INVESTIGATION AND DESIGN OF A STORAGE
AND HANDLING SYSTEM FOR FUTURE COAL FIRED
POWER STATIONS IN SOUTH AFRICA

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg for the degree of Master of Science in Engineering through course work and 4 months project.

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STATEMENT OF ORIGINALITY

I hereby declare that the work presented in this report is my own, except where indicated otherwise, and that it has not previously been submitted for the purposes of obtaining credit for any other degree.

SIGNED: 

DATE: 9/1/2027

373008
ACKNOWLEDGEMENTS

Permission to submit this report for purposes of a higher degree was kindly granted by Escom senior management.

I would like to thank Mel Berry and my supervisor Martin Bailey for their continual support and advice throughout the investigation.
SYNOPSIS

An overall description of the storage needs of a modern coal fired power station in South Africa is given in the report.

Alternative approaches to meeting these needs are explored and the costs, advantages and disadvantages are established.

Finally, recommendation as to which configuration best meets the requirements of a large coal fired power station is made.
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Escom is South Africa's largest electricity utility, generating and distributing 90% of the electricity requirements of South Africa or 60% of the electricity generated on the African continent.

The electricity is produced by 20 coal fired power stations, a nuclear station and 3 hydro stations and 3 gas turbine stations. Escom's new generation coal fired power stations are amongst the most technically advanced in the world and with a total generating capacity of above 3600 MW at a single site are some of the largest in the world. A 3600 MW power station provides employment for 2000 people, consumes 48 408 tons of coal, 120 Mega liters of water and produces 14 400 tons of ash per day. To support such a process many activities not directly related to the generation of electricity are required. An important one of these is the acquisition, storage and supply of the materials and spare parts needed to support the maintenance, administration and secondary process activities. Because of the "high tech" nature of most of the materials required and the location of the power stations far from the industrial centres, much of the required materials have to be stored at site. In 1984 Escom management became aware of several problems experienced with the storage facilities at the new generation power plants and realized that the design of the storage facilities had not kept pace with the development of the power plants. In order to overcome this, management commissioned an investigation to determine the actual storage requirements of a modern power plant and determine...
which storage system would best meet these requirements. (A brochure giving more detail on Escom and the role it plays in the S.A. economy is given in the appendices.)

1.1 Objectives of the investigation

The objectives of the investigation were thus to:

- determine when during the construction of a new power station, the stores facility should be built,
- establish how much storage capacity should be provided for each category of material and the method of storage,
- establish the zoning of the store,
- provide a design brief for new stores showing the necessary building configuration to meet the needs of the recommended materials handling and storage system.

2. STRUCTURE OF THE PROJECT

A standard systems design approach was used in the development of the requirement, design and selection of the storage system. The storage of the design were:

- the definition of the system and boundaries,
- the identification of the required data and simplifying assumptions,
- gather and generate the required data,
3.

DEFINING THE SYSTEM AND BOUNDARIES

A materials handling system consists of two major areas namely the physical aspects such as the facilities and the operational aspects such as processes and procedures. At the time of this investigation a major project with the aim of improving all aspects of Escom's materials management process was being initiated. As the stores operating processes and procedures would be developed during the major materials management project, this investigation was limited to the physical aspects with one of the constraints being that the storage system selected must be compatible with several operating processes.

4.

IDENTIFICATION OF DATA REQUIREMENTS

The data elements required and the analysis technique used at each stage of the system design are shown in diagram 4. A detailed listing of the specific data elements follows the diagram.
Diagram 2.6 - Stores System Development

(A) Initial data has been restricted to storage volume, flow of goods in/out and picking intensities. Current waste information will provide an accurate cost evaluation. However, difficulties in obtaining the correct initial data does not exclude the possibility of carrying out the analysis in a satisfactory manner. An initial evaluation can be made. It is extremely important however, to ensure that the same initial data is used when making comparisons between different solutions for one system.

(B) Stores areas are determined by dividing the goods into storage classes e.g. pallet goods, small goods, crane handled goods, etc.

(C) Separate zones are established for specific classes of good requiring special storage or handling e.g. hazardous materials, bulk liquid, etc.

(D) The storage and handling system is chosen according to the picking characteristics of each class of goods.

(E) Calculating the handling capacity.
   - Storing
   - Relocation
   - Picking

(F) Cost of partial system.

(G) Total system cost.

(H) Sensitivity analysis.

(I) A different handling system.

(j) OK?
4.1 Space requirement data

- Volume of Goods Stored for each class of storage
- Stability of the stock volume
- Growth trends of the volume
- Utilisation Expected
  - Area
  - Height
  - Rack
  - Volume

for each class of storage

4.2 Stock composition data

- Size and weight categories
- Material characteristics (inflammable, ion, fluid, etc.)
- No. of Product lines (NSNs) per class

4.3 Stock Movement and Picking data

- No. of Product lines held (NSNs)
- Amount of buffer stock
- Make up of orders (i.e. from which class of storage)
- Load size moved
- Orders per day
- Lines per order
- Receipts per day
- Lines per receipt
- Pake issues per hour
- Picks per man hour
4.4 Layout Data

- Unique storage zones required
- Service zones required
- Relationship study zones
- ABC analysis of movement for stock location within zones.

4.5 Cost Data

- Storage equipment
- Handling equipment
- Building
- Maintenance
- Labour

5. FINDINGS

Very little of the required data was readily available in a usable form and so most had to be generated using a variety of industrial engineering techniques. The techniques used are explained briefly below but for more detailed explanation references to text on the techniques are given where possible.

5.1 Measurement of the volume (m$^3$) of stock.

There was no way of using the data on the stock recording system to determine the volume of goods stored as none of the data
recorded bore any relation to the physical size of the stock. The only way that the volume could be determined was by physical measurement.

The size of the store, and variety of items stored, made it impractical to measure each individual item. Three techniques were used to overcome this problem:

Where possible, for instance the block stacked areas or large item storage, the volume of goods was measured directly.

In racked or shelved areas the volume occupied by the shelving was measured and then sampling used to determine the rack volume utilisation.

In the remaining areas, the store was divided into suitable areas of a known size in which the average height of materials and area utilisation could be measured and used to calculate the stock volume. (3)(8)

The volume measured at 4 representative stations is given in table 5.1

<table>
<thead>
<tr>
<th>TABLE 5.1 VOLUME OF GOODS STORED PER STORES ZONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATION 1  (2 YRS.)</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>HEAVY PLANT</td>
</tr>
<tr>
<td>LIGHT PLANT</td>
</tr>
<tr>
<td>GENERAL</td>
</tr>
<tr>
<td>OTHER COVERED</td>
</tr>
<tr>
<td>YARD</td>
</tr>
<tr>
<td>TOTALS:</td>
</tr>
</tbody>
</table>
NOTE: The age of each station (yrs of commercial services of set 1) is shown in brackets.

(NOTE: The figures given for the measured volumes include a 20% safety factor to accommodate inaccuracies in measurement, to ensure that peak volumes are catered for and cover any other uncertainties regarding volume. The figures should therefore be used as is, and not increased further by an additional safety factor).

5.2 Stability of stock volume

The stability of the stock volume was measured in 3 ways:

Firstly a 10% sample of stores items was taken and the number of days stock was established for each of these items. The number of days stock was then compared to inventory policy to establish where the measured volume lay on the demand quantity curve and how fast these stocks would be depleted. The results are shown in table 5.2.

<table>
<thead>
<tr>
<th>% OF TOTAL PRODUCT LINES (None)</th>
<th>3 MONTHS</th>
<th>6-12 MONTHS</th>
<th>&gt;12 MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,2%</td>
<td>8,3%</td>
<td>6,7%</td>
<td>0,7%</td>
</tr>
</tbody>
</table>

TABLE 5.2 MONTHS SUPPLY OF STOCK ON HAND
Secondly the volume of stock at one store was measured on two occasions 4 weeks apart to check whether there was any significant change in the stock holding between these two dates.

Thirdly a pareto analysis of movement against line items was carried out to establish what proportion of items were stagnant. The results of this are shown in graph 5.2.

This graph is extremely steep with only 2% of items responsible for 80% of the movement through the store. Its shape is typical of one found in process industries where large quantities of "insurance" spaces are kept.
5.3 Growth in stock

Since records were not kept of the physical volume of stock and there was no large age difference between the representative power stations, no direct projection of volume growth trends could be made. Instead a related index had to be found. Two indices which could possibly be used were identified as:

1) Growth in capital value of stock held.
2) Number of NSNs (Line items)

It must be emphasised however, that these were only trend indicators and could not be used for accurate projection. It was also found that inflation had a varying effect on the capital value of stock held and so it was difficult to use as an indicator. Comparisons of the two indicators over short periods of time, where inflation effects were minimised, showed that the two indicators trends were very similar. The growth trend given by the growth of NSNs is given in graph 5.3.
5.4 Expected utilisation indices

The expected utilisation indices were calculated for each type of storage and handling method, using equipment specifications and standards supplied by the manufacturers (Refer Annexure A1). The indices are given in table 5.4.
TABLE 5.4 EXPECTED UTILISATION FOR VARIOUS STORAGE AND HANDLING METHODS

<table>
<thead>
<tr>
<th>TYPE OF STORE</th>
<th>AREA UTILISATION</th>
<th>HEIGHT UTILISATION</th>
<th>VOLUME UTILISATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Equipment Requiring Crane</td>
<td>60%</td>
<td>42%</td>
<td>25%</td>
</tr>
<tr>
<td>Pallet Racked Area:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Served by counterbalanced fork truck</td>
<td>36%</td>
<td>85%</td>
<td>31%</td>
</tr>
<tr>
<td>Served by reach truck</td>
<td>41%</td>
<td>35%</td>
<td>33%</td>
</tr>
<tr>
<td>Served by narrow aisle truck</td>
<td>50%</td>
<td>85%</td>
<td>43%</td>
</tr>
<tr>
<td>Block Stacked Area:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Served by counterbalanced fork truck</td>
<td>63%</td>
<td>85%</td>
<td>54%</td>
</tr>
<tr>
<td>Served by reach truck</td>
<td>67%</td>
<td>85%</td>
<td>57%</td>
</tr>
<tr>
<td>Long Span Shelving (Hand Picked)</td>
<td>43%</td>
<td>80%</td>
<td>34%</td>
</tr>
<tr>
<td>Steel Shelving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>457 x 914 std. units</td>
<td>41%</td>
<td>80%</td>
<td>33%</td>
</tr>
<tr>
<td>380 x 914 std. units</td>
<td>37%</td>
<td>80%</td>
<td>30%</td>
</tr>
<tr>
<td>305 x 914 std. units</td>
<td>34%</td>
<td>80%</td>
<td>27%</td>
</tr>
</tbody>
</table>
5.5 Utilisation indices achieved

The actual utilisation indices achieved were calculated using the volume of stock that had been measured and the total storage volume available. The available storage volume was obtained from actual measurements or drawings of the facility. The utilisation indices achieved are given in table 5.5 and illustrated pictorially below.

**TABLE 5.5 UTILISATION ACHIEVED**

<table>
<thead>
<tr>
<th>STATION A</th>
<th>STATION B</th>
<th>STATION C</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA</td>
<td>HEIGHT</td>
<td>VOLUME</td>
</tr>
<tr>
<td>UTL.</td>
<td>UTL.</td>
<td>UTL.</td>
</tr>
<tr>
<td>INDEX</td>
<td>INDEX</td>
<td>INDEX</td>
</tr>
<tr>
<td>Heavy plant</td>
<td>.57</td>
<td>.19</td>
</tr>
<tr>
<td>Light plant</td>
<td>.28</td>
<td>.31</td>
</tr>
<tr>
<td>General</td>
<td>.30</td>
<td>.62</td>
</tr>
<tr>
<td>Other Covered</td>
<td>.40</td>
<td>.46</td>
</tr>
<tr>
<td>Yard</td>
<td>.23</td>
<td>-</td>
</tr>
</tbody>
</table>

Where: Area UTL. = Area Covered By Stock
       Total Area (incl. Aisles)

Height UTL. = Storage Height
       Usable Ht. of building

Volume UTL. = Vol. of Racking
       Total Vol. of Building (or Freestanding Stock)
Illustration of the volume utilisation against that expected.

Present:
- Area UTL. = 35%  
- HT. UTL. = 35%  
- VOL. UTL. = 8%

Suggested:
- AREA UTL. = 45%  
- HT. UTL. = 40%  
- VOL. UTL. = 18%
5.6 Size and weight categories

Five representative size and weight categories were chosen and a well-defined benchmark allocated to each. The stores items were then classified by determining which benchmark they were nearest to in terms of size or weight. This is generally referred to as a "Mag" or magnitude count. The results of the "Mag" count are given in Table 5.6.

**Table 5.6 Size and Weight Categories**

<table>
<thead>
<tr>
<th>Storage Method</th>
<th>Weight Category</th>
<th>Size Benchmark</th>
<th>Present Volume</th>
<th>% of NSNs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>1 1/2 Ton</td>
<td>VW Beetle</td>
<td>1096</td>
<td>3.2</td>
</tr>
<tr>
<td>Heavy rack</td>
<td>30kg-1 1/2 ton</td>
<td>Full pallet</td>
<td>952</td>
<td>3.7</td>
</tr>
<tr>
<td>Light rack</td>
<td>20kg-50kg</td>
<td>Office Chair</td>
<td>478</td>
<td>7.3</td>
</tr>
<tr>
<td>Long span shelf</td>
<td>20kg-50kg</td>
<td>Waste bin</td>
<td>370</td>
<td>11.3</td>
</tr>
<tr>
<td>Steel shelf</td>
<td>500g-20kg</td>
<td>Coke can</td>
<td>500</td>
<td>52.5</td>
</tr>
<tr>
<td>Drawer or bin</td>
<td>500g</td>
<td>Match box</td>
<td>21</td>
<td>21.9</td>
</tr>
</tbody>
</table>
5.7 Material characteristics

The material characteristics of the stock held were established by direct observation. It was found that certain materials held in a power station store have unfavourable storage properties such as acidity, corrosiveness, poisonous, perishability, fragility, exposure to heat, light or moisture, are awkward to handle, etc., but do not necessarily require storage in separate rooms. However, it is necessary to provide specialised storage for the following commodities:

**TABLE 5.7(i) VOLUME OF GOODS FOR COMMODITIES REQUIRING SPECIALISED STORAGE**

<table>
<thead>
<tr>
<th>COMMODITY</th>
<th>PRESENT VOLUME (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decanted oil</td>
<td>12</td>
</tr>
<tr>
<td>Gas</td>
<td>30</td>
</tr>
<tr>
<td>Paint</td>
<td>30</td>
</tr>
<tr>
<td>Steel</td>
<td>810</td>
</tr>
</tbody>
</table>

A very large proportion of materials require to protection and may be stored in the open. Refer table 5.7 (ii)
TABLE 5.7(ii) YARD STORAGE REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>PRESENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>3340m³</td>
</tr>
<tr>
<td>Area</td>
<td>8800m²</td>
</tr>
</tbody>
</table>

5.8 Number of product lines held

This figure was obtained from the stock status report. The monthly closing value for each one of three stores over a period of three years was found. The only figures which could be ascertained for all 3 stations were the number of NSNs at 5 years. These are:

Station A 20 225  
Station B 18 186  
Station C 22 437

5.9 Make up of issues and receipt

A 10% random sample of 3 months issue documents was taken and analysed to determine the rate of issues from each storage zone. These findings are presented in graph 5.9(i). A similar exercise was done for the receipts and the results are shown in graph 5.9(ii).
GRAPH 5.9(i) DISTRIBUTION OF ISSUES

GRAPH 5.9(ii) DISTRIBUTION OF RECEIPTS
5.10 Load size moved (% bulk movement)

A 10% random sample of issue documents and a 20% random sample of receipt documents was taken for 3 months to determine what percentage of movements in the store were bulk and hence required mechanical handling. The findings are illustrated in the pictoral below.

PICTORIAL 5.10

LOAD SIZE MOVED

RECEIPTS

72%  99%

28%  1%

ISSUES
5.11 Orders per day

A 10% random sample of the entries in the issue counter log book was taken for records covering a 3 to 5 year period, depending on the store, to establish the number of movements per day and the rate at which they increased over a period of time. A 10% random sample was then used to determine the number of line items picked for each order. A similar exercise was done for issues. The results obtained are given in table 5.11(i) and table 5.11(ii).

**TABLE 5.11(i) RATE OF STOCK MOVEMENT: ISSUES**

<table>
<thead>
<tr>
<th>NOVEMBER 1984 FIGURES</th>
<th>DUVHA</th>
<th>MATIA</th>
<th>KRIEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average orders/day</td>
<td>124</td>
<td>146</td>
<td>191</td>
</tr>
<tr>
<td>Peak orders/day</td>
<td>140</td>
<td>182</td>
<td>216</td>
</tr>
<tr>
<td>Average lines/order</td>
<td>2,20</td>
<td>1,86</td>
<td>2,40</td>
</tr>
<tr>
<td>Average picks/day</td>
<td>273</td>
<td>272</td>
<td>458</td>
</tr>
<tr>
<td>Peak picks/day</td>
<td>308</td>
<td>337</td>
<td>518</td>
</tr>
</tbody>
</table>

**10 YEAR PROJECTION**

| Average orders/day    | 232   |
| Peak orders/day       | 262   |
| Average picks/day     | 499   |
| Peak picks/day        | 563   |

* At 10 years of commercial service of 1st set.
TABLE 5.11(ii) RATE OF STOCK IMPROVEMENT: RECEIPTS

<table>
<thead>
<tr>
<th>NOVEMBER 1984 FIGURES</th>
<th>DUVRA</th>
<th>MATA</th>
<th>KRIEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average receipts/day</td>
<td>26</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>Average lines/receipt</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

10 YEAR PROJECTION *

| Average receipts/day | 49 |

* At 10 years of commercial service of 1st set.

5.12 Unique storage zones required

The number of unique zones required was determined from the size and weight analysis and the movements analysis which establish appropriate storage and handling methods. Safety requirements for hazardous stock were also carefully considered. The storage zones required are thus:
- Very heavy equipment storage area (heavy plant).
- Heavy equipment (racked light plant).
- General storage (shelf & drawer).
- Steel storage (can be accommodated in very heavy and heavy storage areas).
- Gas store.
- Inflammable store.
- Oil decanting store (only required if decanting is done by stores personnel).
- Yard.

In addition to making provision for the actual storage of materials, the building design must make provision for the administration and other supporting activities associated with the operation of the store. It was found that provision had to be made for the following areas in the design:

(i) Receiving:
- Truck loading/unloading area.
- Goods holding area (identification, quantity/quality check).
- Receiving administration area.

(ii) Issuing:
- Issue counter area.
- Order make-up/assembly area.
- Issue administration area.

(iii) General service areas:
- Supervisors office.
- Admin. office.
- Recreation room/General office/Lecture room.
5.13 Relationship of stores zones

In order to determine the optimal placement of one stores zone W.R.T. another a standard relationship study was carried out separately by 3 people with good stores and handling experience. The summarised results of this exercise are given on the next pages.
5.14 ABC analysis of movement from each storage zone.

The intensity of material flow to and from each stores zone was determined by sampling the items listed on the "ABC analysis by usage quantity". From usage, description, category and each item was categorised according to rate of movement, type, storage and handling method. The results are shown graphically on the following page.
5.12 Cost data

Cost data for equipment was obtained from 11 different manufacturers and suppliers. The figures were budget figures and valid for the 2nd quarter of 1985. The building costs were calculated from the contract price of the Lethabo and Tutuka buildings. The mezzanine cost was calculated from the contract price of Kendal store's mezzanine. Maintenance costs of handling equipment were obtained from suppliers and users.

5.16 Storage equipment

Storage equipment costs per m² of building (i.e. including aisles) are shown below. These are approximate figures for comparison of storage system costs only, as in practice, there are wide differences between suppliers.

Shelving:

- Steel shelving 2,2m ht: R170/m²
- Steel shelving 2,2m ht with dividers: R190/m²
- Steel shelving 2,2m ht with plastic bins: R230/m²
- Drawers 1m ht: R230/m²
- Long span shelving 2,5m ht: R110/m²
5.17 Handling equipment

The costs of major items of materials handling equipment that may be appropriate for use in a power station store are given in Tables 5.17.2(i), 5.17.2(ii), 5.17.2(iii) and 5.17.2(iv).

NOTE:  * Based on the racking/m² that can be accommodated in the store when using a reach truck at 41% area utilisation. Adjustments should be made where other materials handling equipment is used.
**TABLE 5.17.2 (ii) VERY HEAVY PLANT HANDLING**

### OVERHEAD CRANES

<table>
<thead>
<tr>
<th>CAPACITY</th>
<th>SPAN</th>
<th>16m</th>
<th>24m</th>
<th>30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 Ton</td>
<td>R159 000</td>
<td>R190 000</td>
<td>R241 000</td>
<td></td>
</tr>
<tr>
<td>25 Ton</td>
<td>R133 000</td>
<td>R150 000</td>
<td>R191 000</td>
<td></td>
</tr>
<tr>
<td>16 Ton</td>
<td>R108 000</td>
<td>R115 000</td>
<td>R161 000</td>
<td></td>
</tr>
<tr>
<td>12 1/2 Ton</td>
<td>R98 000</td>
<td>R103 000</td>
<td>R131 000</td>
<td></td>
</tr>
</tbody>
</table>

Double girder, 80m run typical

**AERO-CASTER SYSTEM**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Typical Size</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Ton</td>
<td>1,8m x 1,1m</td>
<td>R10 500</td>
</tr>
<tr>
<td>16 Ton</td>
<td>1.2m x 0,9m</td>
<td>R 8 000</td>
</tr>
<tr>
<td>7 1/2 Ton</td>
<td>0,9m x 0,8m</td>
<td>R 4 000</td>
</tr>
</tbody>
</table>

**TABLE 5.17.2 (iii) STORAGE / RETRIEVAL (S/R) MACHINES**

### S/R MACHINE:

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Type</th>
<th>Load Carriage</th>
<th>Height</th>
<th>Aisle</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>300kg</td>
<td>Small parts picking</td>
<td>Rigid table.</td>
<td>9m</td>
<td>1,10m</td>
<td>R50 000</td>
</tr>
<tr>
<td>1 1/2 Ton</td>
<td>Heavy parts</td>
<td>Forks</td>
<td>9m</td>
<td>1,50m</td>
<td>R150 000</td>
</tr>
</tbody>
</table>

**ADDITIONS:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor</td>
<td>R 95/m</td>
</tr>
<tr>
<td>Top &amp; Bottom rail</td>
<td>R108/m</td>
</tr>
<tr>
<td>Erection</td>
<td>R7500</td>
</tr>
</tbody>
</table>

**TABLE 5.17.2 (iv) FREE PATH ORDER PICKERS**

### FREE PATH MACHINE:

<table>
<thead>
<tr>
<th>Typical Equipment</th>
<th>Capacity</th>
<th>Load Carriage</th>
<th>Picking Ht. (Fork Ht.)</th>
<th>Aisle</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>BT OPT 1000</td>
<td>1 Ton</td>
<td>Pallet of bins on Forks</td>
<td>9,0m (8,1m)</td>
<td>1,48m</td>
<td>R66 500*</td>
</tr>
<tr>
<td>Atlet UP</td>
<td>1 Ton</td>
<td>Pallet of bins on Forks</td>
<td>10,5m (9,7m)</td>
<td>1,35m</td>
<td>R56 500*</td>
</tr>
<tr>
<td>Atlet APC</td>
<td>1 Ton</td>
<td>Pallet of bins on Forks</td>
<td>7,8m (7,0m)</td>
<td>1,30m</td>
<td>R41 000*</td>
</tr>
</tbody>
</table>

* Guide rail cost R250/m of aisle not included.
5.17.3 Buildings

Construction costs for the main stores building excluding service areas, (i.e. toilets, changerooms, stairways and mezzanine floors, etc.) were found to be as follows:

HEAVY EQUIPMENT BAY \( \pm \$676/m^2 \)
(11m High, excluding crane)

LIGHT EQUIPMENT BAY \( \pm \$630/m^2 \)
(7.6m High)

This is based on the actual tender price for the Lethabo contract and includes the main construction, water supply, drainage, painting and other finishes, but excludes piling, springer system, air conditioning, lighting and compressed air.

5.17.4 Maintenance

Costs for maintenance of materials handling equipment were found to be as follows:

FORKTRUCKS \( \pm \$4500 \) per annum
(incl. Rep. & Maint.)

SWIVELREACH TRUCKS \( \pm \$5000 \) per annum
FREE PATH ORDER PICKERS  ± R4600 (250kg)

S/R MACHINES FOR SMALL PARTS  ± R1200 per annum PICKING (250kg)

S/R MACHINES FOR HEAVY PARTS  ± R3000 per annum PICKING (1 1/2 ton)

This data is based on information obtained from the University of the Witwatersrand Materials Handling Research Unit & equipment suppliers.

Annual maintenance costs for S/R machines were regarded as approximately 2% of the capital investment at a time when the capital value was not artificially inflated by the Rand/dollar exchange rate.

It was found however that a user operating a fairly old S/R installation, budgeted the following amounts:

- R36/month per 400kg (small parts) machine
- R67/month per 1 1/2 ton machine.

which equates to less than 1% of today's cost of equipment.
In view of the sensitive and confidential nature of specific labour rates and the fact that the final selection of the system would not be greatly influenced by this factor, it was considered non essential at this time to include these costs.

6. ESTABLISHMENT OF THE OPERATING CHARACTERISTICS, CONSTRAINTS AND CRITERION OF THE SYSTEM

6.1 System design input data

6.1.1 Storage volume

The measured volumes at the 3 representative stations of similar age, as given in table 5.1, are of the same order, despite the stations being constructed by different contractors and being located in different areas (i.e. close to a large industrial centre or from any town). The volume at station 4 is clearly less than would be expected as it is the older station but this can be attributed to the fact that it is a smaller station than the other 3 stations. This would indicate that the measured volumes could be used as a basis for design for stores of future stations. If the stations are to be larger than the current stations the volumes will have to be increased.
accordingly. Also although table 5.1 shows that there are considerable differences in the volumes of particular stores zones in the different stations, it was found that stock was located according to fairly vague classification. If the stock at the different stores had been classified and grouped according to the same rules the volume in the various classes would be similar. These reclassified volumes are shown in table 6.1.1 below.

TABLE 6.1.1(a) VOLUME OF GOODS PER STORES ZONE AFTER RECLASSIFICATION OF STOCK FOR A STATION OF APPROXIMATELY 5 YEARS OLD

<table>
<thead>
<tr>
<th>MATERIAL CLASS</th>
<th>VOLUME OF GOODS (M³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Equipment (Plant)</td>
<td>1650</td>
</tr>
<tr>
<td>Light Equipment</td>
<td>1140</td>
</tr>
<tr>
<td>General (Consumable)</td>
<td>240</td>
</tr>
<tr>
<td>High security</td>
<td>25</td>
</tr>
<tr>
<td>Rubber</td>
<td>23</td>
</tr>
<tr>
<td>Pata and inflammables</td>
<td>30</td>
</tr>
<tr>
<td>Oil</td>
<td>110</td>
</tr>
<tr>
<td>Chemicals</td>
<td>175</td>
</tr>
<tr>
<td>Steel</td>
<td>810</td>
</tr>
<tr>
<td>Stationery</td>
<td>70</td>
</tr>
<tr>
<td>Instruments</td>
<td>80</td>
</tr>
<tr>
<td>Gas</td>
<td>30</td>
</tr>
<tr>
<td>Clothing</td>
<td>80</td>
</tr>
<tr>
<td>Yard</td>
<td>2975</td>
</tr>
</tbody>
</table>

TOTAL: 7395
The data given in paragraph 5.2. shows clearly that there are no large fluctuations in the volume of stock over short periods like those found in buffer stores. Thus the 20% safety factor built into the measured data should adequately cover any short term peak and no additional provision has to be made for buffer stock storage.

Although there were no short term fluctuations in the volume of stock, graph 5.3 shows that there is constant growth in the volume over much of the life of the power station. The growth is particularly pronounced in the early years and becomes less significant towards the end of the productive life of a power station being negligible between 30 to 40 years after the last set commercial service. This growth in stock volume can be attributed to the fact that a modern power station can have up to 6 separate generating units or sets with the last set being completed up to 6 years after the completion of the first generating set. In addition to this, the continual upgrading of plant means that additional spares must be kept for the new types of plant installed.

For the design of the storage system it is important to realize that graph 5.3 can only be used as an indicator of how the volume requirements may increase and not as a means of determining the exact requirements at any stage in the life of a power station.
Thus it is important to recognize the uncertainty with regard to the volume of stock to be accommodated and design the storage system accordingly.

It is also important to realize that if the storage facility is built to accommodate the stock held after 30 years service, the facility would be grossly underutilized for most of its life.

To overcome these problems it was decided to design a storage facility which provided for easy modular expansion.

Since the volume of stock increased extremely rapidly over the first 10 years of service and since the data was collected from representative stations of up to 8 years of age, and thus could be accurately projected for 2 years, it was decided that the initial facility would be designed to accommodate the volume at 10 years service. This would mean that the facility would reach optimum utilization fairly rapidly and that the additional volume to be provided could be determined with a fair degree of certainty. Using the measured volumes given in table 6.1.1(a) and projecting these in accordance with the growth trend given in graph 5.3 the volumes of stock are as given in table 6.1.1(b).
TABLE 6.1.1(b) PROJECTED VOLUME OF STOCK PER STORE ZONE.

<table>
<thead>
<tr>
<th>STORAGE ZONE</th>
<th>VOLUME AT 10 YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>1745</td>
</tr>
<tr>
<td>Heavy rack</td>
<td>1190</td>
</tr>
<tr>
<td>Long span shelf</td>
<td>1060</td>
</tr>
<tr>
<td>Steel shelf</td>
<td>625</td>
</tr>
<tr>
<td>Drawer or bin</td>
<td>26</td>
</tr>
<tr>
<td>Decanted oil</td>
<td>15</td>
</tr>
<tr>
<td>Gas</td>
<td>38</td>
</tr>
<tr>
<td>Paint</td>
<td>36</td>
</tr>
<tr>
<td>Steel</td>
<td>1013</td>
</tr>
</tbody>
</table>

Yard

<table>
<thead>
<tr>
<th>Volume</th>
<th>4175m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>10280cm²</td>
</tr>
</tbody>
</table>

6.1.2 Rate of stock movement

The rate of stock movement through the store is given in paragraph 5.11. The projected values for a station store 10 years old are reproduced below for convenience.

TABLE 6.1.2 RATE OF STOCK MOVEMENT

<table>
<thead>
<tr>
<th>10 YEAR PROJECTION *</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average orders/day</td>
<td>232</td>
</tr>
<tr>
<td>Peak orders/day</td>
<td>262</td>
</tr>
<tr>
<td>Average picks</td>
<td>439</td>
</tr>
<tr>
<td>Peak picks/day</td>
<td>363</td>
</tr>
<tr>
<td>Average receipts/day</td>
<td>49</td>
</tr>
</tbody>
</table>
6.2 System sub areas

The sub areas that had to be considered in the design, along with this volume requirements are given in table 6.1.1(a). These areas, can however be grouped according to handling requirements. This regrouping is shown in table 6.2

### TABLE 6.2 STORES ZONES GROUPED ACCORDING TO HANDLING METHOD

<table>
<thead>
<tr>
<th>HANDLING REQUIREMENTS</th>
<th>COMMODITIES</th>
<th>STORAGE METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>General storage area:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man-handle</td>
<td>Very small, Small</td>
<td>Bin/Drawer, Shelf/bin, Long span</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Palletised assistance</td>
<td>Heavy</td>
<td>Pallet racking</td>
</tr>
<tr>
<td>Heavy duty handling equipment</td>
<td>Very heavy</td>
<td>Floor</td>
</tr>
</tbody>
</table>

Specialised storage areas:

| Man-handle | Gas | Floor |
| Man-handle | Paint | Long span |
| Man-handle | Steel | Heavy rack |
| Industrial truck | Yard | Floor |
6.3 Storage and handling system chosen according to the picking characteristics.

There are two major groupings of order picking systems, namely:
- selective
- non-selective

Selective picking is used where a large number of slow moving lines are stored which move independently of each other. It also facilitates a FIFO issue policy. This is the situation in power station stores, therefore we must use a selective picking method.

There are three types of selective order picking:
- Low-level: Used in warehouses with high turnover rate, high volume of goods in relation to storage capacity and a large number of lines per order.
- High-level: This is carried out in warehouses where there are a large number of articles and a relatively small requirement for a buffer stock.
- Station picking: Station picking is used when there is a relatively small number of articles and several similar orders can be picked at the same time.
In the 3 general sub areas of a power station store we have similar characteristics namely:

- an average of 2 lines per order;
- a turnover rate upwards of 1 year;
- an optimum space utilisation of 18%;
- a number of lines to capital value of stock ratio of 1/1000 i.e. (little buffer stock & large no of lines);
- orders which are mostly different and difficult to pick at the same time.

Thus these areas are ideally suited to high-level picking and we should attempt to use a materials handling method which facilitates selective, high-level picking.

In the specialized storage areas, there are very few line items per area. Thus these areas, are best suited to selective low level picking.

The handling methods for the various storage areas can thus be the following:

6.3.1 Very heavy sub area (Heavy plant)

Materials handling equipment limitations restrict the type of picking of very heavy goods to low-level picking. With the system design in this section then, our
aim must be to minimise the items stored in this area and maintain selective picking.

There are two materials handling methods capable of moving these items, namely:
- area castors
- overhead crane

If selective picking is to be ensured then the floor area required if an overhead crane is to be used is nearly half that required for the area castors. The cost to provide the additional building area far exceeds the cost of the crane and so it is recommended that an overhead crane is used in this area.

6.3.2 Heavy sub area (Light plant)

In the heavy components section there are two types of handling equipment which allow high level storage. These are the various types of reach truck and the S/R machine. This equipment will allow storage ranging from 7m to above 20m. In order to decide which of these systems should be used a cost comparison must be carried out. This is done in section 6.4.
6.3.3 Medium, small and very small sub area

For handling very small, small, and medium components, there are three feasible handling techniques which provide for high-level picking. These are:

- Mezzanines
- A/V machines
- Order picker with order pickers

A cost comparison has to be carried out in order to determine which of the three methods should be used. This is done in section 6.4.

6.3.4 Specialised storage areas

i) Man-storable areas

In these areas the picking system must be kept simple and the back aids are trolleys and hand pallet trucks which are operated at ground level.

ii) Steel storage area

The handling requirements for this group of stock are complex and if possible the area should be placed so that goods may be man-handled, handled by the industrial trunk or the overhead crane.
iii) Yard area

The handling method best suited to this area is a heavy duty counterbalanced forklift truck in the 5 to 7 ton range.

6.4 Warehouse dimensions, handling capacity and partial system costs

Refer Annexure A3 for detailed calculation of the following system costs.

6.4.1 Very heavy equipment bay (Heavy plant).

Dimensions:

- Width = 24m
- Length = 53m
- Height = 6.5m (To bottom of crane beam)

Costs:

- Handling equipment = R 190 000
  (40 ton crane)
- Building = R 859 872
- SUB SYSTEM COST = R 849 872
6.4.2 Heavy equipment bay (Light plant)

1) Option 1 = Forklift truck
   (Not high level picking.
   Comparative use only).

Dimensions:
- Width = 31m (Multiple of aisle +
  racking width.)
- Length = 53m
- Height = 5m (min clear headroom)

Costs:
- Storage equipment = R93 771
  (pallet racking 3,5m Hr).
- Handling equipment = R27 000
  (1,5 ton forklift)
- Building = R1 035 090
- NPV operating = 96 000
- SUB SYSTEM COST = R1 251 861
ii) Option 2: 2 way Reach truck

Dimensions:

- Width = 16m (multiple of aisle + racking width)
- Length = 52m
- Height = 8m (min clear headroom)

Costs:

- Storage equipment = R 87 360
  (pallet racking 6m Ht.)
- Handling equipment = R 43 000
  (1.5 ton reach truck)
- Building = R 524 160
- NPV Operating = R11 000

SOB SYSTEM COST = R765 520

iii) Option 3: Swivel reach truck

Dimensions:

- Width = 13m (multiple of aisle + racking width)
- Length = 46m
- Height = 9m (min clear headroom)
Costs

- Storage equipment = R 89 335
  (pallet racking to 7m Ht)
- Handling equipment = R106 900
  (1.5 ton swivel reach truck)
- Building = R376 740
- NPV Operating = R176 000
  SUB SYSTEM COST = R748 975

iv) Option 4: S/R machine

Dimensions:

- Width = 8.5m (multiple of aisle + racking width)
- Length = 52m
- Height = 10m (min. clear headroom)
6.4.3 Bay for man-handed goods

i) Option 1: Manual handling on mezzanines

Dimensions:
- Width = 24m (Multiple of aisle + racking width)
- Length = 52m
- Height = 7.6m (min. clear headroom)

Costs:
- Storage equipment = R 541 464
  (drawers, Shelves & Long span)
- Mezzanine floors = R 229 520
- Building = R 786 240
- NPV Operating = Negligible
SUB SYSTEM COST = R1 627 224
ii) Option 2: Manual Handling on Light duty S/R machine

Dimensions:
- Width = 11m (Multiple of aisle + racking width)
- Length = 71m
- Height = 10m (min. clear headroom)

Costs:
- Storage equipment = R 541 464
  (Drawers, shelves & long span)
- Handling equipment = R 247 065
  (3 off 300 kg S/R machines)
- Building = R 492 030
- NPV Operating = R 54 000
- SUB SYSTEM COST = R1 334 559

iii) Option 3: Manual handling on a free path order picking machine

Dimensions:
- Width = 23m (Multiple of aisle + racking width)
- Length = 53m
- Height = 8m (min. clear headroom)
Costs:

- Storage equipment = R 541 466
  (Drawers, shelves & long span)
- Handling equipment = R 188 650
  (3 off high level order pickers)
- Cost of Building = R 767 970
- NPV Operating = R 125 000

SUB SYSTEM COST = R 623 284

6.4.4 Specialised storage areas

i) Decanted oil

Dimensions:

- Width = 4m (Multiple of aisle +
  racking width)
- Length = 8m
- Height = 3m (min. clear headroom)

Costs:

- Storage equipment = R 3 520
- Building = R 20 160

SUB SYSTEM COST = R 23 680
Costs:

- Storage equipment = R 541,464
  (Drawers, shelves & long span)
- Handling equipment = R 185,850
  (3 off high level order pickers)
- Cost of Building = R 767,970
- NPV Operating = R 125,000

SUM SYSTEM COST = R 623,284

6.4.4 Specialized storage areas

i) Decanted oil

Dimensions:

- Width = 4m (Multiple of aisle + racking width)
- Length = 8m
- Height = 3m (min. clear headroom)

Costs:

- Storage equipment = R 3,520
- Building = R 20,160

SUM SYSTEM COST = R 23,680
ii) Gas storage

For the storage of gas a covered wire cage should be provided:

- Width = ± 6m
- Length = ± 13m
- Height = ± 2,5m

Approximate cost:
- Structure = ± R5 500


Dimensions:

- Width = 6m (Multiple of aisle + racking width)
- Length = 12m
- Height = 3m (min. clear headroom)

Costs:

- Storage equipment = R 7 920
- Building = R 45 360

SUB SYSTEM COST = R 53 280
iv) Steel storage

Complex handling & storage requirements

Dimensions:
- Width = 30m
- Length = 30m
- Height = 6m (min. clear headroom)

Costs:
- Storage equipment = R 99 000
- Handling equipment = Refer
  Annexure A3 d(iv)
- Building = R567 000
  SUB SYSTEM COST = R666 000

v) Yard

No special facilities need be provided.

6.5 Capacity check

A storage and handling system must be able to cope with the peak throughput of the system. The peak movements for each area are given in table 6.5
TABLE 6.5 MOVEMENT PER STORES AREA

<table>
<thead>
<tr>
<th>STORES AREA</th>
<th>PEAK PICKS PER MAN HOUR</th>
<th>PEAK RECEIPTS PER MAN HOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very heavy</td>
<td>less than once per day</td>
<td>less than once per day</td>
</tr>
<tr>
<td>Heavy</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>medium</td>
<td>55</td>
<td>28</td>
</tr>
<tr>
<td>small</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>very small</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Decanted oil</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Gas</td>
<td>less than once per day</td>
<td></td>
</tr>
<tr>
<td>Paint</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Steel</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Yard</td>
<td>less than once per day</td>
<td>less than once per day</td>
</tr>
</tbody>
</table>

6.5.1 Very heavy storage

The movement in this area is very low and the overhead crane will easily cope with the throughput.

6.5.2 Heavy goods storage

The peak movement in this area is 4 movements per hour. (3 out and 1 in). An industrial lift truck can cope with 10 to 15 movements per hour. An S/R machine can cope with 30 movements per hour. Thus for all options only one machine is necessary. With only one S/R machine however, a transfer car is necessary to transfer this equipment between aisles. The transfer
Oar is approximately half the price of an S/R machine but slows down the operation considerably and decreases the reliability of the system. In this particular application there is no great cost advantage in using only one machine and therefore it is recommended that 2 machines be installed.

6.5.3 Manually picked storage.

For a manually picked mezzanine storage area of the dimensions given, each picker should be able to handle 27 movements per hour (this excludes the time taken to identify the item and establish its location code) thus a minimum of 3 runners would be required for this area to handle the peak of 83 movements per hour.

An S/R machine used in the power station store picking operation should handle 35 movements per hour thus 3 machines are required to cope with the peak throughput of 83 movements.

A free path order picker in the power station store picking operation should handle 30 picks per hour. Thus 3 machines are required to handle the peak throughput of 83 movements.
6.5.4 Specialized storage

The total peak movement from these areas is only 12 per hour thus one runner with the available equipment will easily cope with the peak throughput.

6.6 Total System Costs

In general it is desirable to choose the sub systems so as to minimise the total system cost. In some cases though, non cost considerations could influence the decision and an option which is more expensive but which provides additional benefits could be used. This is especially true for cases where the difference in cost between systems is marginal.

6.6.1 Most economical system

<table>
<thead>
<tr>
<th>STORE ZONE EQUIPMENT</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Heavy Overhead Crane/</td>
<td>R1 049 872</td>
</tr>
<tr>
<td>Floor</td>
<td></td>
</tr>
<tr>
<td>Swivel reach/ 7m racking</td>
<td>R 748 975</td>
</tr>
<tr>
<td>Man-handled 8/R Machines/</td>
<td>R1 334 559</td>
</tr>
<tr>
<td>9m racking</td>
<td></td>
</tr>
</tbody>
</table>
Specialized Various methods R 742 960

storage

The total system cost will then be:

= R3 876 366

6.6.2 Most expensive system

<table>
<thead>
<tr>
<th>STORE ZONE</th>
<th>EQUIPMENT</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Heavy</td>
<td>Overhead crane/</td>
<td>R1 049 872</td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
<td>Forklift/ 3m racking</td>
<td>R1 251 861</td>
</tr>
<tr>
<td>Man-handled</td>
<td>Mezzanines/ 6.6 racking</td>
<td>R1 627 224</td>
</tr>
<tr>
<td>Specialized</td>
<td>Various methods</td>
<td>R 742 960</td>
</tr>
</tbody>
</table>

Storage

The total system cost will then be:

= R4 871 917
6.6.3 Cost to provide the required volume using the present storage systems.

<table>
<thead>
<tr>
<th>STORE ZONE</th>
<th>EQUIPMENT</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Heavy</td>
<td>Overhead crane/ Fork lift</td>
<td>R1 049 872</td>
</tr>
<tr>
<td></td>
<td>3m racking</td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
<td>Concrete mezz/ 2.2m racking</td>
<td>R2 586 709</td>
</tr>
<tr>
<td>Non-handled</td>
<td>sectionalized</td>
<td></td>
</tr>
<tr>
<td>Specialized</td>
<td>Various methods storage</td>
<td>R 742 960</td>
</tr>
</tbody>
</table>

The total system cost will then be:

= R5 631 402

The difference between this and the most economical system is R1 755 036 or 31%.
1. Costs which remain constant regardless of the option chosen are not included in the costing. For example fire protection equipment which is generally dependent on the volume to be protected and not the configuration.

2. Only equipment which is readily available on the South African market has been considered. For example in Europe some small parts S/R machine systems are higher than 9m. This is considered non-standard, and not readily available in S.A.

3. Labour costs have not been included in the operating costs since the choice of option does not necessarily reduce the number of employees as this remains largely dependent on the operating system.

6.7 Sensitivity analysis

The system costs were calculated for a specific case and all component costs were considered constant. However it has been pointed out that some of the data used in developing the system description was based on estimates. This applies especially to the projected volume of goods to be stored. Furthermore, component costs will fluctuate over a period of time. It is therefore necessary to establish how sensitive the total system cost is to these variables and over what range the chosen option remains the most economical.
6.7.1 Heavy parts storage

1) Sensitivity of option choice to the changes in volume of goods. (graph 6.7.1 (i)).

The graph shows that the swivel reach truck is the cheapest option over a small range close to the projected volume of goods.

A change of 8% makes the S/R machine option the most economical option.

However for volumes above the projected volume the cost difference between the 2 options is minimal and the decision as to which option should be used will have to be based on non cost considerations.
ii) Sensitivity of option choice to changes in building cost (graph 6.7.1 (ii))

The graph shows that the option chosen is not very sensitive to changes in the construction cost per square metre of building. A change of 20% is required before an alternative option is more economical. The cost differences for all but the forklift option are minimal for most of the range.
iii) Sensitivity of option choice changes in exchange rate.

Since all the equipment is imported, any exchange rate fluctuations would affect all options in a similar way and thus not affect the choice. (NOTE: although some forklift trucks are assembled in S.A. most of the components are imported).
6.7.2 Man-handled goods

i) Sensitivity of option choice to changes in volume of goods stored. (Graph 6.7.2 (ii)).

The graph shows that the S/C option is the cheapest over a broad range and the choice of option is not sensitive to fluctuations in volume to be stored. A change in volume of 61% must take place before an alternative option is more economical.

GRAPH 6.7.2 (i) SENSITIVITY TO CHANGES IN VOLUME (SMALL PARTS)
The graph shows that a change in the cost per square metre has virtually no effect on the option chosen. A change of 94% in the cost per square metre must occur before an alternative option is more economical.

GRAPH 6.7.2(ii) SENSITIVITY TO CHANGES IN BUILDING COST (SMALL PARTS)
iii) Sensitivity of option choice to changes in exchange rates and cost of equipment. (Graph 6.7.2(ii)).

All equipment costs given were established for the 2nd quarter of 1985 in order to facilitate comparison of alternative options.

In the period April 1985 to December 1986 the exchange rate has fluctuated widely. This fluctuation will affect the cost of imported goods more than locally produced items. It is therefore important to establish what affect an exchange rate fluctuation will have on the choice of option. The S/R machines and free path order pickers are imported machines and so their price will be affected by exchange rate fluctuations but since the mezzanine is locally produced, its price would not be affected.

On the graph 6.7.2(ii) three lines are shown for S/R machines at various prices. The line for the S/R machine costing R50 000 corresponds to the exchange rate at April 1985 (R=1.5918DM). The line for the S/R machine costing R75 000 corresponds to the exchange rate at October 1985 (R=0.9979DM). The line for the S/R machine costing R90 000 corresponds to an exchange rate of (R=0.8316DM).
Only the line corresponding to the April cost of a free path order picker is shown on the graph since it is also an imported machine subject to exchange rate fluctuations and will remain proportionally more expensive than the S/R machine. In all cases therefore, the free path machine can never become the cheaper option.

From the graphs we see that even with the exchange rate fluctuations the cost of the S/R machine option is well below the mezzanine option at the projected volume and this volume needs to be reduced by 32% before the mezzanine option becomes cheaper.

7. RECOMMENDATIONS

It is recommended that the storage facilities at future coal fired power stations in South Africa be designed according to the following principles:

i) The most cost effective system option (Refer 6.6) be chosen except where substantial reasons against arise at the time of system selection.

ii) Power Station stores systems be developed according to the specifications laid down in section 6.4 using a "systems approach" to new designs.

iii) The power station storage and handling system be provided as per section 6.4 comprising:
   - 3 of S/2 machines to 9m (Small parts picking)
   - Swivel reach truck to 8m (Heavy parts handling)
iv) The final stores facility, rather than several temporary buildings, should be provided at ± 2 years before first set commissioning.

v) The power station store be designed on a modular basis where the first module accommodates 10 years growth and the second module the remaining growth until decommissioning.

vi) The actual stock growth be monitored during the first 10 years of a power station's life in order to accurately project the storage requirements up to decommissioning.

vii) The projected growth rate (5.3) and stock volumes (6.1.1 a) be used initially as a basis to determine the size of future power station stores.

viii) "Open steel" rack supported mezzanines be used in future stores in preference to structural mezzanines.

ix) Internal walls to a store are to be avoided in future designs, i.e. don't provide unnecessary storage cells.

x) All future stores are designed to suit the chosen equipment and requirements of the store.
8. REFERENCES


(5) DR. H.A. ZOLLINGER


(9) SOUTH AFRICAN GOVERNMENT GAZETTE, Vol 237 1 March 1985 No. 9613.


### Determination of Expected Area Utilisation

**Long Span Shelving**

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Specification</th>
<th>Area Utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x Double Sided Stacks</td>
<td>0.10m x 1.00m</td>
<td>80.0%</td>
</tr>
<tr>
<td>9 x Single Sided Stacks</td>
<td>0.10m x 1.00m</td>
<td>90.0%</td>
</tr>
<tr>
<td>2 x Single Sided Shelves</td>
<td>0.10m x 1.00m</td>
<td>80.0%</td>
</tr>
</tbody>
</table>

**Total Area Utilisation**

- 80.0% Double Sided Stacks
- 90.0% Single Sided Stacks
- 80.0% Single Sided Shelves

**Area Calculations**

- N.A. (Not Applicable) = 0.0%
- N.A. (Not Applicable) = 0.0%

**Additional Notes**

- All measurements are in meters (m).
- Area calculations are based on the specified dimensions.
ANNEXURE A1

(b) Standard Shelving
Area Utilisation for Block Stacking

- ± 5 pallets deep x 32 along
  (1200x1000 pallets / fork entry on 1200 side / 1000mm between pallets)

- ± 5 pallets deep x 15 along

- ± 5 pallets deep x 32 along

<table>
<thead>
<tr>
<th>Counterbalance Fork Truck</th>
<th>Reach Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallets Along C'</td>
<td>33 x 1300 mm</td>
</tr>
<tr>
<td>Cases Aisle B'</td>
<td>4.40</td>
</tr>
<tr>
<td>Building Length</td>
<td>45,100</td>
</tr>
<tr>
<td>Stacking Aisle x2</td>
<td>7,000</td>
</tr>
<tr>
<td>Pallets Across Building</td>
<td>17 x 1100 mm</td>
</tr>
<tr>
<td>Building Width</td>
<td>25,000</td>
</tr>
<tr>
<td>Area Utilisation %</td>
<td>66%</td>
</tr>
</tbody>
</table>

* Use 3% less in calculations.
## ABC Analysis by Movement

### Small Parts Storage

#### Assumed Store Requirements (10 Years Commercial Service)

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
<th>Slow Moving</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### Equipment

#### General

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
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<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

#### Small Electrical

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
<th>Slow Moving</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Clothing

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
<th>Slow Moving</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Rubber

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
<th>Slow Moving</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Paint

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
<th>Slow Moving</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Paper

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Moving</th>
<th>Slow Moving</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Typical Storage Times

- **Shelf Spaces:** 15 x 500,000
- **Drainage:** 3 x 500,000
- **Overall:** 1 x 500,000

### Dimensions

- **Width (W):** 287.5 cm
- **Height (H):** 407 cm

---

*Note: Table entries and calculations are placeholders for demonstration purposes.*
### ABC Analysis by Movement

#### Heavy Storage on Pallet Racking:

<table>
<thead>
<tr>
<th>Item Type</th>
<th>Item/Owning</th>
<th>No. Opening</th>
<th>Rack Volume (m³)</th>
<th>Pallets Decking</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Consumable</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>General Use</td>
<td>30</td>
<td>10</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Medical Supplies</td>
<td>5</td>
<td>30</td>
<td>30</td>
<td>250</td>
</tr>
<tr>
<td>Instruments/Small Electrical</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>200</td>
</tr>
<tr>
<td>Clothing</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Kitchen</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Paint</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Inflammables</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Acid</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Stationery</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>High Security</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Chemicals</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total Pallets:**
- Decked Decks: 313 Off Pallets (139 m³)
- Pallets: 937 Off Pallets (1500 m³)

**Overall Line 1: 1944 = 2975 Off**

---

*Typical rack spanning 5 pallet positions: 600 x 1271 x 1600
Permits 1200 x 1200 with fork entry on 1059 side.*

940005
(c) Very Heavy Storage Under C.V.

**ESTIMATED STORAGE REQUIREMENTS**

**EIGH AS COMMERCIAL SERVICES**

<table>
<thead>
<tr>
<th>Item</th>
<th>Fast Notion</th>
<th>Slow Notion</th>
<th>Very Slow Notion</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Consumables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furniture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plan/Special Spaces</td>
<td></td>
<td>15</td>
<td>3750</td>
</tr>
<tr>
<td>Instruments/Small Electrical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOTHING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUBBER</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PAINT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFLAMMABLES</td>
<td></td>
<td></td>
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<tr>
<td>ACID</td>
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</tr>
<tr>
<td>STATIONERY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH SECURITY</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CHEMICALS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL HEAVY STOREAGE**

**OVERALL LINE ITEMS = 1150 OFF (3750m³)**

9.4.0.18
ANNEXURE A3

CALCULATION OF WAREHOUSE DIMENSIONS, HANDLING CAPACITY AND INITIAL INVESTMENT COSTS.

(a) Very heavy equipment bay (Heavy plant).

Volume to be stored = 1745m³
Area utilisation index = 0.6
Storage height = 2.3m
Floor area required = \[
\frac{1745}{0.6 \times 2.3} = 1264\text{m}^2
\]

If 24m span crane is used the run would be 53m.

Sub system building dimensions:

For an overhead crane area, a 2 to 1 length to width ratio is usually considered economical.

Width = 24m
Length = 53m
Height = 6.5m (to bottom of crane beam)

The sub system cost would then be:

- cost of handling equipment
  40t crane = R190 000
- cost of building
  1 272m² @ R676/m² = R859 872

**SUB SYSTEM COST = R1 049 872**

(b) Heavy equipment bay (Light plant)

(1) Option 1: Forklift truck (Not high level picking comparative use only).

- volume of goods = 1190m³
- storage height = 4m
- area utilisation = 36%
- rack volume utilisation = 50%

Rack volume required = 2 380m³

Floor area required = \[
\frac{2380}{0.36 \times 4} = 1653\text{m}^2
\]
Sub system building dimensions:

For a forklift truck, the width of one aisle plus racking is 6050mm.

Thus the width should be approximately a multiple of this.

3 aisles = 30,25m ; use 31m wide.

Width = 31m
Length = 53m
Height = 8m min clear headroom

The sub system cost would be:

- Cost of storage equipment
  \[ 1643m^2 \times R65/m^2 \times 0.36 = R93,771 \]

- Cost of handling equipment
  \[ 1.5 \text{ ton forklift} = R27,000 \]

- Cost of building
  \[ 1643m^2 @ R630/m^2 = R1,035,090 \]

**SUB SYSTEM COST = R1,155,861**

(ii) Option 2: 2-way reach truck

- Volume of goods = 1190m³
- Storage height = 7m
- Area utilisation = 41%
- Rack volume utilisation = 50%

Rack volume required = 2380m³

Floor area required = 2380

\[ 0.41 \times 7 = 829m^2 \]

Sub system building dimensions:

The width of one aisle plus racking for a 2-way reach truck is 5130mm. Thus the width of the building should be approximately a multiple of this.

3 aisles = 15,43m ; use 16m.

Width = 16m
Length = 52m
Height = 8m min clear headroom.
ANNEXURE A3

The sub system costs would be:

- cost of storage equipment
  832m² @ R105/m² = R87 360

- cost of handling equipment
  1,5t 2 way reach truck = R43 000

- cost of building
  832m² @ R530/m² = R524 160

SUB SYSTEM COST = R654 520

(iii) Option 3 Swivel reach truck

- volume of goods = 1190m³
- storage height = 8m
- area utilisation = 50%
- rack volume utilisation = 50%

Rack volume required = 2 380m³

Floor area required = \( \frac{2380}{0.5 \times 8} \)
  = 595m²

Sub system building dimensions:

The width of one aisle plus racking for a swivel reach truck is 4250mm.

(NOTE: At this width guide rails at the base of the racks are required). Thus the width of the building should be approximately a multiple of this.

3 aisles = 12,75m, use 13m

width = 13m
length = 46m
height = 9m min clear headroom

The sub system cost would be:

- cost of storage equipment
  598m² x R105/m² x 0.50 x (7 / 8) x (0.41 / 0.50) = R89 335

- cost of handling equipment
  1,5t swivel reach truck = R100 000
  guide rails, 138m @ R50/m = R6 900

*See note at 5.14.1
† cost adjustment for RED HT
ANNEXURE A3

(iv) Option 4: S/R machine

- volume of goods = 1190m³
- storage height = 9m
- area utilisation = 60%
- rack volume utilisation = 50%

Rack volume required = 2 380
Floor area required = \( \frac{2380}{0.6 \times 9} \)
\( = 441m² \)

Sub system building dimensions:

The width of one aisle plus racking for a 1 1/2 ton S/R machine is 4050mm. Thus the width of the building should be approximately equal to a multiple of this.

2 aisles = 8,1m . . . use 8,5m

width = 8,5
length = 52m
height = 10m min clear headroom.

The sub system costs would be:

- cost of storage equipment

\( 442m² \times R105/m² \times \left( \frac{0.6}{0.41} \right) ) = R90 556 \)

- cost of handling equipment

2 off 1,5 ton S/R machines = R300 000
104m support rail @ R203/m = R21 112

- cost of building

442m² @ R630/m² = R278 460

SUB SYSTEM COST = R690 128

See note at 5.14.1:

† cost adjustment for rack ht.
Option 1: Manual handling on mezzanines.

The type of mezzanine used has a major impact on the cost of the system. The most economical type of mezzanine, from both the material cost point of view and space utilisation is the rack supported mezzanine. Thus only this system will be considered.

- volume of goods = 1 711m³ (Long span + shelves + drawers)
- storage height = 6,6m
- area utilisation = 41%
- rack volume utilisation = 50% (shelves)
- rack volume utilisation = 75% (drawers)

Rack volume required

For very small components the rack volume utilisation achieved when drawers are used is 3 times better than the rack volume utilisation achieved when steel shelves are used. The cost of drawers is twice that of shelving for the same rack volume. However since only 1/3 of the rack volume is required if drawers are used, the drawer system is the most economical. A rack volume utilisation of 75% can be achieved if drawers are used.

Rack volume required:

\[
\text{shelves} = \frac{1 685m^3}{0,3} = 3 370m^3
\]

\[
\text{drawers} = \frac{26m^3}{0,75} = 35m^3
\]

Total = 3 405m³

Ground floor area required (with 2 levels of mezzanines above i.e. 3 x 2,2m high tiers of racking) = 3 405 \times 6,6

= 1 258m²

Sub system building dimensions:

The width of one aisle plus racking for a small parts pick area is 2m. Thus the building width should be approximately equal to a multiple of this.

12 aisles = 24m

- width = 24m
- length = 52m
- height = 7,6m min clear headroom

The sub system cost would be

- cost of storage equipment
ANNEXURE A3

long span shelving = 78m² x 4 levels x R110/m² = R258 390
steel shelving = 462m² x 3 levels x R190/m² = R263 340
drawers = 13m² x 3 levels x R506/m² = R19 734
- cost of mezzanine
  2 levels x 1248m² x R120/m² = R299 520
- cost of building
  1248m² x R630/m² = R786 240
SUB SYSTEM COST = R1 627 224

- Volume of goods = 1 711m³ (Long span + shelves + drawers)
- storage height = 9m
- area utilisation = 48%
- rack volume utilisation = 50% (shelves)
- rack volume utilisation = 75% (drawers)

Rack volume required = 3 405m³

Floor area required = 3405
  \( \times \frac{0.48 \times 9}{1} \)
= 788m²

Sub system building dimensions

The width of one aisle for an S/R machine of this type plus the width of racking is 2100mm. Thus the building width should be approximately a multiple of this.

5 aisles = 10,5m \( \therefore \) use 11m

Width = 11m
length = 71m
height = 10m min clear headroom

The sub system costs would be
- cost of storage equipment
  (see option 1 for calculation)
  = R541 464
- cost of handling equipment
  3 off 300kg S/R machines = R150 000
  355m rail & conductor @ R203/m = R72 065
  Transfer car = R25 000

SUB SYSTEM COST = R1 627 224

SUB SYSTEM COST = R1 627 224
ANNEXURE A3

- cost of building
  781m² @ R630/m² = R492 030

  SUB SYSTEM COST = R1 280 559

(iii) Option 3. Manual handling of a free path order picking machine

- volume of goods = 1 711m³
- storage height = 7m
- area utilisation = 40%
- rack volume utilisation = 50% (shelves)
- rack volume utilisation = 75% (drawers)

Rack volume required = 3 405m²

Floor area required = 3 405
  \[ \frac{0.4 \times 7}{1} \]
= 1 216m²

Sub system building dimensions

The width of one aisle plus racking for a free path order picker is 2500mm. Thus the building width should be approximately a multiple of this.

9 aisles = 22.5m \( \therefore \) use 23m

width = 23m
length = 53m
height = 8m min clear headroom

The sub system costs would be:

- cost of storage equipment
  (see option 1 for calculation) = R541 464
- cost of handling equipment
  3 off highlevel order pickers = R165 000
  477m of guide rail @ R50/m = R23 850
- cost of building
  1 219m² @ R630/m² = R767 970

  SUB SYSTEM COST = R1 498 284

(d) Specialized storage areas


- volume of goods stored = 15m³
- storage height = 2.2m
- area utilisation = 43%
- rack volume utilisation = 50%
Rack volume required = 30m³

Floor area required = \[
0.43 \times 7.2
\]
\[
= 32m²
\]

Sub system building dimensions

The width of one aisle plus racking is 2 000mm. Thus the building width should be approximately a multiple of this. (For this type of picking, Kellywast (1) suggests that the length to width ratio should be 1:1 to 2:1 as a rule of thumb).

2 aisles = 4m
width = 4m
length = 8m
height = 3m min clear headroom

The sub system cost would be.
- cost of storage equipment
  32m² x R110/m² = R3 520
- cost of building
  32m² @ R630/m² = R20 160

Sub system cost = R23 680

(ii) Gas storage: Manual picking - low level - on ground storage.

For the storage of gas a covered wire cage should be provided. The cost of this is minimal and will not be included in the total system cost. A cage of approximately 76m² should be provided well away from the main stores building.

- volume of goods stored = 38m³
- storage height = 2.5m
- area utilisation = 43%
- rack volume utilisation = 50%

Rack volume required = 76m³

Floor area required = \[
0.45 \times 7.3
\]
\[
= 71m²
\]

Sub system building dimensions.

The width of one aisle plus racking for manually picked long span shelving is 2 000 mm. Thus the building width should be a multiple of this.
3 aisles = 6m
width = 6m
length = 12m
height = 3m min clear headroom

The sub system cost would be:
- cost of storage equipment
  \[72m^2 \times R110/m^2 = R7,920\]
- cost of building
  \[72m^2 \times R630 = R45,360\]

**SUB SYSTEM COST = R 53,280**

(iv) Steel storage. Complex handling and storage requirements.
- volume of goods stored = 1,013m³
- storage height = 2,5m
- area utilisation = 60%
- rack volume utilisation = 0,75%

* (It was found that with a good layout in this section of the store, good area and rack volume utilisation figures were easily obtained at the 3 representative stores.)

Rack volume required = 1,351m³

Floor area required = \[
\frac{1351}{0.60\times2.5} = 901m^2
\]

Sub system building dimensions
Since the major portion of stock in this area is boiler tubing and this tubing is generally in lengths of 8 to 10m the best layout for this area is a block of racking 10m deep either side of a 10m wide gangway.
- width = 30m
- length = 30m
- height = 6m min clear headroom

The sub system costs would be
- cost of storage equipment

A range of storage equipment will have to be used but the cost of long span shelving will be used as an average figure for costing purposes.
- \[900m^2 \times R110/m^2 = R99,000\]
- cost of handling equipment

547003
The steel store should, if possible, be placed in an extension of the heavy plant bay and close to the light plant bay so that the goods can be handled by the overhead crane and the industrial truck serving the light plant bay. If this is not possible a small (3 ton) overhead crane would have to be provided over the plate storage in the steel store. The cost of a small crane would vary greatly with changes in span and run but generally is very low (one to two thousand rand) in comparison with other handling equipment in this report and since it does not affect decision making it is felt that an estimated cost is not necessary.

- cost of building
  
  \[ 900 \text{m}^2 \times R630/\text{m}^2 = R567,000 \]

SUB SYSTEM COST = R666,000

(v) Yard

Volume of goods to be stored = 4,175 \text{m}^3

area required = 10,980 \text{m}^2

In general no special facilities need be provided for yard storage. However this is dependent on the soil and drainage characteristics of the specific store site and the requirements will have to be established for each store.
ANNEXURE A4

OPERATING COSTS

The operating cost comparison of alternative options.

Only costs which differ significantly depending on which option is used will be considered. The real cost of capital was considered to be 5% in accordance with the "Economic parameters" memo dd 17.10.85. (Econ Internal).

(a) Heavy plant storage

A 10 year life is used for the industrial lift trucks and a 30 year life for the S/R machines.

(i) Forklift truck

NPV of maintenance cost over 30 years
= R69 000

NPV of replacement cost over 30 years assuming a 10 year life (i.e. 2 replacements)
= R27 000

NPV of operating costs are thus
= R96 000

(ii) Reach truck

NPV of maintenance cost over 30 years
= R69 000

NPV of replacement cost over 30 years assuming a 10 year life
= R92 000

NPV of operating costs are thus
= R111 000

(iii) Swivel reach

NPV of maintenance cost over 30 years
= R77 000

NPV of replacement cost over 30 years assuming a 10 year life
= R99 000

NPV of operating costs are thus
= R176 000

(iv) S/R machine

NPV of maintenance costs over 30 years
= R92 000

547004
No replacement cost since has a life of 30 years.

NPV of operating costs are thus
\[= R92\,000\]

(b) Manhandled goods

(1) Mezzanine

The maintenance cost associated with mezzanines is negligible.

There will be no need for replacement within a 30 year period.

(II) S/R machine

NPV of the maintenance cost over a period of 30 years.
\[= R54\,000\]

No replacement of equipment will be necessary in the 30 year life.

NPV of operating costs \[= R54\,000\]

(III) Free path order picker

NPV of the maintenance cost over a period of 30 years
\[= R71\,000\]

NPV of replacement costs assuming a life of 10 years.
\[= R54\,000\]

NPV of operating costs \[= R125\,000\]
The cost per cubic metre of building reduces with the increase in height up to 20m.
ADVANTAGES & DISADVANTAGES OF S/R MACHINES

(a) Advantages:

(i) Make better use of existing space eliminating need for additional space or new building.
(ii) Keep cost of new building construction to a minimum.
(iii) More efficient use of manpower increases productivity.
(iv) Cut time needed for supervision.
(v) Reduce or eliminate damage to material stored.
(vi) Reduce the amount of present material handling.
(vii) Cut maintenance costs of system compared to conventional equipment.
(viii) Reduced pilferage.
(ix) More efficient handling of material to and from storage area.
(x) More effective inspection of material.
(xi) Reduced customer waiting time.
(xii) Smoother operation.

Conventional order picking stores have goods located either over a wide area on a single storey or on a number of mezzanine floors. In most cases, the pedestrian picker has long distances to cover on foot and steps to climb. Other factors which reduce efficiency include the difficulty of working in confined positions requiring stooping or stretching, or on unsteady trestles.
Far greater operational efficiency can be achieved by using S/R order picking machines. In the shortest time the stores person is transported by the machine to any required compartment by simultaneous horizontal and vertical movement of the cabin.

The S/R machine facilitates fast multi-line order assembly or retrieval of several orders on one cycle.

However picking one single line order per cycle is still 75% faster than the present manual pick method.

(b) Disadvantages:

(i) Some inflexibility.

(ii) Fairly accurate racking required.

(iii) Aisle bound machines.

(iv) Limited local supply.

(v) Demands proper locality coding.
<table>
<thead>
<tr>
<th>HEAVY PARTS:</th>
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</thead>
<tbody>
<tr>
<td>1) REACH TRUCK</td>
<td>High to Low</td>
<td>Short to Medium</td>
<td>Palletized</td>
<td>Small</td>
<td>RB5 000</td>
<td>No</td>
<td>7%</td>
<td>1 Ton</td>
</tr>
<tr>
<td>2) DROPSHINE</td>
<td>High to Low</td>
<td>Short to Medium</td>
<td>Palletized</td>
<td>Medium</td>
<td>RB10 000</td>
<td>No</td>
<td>7%</td>
<td>1 Ton</td>
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<tr>
<td>3) SKE MACHINE</td>
<td>High to Low</td>
<td>All</td>
<td>Palletized</td>
<td>Large</td>
<td>RB5 000</td>
<td>Yes</td>
<td>40%</td>
<td>1 Ton</td>
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<th>SMALL PARTS:</th>
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</thead>
<tbody>
<tr>
<td>1) NUK HIGH BASKET</td>
<td>High to Low</td>
<td>Short</td>
<td>Small</td>
<td>Medium</td>
<td>RB5</td>
<td>No</td>
<td>7%</td>
<td>0.5 kg</td>
</tr>
<tr>
<td>2) NUK WITH HAND TRAILER</td>
<td>High to Low</td>
<td>Short</td>
<td>Small/ Medium</td>
<td>Medium</td>
<td>RB10</td>
<td>No</td>
<td>7%</td>
<td>100 kg</td>
</tr>
<tr>
<td>3) POWER TRUCK (low level picker)</td>
<td>Medium to High</td>
<td>Medium</td>
<td>Small to Fairly</td>
<td>Medium to High</td>
<td>RB5 000</td>
<td>No</td>
<td>7%</td>
<td>750 kg</td>
</tr>
<tr>
<td>4) FREE PATH ORDER PICKER</td>
<td>High to Low</td>
<td>Medium</td>
<td>Small</td>
<td>Medium to High</td>
<td>RB5 000</td>
<td>No</td>
<td>7%</td>
<td>1 Ton</td>
</tr>
<tr>
<td>5) SKI MACHINE (Swing)</td>
<td>High to Low</td>
<td>All</td>
<td>Small</td>
<td>Medium to High</td>
<td>RB5 000</td>
<td>Yes</td>
<td>12%</td>
<td>500 kg</td>
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SCHEMATIC OF RECOMMENDED SYSTEM
TYPICAL HIGH RISE INSTALLATIONS

Installation at Iscor showing high rise shelving/drawer system for small parts storage.
TYPICAL HIGH RISE INSTALLATIONS

Small mechanical spares storage.
TYPICAL HIGH RISE INSTALLATIONS

Order picker in main store, Demag, Boksburg.

Installation in engineering industry similar to Demag's own facilities at Boksburg.
TYPICAL HIGH RISE INSTALLATIONS

Order picking of motor vehicle parts, Volvo.
TYPICAL HIGH RISE INSTALLATIONS

Installation in electrical engineering industry (Europe).
Storing small components in tote bins.
ACCEPTING THE CHALLENGE
ONS AANVAAR DIE UITDAGING

ESCOM
EVKOM

All our energy for you · Al ons energie vir u
Making the most of available resources

In South Africa, electricity is generated mainly by coal-fired power stations. Hydro- and nuclear power stations contribute additional power. There are insufficient water resources in this country to make large hydroelectric schemes possible. Available water supplies are more effectively used for irrigation and for town and city requirements.

Nuclear power is particularly advantageous in coastal areas where seawater may be used to conserve scarce supplies of fresh inland water. It will be increasingly adopted as coal resources are depleted, towards the middle of the next century.

Die benutting van beskikbare hulpbronne

In Suid-Afrika word elektrisiteit hoofsaaklik deur steenkoolkragstations ontwikkel. Hydro- en kernkragstations verskaf additional krag. Daar is te min water in hierdie land om groot hydro-elektriese sekes moontlik te maak. Die beskikbare water word meer effektief vir besproeiing en die behoefte van dorpe en stede gebruik.

Kernkrag is veral in kleinskelette voordelig waar die water gebruik kan word om die skars van water van die diensland te bewaar. Dit sal toenemend gebruik word soos steenkoolreserves uitgeput raak teen die middel van die volgende eeu.
Protection and restoration of the environment are priority issues in Escom's policy.

Environment-friendly construction programmes prevent the destruction of local natural life and guarantee almost total restoration of natural surroundings on completion of construction work. Close cooperation with communities affected by Escom construction projects ensures that adequate provision is made to cater to the needs both of the local populace and the incoming construction workers and employees.

Permanent anti-pollution measures in power stations limit water and air pollution.

Die beskerming en herstel van die omgewing is prioriteite in Evkom se beleid.

Programme om invloed op die omgewing te voorkom en die geskiede toe te voer aan en waarborg beskerming en die herstel van die natuurlike omgewing na voltooiing van konstruksiewerk.

Noue samewerking met gemeenskappe wat deur Evkom se konstruksiewerke geraak word, het met die nodige voorbereiding om inkomende konstruksiewerkers en werknemers te voorsien.

Permanente besoedelings-maatregele in kragstasies om water- en lugbesoedelings te voorkom.
Electricity is the driving power behind our modern industrial society. It is both the starting point and the road for progress.

Escom is the national electricity utility of South Africa, and one of the top ten utilities in the world. It provides electricity not only for the needs of the whole of South Africa, but also exports to Bophuthatswana, Ciskei, Lesotho, Mozambique, Namibia, Swaziland, Transkei, Venda and Zimbabwe.

Escom is internationally renowned for its achievements in:
- high-voltage and ultra-high-voltage transmission at high altitudes
- lightning research
- developing variable speed drives at power stations
- static compensation
- dry-cooling technology

Escom is at the forefront of energy generation technology. Many of its engineering achievements in this field have been part of progressive progress in the Western World. Research and development benefit from the exchange of information with foreign research institutes.

Elektrisiteit is die dryfkrag agter ons moderne nywerheidsgemeenskap. Dit is die beginpunt sowel as die weg na vooruitgang.

Daar moet 'n oorgedoen toëver van elektrisiteit van hoe gehalte word om ekonomiese en tegnologiese ontwikkeling te waarborg. Escom, die nasionale nywerheidsgan in Suid-Afrika en een van die eerste twee in die wêreld, verskaf elektrisiteit ook aan die lande in die geboaôsig van Suid-Afrika, naamlik: Phutha, Lesotho, Mozambique, Namibia, Swaziland, Transkei, Venda and Zimbabwe.

Escom word internasjonaal gekenmerk deur sy prestasies op die gebied van:
- hoogspannings-en hoogspanningsontvanger transmisie in gebiede hoeg bo seepeil
- wisselspannings-onderwysing
- die ontwikkeling van wisselspanningsaandrywing by kragfasies
- statiese kompensasie
- droogkoelteknologie

Escom is aan die spits van
die tegnologie van kragontwikkeling. Besonders prestasies op die gebied van die ingenieurswees is aangetoon in die Weste se vooruitgang.

Navoring en ontwikkeling trek vooruit uit die uithaal van inligting met buitenlandse navoringsinstansies.
Every facet of our way of life is touched by Escom's role in producing electricity.

Escom's activity over almost 70 years gives it the necessary experience to provide for the country's energy needs. Escom has adapted its objectives and methods to the changing requirements of Southern Africa's development.

Professionalism and customer awareness are keys that are enabling Escom to meet its customer needs without placing additional financial burden on the customer.

Escom is an educational organization - we exist to ensure that our customers develop to their fullest potential.

I believe that people and ideas are created, built by people with a vision and that we want to be on the one side of this through. We have to learn to meet the challenge of today with this principle.

John Marais, Chairman

Eike faset van ons leefwyse word deur Evkom se rol in die ontwikkeling van elektriesiteit geraak.

Evkom se bedrywighede oor bykans 70 jaar geë an hou die ervaring om in die land se kragbedoele (te voorsien) Evkom het sy spesiale wetenskaps- en technologieë deur die wisselende behoeftes van Suid-Afrika se ontwikkeling slegs geraak.

Professionalisme en klientbewusheid is skoon wat Evkom in staat het om insy klient se behoeftes te voorsien sanger om in noreëdelike finansiële wags om hulle te plaas.

Evkom is 'n educatiewe organisasie - ons bestaan om ons kliënte se behoeftes te voorsien om hulle se potensiaal in die toekoms te ontwikkel.

Evkom se leiers word nuut om met verskafers deur te spoed om in die lang termyn die land te lei. Evkom is 'n deel van die wêreld se grootste energieorganisasie. Ons hê ook saam met ons potensiaal om volle te ontwikkel.

Godsende vloeis van ontwikkeling deur
die mens met wêreld van

eenheid en verskeie van

t'wêreld se reëde van
die energie en die opvoeding

t se deur te voer. Ons hê

deel in nodige toekom Evkom

die onse lewe kortings in

Suid-Afrika die hoof te plaas.

John Marais, Voorstander
The national grid is the web of power that links the generating stations to the centres of commercial and industrial activity. The total length of its powerlines measures nearly 172 000 km with about 5 000 km of underground cables. Power stations are constructed to exploit natural resources even in remote areas, and the extensive network provides transmission over vast distances to centres where it is needed.
**Changing face of power**

**Escom is emerging from its remodelling process with a new personality**

South Africa's national power utility, Escom, has undergone a radical restructuring since 1985 which has changed the character of the organisation. Increasingly, the company's focus is on its customers (with intense concern given to holding down tariff rises), on developing its personnel and on its broader responsibilities to the community.

Today, Escom is being run as a meritocracy rather than a bureaucracy, and it measures its success in business terms. Nevertheless, the supply of electricity is not seen exclusively as a business, with the objective of making profits, but as a vehicle to create prosperity and to raise living standards in SA as a whole.

"Though it operates under an Act of Parliament, Escom is not a state-owned corporation but an independent, self-financing, non-profit undertaking whose purpose is to supply electricity in the most cost-effective way—subject to resource constraints and the national interest," says chairman John Maree. "We have to operate efficiently for the good of the country. We take the strong view that if we do our job badly it will affect the economy adversely. If we do it well, it can assist the South African mining and manufacturing industries to maintain their competitiveness.

"The prime mission of Escom is to satisfy the electricity needs of customers in the most cost-effective way, subject to resource constraints and the national interest." But there is a broader mission to use the organisation's expertise, capacity and resources to benefit the whole southern African region, without regard to political boundaries. Escom sees electricity as a way of achieving social and economic development.

Escom receives no money from the state," says chairman John Maree. "We have to operate efficiently for the good of the country. We take the strong view that if we do our job badly it will affect the economy adversely. If we do it well, it can assist the South African mining and manufacturing industries to maintain their competitiveness.

"The pride mission of Escom is to satisfy the electricity needs of customers in the most cost-effective way, subject to resource constraints and the national interest." But there is a broader mission to use the organisation's expertise, capacity and resources to benefit the whole southern African region, without regard to political boundaries. Escom sees electricity as a way of achieving social and economic development.

The organisational structure of Escom has been changed at two levels. As already mentioned, the control system at the top has been changed so that it is highly responsive to consumer needs. The Council and the Management Board operate in close harmony and have a sound relationship.

At a lower level, management control has been decentralised with the establishment of 52 strategic business units, each with its own support system and area of control. This has had an immediate impact on management efficiency and innovation, and has enhanced the quality of communication throughout the organisation.

Another factor improving communication has been the flattening of the reporting structure. The previous middle level has been disbanded, and new lines of communication from the lowest levels of the organisation to top management have been considerably shortened.

"A system which forces the superior and his subordinates to communicate will accelerate this culture change," says Maree. Making fundamental cultural changes to so large an organisation cannot be accomplished overnight. It takes time for the new philosophies to permeate through all levels. Initial plans to reduce the size of the head office structure are now going to take longer than originally envisaged. This required that some head office functions would be devolved on to the shoulders of the SBUs, and will have to wait until the units are ready to take on additional functions.

However, a heartening development is that for the first time the top manager...
Econ today is an equal opportunity employer, committed to advancement purely on merit regardless of the sex or colour of the individual. With 57 000 people on its payroll, its policies are bound to have a major impact.

The corporation has proceeded cautiously, negotiating with the trade unions involved, and has established parity for 12 000 employees in the course of the past year. Because of established practice and vested interests on the one side, and trade union pressures on the other, however, achieving this is a lot more complex than would appear at first sight. Thus an employee has proved his competence at a job, regardless of his qualifications, he can acquire parity with a white person doing the same job. Achieving equality of opportunity is not a passive operation, Lindeque notes, "It has to be developed. We have to infuse the organisation," he says. "We will not be satisfied to establish tokenism. On the other hand, we don't have an affirmative action programme, and we don't want to create fences. We want to be some meritocracy. We have to balance and manage our equal opportunity programme." It is a low profile programme which

Power station workers: no bars on advancement

[Image of Power station workers]
Spreading the light

Electricity in the home is still a dream for most of SA's blacks, an estimated 20m-22m of whom are without it despite progress in electrifying major townships like Soweto.

Escom believes that the fastest, most cost-effective way of improving the quality of life in SA is to extend the use of electricity to the homes of all its people.

This will reduce the cost of energy to the average black family. The dominant source of fuel at present (particularly in rural areas) is wood, which is consumed at a rate of 12m-14m tons a year, denuding woodlands, destroying trees and causing pollution. It is followed in importance by coal, dung (in rural areas), paraffin, candles and gas.

But the alternative fuels are expensive. Paraffin costs nine times as much as electricity, candles four times as much and coal twice as much. In addition to reducing energy costs, a switch to electricity enhances the earning potential of a black family. It makes possible the development of home industries, and improves study conditions for students used to reading by the inadequate light of a candle.

The convenience of a hot bath at the turn of a tap will be a new experience for most blacks. More important though are the health advantages derived from reduced pollution, proper sewage disposal (which requires electrical pumps), improved hygiene and the ability to boil drinking water.

"Not only does electrification improve the quality of life in SA," says Lindeque. "People begin to see themselves winning."
the quality of life immeasurably for black members of our society, but it offers the opportunity for increased employment opportunities through the development of home or local industries,” says chief executive Ian McRae. “Once you go down that road you start to create other growth potential for the electricity supply industry and for appliance sales. Increased use of electric sewing machines and power tools in turn spins off into sales of textiles, building materials and the like.”

So while Escom sees a social responsibility element in this programme, it also sees it as a means of stimulating economic growth.

Urbanisation is a fact of life in SA,” says McRae. “We will not stop the movement of people into towns and cities, so we must learn to manage it.”

The major obstacle preventing this transformation is the cost of reticulation and installation, which works out at about R2 400 per stand using conventional Western standards. But Escom has devised ways of reducing these costs by half, to R1 60 per stand, using appropriate technology rather than the excessively high standards of Western technology now enforced.

Present practice, for example, favours underground cabling, miniature substations and individual house metering. While these practices might be appropriate to SA’s sophisticated First World component, they impose constraints in the form of costs, planning and resources for both construction and maintenance. Urban and rural areas can be readily and relatively cheaply electrified using aerial conductors, pole-mounted transformers and prepaid metering systems.

Methods of wiring homes should also be reassessed. The conventional method costs thousands of rands. But a single connection box could be provided to each home, allowing the use of a single light fitting and a plug outlet, at costs between R150 and R300.

This may not be up to the standard of a fully electrified home in a sophisticated suburb, but it is cheap and quick to install and would be a tremendous step forward for people at present locked into the use of primitive heating and lighting. Surveys have found that the top power priority among blacks is lighting, followed by cooking and then heating.

In pursuit of these objectives, Escom has launched a plan to bring electricity to 60 black townships, home to 9m people, for R348m -- compared to the estimated R700m that would normally be needed.

Before it can get off the ground, however, local authorities must dream unnecessary regulations and accept the need for implementation of the proposals.

The scheme also requires money — and money — from government, local authorities, ESCOs, development aid agencies and foundations. Not even overseas financing has been ruled out, though it obviously will not be readily available.

Finally, the users themselves will ultimately have to make a contribution. Escom plans to act as the catalyst for and driving force behind the scheme.

The initial response to the township electrification programme has been positive, and McRae is confident the money needed will be forthcoming. “I believe that if you have a clear goal the money will come,” he says. But it is important that the intermediaries — the municipalities, local authorities or regional services councils — which retail electricity to the public, do not charge too much for that service.

Escom is prepared to assist local authorities with the planning and implementation of the schemes, training of staff and providing guidance on maintenance. But this would be an interim arrangement, and Escom would intend eventually to disengage from such activities.

Escom has determined sufficient generation capacity already to cope with the increased demands of this programme, which would require 1 000MW of capacity — a third of the capacity of a standard power station. Minimal additional infrastructure and manpower would be required.

Much of the inspiration for the proposal came from Escom’s Alexandra project, where it is involved with the local authority in upgrading one of the Rea’s most notorious black townships. Asked by Alexandra administrator Steve Burger to come up with a plan to electrify Alexandra, Escom decided that providing electricity to shanties was not the answer. What was needed was a complete refurbishment of the dilapidated township.

To date, contracts involving a third of the R90m allocated by government for this project have been placed, but by the time the job is complete, Alexandra will have been extensively renewed. Under a 1980 redevelopment plan which failed because it required wholesale flattening and rebuilding of much of Alexandra and resettlement of its people, the cost would have been R276m.

As chief executive Ian McRae believes the Alexandra project can be completed in three years, though a lot has been learned from it.

While urbanisation is a fact of life in SA, it is probably impossible to amplant the model to another township. When a number of similar projects have been completed, Escom will have a body of knowledge and experience sufficient to meet most township problems it is likely to encounter.

Escom believes in principle that electrification should not be undertaken without an upgrading programme. “It makes no sense to electrify a squatter home,” says McRae. “It is far better to upgrade the dwelling and then electrify. But we believe it is necessary to accept that the squatter is there because he wants to be there — perhaps because it is convenient, or close to work.”

In parallel with the urban electrification project, which has top priority, Escom is looking at electrification in rural areas and has already committed itself to a programme in KwaZulu. More than 2 000 applications have been received for electrification in KwaZulu.

The supply of electricity to Ulundi, for example, could transform the potential for small industry in the town. Investigations are also being conducted concerning Xangwe and Lebowa.

In the long term — by the end of the century — Escom hopes to be providing electricity to between two-thirds and 75% of the black population, which by then will be 35 million. But McRae hopes to have made significant inroads into major urban and rural communities by the mid-Nineties.
Managing the funds

Financial liability management has become a critical factor in the way Escom operates as a business enterprise. Debt servicing, both within SA and abroad, accounts for 50% of total Escom costs, and it thus represents the biggest opportunity for increased business efficiency.

Escom is a not a passive player in achieving this, according to Larry Harper, who, as general manager (finance), is behind the corporation's new dynamic approach. "You don't simply pass on to the customer the effects of market changes," he says. "We try and minimise the impact of adverse effects in the markets."

Escom has a major borrowing requirement which it has reduced by cutting expenditure and generating revenue at levels that are adequate to meet costs and allow the maintenance of internal funding at about 30% of total funding.

Clearly, as a business enterprise, Escom cannot finance everything by borrowings. Because it is such a large borrower, it can never totally isolate itself from the impact of rising interest rates or a deteriorating exchange rate, but the objective is to develop financial instruments that satisfy the requirements of Escom and the electricity customer as well as the wishes of investors.

Among examples of this financial engineering:

- Interest rate swaps. Long-term (three-year) money is swapped into shorter dated interest rates while still having the money available for the three-year period.
- Escom has adopted a much more active approach to foreign exchange management. The previous policy of covering all forex transactions irrespective of the outlook or the cost of cover has given way to a more flexible approach. The corporation is still risk-averse, and will always fix its costs if it can do so at a reasonable price. But sometimes the cost of doing this looks too high in relation to the potential benefit, so on a managed and selective basis Escom is now prepared to take a stance in the market and possibly leave some foreign exchange commitments uncovered.

"We will take a view on the market, but we won't bet everything on this," says Harper. "The portion of our exposure that we are prepared to manage in this way is about $500m. We get views on which currencies are over-valued and which under-valued. We want to denominate our liabilities in over-valued currencies which are then expected to decline."

Escom's foreign exchange exposure amounts to roughly $10bn, a large portion of which is covered with the Reserve Bank.

Harper: not a passive player

- Interest rate caps. This involves taking out an insurance policy against interest rate rises above a given level. Escom's objective is not to save a fortune but to reduce the cost of debt by a fraction of 1%. "If we reduced the cost of our total debt by a tenth of 1% we would save R20m a year," says Harper. "Our objective is to save that tenth. Hopefully it will grow until we are saving the whole 1%, which will be worth R20bn a year to us."
- Interest rate futures. It is possible to hedge against an increase in rates by buying a future. The relatively small cost of buying a futures contract gives protection against higher rates. Escom's Treasury Department, which is managing a liability portfolio of R20bn and a foreign currency exposure of the same size, is probably the single biggest corporate operation of its kind in the country — bigger, indeed, than that of many banks.

Another important financial activity revolves around determination of electricity tariffs. Escom is constantly doing projections of inflation rates, interest rates and costs, always with the question in mind: how can we minimise tariff increases?

Escom had hoped to contain tariff increases over three years to 12%, 10% and 18%, starting in 1986. This, however, was dependent on the inflation rate holding below 15%. It now looks as if it will not be possible to meet the third leg of this undertaking in 1988.

Although interest rates have come down, and costs have been contained (Escom expects to end the year R200m inside its budget), this year has seen an acceleration in the inflation rate coupled with reduced revenue because electricity sales have been below expectations. Additionally, interest rates are expected to start rising in 1989.

Another factor is that Escom's inflation rate funds tend to be higher than the national rate because of exposure to foreign exchange rates. As a result, interest rate caps, which in the past have reduced the cost of debt by 15% of Escom's costs currency-related.

The alternative to raising tariffs is to reduce internal financing (currently accounting for 30% of capital expenditure), but this would require increased levels of borrowing and would provide only a short-term advantage.

Supply & demand

SA has for four decades been one of the fastest growing electricity markets anywhere. Today it has a well-developed infrastructure of 27 power stations with a total installed capacity of 28 000 megawatts and 170 000 km of transmission lines.

But the beginning of the Eighties ushered in a dramatic change for Escom, during which the growth rate flagged markedly in response to deteriorating economic conditions.

Now, instead of a projected 7% a year, Escom is planning for long-term demand growth of 5%.

This has brought about some important changes in the corporation's approach. Firstly, it has slowed down its power station development programme. Indeed, for some years it will have spare capacity as a result of the programme which was set in motion in the early part of the decade.

Five major power stations requiring
Workers at Matimba: dry cooling breakthrough

an eventual investment of about R18bn, are currently under construction or on order. Together, they will increase Escom’s capacity by about 18 000 MW — a 64% increase on present capacity. The slowdown of future expansion plans has, in turn, made it possible to reduce future borrowings. These peaked in 1987 and will progressively decline in the years ahead. In any event, they have been subject to constraints because of the debt ceiling imposed in 1985. Foreign loans are no longer available as they once were, except to a limited extent in export credits.

This means greater dependence on the domestic capital market for funding, and also greater dependence on internal financing (by way of electricity tariffs). Despite the latter, however, severe cost-cutting has enabled Escom to commit itself to rate increases of only 12% last year and 10% this year — well below the rate of inflation.

The increased amount of spare capacity in the system, while not welcome, has allowed Escom to operate more efficiently — running the newer stations at near full capacity while reducing operations at the older, less efficient stations. This, in turn, has reduced coal consumption per unit of electricity sent out and eliminated winter power reductions and interruptions due to overloading.

Despite the capacity excess, Escom has launched a campaign to promote more efficient and cost-effective uses of electricity. Its former orientation towards supply-side management (focusing so much on the efficiency of supply) has now been complemented by demand-side management.

This is being done in recognition of two needs. Firstly, to ensure that customers feel Escom has their interests at heart; and secondly, to reduce future capital requirements.

The belief is that more efficient use of power could lower the long-term demand growth rate by half a percentage point without negatively affecting the economy. This could save hundreds of millions of rands. This saving, it is hoped, will be accomplished by such measures as ironing out peaks and valleys in demand by means of variable tariffs, educating consumers in the efficient use of electricity, encouraging the construction of energy-efficient buildings, and encouraging manufacturers to produce more energy-effective domestic appliances.

SA still has low electricity prices — lower than Canada, despite its abundant cheap hydro-power, and about half the price in Britain. But the price rose faster than in most other Western countries last year, and this has created a perception of high prices.

Technically, the corporation is a

world leader in coal-fired power station operation and design. The 4 000 MW Matimba power station, now nearing completion, will be the world’s largest direct dry-cooled station, while Kendal (4 100 MW), also under construction, will be the world’s largest indirect dry-cooled station. Although dry-cooled stations are thermally less efficient than evaporation-cooled stations, the shortage of water in certain areas of the country makes it necessary to take this option.

Another technical advance has been in the use of low-grade coal. The 3 700 MW Lethabo station, with three of its eventual six generating sets already in operation, is burning the lowest grade bituminous coal ever used in such a large power station. It is capable of using coal with an energy content as low as 16 MJ/kg, and has a reactivity of combustion 30% lower than the norm for low-grade coal in Europe or the United States.

Coal-fired stations account for 86% of Escom’s installed capacity, nuclear for under 7%, pumped-storage for 3.6%, hydro-electric for less than 2%, and wind for 1.4%. Although nuclear capacity will be increased during the next century, the scope for increasing other types is limited and coal will remain the dominant fuel for decades.

**REGIONAL DREAMS**

Despite the obvious political obstacles, the dream of a southern African power network stretching as far north as Zambia is a potent one for Escom executives.

"Although the political problems are greater than ever. But there is an interdependence in the region which cannot be gainsaid," says chief executive Jan McRae.

A southern African grid would allow other nations to export some of the abundant power potential within their borders to SA, and thus develop the resources for the benefit of the region as a whole. In most cases, these countries do not have the internal demand to justify the huge capital cost of such schemes.

The Cahora Bassa scheme was designed to achieve this objective, though political turbulence within Mozambique has prevented it achieving its potential. But Escom has not lost hope that the Cahora Bassa scheme will become a productive part of its grid as originally envisioned.

"The corporation has working arrangements with six of the nations of the region already, and is hoping to extend that to another two or three of the Southern African Development Coordination Committee countries.

"We are already cooperating extensively with other nations in the region," says McRae. "We have had a get-together with them, and have talked about sharing our knowledge and capabilities, and have identified some opportunities and common problems. We will be moving into the area of strategic planning, and ultimately the interconnection of power distribution systems."
Escom's objective is to supply reliable and cost-effective supplies of electricity when and where it is required, subject to the resources available and the national interest. In order to accomplish this, Escom must forecast the country's need for electricity up to twenty years ahead of time so that it can plan and construct the power stations required to generate this power. It takes nearly nine years to complete construction of the first turbo-generator set of a power station and a further five years before an entire 600 MW coal-fired station is in operation.
Escom presently has six power station construction projects at different stages of development. Of the five 3,600 MW coal-fired power stations, three, Kendal, Matimba and Majuba are dry-cooled. Kendal by the indirect and Matimba and Majuba by the direct dry-cooling technique. The sixth project, Palmiet, is a pumped storage scheme which Escom is developing in conjunction with the Department of Water Affairs.

Palmiet

Palmiet is the second pumped storage scheme Escom has undertaken in conjunction with the Department of Water Affairs. The first, the 1,000 MW Drakensberg scheme, was completed in 1982. Palmiet's first unit will be taken into commercial operation in November 1987 and the second in March 1988 to generate a total of 400 MW. Power generated here will be fed into the national transmission network at the Bacchus substation near Worcester.

Tutuka

Tutuka's first set was put into commercial operation in May 1985 and its final set is due to be commissioned in June 1990. Situated near Standerton in the eastern Transvaal, it will be the first power station to feed energy into Escom's new 765 kV extra-high-voltage system which will be erected over the next ten years. Tutuka uses a dry ashing technique which will save approximately 2 million litres of water per day when all six of its sets are operative.

Lethabo

Lethabo is located in the northern Orange Free State about 8 km south of Vereeniging. Its proximity to the heart of the Vaal Triangle enables Lethabo to feed energy into Escom's local 275 kV transmission network. The first set came into operation in December 1985 and the last is scheduled for completion in December 1990.

Special techniques of piling had to be developed in the construction of the power station to overcome the problems caused by the expansive characteristics of the "heaving soils" prevalent in this area. The coal used at Lethabo has a particularly high ash content (28-42%) and this has necessitated the development of a special type of boiler to burn the poor quality coal. Both Escom and the contractor were involved in the design of the boiler.

Dry-cooling and Matimba

With the construction of Kendal, Matimba and Majuba, Escom is pioneering development in the field of dry-cooling technology. Matimba will be the first direct dry-cooled power station in the world and until Majuba is completed, also the largest. The first set is due to be taken into commercial operation in February 1987 and the last in September 1991. The choice of dry-cooled technology for Matimba was heavily influenced by the shortage of water in the area. Dry-cooled systems consume approximately 0.5 to 0.8 litres/kW.h compared to the 2.5 litres/kW.h required by wet-cooled systems. Matimba runs no cooling towers since all cooling is performed by forced draught fans. Power generated at Matimba will be transformed to 400 kV for distribution via the national grid.

1 See Technical brochure/Kendal/985
2 See Technical brochure/Matimba/985
3 See What is dry-cooling and how does it work? DB/E21
4 See Technical brochure/Palmiet/985
5 See Pumped storage and water transfer DB/E218
6 See Technical brochure/Tutuka/985
7 See Technical brochure/Lethabo/1185
Kendal power station uses the Indirect dry-cooling method. Construction began in 1982 and the first set will be completed in June 1988. The last set will go into commercial operation in September 1994. The power station's output will be fed into the national grid at 400 kV. Kendal's cooling towers at a height of 165 m and base diameter of 185 m are the largest in the world. To support this structure, special "X"-shaped cross columns were used in its construction for which the contractor had to develop special construction techniques.

Majuba's first set will be completed only in September 1991 and the last in 1996. These dates reflect the unfavourable economic climate and consequent decrease in estimated demand for electricity which caused Escom to defer the construction of Majuba's sets.
### ESCOM'S POWER STATION PROJECTS

<table>
<thead>
<tr>
<th>Station (Location)</th>
<th>Installed Capacity</th>
<th>Total Installed MW</th>
<th>Total Sent-Out MW</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Majuba (Volkswat)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>September 1998</td>
</tr>
<tr>
<td>Kendal (Witbank)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>September 1998</td>
</tr>
<tr>
<td>Matimba (Vereeniging)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>September 1998</td>
</tr>
<tr>
<td>Lethabo (Standerton)</td>
<td>3612</td>
<td>4116</td>
<td>3900</td>
<td>September 1998</td>
</tr>
<tr>
<td>Tilekwa (Standerton)</td>
<td>—</td>
<td>—</td>
<td>2615</td>
<td>September 1998</td>
</tr>
<tr>
<td>Palmiet (Grabouw)</td>
<td>—</td>
<td>—</td>
<td>3610</td>
<td>September 1998</td>
</tr>
</tbody>
</table>

**Main Contractors**

- **Station**
  - Majuba (Volkswat): Data Bank Consultants
  - Kendal (Witbank): Data Bank Consultants
  - Matimba (Vereeniging): Data Bank Consultants
  - Lethabo (Standerton): Data Bank Consultants
  - Tilekwa (Standerton): Data Bank Consultants
  - Palmiet (Grabouw): Data Bank Consultants

- **Station (Location)**
  - Majuba (Volkswat): Data Bank Consultants
  - Kendal (Witbank): Data Bank Consultants
  - Matimba (Vereeniging): Data Bank Consultants
  - Lethabo (Standerton): Data Bank Consultants
  - Tilekwa (Standerton): Data Bank Consultants
  - Palmiet (Grabouw): Data Bank Consultants

- **Installed Capacity**
  - Majuba (Volkswat): —
  - Kendal (Witbank): —
  - Matimba (Vereeniging): —
  - Lethabo (Standerton): 3612 MW
  - Tilekwa (Standerton): —
  - Palmiet (Grabouw): —

- **Total Installed MW**
  - Majuba (Volkswat): 4116 MW
  - Kendal (Witbank): 3900 MW
  - Matimba (Vereeniging): 3788 MW
  - Lethabo (Standerton): 3634 MW
  - Tilekwa (Standerton): 2558 MW
  - Palmiet (Grabouw): —

- **Total Sent-Out MW**
  - Majuba (Volkswat): 3900 MW
  - Kendal (Witbank): 2615 MW
  - Matimba (Vereeniging): 3610 MW
  - Lethabo (Standerton): 3610 MW
  - Tilekwa (Standerton): —
  - Palmiet (Grabouw): —

**Essential Equipment**

- Majuba (Volkswat): Data Bank Consultants
- Kendal (Witbank): Data Bank Consultants
- Matimba (Vereeniging): Data Bank Consultants
- Lethabo (Standerton): Data Bank Consultants
- Tilekwa (Standerton): Data Bank Consultants
- Palmiet (Grabouw): Data Bank Consultants

**Key Suppliers**

- Majuba (Volkswat): Data Bank Consultants
- Kendal (Witbank): Data Bank Consultants
- Matimba (Vereeniging): Data Bank Consultants
- Lethabo (Standerton): Data Bank Consultants
- Tilekwa (Standerton): Data Bank Consultants
- Palmiet (Grabouw): Data Bank Consultants

**Additional Information**

- Majuba (Volkswat): Data Bank Consultants
- Kendal (Witbank): Data Bank Consultants
- Matimba (Vereeniging): Data Bank Consultants
- Lethabo (Standerton): Data Bank Consultants
- Tilekwa (Standerton): Data Bank Consultants
- Palmiet (Grabouw): Data Bank Consultants

**ESCOM'S POWER BEHIND TOMORROW**

**Databank** is an information service provided by Escom's Communication Department, P.O. Box 1091, Johannesburg 2000. Tel (011) 900-3687
An excellent organisation maintains superior performance reflected in sound management, tight financial control, constant innovation and exceptional customer service. Escom is committed to meeting this challenge.
PROFILE OF ESCOM

In the profile of the availability of South Africa, it is clear among the largest and most valuable natural resources. The country has a large population of about 53 million people. The country's industry is divided into two main sectors: mining and manufacturing.

The mining sector is the largest contributor to the country's GDP, with gold, platinum, and diamonds being the main products. The manufacturing sector includes industries such as automotive, chemical, and electronics.

The country has a well-developed infrastructure, with a strong railway network that connects major cities and towns. The country also has a well-developed road network, with airports located in major cities.

The country has a high literacy rate, and education is emphasized in the country. The country has a strong workforce, with a large number of skilled workers.

The country's climate is mild, with moderate temperatures year-round. The country has a diverse range of vegetation, with forests, savannas, and deserts all found in the country.

The country has a diverse culture, with a blend of African, European, and Asian influences. The country has a rich history, with a long and complex set of events that have shaped the country.

The country's economy is diverse, with a mix of industries and services. The country has a diverse range of exports, with agricultural products, minerals, and manufactured goods all being significant exports.

The country is a member of several international organizations, including the United Nations, the African Union, and the Commonwealth.

The country is a leader in the continent, with a strong economy and a stable political system. The country is a major player in the global economy, with a strong presence in the African market.

The country is a tourist destination, with a range of attractions, including beaches, mountains, and cultural sites.

The country is a vibrant and dynamic society, with a rich culture and a strong sense of national identity. The country is a leader in the continent, with a strong economy and a stable political system.
ESCOM AT A GLANCE

<table>
<thead>
<tr>
<th></th>
<th>Average 1985-86</th>
<th>Increase 1985-86</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue (Rand)</td>
<td>5 646</td>
<td>23.3</td>
<td>22.2</td>
</tr>
<tr>
<td>Expenses (Rand)</td>
<td>5 445</td>
<td>23.3</td>
<td>20.8</td>
</tr>
<tr>
<td>Net profit (Rand)</td>
<td>2 011</td>
<td>23.3</td>
<td>22.2</td>
</tr>
<tr>
<td>Fixed assets at 31 December ( Rand)</td>
<td>12 678</td>
<td>3.9</td>
<td>6.1</td>
</tr>
<tr>
<td>Average price per unit (Cents)</td>
<td>4 368</td>
<td>20.7</td>
<td>10.0</td>
</tr>
<tr>
<td>External cost per unit (Rand)</td>
<td>4 368</td>
<td>20.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Electricity sold (Rand)</td>
<td>18 775</td>
<td>4.3</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Operating statistics

- Total electricity supplied by Eson (mWh, kWh): 12 678
- Electricity available for distribution (mWh, kWh): 123 748
- Contributions in Escon power stations (mWh): 58 239
- Water turnover in Eson power stations (mWh): 202 372
- Peak demand on integrated Escon system (mWh): 123 748

ESCOM at Leisure services as at 31 December

- Installed capacity (MW): 28 698
- Adult and child sales (MW): 28 692
- Recreation areas:
  - 760 V: 437
  - 10000 V (bus): 30
  - 200/400 V (bus): 10 612
  - 105 V (in house): 153 123
- Staff employed at 31 December: 66 400

SUMMARISED BALANCE SHEET

as at 31 December 1986

(All figures in Rand millions)

<table>
<thead>
<tr>
<th></th>
<th>1986</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed assets</td>
<td>27 670</td>
<td>25 960</td>
</tr>
<tr>
<td>Non-current assets</td>
<td>8 339</td>
<td>6 749</td>
</tr>
<tr>
<td>Current assets</td>
<td>1 652</td>
<td>1 457</td>
</tr>
<tr>
<td>Total assets</td>
<td>37 661</td>
<td>34 166</td>
</tr>
<tr>
<td>Finance by:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loans and associated credit</td>
<td>19 348</td>
<td>18 153</td>
</tr>
<tr>
<td>Current liabilities</td>
<td>3 052</td>
<td>2 231</td>
</tr>
<tr>
<td>Total net debt</td>
<td>22 400</td>
<td>20 384</td>
</tr>
<tr>
<td>Statutory hands</td>
<td>9 378</td>
<td>7 948</td>
</tr>
<tr>
<td>Reserves</td>
<td>3 641</td>
<td>2 723</td>
</tr>
<tr>
<td></td>
<td>35 664</td>
<td>31 145</td>
</tr>
</tbody>
</table>

SUMMARISED INCOME STATEMENT

for the year ended 31 December 1986

(All figures in Rand millions)

<table>
<thead>
<tr>
<th></th>
<th>1986</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity sold</td>
<td>12 678</td>
<td>12 378</td>
</tr>
<tr>
<td>Operating expenses</td>
<td>2 485</td>
<td>2 144</td>
</tr>
<tr>
<td>Operating income</td>
<td>2 523</td>
<td>2 461</td>
</tr>
<tr>
<td>Loan charges</td>
<td>3 098</td>
<td>2 395</td>
</tr>
<tr>
<td>Contribution to Reserve Fund</td>
<td>182</td>
<td>130</td>
</tr>
<tr>
<td>Net income</td>
<td>230</td>
<td>20</td>
</tr>
<tr>
<td>Accumulated deficit at beginning of the year</td>
<td>4 402</td>
<td>4 509</td>
</tr>
<tr>
<td></td>
<td>(207)</td>
<td>(105)</td>
</tr>
<tr>
<td>Prior year adjustment</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Accumulated deficit at end of the year</td>
<td>(207)</td>
<td>(407)</td>
</tr>
</tbody>
</table>
### Statement of Source & Application of Funds

<table>
<thead>
<tr>
<th>Category</th>
<th>1988</th>
<th>1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funds generated internally</td>
<td>3,792</td>
<td>1,687</td>
</tr>
<tr>
<td>Proceeds of external borrowings</td>
<td>1,565</td>
<td>1,717</td>
</tr>
<tr>
<td>Income from investments</td>
<td>776</td>
<td>878</td>
</tr>
<tr>
<td>Expenditure</td>
<td>4,032</td>
<td>3,287</td>
</tr>
<tr>
<td>Difference</td>
<td>154</td>
<td>160</td>
</tr>
<tr>
<td>Total Source of Funds</td>
<td>3,775</td>
<td>1,657</td>
</tr>
</tbody>
</table>

#### Application of Funds

- **Repayment of debt**: $1,650
- **Investment in property, plant and equipment**: $1,100
- **Government transfers**: $250
- **Other**: $500

#### Expenditure as a % of costs

- **Salaries and wages**: 40%
- **Rent**: 20%
- **Travel and entertainment**: 10%
- **Other**: 30%

#### Type of debt

- **Short-term**: 40%
- **Long-term**: 60%

#### Sales by category, 1988

- **Industrial**: 20%
- **Residential**: 30%
- **Non-residential**: 50%

#### Total electricity sales, from 1977

- **1977**: 1,000
- **1978**: 1,100
- **1979**: 1,200
- **1980**: 1,300
- **1981**: 1,400
- **1982**: 1,500
- **1983**: 1,600
petlom nce  reflected In sound management, tlghl financial control, constant innovation and exceptional customer serv/ce. Escom is committed to meeting this challenge.

An excellent organisation maintains superior performance reflected in sound management, tight financial control, constant innovation and exceptional customer service. Escom is committed to meeting this challenge.
Author  Harebottle Charles
Name of thesis  Investigation And Design Of A Storage And Handling System For Future Coal Fired Power Stations In South Africa.  1987

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