Therefore waste required to be trammed as waste from 0.27 m advance access roadway

\[ = 0.27 \times 1.80 \times 60\% \times W_1 \text{ m}^3 \]

\[ = 0.29 \text{ W}_1 \text{ m}^3 \]

But \( W_1 = 4.5 \text{ m} \)

or \( W_1 = \frac{4.5W}{3.5} \)

Therefore waste from access roadways for 1 metre advance in A.S.D. \( = 0.37 \text{ W m}^3 \)

Therefore total waste to be packed in 1 m worked-out A.S.D \( = (1.08 \text{ W } + 0.37 \text{ W}) \text{ m}^3 \)

Waste (volume) to be packed in 1 m of A.S.D \( = 1.45 \text{ W m}^3 \)

But total volume available in 1 m of a worked-out drive assuming 100\% packing (theoretically possible with bulldozer)

\[ = 3.00 \text{ (height) } \times \text{ W } \times 60\% \text{ m}^3 \]

Where 60\% represents the ratio of broken rock to rock in situ by volume

Therefore volume available in 1 m of A.S.D \( = 1.80 \text{ W m}^3 \)

The theoretical volume available for waste packing in worked-out drives is therefore greater than the volume of rock to be blasted as waste in access Roadways and A.S.D's (but excluding any other waste broken).

Hence it is theoretically possible to pack underground all waste broken in the operation and this possibility must be the objective in practice.
6.2 Conventional Operations

The UEIA Reef to be exploited in the 95 Level Basin area is extremely flat (the reef dipping from less than 5° to 0°) and is also heavily faulted with throws of between 1 metre and 3 metres.

In order to carry out conventional mining operations in this area it would be necessary to develop centre gulley raises and A.S.G's with a minimum depth (from the top reef contact) of 3 metres in order to negotiate these faults. In such conventional mining operations it can be shown that waste dilution from centre gulley raises and A.S.G's will be of the order of 7.0 %.

6.3 Summary

To sum up it is believed that waste dilution from mechanised trackless operations need not be greater than for conventional mining provided that control is exercised by management.

The operation of large equipment on the reef horizon does not therefore imply the acceptance of excessive waste dilution.

7. EQUIPMENT

The inventory of the trackless equipment required for the operation is as follows:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Number of Units Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.H.D (3.8 m³)</td>
<td>4</td>
</tr>
<tr>
<td>Electro-hydraulic Rig</td>
<td>4</td>
</tr>
<tr>
<td>Dump Truck (24 ton)</td>
<td>6</td>
</tr>
<tr>
<td>Utility Vehicle</td>
<td>2</td>
</tr>
<tr>
<td>Transport Vehicle</td>
<td>6</td>
</tr>
</tbody>
</table>

7.1 Numbers of Units

The numbers of the drilling and cleaning units required have been determined in accordance with the following parameters and assumptions.
Rigs

(a) It can be determined that it will be necessary for twenty panels to be worked to advance 20 metres/month/panel to provide for the planned output; therefore A.S.D development will be a minimum of 400 metres/month.

It can be assumed that a rig can drill three rounds per day (on a double shift basis); each round advancing 3 metres (minimum).

(b) Ore reserves generated from a 1 metre advance in access roadways is previously calculated at 495 tons. For the planned production the minimum advance per month is therefore 101 metres (assuming all development is pay). It can be assumed for primary reef development that two rounds per day (3 metres advance/round) will be achieved (less drilling time will be available for A.R.D development drilling due to increased tramming distances between development ends).

(c) Provision must be made for roofbolting operations with the electro-hydraulic rig.

LHD (3,8m³ bucket)

(a) Availability of unit is assumed at 85 %; utilization of availability is 80 %.

(b) Expected performance from LHD units (3,8m³) tramming one way distances of 75 metres (maximum) is 16 - 18 000 tons/month.

(c) An additional unit is required to provide for waste packing operations.

Trucks (24 Ton)

(a) Maximum tramming distance (one-way) has been assumed to be 1000 metres.

(b) Availability of truck is assumed to be 85 %; utilisation 85 %.
The performance of the 24 ton trucks is therefore calculated to be 8 - 10 000 tons/month/truck.

**N.B** Availability and Utilization are defined as follows for L.H.D units and trucks.

\[
\text{Availability} = \frac{\text{Available Hours (23 hours per day) - Engineering Downtime}}{\text{Available Hours}}.
\]

\[
\text{Utilization} = \frac{\text{Metre Hours Worked}}{\text{Available Hours} - \text{Engineering Downtime}}.
\]

7.2 **Size of Equipment**

In a previous paper on wide reef mechanised mining it has been stated that for such an operation the largest size units were selected for the reason that the largest size unit will cause a reduction in working costs; this argument remains relevant to narrow reef mining operations.

Factors in favour of large equipment are as follows:

(a) A significant reduction in the number of machines in the total fleet. A larger fleet requires additional drivers, additional artisans to maintain the extra machines (the ratio of machine units to one artisan does not vary with the size of the unit) and further the operating cost of the different sizes of equipment does not show a marked variation.

(b) A major consideration will be traffic congestion in arterial roadways when operating a large fleet; it is axiomatic that a lesser number of larger units would reduce the severity of such a problem.

Notwithstanding the above in narrow reef conditions consideration must be paid to the roadway dimensions and the possible effect on dilution. However taking cognizance of the advantages for the use of large units and the commitment of management to exercise control over waste tramming operations the largest practicable size unit was recommended for this operation.
7.3 Ancillary Equipment

In addition to the above it is envisaged that face pumps (30) will be required and a single pedestal impact breaker at the main tip will be necessary.

Included as a utility vehicle in the above equipment is a flat bed transporter with mounted crane. This unit was planned for the transfer of timber (palletised) from the timber storage bay (at end of rail system on 95 Level) to the stope face and for the forward move of the face winch in the A.S.D; since its introduction the unit has proved to be of immense value as a materials/heavy equipment transporter.

8. WORKSHOP LAYOUT

Assembly Bay

All large trackless equipment for operation at Cooke 2 Shaft must be stripped on surface before transfer underground and experience with the re-assembling of such equipment on 90 Level with the wide reef trackless project had shown that an assembly bay at the entrance to the trackless area (at the end of the rail system) was essential. The assembly bay on 95 Level in immediate proximity to the trackless access ramp to the reef horizon was therefore constructed before any trackless equipment was allowed to be transferred underground; refer to Figure 12.

Major features of the assembly bay included a 10 ton crawl in line with the track system; height provision for future use as a wash bay for all equipment including trucks; 3 ton overhead crawl for changing tyres (wheels).

General

Certain footwall development for conventional scattered mining operations had already been completed before planning for the trackless operation had commenced and use was made of this development when workshop facilities were laid out on 95 Level; the workshop layout for the operations is not therefore considered ideal but in the circumstances is practical. The actual layout is shown in Figure 13.

9. LABOUR AND EFFECTIVENESS

9.1 Union Labour
9.1 Union Labour

The Union (non specialist) labour force complement required for a production of 50 000 tons per month (for a stoping width of 100 cm - 110 cm) is estimated to be 646; this complement provides for conventional stope labour calculated using standard minutes and in addition haulage and transport labour, stope preparation work and other construction work and engineering labour.

The estimated equivalent complement for a trackless operation for the same tonnage is 385 and therefore a comparison of the efficiencies for both methods of mining is given below.

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Trackless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Union complement</td>
<td>646</td>
<td>385</td>
</tr>
<tr>
<td>Tons/Man Shift (Union)</td>
<td>3.2</td>
<td>5.4</td>
</tr>
</tbody>
</table>

9.2 Labour (Officials)

The comparisons of (specialist) labour for the conventional and trackless option is as follows:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Conventional</th>
<th>Trackless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine Overseer</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Shift Boss</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Stopers/Developers</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>General Miners (including N/S cleaners)</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Engineering Foreman</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Artisans</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Tons/Month</td>
<td>50 000</td>
<td>50 000</td>
</tr>
<tr>
<td>Tons/Manshift (Officials)</td>
<td>83</td>
<td>94</td>
</tr>
</tbody>
</table>
The safety of the operation will be improved.

There is strong evidence to support the argument that accidents are reduced significantly with a reduction in complement (this operation will reduce the underground complement by at least 250 men); with fewer people in the workings falls of ground accidents can be expected to reduce.

Also accidents can be expected to reduce with the introduction of mechanical cleaning without the use of locomotive haulages for tramming from stopes: locomotive haulages have been the major source of serious accidents at Randfontein Estates Gold Mine.

The third major source of serious and fatal accidents in conventional mining after falls of ground and tramming is orepasses due to gassing and persons falling from the orepass; this type of accident will be eliminated as reef will be trammed to a central tip developed by raise borer.

Notwithstanding the above however it will be necessary for management to enforce discipline over the operators of large mechanised equipment; it is essential to have driver discipline.

In this respect the dangers associated with the operation of equipment on ramps and declines cannot be over-emphasized.

11. COSTS

Comparative estimations made in early 1985 (at the commencement of the operation) clearly indicate that working costs for the trackless access operation will be markedly lower than for the conventional methods of mining; this difference is shown below:

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Trackless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>1,59</td>
<td>0,19</td>
</tr>
<tr>
<td>Labour</td>
<td>6,66</td>
<td>4,40</td>
</tr>
<tr>
<td>Blasting</td>
<td>1,46</td>
<td>1,42</td>
</tr>
<tr>
<td>Support</td>
<td>0,94</td>
<td>1,05</td>
</tr>
<tr>
<td>Drilling</td>
<td>1,07</td>
<td>1,88</td>
</tr>
<tr>
<td>Cleaning</td>
<td>2,70</td>
<td>1,94</td>
</tr>
<tr>
<td>Other</td>
<td>0,64</td>
<td>0,62</td>
</tr>
<tr>
<td>Total</td>
<td>15,06</td>
<td>11,50</td>
</tr>
</tbody>
</table>
The difference in favour of the trackless option is therefore R3,56/ton. (say) R3,50.

N.B The above costs do not represent a comparison of development and stoping costs only but also include certain ancillary operations: this comparison reflects comparative costs for both methods of mining for mining the UEIA Reef in the 95 Level Basin Area of Cooke 2 Shaft.

The major differences (advantages of the trackless option) can be identified as follows:

(a) Development costs must be less for the trackless access option as all development (except the single footwall gathering haulage and workshop development) is carried out on reef and is linked to the stoping operation.

(b) A significant reduction in labour (particularly unskilled) is achieved and the difference in costs will continue to favour the trackless option as the cost of labour continues to escalate with time.

(c) A major decrease in cleaning costs (streamlined tramming by L.H.D and dump truck versus winches and locomotive haulage); however this advantage will be partially negated by the increased cost of drilling by electro-hydraulic drill rig.

12. JUSTIFICATION

The concept of a trackless operation for the narrow UEIA Reef on 95 Level at Cooke 2 will be financially viable because working costs will be less. This reduction in working costs will be realised for reasons that stoping costs will be less; footwall development costs are markedly reduced; ancillary operations on footwall service levels are virtually eliminated except for the gathering haulage.

In addition because waste development will be minimised therefore additional reef hoisting (waste hoisting replaced by reef hoisting) will provide for additional revenue.

Further as a result of the reduction in working costs the pay limit is reduced causing an increase in ore reserves which can be quantified.
13. CONCLUSIONS

The mechanised method of mining utilising the trackless access gathering haulage concept is considered to be technically viable.

Working costs will prove to be lower mainly for the reason that there is significantly less development and there will be a marked reduction in labour.

The trackless system of mining will be a safer operation than a conventional operation.

It is realised that dilution could be a main area of concern for a trackless operation (using large equipment on the reef horizon) in narrow reef conditions. However in terms of the planned methods for handling waste in development and taking cognizance of practical experience to date it is confidently predicted that this area of concern will be overcome.

14. ACKNOWLEDGEMENT

The author wishes to thank the Consulting Engineer (Gold and Uranium Division) Johannesburg Consolidated Investments Company Limited, for permission to publish this paper.

15. REFERENCES

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   K.A. Rhodes, AMM Circular 1/86.

   K.A. Rhodes, AMM Circular 1/86.

K.A. RHODES

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4 Conventional Development (With Interlevel)
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6 Panel Layout
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13 Workshop Area
PLANNED DEVELOPMENT LAYOUT FOR CONVENTIONAL MINING: 95 LEVEL BASIN AREA. (NO INTERLEVEL.)

LEGEND:

--- 95 LEVEL.
--- 101 LEVEL.

NOT TO SCALE
PLANNED INTER LEVEL DEVELOPMENT
LAYOUT FOR CONVENTIONAL MINING
95 LEVEL BASIN AREA.

LEGEND:
- 95 LEVEL.
- 99 INTER LEVEL.
- 101 LEVEL

TYPICAL OREPAS LAYOUT
IN CROSSCUT

NOT TO SCALE