces will become much more than the gravitational forces working on the particle, and even at relatively low tangential velocities the gravitational forces are of no relevance to the separation any more. Indeed, a cyclone separator can work upside-down without detrimental effect to the separation efficiency.

![Figure 6.6 Principle of centrifugal separation](image)

The centrifugal force can be described as

\[ F_c = (\rho_p - \rho_f) \times \frac{v^2}{r_c} \]  

(1)
where \( F_c \) = the centrifugal force
\[
\rho_p = \text{the relative density of the particle}
\rho_f = \text{the relative density of the medium}
\nu = \text{the tangential velocity of the particles}
\]
and \( r_c \) = the radius of the cyclone

From the formula (1), it can be seen that the material of density higher than the medium should move to the outer spiral, and leave the cyclone at the bottom with the medium that moves along the walls of the cyclone. The material that is lighter than the medium will move to the inner spiral, towards the vortex, and leaves the cyclone at the overflow.

An example may demonstrate the principle.
Assume a medium relative density \( df \) of 1.95, a coal relative density of 1.7 and a discard relative density of 2.4, as well as the same particle size for both the discard and the coal (to demonstrate just the effect of the centrifugal force).

For the coal particle, the driving force would be negative:
\[
F_c = (\rho_p - \rho_f) \times \frac{v^2}{r_c} = (1.7-1.95) \times \frac{v^2}{r_c} = -0.25 \times \frac{v^2}{r_c} \tag{2}
\]
which means that the particles will move towards the centre of the cyclone, towards the vortex. The driving force is positive for the discard particle, which means that they will be moving towards the wall and will be entrained in the medium to the outlet:
\[
F_c = (\rho_p - \rho_f) \times \frac{v^2}{r_c} = (2.4 -1.95) \times \frac{v^2}{r_c} = +0.45 \times \frac{v^2}{r_c} \tag{3}
\]
This is the principle on which all the centrifugal force based separators work, whether they are water-only medium based or a medium based on a mixture of a liquid and a finely ground solid material (like magnetite).

The energy required to create the centrifugal force comes from the velocity (kinetic energy) with which the mixture enters the separator. Fluid velocity equates to pressure, and pressure equates to horsepower. If sufficient height is available in the building that houses the beneficiation process, the pressure can be derived from the static head of the medium/coal mixture above the inlet of the cyclone. With the higher throughput requirements of the current processes and the desire to keep buildings lower (better economics), pressure is supplied by means of pumps. Large volume (throughput) centrifugal separators require substantial drivers to move the dense medium and the solid material around. The capital and operating expenses associated with that need to be
considered when selecting centrifugal force based separating processes over dense medium baths.

Various separators have been developed using the principles of centrifugal separation for the beneficiation of mineral matter. Following is a brief description of the commonly used ones.

6.3.1 D.S.M. cyclone

Developed in the Netherlands by De Staats Mijnen, this cyclone stands at the basis of all later cyclone developments. Used originally to beneficiate coal of size 40 mm to approximately 0.1 mm, the innovative variations developed later are able to handle particles as large as 100 or 125 mm (Multotec large diameter cyclones). A brief overview of the past, present and future of dense medium cyclones is given by Bosman (101).

![D.S.M. cyclone diagram](image)

**Figure 6.7** D.S.M. cyclone [Horsfall (99)]

Raw coal is mixed with the medium, which is usually magnetite finely ground to smaller than 45 micron. The mixture is fed into the cyclone at a tangent. The inlet section is cylindrical, and houses the vortex finder. Centrifugal (outward) and centripetal (inward) forces effect the separation in the conical part of the cyclone. The discard leaves the cyclone at the apex (or spigot), the coal exits via the vortex finder through the overflow top orifice. Inlet pressure is the predominant mode of controlling the forces inside the cyclone. Reduction in inlet pressure will reduce the forces in the cyclone, reduce the throughput and reduce the separation efficiency.
Cyclones are widely used in South Africa for the beneficiation of coal. In general, the particle size of the raw coal ranges from approximately 50 mm to 0.5 mm. When the coal particle size becomes smaller, the separation becomes influenced by the size consist of the medium, and medium stability as well as the viscosity of the medium may become an issue. Large diameter cyclones (larger than 900 mm and up to 1250 mm in diameter) are able to handle particles as large as 100 mm, and still have very good efficiencies. This would make them suitable candidates for the beneficiation of the feed to the gasifiers.

### 6.3.2 Dynawhirlpool separator

Developed in the USA by the Minerals Separation Corporation of Arizona, this separator employs centrifugal forces in a cylindrical vessel. Other than in the DSM cyclone, the feed and the medium are not introduced together, but separately.

![Dynawhirlpool separator diagram](image)

**Figure 6.8** Dynawhirlpool separator

The vessel is installed at an angle of approximately 25 degrees to the horizontal. The medium is introduced at the bottom, tangentially, and creates the vortex. This open vortex spirals upwards towards the discards outlet. Raw coal is introduced at the top with a very small amount of medium (as to not disturb the existing open vortex). As the coal moves down, the centrifugal forces move the heavier material towards the wall in the outer spiral, and upwards with the medium towards the discards outlet. The lighter
material (coal) moves towards the inner spiral under centripetal forces, and with the rest of the medium out towards the product outlet at the bottom of the separator.

Less horsepower is required to supply the energy required to create the vortex, as this pumping energy only needs to be applied to the medium that enters at the bottom and not to the combined medium and coal mass. The feed enters at the top non-pressurized. This reduces the capital and operating costs of the process. There is also a medium-density gradient over the length of the separator. As the discards are moved to the outer spiral and up in the separator, the density of the medium increases. Hence, the feed experiences a higher density at the entrance of the separator, which improves the separation.

As with all cyclonic separators, the material of construction for the separator is crucial since the more abrasive material (the discards) moves with significant velocity against the wall of the vessel. Ceramic inserts or liners are used, as well as special nickel based hard metal alloys to prevent excessive erosion. An advantage of the Dynawhirlpool’s design is that the length of the vessel exposed to the harshest conditions is shorter than with the standard cyclones, as the highest concentration of discard material is closest to the outlet. Nevertheless, manufacturers prefer to fabricate the cyclones of wear resistant material or incorporate liners, to extend vessel life.

These separators are also capable of handling large size coal particles (up to 100 mm).

6.3.2 Vorsyl separator

A development by the Mining Research and Development Establishment (MRDE) of British Coal in 1967 for the treatment of coal sized from 50 to approximately 0.5 mm.

This separator is vertically mounted, and has a separate discard removal section called the Vortextractor. The principles are the same as for the Dynawhirlpool, except that here the feed and medium are in co-current flow versus the counter-current flow in the DWP. A separate extractor is provided for the separation of the discards and the floats from the main vessel.
6.3.4. LARCODEMS separator

A further refinement of the Vorsyl separator was developed by MRDE, named the Large Coal Dense Medium Separator or LARCODEMS. The unit is also cylindrical, but mounted at an angle of approximately 30 degrees to the horizontal. Here, the medium flow and the feed material are in counter-current, like the DWP, and a separate discard extractor is provided analogue to the Vorsyl separator. The vortexextractor regulates the medium exit rate. This extractor is different from the one on the Vorsyl in that the outlet of the extractor of the LARCODEMS is off-centre, which gives improved control. The medium split between discard and product outlet can be varied from 60/40 to 40/60, to suit the yields of product and discard, without detrimental effect on the separation. Furthermore, the separating efficiency is not materially affected when handling a feed with large percentages of discard material, which is an issue with dense medium cyclones. Efficiency characteristics can be maintained from discards yields as high as 100% and low as 20 % [Rudman (102)].

LARCODEMS separators are employed at the Duhva CRU section of Middelbult Mines near Witbank, South Africa, with very good result. The operation destones a 100x12 mm feed material to a power station to produce 350 ton per hour of product from approximately 450 ton per hour feed. The relative density of separation is 1.81 to 1.88 with an Epm of 0.0095 to 0.0105, which is outright excellent [McCulloch (103), Woodman (104)].
What is worth noting from the Duhva experience is that despite the relatively high abrasiveness of the discard material, hardly any wear was found after 7 million ton of material had passed through the separators. This indicates that the selection of the fabrication material and the way the wear sections were designed and fabricated was very important (and correct).
6.4 Coal Beneficiation Using Jigs

Jigging is the oldest method employed to beneficiate coal, and still very popular outside South Africa in countries like the USA, Australia and China.

Jigging relies on the repeated movement of a fluid (usually water) through a bed of mixed material. The earliest method of jigging was through the use of a basket and ample water. Raw coal was put into the basket and the basket, coal and all were repeatedly dunked into water and moved up and down. This stratified the material: lighter material (coal) rose to the top, heavier material (discard) sank to the bottom. Later, the basket was fixed and using a plunger or another means of moving the water up and down in a pulsating way moved water. Stratification and hence separation improves with the number of movements, or strokes.

![Early jigging process, after Agricola De Re Metallica](image)

**Figure 6.11** Early jigging process, after Agricola *De Re Metallica*

The stratification takes place in two distinct steps. During the up-stroke (water rises through the bed), coal particles are lifted up from between the discard particles based on the ability of water at certain speeds to lift coal particles and not discard particles of the same size. Hence, a separation occurs between coal and discard particles. At the end of the up-stroke, before the down-stroke starts, the water stops for a very brief moment. During this moment particles can start to settle out. Since the particles are very close to each other, hindered settling takes place and particles of higher density (the discards)
settle quicker than coal particles of the same size but of lighter density particles that are slowed down by hindrance from the other particles.

During the down-stroke, the water flow moves both the coal and the discards particles downwards. Hindered settling conditions still apply. At the end of the down-stroke a measure of stratification has taken place, which is enhanced with further strokes.

Three effects control the separation during the down-stroke. The settling of particles is determined by both size and relative density. At the end of the up-stroke, when the particles start to fall down, the initial acceleration of the heavier particles, the discards, is faster than that of the coal. After a certain time, the larger coal particles start to fall faster than discard particles of smaller size and they may actually overtake the discards. This could lead to layers of material not only differentiated by density but also by size. It is therefore very important to control the duration and the frequency of the stroke of the jig. The second effect is that of hindered settling, as described above.

![Figure 6.12 Stages of separation in jig operation](Osborne (106))

The third effect is that of consolidation or compaction. When the end of the down-stroke is reached, the particles are so close to each other that their free movement stops and
the bed starts to compact. The larger particles will lock together first, leaving openings between these particles where the smaller particles can still move through before they are also caught in the compacting bed. Small discards will fall faster than same size coal particles; hence the discard particles will trickle through further into the bed than coal. Further density separation takes thus place. Again, if the consolidation phase takes too long, fine coal particles may end up below the larger size discard particles, reducing the efficiency of operation. The operation of jigs will need to be fine-tuned to obtain the maximum contribution of all three effects to ensure the best separation possible and that this separation is based on density only.

The separation efficiency of the jig is greatly influenced by the amount of near-density material (material of a relative density within 0.1 unit of the separation density). Material of density close to the separation density will reduce the sharpness of the separation as the three effects described above are no longer so distinct. The amount of near density material that can be tolerated in a jig is approximately 10%, rarely higher.

In South Africa, coal preparation is mainly for export steam coal purposes. For the production of a low ash coal of sufficient heating value, separation densities between 1.4 and 1.5 relative density are usually employed. Due to the origin and formation of the coal deposits in Gondwana land (which includes South Africa), the amount of near density material in the coal at these separation densities can be as high as 40% making a jig unsuitable for effective separation at these densities. This, and the high level of operator skills required to successfully operate the jigs, make that jigs were never a popular choice in South Africa for export coal preparation. The sharpness of separation with dense medium separation technologies is required to have high enough yields of on-spec material for an economically viable operation.

Figure 6.13 Near density material affecting sharpness of separation [Osborne (106)]
However, jigs separate well at higher densities where the amount of near density material is relatively low. In de-shaling operations (the removal of stone and shale from a raw coal prior to final beneficiation), the separation density is high, generally above RD 1.8, and the amount of near density material lower than 10%.

When the application of jigs in coal preparation processes for South African coal was mentioned in 1993 (when the concept for this thesis was first considered) there was a distinct amount of scepticism in the coal preparation fraternity. This scepticism was predominantly founded on the experiences with jigs to produce export coal at relative densities of 1.3 to 1.5. Koper (107) showed that jig technology could be employed in the de-stoning of coal for a steam plant or a gas production facility like the one of Sasol Synfuels in Secunda, as the washability curves indicated very low amounts of near density material (< 5%). High organic efficiencies could be achieved, comparable to those of dense medium separation technologies. Still, the reluctance in industry to accept jigs as a viable technology prevailed. Interest in the application of jigs in coal preparation was however aroused, aided by requests from Sasol to the industry to evaluate opportunities for the Secunda complex. Work performed by Bateman/Titaco [van Wyk (108)], KHD [Jung (109)] and Allmineral proved that jig technology can indeed play a substantial and economically viable role in South African coal preparation and especially in de-stoning operations [Dieudonne (110, 111)]. This led to a project to establish a jig plant at the BHP/Billiton Optimum Colliery to upgrade (destone) Run of Mine coal ahead of the main washing plant (112, 113). This plant is based on KHD ROMjigs, and will treat 350 ton per hour at a separating density between 1.9 and 2. The plant has been successfully commissioned in September 2002 (113). The plant has unfortunately been decommissioned during 2006 following high maintenance cost experiences due to the handling of very large material. During the period of operation, the jig performed well.

With the commissioning of the first commercial scale jig for destoning, it appears that the early-day promoters of jig-based coal beneficiation in a destoning operation seem to have been proven correct at least from a process perspective. This may lead the way for more beneficiation plant operators to accept the jig as an integral part of the overall coal beneficiation process chain, similar to what has already happened in Australia [Sanders (114)].

The next jig plant in South Africa in a coal destoning operation was the KHD jig at the Leeuwpan mine of Exxaro, close to Delmas. This plant has also experienced its share of commissioning and optimisation issues, but is reported to currently operate well [Lundt, Claassen (115, 116)].
6.4.1 Types of jigs

There are basically two jigging principles: air pulsed or mechanical pulsed. For coal beneficiation, the air pulsed jigs are the most common [Albrecht (117)]. There are two different ways of air-pulsating the jig: with an airbox on the side of the jig (Baum type) or where the airbox is under the bed (Batac type). The Batac (Baum-Tacub) jig is a refinement on the Baum jig.

The Baum jig for coal was developed in Germany by Fritz Baum and is in operation in Germany since 1892. The movement of the water in the jigbox was created with pressurized air. This is the principle distinction from the mechanically pulsed jigs, where movement of the water is induced through the up and down movement of a piston-like plunger connected to an eccentric driver. The airbox of the Baum jig is on the side of the actual jigbox. See figure 6.14. The Batac jig has the airboxes inside the jigbox, under the bedplate. This makes the Batac jig slightly more space-efficient in comparison to a Baum for the same throughput.

![Baum and Batac jigs](image)

**Figure 6.14** Side air box (Baum) vs. under bed air box (Batac) [Osborne (106)]

The Baum jig is described in figure 6.15. A U-tube like tub with two compartments connected to each other. The one is the airbox, the other the actual jigbox. The airbox is sealed, and filled with air. Compressed air pressurizes the airbox in a short instance, and causes the water to move from the airbox leg of the U-tube, through the bedplate, into the jigbox. The material on the bedplate moves up and down with the movement of the water, and separation takes place.
The movement of water upwards through the bedplate caused by the plunger or air pressurization is referred to as the pulsion stroke; the downward movement is called the suction stroke.

During the 1950’s, Baum jigs were designed with widths up to 2.5 meter, and it was felt that the maximum throughput and width had been reached. With wider jigs, the distribution of water and coal over the bed became less optimal. The development of the Batac jig overcame these limitations. The airbox was placed under the bedplate in the jigbox, and the jigbox could be compartmentalized to handle high loads and still have a good separation [Zimmerman (118)].
At the end of the bedplate in each compartment, a gate routes the discards to the bottom and the product to either the next compartment or out to the product collection system. The discards are removed from the volume under the bedplate, or hutch, by means of a scroll or chain-bucket removal system. The product flows of the final weir into a product collection system.

As discussed previously, the control of the pulse is of utmost importance (that, and the gate settings, are the two critical control parameters of a jig). Over the years, the various manufacturers of jig equipment have spent significant amounts of resources to develop their versions of the optimal control system and air supply system for their jig type. Jigs can be used for coarse coal and fine coal beneficiation, but the particle size range that can be handled in one jig is limited. This is due to the hindered settling and consolidated trickling actions during the down-stroke, and the effect particle size has on these actions.

Table 6.2 gives an indication of the size ranges that can be handled in one single jig. As mentioned before, the selection of the correct size range is important as this influences the separation efficiency (because of the hindered settling and consolidation effects). The size range treated also determines the frequency and amplitude of the pulsations required to achieve proper separation.

### Table 6.2 Operating parameters for various jigs [Sanders (119)]

<table>
<thead>
<tr>
<th>Type of Jig</th>
<th>Top size, mm</th>
<th>Bottom size, mm</th>
<th>Frequency, pulse/minute</th>
<th>Amplitude, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROMjig</td>
<td>350</td>
<td>40</td>
<td>38-43</td>
<td></td>
</tr>
<tr>
<td>Coarse coal, Batac type</td>
<td>150</td>
<td>10</td>
<td>45-55</td>
<td>200-100</td>
</tr>
<tr>
<td>Intermediate size, Batac type</td>
<td>70 to 50</td>
<td>8 to 3</td>
<td>50-60</td>
<td>80-30</td>
</tr>
<tr>
<td>Fine coal, Batac type</td>
<td>10</td>
<td>0.5</td>
<td>55-75</td>
<td>30-15</td>
</tr>
<tr>
<td>Very fine coal, Batac type</td>
<td>3</td>
<td>0.1</td>
<td>70-100</td>
<td>20-5</td>
</tr>
</tbody>
</table>

KHD developed a jig especially suited to handle very large size particles, particularly suitable for Run of Mine coal destoning, the ROMjig [Wesp (120), Flor (121), Heintges (122)]. This is the type jig that has been installed at the Optimum Colliery of BHP/Billiton, to destone RoM coal prior to the main wash plant. The jig can handle large coal, 350 mm top size, with a bottom size of nominally 40 mm. The water movement in this jig is not induced by air, but through the hydraulic lifting of the feed end of the screen. This is then allowed to lower again under gravity. The so induced jigging action causes the
separation of discards from the product, the discards being on the bottom of the bed, the products on top [Sanders 114]. The ROMjig is particularly useful, as proven in the Optimum Colliery application, to scalp high-density material from the raw coal feed prior to a "conventional" dense medium based beneficiation unit. The main benefit of the application of the ROMjig is the reduction of material to be treated in the next separation steps. Since the material removed is predominantly high mineral-content material, the abrasive tendencies of the product will be reduced and the downstream processes will suffer less mechanical wear, thus reducing maintenance costs.

Batac-type jigs are capable of handling high feed rates per single unit, up to 100 ton per hour per meter jig width is possible, and jigs have been manufactured to handle 700 ton per hour raw coal with good results.

![Figure 6.17 KHD ROMjig](image) [courtesy KHD]
6.5 Technology To Use

The previous paragraphs show that various technologies are available to beneficiate the coarse coal for the gasifiers. The selection of the technology to use should be based on the achievable separation efficiency, the capital costs of the equipment, operating costs associated and the effects misplaced material may have on the mass balances for whole complex.

All technologies have proven track records, some longer than others. There are suppliers for each technology in South Africa, and test work can be done if so desired to improve the knowledge on the applicability of a technology.

For the purpose of this thesis, it was decided to select jigs, large diameter dense medium cyclones, LARCODEMS and baths as the coal beneficiation alternatives for the comparison with the “Cure” alternatives of Flexsorb/Oxyclaus and sulphuric acid production.