ANNEXURE 6.1

An Investigation into the Availability of Low Profile Trackless Mechanised Mining Equipment for Narrow Stope Widths

By K.A.RHODES, June 1999
AN INVESTIGATION INTO THE AVAILABILITY
OF
LOW PROFILE TRACKLESS MECHANISED
MINING EQUIPMENT
FOR
NARROW STOPE WIDTHS

K.A. RHODES
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**ANNEXURE 1**
Specifications of Relevant Low Profile Trackless Equipment.

**ANNEXURE 2**
Low Profile Drilling and Bolting Rigs for Narrow Width Mining at KGHM Mines in Poland
EXECUTIVE SUMMARY

There is a necessity to improve productivity and reduce operating costs at Amplats' mines and in this respect the objective of this project is to consider the application of trackless mechanised equipment in a mining width of 1.5 metres. The first phase of the project is to identify low profile drilling and loading equipment capable of working in such a narrow width; the next phase of the project would be to define mining methods and evaluate the viability of such methods for Amplats' mines. This report considers the first phase only of the project.

Discussions have been held with representatives of the original equipment manufacturers (OEM's) and the findings have been documented in the report. Notwithstanding that a pre-requisite for Phase 1 of the report is the identification of equipment designed specifically for hard rock mines, a matrix of drilling and loading equipment from all OEM's (hard rock and other) has been set out.

The equipment matrix reflects specific equipment capable of working in a mining width of 1.5 metres for hard rock mines even though such equipment is limited. Nevertheless, the only known hard rock mining operation where a full range of trackless mechanised equipment is working in 1.5 metres mining width is at the KGHM copper mines in Poland.

The fact that equipment manufactured by recognised hard rock OEM's is working in Poland on a significant scale, and further that leading OEM's Tamrock and Boart Longyear Seco are planning to develop low profile equipment, confirms the availability of low profile trackless equipment for a mining width of 1.5 metres. Phase 1 of this project is therefore complete, subject to the findings of a technical visit to KGHM's mines in Poland.

In terms of the conclusions in the report it is therefore recommended that approval be given for the technical visit to KGHM's mines in Poland and subject to a positive report on these operations, it is further recommended that the next phase of the project, to define mining methods for Amplats' mines and to assess the financial viability of such methods, be allowed to proceed.
AN INVESTIGATION INTO TRACKLESS MECHANISED MINING IN NARROW STOPE WIDTHS

1. INTRODUCTION
In terms of the necessity to improve productivity and reduce operating costs at Amplat's underground mines it is the purpose of this project to consider the use of trackless mechanised in mining widths of 1,5 metres. A further application for low profile equipment would be Stylrdrift where the Merensky reef is flat dipping and where mining widths could be 1,5 to 2,0 metres.

It is intended to divide the project into two phases: the first phase being to identify the availability of low profile equipment capable of working in narrow widths of 1,5 metres and the second phase would be to define mining methods for mechanised narrow width mining and to evaluate the viability of such methods. This report will consider the first phase only. The approval to proceed with the second phase of the project will depend on the availability of proven equipment working in narrow widths world-wide.

2. EQUIPMENT INVESTIGATION
Investigations into the availability of low profile equipment capable of working in a narrow width of 1,5 metres have been carried out. Numerous discussions have been held with representatives of original equipment manufacturers (OEM's); the findings of these investigations have been split under the headings of hard rock OEM's and other OEM's, for reason that it is considered to be a pre-requisite for the success of Phase 1 of this project to identify equipment specifically designed for hard rock mines.

2.1 Hard Rock OEM's
OEM's which sell equipment predominantly to hard rock mines are included under this heading.

**Atlas Copco**
Atlas Copco market a full range of trackless equipment: face drill rigs, production drill rigs and roof bolters; LHD's and trucks manufactured by Wagner (Wagner being part of the Atlas Copco organisation). At this time Atlas Copco do not have any equipment designed for hard rock mines which can operate in a mining width of 1,5 metres and further, they do not intend to develop any such equipment in the immediate future.

- **LHD's**
The minimum height of any Wagner LHD designed for hard rock mines (ST2D and ST3.5) is 1,55 metres. The LST-5S coal scoop,
manufactured by Wagner, has a height marginally less than 1.5 metres but Wagner state categorically that they are not prepared to sell a ‘coal scoop’ to hard rock mines. They have good reasons for this policy as coal scoops are not designed to load a muckpile in hard rock conditions. The coal bucket is designed to load by pushing into broken coal at floor level with only the assistance of a lifting cylinder. The hard rock bucket on the other hand is designed to dig into the muckpile with an additional (dump) cylinder which gives the LHD designed for hard rock mines the capability of swivelling the bucket in a vertical plane thereby enabling the machine to dig.

- **Face Rigs**
  The Boomer 281L face rig has the lowest profile of any Atlas Copco drill rig and yet is 1.73 metres off the ground.

- **Roofbolters**
  No low profile roofbolters are available.

*In summary therefore the Atlas Copco range of equipment is not suitable for narrow width on reef mining for Amplats’ mines and therefore cannot be considered for this project.*

**Tamrock**
Tamrock market a complete range of trackless equipment world-wide: Tamrock, Secoma and Quasar rigs, Toro and EJC loaders and trucks.

- **Face Rigs**
  Tamrock have designed and manufactured a low profile drill rig: three units have been imported into this country from France. A fourth machine has yet to be sent to South Africa. The decision to manufacture these four machines is custom driven; Tamrock expect to sell low profile face rigs to the chrome mines. Initial discussions with the management of Western Chrome Mines (WCM) caused Tamrock to bring the first rig to South Africa in February 1999 and this unit is expected to be sent to Millsell at the end of May 1999. Two additional machines are at Tamrock’s Jet Park workshops with no decision yet regarding their destination.

This low profile drill rig is known as the P-Low 1F; some salient design points are as follows.
- Single boom.
- Lateral coverage 6.50 metres.
- Effective hole length 2.70 metres.
- Height overall 1,40 metres.
- Ground clearance 450mm.

The machine is designed specifically for a mine such as Millsell where the stoping height is 1,70 metres and faces (rooms) in a room and pillar operation are 14 metres wide, thereby requiring only two set-ups to complete the drilling of a face.

In terms of mining a width of 1,5 metres, the overall height of the P-Low at 1,40 metres would not be acceptable; however, with a ground clearance of 450mm a change in tyre profile could lower the machine to (say) 1,30 metres and still maintain a ground clearance greater than 300mm which is more than adequate for a slow tramming rig. Discussions with Tamrock (SA) confirm that this modification could be carried out to enable the P-Low to work in a height of 1,5 metres.

The P-Low 1F, although considered to be a prototype machine (and significantly four machines have been manufactured), contains no new components; proven components/sub-assemblies have been put together only in a different configuration known as 'smart supply'.

- **LHD's**
  Tamrock have a 270 low profile loader which has a height to canopy of 1,496 metres with minimum ground clearance of 270mm. Clearly the height of this machine makes it unsuitable for this project. However, Tamrock intend to re-design this machine to enable it to work in 1,5 metres thereby necessitating a reduction in overall height to say 1,30 metres; this re-design work will probably take place following the successful trials of the P-Low 1F drill rig.

Tamrock (SA) are committed to the development of low profile equipment and although their current objective is to meet the requirements of South African semi-mechanised chrome mines, which generally exploit the LG6/LG6A seam package of 1.7 – 1.8 metres, they are certainly prepared to consider the design of a face rig and LHD (based on the P-Low 1F and the 270 loader respectively) to be capable of working in a mining width of 1,5 metres.

*In conclusion Tamrock (SA) is perceived to be committed to the design and manufacture of low profile drilling and loading equipment.*
Boart Longyear Seco
Boart Longyear Seco (BLS) concentrates on drill rigs and specialised vehicles and do not manufacture or market loading equipment.

- **Face Rigs**
  At the present time BLS do not have any low profile rigs available; however, it is their intention to design for such machines. BLS are currently designing a two boom rig which will be 1,50 metres high: this design being motivated by a feasibility study presently being carried out for a new chrome mine on the eastern limb of the BIC. However, BLS have stated their intention to design both a single and double face rig to work in 1,5 metres, such a machine having a height of 1,30 metres.

- **Roofbolters**
  In discussions with BLS considerations may have to be given to rotary drilling (as against percussive) in order to lower the working height of any roofbolter; the height of a drifter upright is approximately 700mm.

The commitment by BLS to market low profile equipment stems from South African chrome mines and also from Boart Longyear Lena, a sister company of BLS which manufactures low profile equipment in Poland.

*Boart Longyear Seco is therefore perceived to be committed to develop low profile trackless equipment in heights of 1,5 metres.*

Boart Longyear Lena
Boart Longyear Lena (BLL) in Poland manufacture drill rigs and roofbolters for narrow width mining specifically for KGHM’s copper mines near Polkowice, Poland.

- **Face Rigs**
  The BLL face rig (Face Master 1.5) is a mechanised face rig for mining widths of 1,5 metres. The height of the rig when tramming is 1,25 metres. The drifter used is the Board Longyear HD150.

- **Roofbolters**
  The BLL roofbolter (roof Master 1.5) is designed for bolting operations in a minimum height of 1,5 metres. This specific machine is designed for dry rotary drilling. The tramming height of the machine is also 1,25 metres.
Rotary drilling (specifically for roofbolting) should be investigated in terms of any roofbolting requirements at Amplats' mines.

The existence of low profile drilling equipment working at KGHM's mines in Poland is clearly significant for the project. In addition, the association between BLS and BLL means that BLS would be able to build low profile drill rigs in South Africa based on the Polish design in order to meet any demand in South Africa.

*In conclusion it can be stated, subject to a hands-on visit to KGHM's mines, that face drill rigs and possibly roofbolters are available and could be manufactured in South Africa to work effectively in mining widths of 1.5 metres.*

**GHH**
This company in South Africa manufactures the well-known Fahrlader LF-4.2 or Aardvark as it is commonly called. This machine was designed primarily for the South African chrome mining industry and at the present time there are probably nearly 100 such units working in Southern Africa.

The Original GHH Fahrlader LF-4.2 has recently been modified by a tyre profile change (dictated by tyre manufacturers), which now provides for a ground clearance of 218mm (from previously 160mm). This modification has of course caused an increase in height of the machine, which is now 1,356 metres to the boom. The height of the machine to the canopy is not accurately known as no Aardvarks operating in South Africa are fitted with a canopy. However, because it would not be acceptable to Amplats to have LHD's operating without canopies, it is important to estimate the canopy height and in this respect it would appear to be realistic, after close scrutiny of the Aardvark and with the consensus of GHH technical management, that the positioning of the driver under a canopy will enable the canopy height to be no greater than the boom height or 1,356 metres.

Notwithstanding, the Aardvark manufactured in Germany by GHH which is equipped with a slightly different tyre profile (1200 x 24 as against the local 1200 x 20) is known to be 1,320 metres to the canopy (not the boom). Canopies are fitted to the German Aardvark equivalent and dimensions must be confirmed on site at their factory at Oberhausen in the Ruhr.

The German parent company of GHH supplies LHD's to KGHM in Poland and although these machines were based on the SA specifications
(the original two machines sent to KGHM came directly from South Africa) recent machines supplied to KGHM appear to be according to a new German specification; these modifications to the South African specifications include an extended cab offset from the LHD in order to provide for increased legroom necessitated by a lower seating arrangement.

*It is therefore believed that the GHH Aardvark is a proven hard rock LHD capable of working in a mining width of 1,5 metres; this will be confirmed following a technical visit to Germany and KGHM’s mines in Poland.*

**Furukawa**

Furukawa manufacture and market underground drill rigs world wide; they are a major supplier in the Far East and the Pacific Rim but with very few units in South Africa. At Chrome Resources’ chrome mine near Kroondal a Furukawa pneumatic two boom rig is undergoing trials; this machine is 1,42 metres high excluding consideration of the drivers position and is therefore too high for working in 1,5 metres. A second hydraulic rig at Greenside Colliery is even higher and in discussions with Bateman, suppliers of Furukawa equipment in South Africa, Furukawa appear to have no options for drill rigs in a mining width of 1,5 metres.

**Furukawa drill rigs cannot therefore be considered for this project.**

**Conclusions on Hard Rock OEM’s**

- There is available at this time certain limited drilling and loading equipment which will be capable of working in a planned mining width of 1,5 metres at Amplats’ mines. These machines include the Tamrock P-Low IF to be modified by a marginal reduction in height; drill rigs and roofbolters manufactured by Boart Longyear Lena in Poland; the GHH Fahrlader LF-4.2 manufactured both in South Africa and Germany.

- KGHM’s copper mines in Poland have been identified where mechanised trackless mining is being practiced on a significant scale in mining widths of 1,5 metres. Boart Longyear Lena and GHH equipment is in use at these mines and therefore these operations should be seen.

- Tamrock (SA) and Boart Longyear Seco have clearly stated their intentions to develop further equipment for narrow width mining. In this respect Tamrock (SA) have brought to South Africa the P-Low IF for use on chrome mines and this machine is perceived as being capable of operating in narrower widths (1,5 metres) with minor
modifications. Further, Boart Longyear Seco in association with their Polish sister company Boart Longyear Lena will be able to manufacture Polish designed machines in this country and also Boart Longyear Seco have designed their own independent drill rig for local chrome mines.

- In respect of roofbolting operations, consideration could be given to rotary drilling; this necessitates a further investigation.

2.2 Other Trackless OEM’s

There are other trackless OEM’s who manufacture trackless equipment which are not considered to be major world suppliers to hard rock mines but they still warrant attention.

Licence Mining

Licence Mining are a South African distributor of Fairchild coal mining equipment and in addition manufacture their own roofbolters which may be considered for a narrow mining width at Amplat’s mines. The Licence roofbolter is very low profile and could be either rotary or percussive.

Elphinstone

Elphinstone LHD’s are manufactured in Australia and distributed by Barlows (Caterpillar) in South Africa. Their lowest profile machine is 2.0 metres to the canopy and therefore not suitable for narrow width mining.

Long Airdox

Long Airdox market three coal scoops worldwide, the lowest profile 482 series is in operation at Bleskop in UG2 workings. This machine has not proved satisfactory and negotiations are underway to replace the 482 with a 488-L. These coal mining machines can obviously operate in a 1.5 metre width but they are not designed for hard rock mines: they have no digging capability (no dump cylinder) and are designed to operate on an even footwall (the floor of the coal seam). The Bleskop machine is the only Long Airdox scoop operating in a hard rock mine anywhere in the world. Notwithstanding, the low profile of these coal scoops is designed for narrow coal seams and they cannot be recommended for use in hard rock mines and should not be considered for this project.

Long Airdox also market Fletcher roofbolters which can be either rotary or percussive. The use of such a roofbolter in a South African chrome mine is being considered and some development is being undertaken in the USA by Fletcher/Kenametal.
**Rham**

Rham is a local company which primarily services the South African coal mining industry and chrome mines; its main business is transporters (UV’s). These machines have an overall height of less than 1,2 metres and therefore they should operate satisfactorily in mining widths of 1,5 metres. However, detailed specifications, specifically ground clearance, must be checked.

Some time ago Rham designed and manufactured an LHD for a local chrome mine but following trials the mine were not satisfied and the machine is now back at Rham’s workshop. It is a hydrostatic machine with a motor on each wheel. It has an overall height of 1,40 metres and it could probably be re-designed to a height of 1,25 metres and with other front end modifications this machine could be the prototype of a future production vehicle in a 1,5 metre mining width. Further discussions with Rham related to this LHD would therefore be beneficial.

**Lee**

It is believed that Lee market LHD’s for coal mines in the USA. It is understood that some of their units are at KGHM mines in Poland but this needs to be confirmed.

**Jackson Clark Incorporated (JCI)**

This is a North American company marketing LHD’s; it is believed some units are at Stillwater Platinum Mine, Montana, USA. However the lowest profile of any LHD is 1,85 metres and is therefore not applicable for this project.

3. **EQUIPMENT MATRIX**

In terms of this investigation into low profile drilling and loading equipment for mining in a width of 1,5 metres the following equipment matrix summarises the findings.
#### EQUIPMENT AVAILABILITY MATRIX FOR A MINING WIDTH OF 1.5 METRES IN HARD ROCK MINES

<table>
<thead>
<tr>
<th>OEM</th>
<th>Face Rig</th>
<th>Roofbolter</th>
<th>LHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlas Copco</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Tamrock</td>
<td>Yes</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Boart Longyear Seco</td>
<td>X</td>
<td>X</td>
<td>No</td>
</tr>
<tr>
<td>Boart Longyear Lena</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>GHH</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Furukawa</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>Licence Mining</td>
<td>No</td>
<td>?</td>
<td>No</td>
</tr>
<tr>
<td>Elphinstone</td>
<td>No</td>
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</tr>
<tr>
<td>Long Airdox</td>
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<td>No</td>
<td>?</td>
</tr>
<tr>
<td>Lee</td>
<td>No</td>
<td>No</td>
<td>?</td>
</tr>
<tr>
<td>JCI</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Key**
- Yes = Available
- No = Not available
- X = Not available now but is being considered
- ? = Warrants further investigation
4. CONCLUSIONS
The conclusions reached for Phase 1 of the trackless mechanised mining project for narrow stope widths are as follows.

- The equipment matrix demonstrates that drilling and loading equipment is available for working in a 1.5 metre mining width in hard rock mines even though the selection of such equipment is limited.
- It can be expected that additional low profile equipment will become available from hard rock OEM’s (Tamrock and Boart Longyear Seco) in the near future, provided that there is a demand for such equipment.
- It is realised that the only known hard rock operation, where a full range of trackless equipment is working in 1.5 metre mining width, is at KGHM copper mines in Poland. At this stage only limited practical knowledge is available from Poland and therefore, in order to increase the confidence in this project, it will be advantageous to visit KGHM’s mines.

5. RECOMMENDATIONS
In terms of the conclusions stated in this report it is recommended that the following action be taken.

- **Firstly, carry out a hands-on visit to KGHM’s mines in Poland.**
- **Subject to a positive report on KGHM’s operations it is then recommended to proceed with Phase 2 of the project which will define mining methods, establish operating costs and assess the financial viability of these trackless options for Amplit’s mines.**

In addition to the above main recommendations which emanate from these preliminary investigations into the availability of equipment capable of working in 1.5 metre stope widths, it is further recommended that consideration be given to widening the scope of the project for rescue mining methods where marginally wider stope widths may be planned for. This recommendation is not given because of the present limited availability of low profile equipment but in order to provide greater flexibility for trackless mechanised projects at Amplit’s mines.

There is also the necessity to define the requirements and overall cost of machines in a 1.8 metre mining width, at say Bleskop or Waterval.

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