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Malawi - General - 1987-1991

2918. 03 COMPLETED PROJECT

MALAWI - GENERAL - 1987 - 1991

THE WORLD BANK/IFC/MIGA

Office Memorandum

DATE: November 15, 1991

TO: Mr. David Cook, Chief, AF6IE

FROM: Hossein Razavi, Chief, IENOD

EXT.: 31039

SUBJECT: **ESMAP: MALAWI - Power Loss Reduction Study**

1. Attached please find the final draft of a consultants' report on the Electric Power Loss Reduction Study conducted as an ESMAP technical assistance activity in Malawi.

2. Important issues covered in this report include:

(a) The study has already reduced non-technical losses and "unaccounted for" energy consumption by 4% (from 17% of net generation to 13%).

(b) An investment program (totalling US$18 million) has been developed for three distribution systems. This program is expected to reduce technical losses by 1%. Economic justification for the proposed investment is provided in the report.

(c) Recommendations are also included for actions to be taken to effect further reduction in non-technical losses. An investment program of US$9 million is included in the recommendations. Important aspects of these recommendations are implementation of a new computerized billing system and installation of meter boxes at consumers premises.

3. Your clearance is requested for discussion of the consultants' report with the Malawian authorities.

Attachment

Cleared with and cc: Mr. Berrah (IENOD).

cc: Messrs. Patel, Grawe (AF6CO); Bond (AFTIE);
Saunders (IENED); Gilling (IENPD); Kalim (PRSCG);
Charpentier, Armar, Nore, Ratnayake, Nickson (IENOD);
Regional Info Center
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DRAFT
CONFIDENTIAL
Report No.

Joint UNDP/World Bank
Energy Sector Management Assistance Programme
(ESMAP)

MALAWI

POWER LOSS REDUCTION STUDY

NOVEMBER 13, 1991

ESMAP Operations Division
Industry and Energy Department
The World Bank
1818 H Street, N.W.
Washington, D. C. 20433

ELECTRICITY SUPPLY COMMISSION OF MALAWI

POWER SYSTEM LOSS REDUCTION STUDY FOR THE ELECTRICITY SUPPLY COMMISSION OF MALAWI

FINAL REPORT

KENNEDY & DONKIN POWER

Power and Energy Systems Engineers and Economists

40365

SEPTEMBER 1991

JOB NUMBER	COMPILER	SIGNATURE	DATE
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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This report discusses the findings of a Power System Loss Reduction Study which was carried out under the supervision of ESMAP to establish the present levels of losses and to develop loss reduction strategies for the transmission and distribution systems operated by the Electricity Supply Commission of Malawi (ESCOM). A package of loss reduction measures is presented, together with estimated budgetary requirements for its implementation and a suggested timescale for the execution of each project.

Breakdowns of existing estimated energy losses associated with each level of the system and the target loss levels which may be achieved by the implementation of the proposed loss reduction projects are as follows; these are given as percentages of the metered net system generation:

	Energy Loss Levels	
	Existing	**Target**
132/66/33kV Transmission System	6.7%	6.7%
11kV Feeder Losses	1.0%	0.7%
11/0.4kV Transformer	0.9%	0.7%
LV Distribution	1.5%	1.0%
Non-Technical Losses Found	4.0%	-
Non-Technical Losses Remaining	2.9%	0.5%
TOTAL SYSTEM ENERGY LOSS	17.0%	9.6%

It will be observed that significant non-technical losses were identified from major consumer and generator metering errors. These were found during the measurement work undertaken by ESCOM and Kennedy & Donkin Power (KDP) engineers during the course of the study. Whilst generator metering errors do not result in lost revenue to ESCOM, they cause incorrect figures to be used in the basic loss calculations, and will therefore historically have contributed to the perceived level of losses on the ESCOM system. The consumer metering errors detected represent some MK413,000 of potential annual increased revenue to ESCOM, providing an immediate indication of the value of undertaking non-technical loss reduction.

Technical and economic analysis of sample areas of the ESCOM system have been undertaken with regard to technical losses on the basis of a programme of measurements carried out in Malawi to develop viable loss reduction projects. These have then been extended to a system-wide package of loss reduction measures.

The key recommendations of the study are as follows:

132/66/33kV System

The results of the work carried out on the transmission system indicate that there is very little work which can be justified in addition to the developments which are already programmed by ESCOM in order to reduce losses. Upgrading of the Mtunthama 105 33kV circuit to 66kV operation is a justifiable loss reduction measure due to the fact that the line is already constructed for 66kV operation.

The Least Cost Development Plan for the ESCOM system included recommendations for the installation of static compensation equipment on the 132kV system. Whilst the capital cost of such equipment is such as to make it unattractive when viewed solely from the angle of loss reduction, benefits in terms of reduced losses should be examined if the current work being carried out in the Transmission and Distribution Study recommends its introduction as part of the optimal development of the system.

It is recommended that the design loading levels for conductors which have been developed in this report are used as the basis for planning the transmission system with a view to minimising losses at all stages of system development.

11kV System

A substantial programme of feeder reconductoring at 11kV is proposed, together with limited application of capacitors, on account of the generally good system power factors. Reconductoring generally takes the form of introducing a new 150 sq mm conductor size at 11 kV, together with some cable replacement.

It is recommended that the overall configuration of the 11kV system be optimised in terms of loss minimisation once the basic system plan has been established in the Transmission and Distribution Study. It is anticipated that the study should include consideration of losses as a matter of course, but it is emphasised that for full benefit to be derived from the design criteria presented in this report a coordinated approach to the optimisation of the 11kV system should be adopted. It is also recommended that at an operational level ESCOM should examine the effects of switching operations and consequent local system reconfiguration in terms of losses as part of their normal procedures.

LV Systems

Proposals have been developed for the purchase of 11/0.4 kV transformers and the execution of LV reconductoring projects with a view to reducing losses associated with distribution transformers and LV systems.

The magnitude of the task of optimising the detailed investment programme based on these measures is such that it can only effectively be finalised by means of a detailed LV study whereby transformer placement and LV feeder lengths can be coordinated to minimise losses overall.

It is envisaged that this work could be carried out with considerable input from ESCOM's Central Planning Unit in conjunction with a distribution planning specialist, and a proposal based on this approach has been included in the loss reduction package.

Load balancing on the LV systems has been shown to play an important role both in reducing loss levels and in improving voltages at remote ends of the feeders. This measure involves minimal capital cost, and is therefore strongly recommended as a loss reduction measure.

The voltage profile across the LV networks in general would be substantially improved by changing the tap settings on all of the 11kV/LV and 33 kV/LV transformers to their +5% levels. Most of the distribution transformers are currently operating on nominal rap and not therefore utilising the opportunity to improve voltages at consumer's premises.

Non-technical Losses

The key recommendations relating to non-technical loss reduction involve a number of capital purchases and measures to improve organisational aspects of the detection and investigation of losses arising from metering errors and fraud. In summary, these recommendations are as follows:

- Implementation of a new computer billing system.
- Installation of meter boxes at all new consumers' premises and retrospectively at all small power, high density, low density and general consumers.
- Purchase of two meter test benches and construction of a new meter test room in Blantyre.
- Purchase of fifty pairs of meter pliers
- Purchase of fifteen solid state kWh meters for use by the ESCOM metering department in carrying out on-site meter accuracy checks.

A number of detailed recommendations are made regarding organisational aspects of the metering and billing operations which should be implemented by ESCOM to reduce the scope for non-technical losses arising in these processes. These include recommendations of increased rewards for meter readers discovering abnormalities at consumers' premises, modifications to the reporting and recording procedures for detecting and investigating illegal abstractions, and specific details which should be recorded in the computer billing system.

It is also recommended that continued monitoring of loss levels be carried out by ESCOM to ensure that the effectiveness of loss reduction projects can be measured and the identification of particular sources of losses be continued.

Budgetary Requirements

The budgetary requirements for carrying out the above technical and technical loss reduction projects are as follows:

	Local Cost MK m	Foreign Cost US$ m
Non-Technical Loss Reduction	6.56	0.78
Technical Loss Reduction	4.90	11.17
Physical Contingencies (10)	1.15	1.20
Engineering Contingencies (5%)	0.57	0.60
TOTAL	13.18	13.75

This gives an overall total for the package of US$19.1 m, based on an exchange rate of MK 2.5 = US$ 1.0.

Programme

It is proposed that all the measures to reduce losses should be implemented over a five year period, with the exception of the installation of meter boxes, which, given the number consumers to be addressed, it is intended should be carried out over fifteen years.

General

In addition to specific recommendations for loss reduction projects, a number of design criteria have been produced which it is recommended that ESCOM adopts in carrying out future planning in such a way as to reduce system losses to economic levels.

The measurement work and associated technical and economic analysis performed in the course of this study has been undertaken with a high degree of involvement of counterpart teams of ESCOM engineers. The degree of commitment and enthusiasm demonstrated by these teams has to a large extent contributed to the sound base of analytical results used in the study, which has enabled the compilation of the loss reduction package. KDP would like to acknowledge with thanks the considerable assistance received from ESCOM in the execution of the study phases in Malawi.

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SECTION 1

INTRODUCTION

1. INTRODUCTION

This report describes the work which has been undertaken in carrying out a Loss Reduction Study for the system operated by the Electricity Supply Commission of Malawi (ESCOM). This comprised periods of measurement and investigation work carried out in Malawi by engineers and economists from Kennedy & Donkin Power (KDP) and ESCOM, together with analysis of results and identification of loss reduction strategies carried out both in Malawi and in the UK. This work has culminated in the recommendation of a number of measures to reduce the existing levels of both technical and non-technical losses in the ESCOM system.

The study was performed under the supervision of the Energy Sector Management Assistance Program (ESMAP), which is a joint aid program sponsored by the World Bank, UNDP and Bilateral Aid agencies. The key objectives of the study were defined by ESMAP at the outset to (a) identify the various sources of energy losses on the ESCOM transmission and distribution systems, (b) quantify the contribution of each of these sources to overall losses, and (c) develop a program of discrete, monitorable and phased projects to reduce losses to economic levels.

The economic and technical assessment of loss reduction strategies depends upon the calculation of marginal power and energy costs and the existence of an up to date load forecast for the system under investigation. Both of these areas have been addressed as the starting point for the analysis phase of the Loss Reduction Study, and are described in the opening sections of the report.

The report summarises the measurement and analysis techniques which have been applied in order to assess the scope for reducing technical losses at all voltage levels on the transmission and distribution systems. This is then expanded into a programme of system-wide measures to reduce technical losses, on the basis of detailed technical and economic analysis of typical sections of the system.

The analysis which has been performed on the accuracy of generator and consumer metering and the procedures adopted by ESCOM for detecting and investigating non-technical losses is also presented and developed into a series of financially and economically justifiable measures to reduce non-technical system losses.

The report concludes with the recommendation of measures to be implemented to reduce the present level of system losses, including budgetary estimates of the cost associated with the set of measures and the suggested programme for their implementation. Attention is drawn to the need for loss minimisation to be at the forefront of the planning and design strategies used by ESCOM, with recommendations which will ensure that losses can be maintained at economic levels during the expansion of the system in response to increasing demand.

Many of the key ESCOM system parameters are introduced in the main body of the report. Table 1.1 gives an overview of the total equipment installed in the transmission and distribution systems for reference purposes.

Table 1.1 : ESCOM Transmission and Distribution Systems

Description		INTERCONNECTED SYSTEM			
		Southern Area	Central Area	Northern Area	Total
132 kV Overhead Lines (steel tower)	(km)	112.67			112.67
132 kV Overhead Lines (wood poles)	(km)	52.35	250.57		302.92
66 kV Overhead Lines	(km)	374.01	450.73	193.30	1018.04
33 kV Overhead Lines	(km)	975.40	406.84	131.31	1513.54
11 kV Overhead Lines	(km)	867.30	705.28	129.38	1701.96
400/230 V Overhead Lines	(km)	838.85	598.70	159.51	1597.05
33 kV Underground Cable	(km)	2.62	0.04	0.03	2.69
11 kV Underground Cable	(km)	52.37	22.96	2.99	78.33
400/230 V Underground Cable	(km)	52.08	73.38	10.97	136.43
Step-up 11/132 kV Substations	(kVA)	50000			50000
Step-up 11/66 kV Substations	(kVA)	126000			126000
Step-up 11/33 kV Substations	(kVA)	3500		500	4000
Step-up 0.4/3.3/11 kV Substations	(kVA)		3100	3000	6100
Step-down 33/11 kV Substations	(kVA)	48000	4000	5500	57500
Step-down 33/0.4/0.23 kV Substations	(kVA)	31000	10480	4090	45570
Step-down 11/0.4/0.23 kV Substations	(kVA)	123050	71432	8943	203425
Step-down 66/11 kV Substations	(kVA)	36000	55500	5000	96500
Step-down 66/33 kV Substations	(kVA)	113000	10000	10000	133000
Step-down 132/11 kV Substations	(kVA)	50000			50000
Step-dwon 132/66/11 kV Substations	(kVA)		25000		25000
Interbus Transformers 132/66 kV	(kVA)	50000	25000		75000

SECTION 2

DISTRIBUTED LOAD FORECAST

2. DISTRIBUTED LOAD FORECAST

2.1 General

The ESCOM load forecasting model has been described in various documents including a manual and users guide produced at the end of the Power System Planning training programme conducted by Kennedy & Donkin with the last phase completed in May 1990. The model used in this Loss Reduction Study is an updated version of this earlier model, the structure of which was created in 1985. In particular, the equations describing the relationship between electricity sales and external variables have been revised and re-estimated.

The forecast has been modified to incorporate the latest macroeconomic projections from The Department of Economic Planning and Development, (EP&D). The Energy Planning Unit within EP&D provided government information relevant to the load forecast. The projections that were particularly relevant were the revised GDP figures which were provided in 1978 prices. The forecast described below therefore, uses the latest GDP projections, however these were not substantially different from the projections used in the 1988 "Least Cost Development Programme". Further macroeconomic data was also provided by the National Statistical Office.

The estimated relationships discussed below are the final versions. A number of alternative specifications, lags and proxy variables have been tried and rejected for various reasons. These alternatives are not discussed.

2.2 Revised Equations for Electricity Sales

2.2.1 High Density

There are two categories of domestic consumer: high density, and low density.

High density sales represent only 2.4% of total kWh generation. In view of this fact and in the context of this study, the relationship established in the 1985 study has not been revised. The short and long run elasticities are as follows:

Consumer nos: 0.61*Government Employment
: 0.85*Private Employment

kWh sales per consumer: 0.35*Income

The use of employment as the independent variable in these equations was established in 1985 based on the correlation between levels of employment and proper housing. The latter in turn is a pre-requisite for electricity connection.

2.2.2 Low Density

The equations for low density consumption have been revised. The growth in the number of consumers was not found to be statistically dependent on any of the external variables. This is not particularly surprising since the connection of consumers in the large part has generally been dictated more by the development of the interconnected grid system and in the late 1970's, the development of Lilongwe rather than any increases in income or changes in electricity prices. It appears to have followed a relatively smooth pattern of annual increases at 7.5% per annum. ESCOM is continuing to extend electricity supplies both within urban centres and to rural areas. This trend is therefore extrapolated into the future.

The equation for low density consumption per consumer has been re-estimated as shown in Table 2.1. Lag relationships have been introduced to allow for delays between income increases or price decreases and changes in spending patterns or appliance ownership. Analysis showed that income (GDP) increase in one year does not significantly affect electricity usage in that same year. The impact is delayed to the following year. The income variable chosen was GDP for the economy as a whole. No data are available on the distribution of income in Malawi. However, it is clear that the 18,000 households in the low-density category receive income disproportionate to their numbers. A useful independent variable would be a measure of the inequality of income distribution. Whilst GDP per capita might be considered to be the normal variable, in Malawi the distribution of income is such that total GDP reflects more accurately the income of low density consumers.

Consumer numbers were entered into the equation to reflect the tendency for average consumption per consumer to be depressed as new consumers with low consumption levels join the ranks of the electrified. In most power systems in developing countries there is a strong tendancy for the wealthier consumers to connect first followed by the less wealthy consumers over time. The wealthy consumers have relatively high levels of consumption and the average level of consumption starts off at a relatively high level. Over time, all else being equal, the connection of new consumers will dilute the average level of consumption.

Table 2.1 also shows the long run stable relationship when the dynamic effects have died down. This shows that the long term elasticity between income (GDP) and kWh sales is 0.45. For every 1% increase in income, consumption increases by 0.45% in the long run. The long term elasticity with respect to real electricity prices is -0.2. With consumer numbers the elasticity is -0.28. This latter result, taken in conjunction with the extrapolation of consumer numbers of 7.5% per annum implies that in the absence of income growth or decreases in prices then the average kWh sales per consumer would decline in the long run by 2.1% per annum. This is the result of the dilution effect discussed above.

2.2.3 General

The two equations for the general consumer category have been amalgamated into only one which describes the total kWh sales. This has been done for simplicity and because, given the diversity of types of consumers in this consumer category, the split is arbitrary.

The estimated equation is shown in Table 2.1. A dynamic relationship has again been adopted signifying that there are lags involved here. The GDP variable used for this consumer category is that of the distributional and financial services category of economic output. This is regarded as being the most representative of activity among these consumers. A positive time trend was also found to be statistically significant. This implies that these consumers are tending to become more dependent on electricity over time. This is consistent with the expectation that shops, offices and workshops will tend to become more mechanised and automated with time.

The long term relationships are also shown in Table 2.1. An increase in the output (GDP) of the distributional and financial services sector leads, in the long run, to a 0.8% increase in electricity sales in this sector, ie., an elasticity of 0.8. The long run elasticity with respect to electricity prices is -0.87. The long run trend increase in electricity sales is 5.3% per annum.

2.2.4 Small Power

Small Power consumers are, in terms of electricity sales, the largest and most important sector for ESCOM. Corresponding attention has therefore been devoted to the forecast for this sector. Unfortunately, the Small Power category contains a large mixture of organisations ranging from large shops and offices to relatively large scale manufacturers and processors. Given the relatively small number of customers (approximately 450) and the distortions caused by the larger of these, the estimation of a statistical relationship is fraught with difficulty. Nevertheless, a relatively good equation has been derived, as demonstrated by the analysis shown in Table 2.1.

The specification of the equation is based on the ratio of electricity consumption to the output of the manufacturing sector of the economy, including agricultural processing. This is shown in Table 2.1. There are two driving forces behind the equation. The first is GDP; in the long run electricity sales increase one for one with the output of this sector (as measured by GDP). The second factor is a time trend; each year, in the absence of any other effects, sales would increase by 3%. This is again the phenomenon of increased mechanisation and use of electricity. Dynamic relationships are also evident in the equation specification.

2.3 Sales to Large Power Consumers

Projections of sales to the large consumers, including SUCOMA, David Whitehead, Blantyre Water Board (Chileka and Walkers Ferry), Portland Cement (Blantyre and Changalume) and Viphya Saw Mill, are largely based on the results of interviews conducted with these consumers in 1987/88, however in some cases these have been revised on the basis of the 1989 survey of large consumers. In particular the forecasts for Blantyre Water Board, David Whitehead and Viphya Saw Mill have been changed in order to reflect their revised loads and investment programmes.

2.4 Load Factors, Diversity Factors and Coincidence Factors

The relationships between electricity sales and maximum demand were derived in the earlier model from analysis of the load shape from feeder monitoring exercises. It has not been necessary to update these for consumer categories I to IV. For the large power consumers some revision has been undertaken to take account of actual relationships observed between 1986 and 1989.

For SUCOMA the on-peak coincident load factor has varied between 63% and 85%. Assuming an average of 67.5% and an average diversity factor of 0.9 gives a coincident, after diversity load factor (CADLF) of 75%. This is a reduction from the previous 85%.

For David Whitehead a fairly consistent pattern emerges with coincident load factors between 61% and 67%. An average of 65.25% has been assumed together with a diversity factor of 90%. This increases the CADLF slightly from 69% to 72.5%. The demand forecast has been slightly modified since David Whitehead have expressed the intention to carry out further expansion of their operation.

The maximum demand forecast for Blantyre Water Board was originally produced for the 1987 Capacity Utilisation Study and updated for the Least Cost Development Programme. This has now been updated again in order to take account of the progressive increase in the demand for water, thus requiring more pumping capacity than was originally envisaged.

The Portland Cement coincident load factor has remained relatively stable with a slight upward trend. This is projected to continue, rising from 42.1% in 1990 to 46.6% in 2005. A 90% diversity demand factor has also been assumed.

Viphya Saw Mill began operation in June of this year. Its peak demand, coincident with the July peak, was 1500 kVA. The original forecast of demand from the saw mill has been retained with a one year delay in reaching full production. This is now assumed to occur in 1992 with a coincident, after diversity of 2.14 MW.

2.5 Losses

The purpose of this study is to prepare recommendations to reduce losses to an optimum level. The optimum level will be determined following a full analysis of the results of feeder monitoring exercises and examination of the options available. Nevertheless, a load forecast is necessary to undertake this analysis and a provisional estimate of loss levels is required for this. On the basis of the existing loss level, a target of 10% energy losses by 1994 has been adopted, as a figure indicative of the level which may be achieved by the introduction of loss reduction measures.

2.6 Impact of Improvement in Voltages

The improvement in supply voltages to within ESCOM technical standards, will result in an increase in demand and energy. The impact differs between power and energy and between the short term and the long term. In the short term light bulbs, for example will burn more brightly. In the longer term some consumers may decide that they can make do with lower wattage light bulbs. As another example, fridges may have burnt out more frequently because of low voltage. In the short term, the energy consumption of fridges will not increase because of the return to standard voltages. In the longer term, the fact that fewer fridges burn out will lead to a longer term increase in energy consumption.

Experience elsewhere shows that the suggested improvements may lead to a 7.5% increase in kWh consumption for domestic consumers and shops and offices leading to an overall 2.5% increase and that demand may increase to a greater extent. This has now been incorporated into the forecast. Evidence of this is provided in Appendix A.

2.7 Load Forecast for the Interconnected System

The load forecast is presented in Table 2.2 showing energy and maximum demand. The maximum demand forecast for 1990 has not been adjusted to show what is likely to be the actual peak for this year of 119.4 MW at 18:00 hours on July 4th. This is deliberate to emphasise that the forecast is only expected to be accurate to perhaps +/- 5%. The expectation is that, on average over a number of years, the over predictions will match the under-predictions. One, two or even three years in which the model consistently over or under predicts does not necessarily mean that the model is wrong.

The growth rate of maximum demand shown in Table 2.2 settles down to between 6.5% and 7.0% per annum beyond 1995. This is somewhat lower than presented in the Least Cost Development Programme. On this basis Kapichira Falls would not be required until two years later than originally expected.

2.8 Future Pattern of Load Growth

The broad pattern of future growth in the country have been derived using the same basic equations described above but taking account of known development (eg, the Viphya Saw Mill). The resulting annual average growth rates for the three areas are as follows:

	1990 - 1999	2000 - 2005
Southern	5.4%	7.4%
Central	7.0%	7.6%
North	8.8%	5.6%

The interconnected system forecast has now been distributed into three regions above. This was achieved by taking actual demands in the Blantyre, Lilongwe and Mzuzu regions for 1990 and projecting them forward using the average growth rates above to 2005. In each area the demands of the high density, low density, general and small power categories were assumed to remain the same proportion of the total demand as calculated in the forecast for the interconnected system since no data was available to indicate the actual proportions. It is not anticipated that this will introduce any significant errors to the overall analysis. The demands of the large power consumers have been allocated to the regions in which the consumer is actually located.

The load forecasts for the regions are presented in Tables 2.3 to 2.5. They are also shown graphically in Figures 2.1 and 2.2.

For the analysis of non-technical losses it was necessary to derive, from the load forecast, growth rates for industrial feeders and for general feeders. General feeders were to include domestic, general and small power categories. The resulting annual growth rates for the three areas are as follows:

	1990 - 1999	**2000 - 2005**	**Average**
Industrial:			
Southern	3.5%	1.2%	3.0%
Central	14.9%	0	9.6%
Northern	5.2%	0	3.4%
Other:			
Southern	9.5%	7.9%	8.5%
Central	7.3%	8.3%	7.6%
Northern	11.4%	6.4%	9.6%

TABLE 2.1

RESULTS OF ECONOMETRIC ANALYSIS

LOW DENSITY DOMESTIC:

$$\text{Ln(kWh)}=2.17+0.288*\text{Ln(kWh-1)}+0.318*\text{Ln(GDP-1)}-0.139*\text{Ln(Real Price)}-0.877*\text{Ln(Nos.)}+0.675*\text{Ln(Nos-1)}$$

(0.28) (0.232) (0.128) (0.465) (0.471)

Where:		
	kWh	=kWh sales per consumer
	kWh-1	=kWh lagged one period
	real price	=average price/composite retail price index
	nos.	=consumer numbers

$R^2=0.913$

Long Term Relationship:

$$\text{Ln(kWh)}=3.084+0.447*\text{Ln(GDP)}-0.195*\text{Ln(Real Price)}-284*\text{Ln(nos.)}$$

GENERAL:

$$\text{Ln(kWh)}=1.893+0.43*\text{Ln(MWh-1)}+0.458*\text{Ln(GDP)}-0.498*\text{Ln(Real Price)}+0.03*\text{Trend}$$

(0.251) (0.163) (0.212) (0.022)

Where:		
	MWh	=total MWh sales
	real price	=average price/GDP deflator

$R^2=0.994$

Long Term Relationship:

$$\text{Ln(MWh)}=3.321+0.804*\text{Ln(GDP)}-0.874*\text{Ln(real prices)}+0.053*\text{Trend}$$

SMALL POWER:

$$\text{Ln(GWh/GDP)}=-0.1356+0.67*\text{Ln(GWh-1/GDP-1)}+0.0099*\text{Trend}$$

(0.212) (0.0091)

Where: GWh =total GWh sales

$R^2=0.967$

Long Term Relationship:

$$\text{Ln(GWh)}=-0.411+\text{Ln(GDP)}+0.03*\text{Trend}$$

NOTE: Figures in parentheses represent standard errors.

TABLE 2.2 (Sheet 1 of 2)
ESCOM Load Forecasting Model
(Author: Kennedy & Donkin Power Systems, August 1990)

		Actual																				
		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CONSUMER NUMBERS																						
Low Density		12348	13332	14259	15443	16853	18117	19476	20936	22507	24195	26009	27960	30057	32311	34735	37340	40140	43151	46387	49866	53606
High Density		12200	12778	12946	13144	13609	14448	15315	16307	17467	18736	20039	21432	22922	24515	26219	28042	29992	32077	34307	36692	39242
kWh/CONSUMER																						
Low Density		4500	4614	4527	4608	4697	4471	4703	4404	4292	4258	4247	4240	4234	4228	4223	4217	4212	4207	4201	4196	4190
High Density		967	982	965	1034	1098	1113	1212	1230	1249	1269	1289	1309	1329	1349	1370	1391	1413	1434	1457	1479	1502
SALES (GWh)																						
Low Density		55.56	61.52	64.55	71.16	79.16	81.00	91.59	92.21	96.61	103.02	110.46	118.54	127.26	136.62	146.68	157.48	169.07	181.51	194.88	209.22	224.63
High Density		11.80	12.55	12.49	13.60	14.94	16.08	18.57	20.06	21.82	23.78	25.83	28.05	30.46	33.08	35.92	39.01	42.37	46.01	49.97	54.26	58.93
General		55.58	62.02	68.27	74.89	80.51	90.39	105.13	107.57	112.18	120.15	130.06	141.43	154.09	168.03	183.29	199.97	218.19	238.07	259.77	283.45	309.28
Small Power		149.08	164.12	164.07	170.80	192.85	207.64	231.93	246.19	263.24	282.40	302.84	325.11	349.25	375.36	403.56	433.96	466.72	501.99	539.97	580.85	624.84
Large Power																						
- SUCOMA		40.34	47.58	64.72	52.45	51.67	44.58	44.97	45.38	45.80	46.24	46.69	47.15	47.62	48.11	48.62	49.13	49.67	50.22	50.79	51.37	51.97
- Blantyre Water Board		45.02	46.74	50.53	52.42	55.71	61.18	64.94	67.25	69.14	71.60	74.33	77.18	80.68	83.76	87.15	91.07	95.98	101.10	105.57	110.22	115.04
- Portland Cement		9.20	11.30	11.16	11.44	12.29	12.95	13.18	13.41	13.64	13.86	14.08	14.29	14.50	14.70	14.90	15.09	15.27	15.44	15.60	15.74	15.88
- David Whitehead		29.04	27.18	29.68	29.50	31.79	31.79	41.32	44.49	54.01	57.18	60.35	74.96	76.86	78.77	80.67	82.58	82.58	82.58	82.58	82.58	82.58
- Viphya Saw Mill		0.00	0.00	0.00	0.00	0.00	7.10	7.10	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83
- Other		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total		123.60	132.80	156.10	145.81	151.47	157.59	171.50	182.35	194.41	200.70	207.27	225.40	231.49	237.17	243.16	249.70	255.32	261.16	266.36	271.74	277.29
Export		1.09	0.71	0.00	0.00	0.00	1.00	1.03	1.06	1.08	1.11	1.14	1.17	1.19	1.22	1.25	1.29	1.32	1.35	1.39	1.42	1.46
INTERCONNECTED SYSTEM																						
Total Sales	(GWh)	396.71	433.72	465.66	476.27	518.94	553.70	619.76	649.44	689.35	731.17	777.59	839.69	893.74	951.48	1013.87	1081.40	1152.98	1230.10	1312.33	1400.94	1496.43
Auxilary Consumption	(GWh)	2.44	2.50	2.62	2.49	2.58	3.36	3.57	3.70	3.89	4.08	4.34	4.69	4.99	5.32	5.66	6.04	6.44	6.87	7.33	7.83	8.36
Tx. & Dbn. Losses	(%)	15.8%	16.1%	16.5%	17.5%	17.1%	17.0%	12.6%	11.7%	10.8%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Losses	(GWh)	74.90	83.71	92.58	101.81	107.24	114.10	89.86	86.12	83.93	81.69	86.88	93.82	99.86	106.31	113.28	120.83	128.82	137.44	146.63	156.53	167.20
Generated	(GWh)	474.05	519.93	560.86	580.57	628.77	671.16	713.19	739.26	777.17	816.94	868.82	938.20	998.59	1063.11	1132.81	1208.27	1288.25	1374.42	1466.29	1565.30	1671.98

TABLE 2.2 (Sheet 2 of 2)
ESCOM Load Forecasting Model

	Actual																				
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
DEMAND (MW)																					
Low Density	7.73	8.56	8.99	9.91	11.02	19.67	12.75	12.84	13.45	14.34	15.38	16.50	17.72	19.02	20.42	21.92	23.54	25.27	27.13	29.13	31.27
High Density	1.90	2.02	2.01	2.19	2.40	5.40	2.99	3.22	3.51	3.82	4.15	4.51	4.90	5.32	5.78	6.27	6.81	7.40	8.03	8.72	9.48
General	11.33	12.64	13.92	15.27	16.41	18.43	21.43	21.93	22.87	24.49	26.51	28.83	31.41	34.25	37.36	40.76	44.48	48.53	52.95	57.78	63.05
Small Power	28.36	31.23	31.21	32.50	36.69	25.76	44.13	46.84	50.08	53.73	57.62	61.85	66.45	71.42	76.78	82.56	88.80	95.51	102.73	110.51	118.88
Large Power																					
- SUCOMA	4.92	6.21	6.26	6.71	6.52	7.08	7.29	7.51	7.74	7.97	8.21	8.46	8.71	8.97	9.24	9.52	9.80	10.10	10.40	10.71	11.03
- Blantyre Water Board	6.30	6.57	6.44	6.21	6.39	8.81	8.98	10.04	10.22	10.89	11.41	11.80	12.22	12.69	13.17	13.59	14.19	14.81	15.46	16.14	16.85
- Portland Cement	1.63	2.70	2.71	2.95	3.02	3.16	3.19	3.23	3.26	3.29	3.32	3.34	3.37	3.39	3.42	3.44	3.46	3.47	3.48	3.49	3.50
- David Whitehead	4.80	4.55	4.63	4.86	4.86	5.01	6.51	7.00	8.50	9.00	9.50	11.80	12.10	12.40	12.70	13.00	13.00	13.00	13.00	13.00	13.00
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	1.29	1.29	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	17.65	20.03	20.04	20.72	20.79	25.34	27.26	29.93	31.86	33.29	34.58	37.54	38.55	39.60	40.67	41.69	42.59	43.52	44.49	45.49	46.53
Export	0.26	0.17	0.00	0.00	0.00	0.24	0.25	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.30	0.31	0.32	0.33	0.34	0.34	0.35
INTERCONNECTED SYSTEM																					
Total (MW)	64.25	74.15	75.49	77.10	87.56	94.85	108.80	115.02	122.03	129.95	138.52	149.52	159.31	169.90	181.31	193.53	206.53	220.56	235.68	251.98	269.56
Auxilary Consumption (MW)	0.43	0.44	0.46	0.44	0.45	0.59	0.63	0.65	0.68	0.72	0.76	0.82	0.88	0.93	0.99	1.06	1.13	1.21	1.29	1.37	1.47
Tx. & Dbn. Losses (%)	20.9%	21.3%	21.9%	23.2%	22.6%	22.5%	16.7%	15.4%	14.3%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%
Losses (MW)	17.12	20.22	21.25	23.46	25.69	27.69	21.90	21.09	20.47	19.93	21.25	22.94	24.44	26.06	27.81	29.69	31.68	33.83	36.15	38.65	41.35
Generated (MW)	81.80	94.80	97.20	101.00	113.70	123.00	131.22	136.65	143.08	150.51	160.43	173.18	184.51	196.78	209.99	224.13	239.20	255.44	272.95	291.83	312.18
Growth rate in maximum demand		15.9%	2.5%	3.9%	12.6%	8.2%	6.7%	4.1%	4.7%	5.2%	6.6%	7.9%	6.5%	6.6%	6.7%	6.7%	6.7%	6.8%	6.9%	6.9%	7.0%
Load Factor (generated)	66.2%	62.6%	65.9%	65.6%	63.1%	62.3%	62.0%	61.8%	62.0%	62.0%	61.8%	61.8%	61.8%	61.7%	61.6%	61.5%	61.5%	61.4%	61.3%	61.2%	61.1%

TABLE 2.3 (Sheet 1 of 2)
ESCOM Load Forecasting Model
(Author: Kennedy & Donkin Power Systems, August 1990)
Southern Region

			Actual																		
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CONSUMER NUMBERS																					
Low Density	7914	8610	9007	9661	10843	11918	12063	13344	14539	15636	16754	17977	19237	20594	22020	23981	26139	28454	30976	33680	36580
High Density	7819	8253	8178	8223	8756	9504	9486	10393	11283	12108	12908	13780	14670	15625	16622	18010	19531	21152	22909	24782	26779
kWh/CONSUMER																					
Low Density	4500	4614	4527	4608	4697	4793	5505	4951	4805	4803	4816	4812	4820	4821	4826	4751	4709	4685	4662	4644	4629
High Density	967	982	965	1034	1098	1113	1212	1230	1249	1269	1289	1309	1329	1349	1370	1391	1413	1434	1457	1479	1502
SALES (GWh)																					
Low Density	35.61	39.73	40.77	44.52	50.93	53.28	56.73	58.77	62.41	66.58	71.15	76.22	81.45	87.08	92.99	101.14	110.10	119.69	130.13	141.31	153.28
High Density	7.56	8.11	7.89	8.51	9.61	10.58	11.50	12.78	14.10	15.37	16.64	18.03	19.50	21.08	22.77	25.06	27.59	30.34	33.37	36.65	40.21
General	35.62	40.05	43.12	46.85	51.80	59.47	65.12	68.56	72.47	77.65	83.78	90.93	98.62	107.09	116.20	128.43	142.09	156.99	173.47	191.44	211.05
Small Power	95.55	106.00	103.64	106.85	124.08	136.60	143.66	156.91	170.05	182.50	195.08	209.03	223.53	239.24	255.84	278.71	303.93	331.02	360.58	392.31	426.38
Large Power																					
- SUCOMA	40.34	47.58	64.72	52.45	51.67	44.58	44.97	45.38	45.80	46.24	46.69	47.15	47.62	48.11	48.62	49.13	49.67	50.22	50.79	51.37	51.97
- Blantyre Water Board	45.02	46.74	50.53	52.42	55.71	61.18	64.94	67.25	69.14	71.60	74.33	77.18	80.68	83.76	87.15	91.07	95.98	101.10	105.57	110.22	115.04
- Portland Cement	9.20	11.30	11.16	11.44	12.29	12.95	13.18	13.41	13.64	13.86	14.08	14.29	14.50	14.70	14.90	15.09	15.27	15.44	15.60	15.74	15.88
- David Whitehead	29.04	27.18	29.68	29.50	31.79	31.79	34.96	38.14	41.31	44.48	47.65	49.55	51.46	53.36	55.27	57.17	57.17	57.17	57.17	57.17	57.17
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	123.60	132.80	156.10	145.81	151.47	150.50	158.06	164.18	169.89	176.18	182.74	188.17	194.26	199.94	205.93	212.47	218.09	223.93	229.13	234.51	240.06
Export	0.82	0.53	0.00	0.00	0.00	0.75	0.77	0.79	0.81	0.83	0.85	0.87	0.90	0.92	0.94	0.96	0.99	1.01	1.04	1.06	1.09
INTERCONNECTED SYSTEM																					
Total Sales (GWh)	298.76	327.22	351.52	352.54	387.90	411.17	435.84	462.00	489.71	519.10	550.24	583.26	618.25	655.35	694.67	746.77	802.78	862.99	927.71	997.29	1072.08
Auxilary Consumption (GWh)	1.78	1.96	2.12	2.15	2.35	2.49	2.51	2.63	2.76	2.90	3.07	3.26	3.45	3.66	3.88	4.17	4.48	4.82	5.18	5.57	5.99
Tx. & Dbn. Losses (%)	15.8%	16.1%	16.5%	17.5%	17.1%	17.0%	12.6%	11.7%	10.8%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Losses (GWh)	56.40	63.17	69.88	75.24	80.50	84.73	63.19	61.27	59.63	58.00	61.48	65.17	69.08	73.22	77.62	83.44	89.70	96.42	103.65	111.43	119.79
Generated (GWh)	356.94	392.35	423.52	429.93	470.75	498.39	501.55	525.89	552.10	580.00	614.80	651.69	690.79	732.23	776.17	834.38	896.96	964.23	1036.55	1114.29	1197.86

TABLE 2.3 (Sheet 2 of 2)
ESCOM Load Forecasting Model
Southern Region

	Actual									
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
DEMAND (MW)										
Low Density	4.96	5.53	5.68	6.20	7.09	12.94	7.90	8.18	8.69	9.27
High Density	1.22	1.30	1.27	1.37	1.55	3.55	1.85	2.06	2.27	2.47
General	7.26	8.17	8.79	9.55	10.56	12.12	13.27	13.98	14.77	15.83
Small Power	18.18	20.17	19.72	20.33	23.61	16.95	27.33	29.85	32.35	34.72
Large Power										
- SUCOMA	4.92	6.21	6.26	6.71	6.52	7.08	7.29	7.51	7.74	7.97
- Blantyre Water Board	6.30	6.57	6.44	6.21	6.39	8.81	8.98	10.04	10.22	10.89
- Portland Cement	1.63	2.70	2.71	2.95	3.02	3.16	3.19	3.23	3.26	3.29
- David Whitehead	4.80	4.55	4.63	4.86	4.86	5.01	5.51	6.00	6.50	7.00
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	17.65	20.03	20.04	20.72	20.79	24.05	24.97	26.79	27.72	29.15
Export	0.20	0.13	0.00	0.00	0.00	0.18	0.19	0.19	0.20	0.20
INTERCONNECTED SYSTEM										
Total (MW)	49.46	55.32	55.49	58.16	63.60	69.80	75.51	81.05	85.99	91.64
Auxilary Consumption (MW)	0.31	0.34	0.37	0.38	0.41	0.44	0.44	0.46	0.48	0.51
Tx. & Dbn. Losses (%)	20.9%	21.3%	21.9%	23.2%	22.6%	22.5%	16.7%	15.4%	14.3%	13.2%
Losses (MW)	13.16	15.07	15.60	17.64	18.72	20.38	15.20	14.86	14.42	14.06
Generated (MW)	62.87	70.66	71.38	76.09	82.63	90.52	91.08	96.30	100.83	106.14
Growth rate in maximum demand		12.4%	1.0%	6.6%	8.6%	9.6%	0.6%	5.7%	4.7%	5.3%
Load Factor (generated)	64.8%	63.4%	67.7%	64.5%	65.0%	62.9%	62.9%	62.3%	62.5%	62.4%

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
DEMAND (MW)											
Low Density	9.91	10.61	11.34	12.12	12.94	14.08	15.33	16.66	18.12	19.67	21.34
High Density	2.67	2.90	3.13	3.39	3.66	4.03	4.44	4.88	5.36	5.89	6.47
General	17.08	18.54	20.10	21.83	23.69	26.18	28.96	32.00	35.36	39.03	43.02
Small Power	37.12	39.77	42.53	45.52	48.67	53.03	57.82	62.98	68.60	74.64	81.12
Large Power											
- SUCOMA	8.21	8.46	8.71	8.97	9.24	9.52	9.80	10.10	10.40	10.71	11.03
- Blantyre Water Board	11.41	11.80	12.22	12.69	13.17	13.59	14.19	14.19	14.19	14.19	14.19
- Portland Cement	3.32	3.34	3.37	3.39	3.42	3.44	3.46	3.47	3.48	3.49	3.50
- David Whitehead	7.50	7.80	8.10	8.40	8.70	9.00	9.00	9.00	9.00	9.00	9.00
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	30.44	31.40	32.40	33.46	34.53	35.55	36.45	36.76	37.07	37.40	37.72
Export	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.25	0.25	0.26	0.27
INTERCONNECTED SYSTEM											
Total (MW)	97.42	103.43	109.73	116.54	123.72	133.10	143.24	153.53	164.77	176.88	189.94
Auxilary Consumption (MW)	0.54	0.57	0.61	0.64	0.68	0.73	0.79	0.85	0.91	0.98	1.05
Tx. & Dbn. Losses (%)	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%
Losses (MW)	14.95	15.87	16.83	17.88	18.98	20.42	21.97	23.55	25.28	27.13	29.14
Generated (MW)	112.84	119.79	127.09	134.98	143.29	154.15	165.90	177.81	190.84	204.87	219.99
Growth rate in maximum demand	6.3%	6.2%	6.1%	6.2%	6.2%	7.6%	7.6%	7.2%	7.3%	7.4%	7.4%
Load Factor (generated)	62.2%	62.1%	62.0%	61.9%	61.8%	61.8%	61.7%	61.9%	62.0%	62.1%	62.2%

TABLE 2.4 (Sheet 1 of 2)
ESCOM Load Forecasting Model
(Author: Kennedy & Donkin Power Systems, December 1990)
Central Region

		Actual									
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
CONSUMER NUMBERS											
Low Density	3465	3683	4010	4377	4518	4872	4726	5294	5540	6054	6590
High Density	3423	3530	3641	3726	3649	3885	3716	4123	4299	4688	5077
kWh/CONSUMER											
Low Density	4500	4614	4527	4608	4697	5817	7238	6403	6462	6268	6211
High Density	967	982	965	1034	1098	1113	1212	1230	1249	1269	1289
SALES (GWh)											
Low Density	15.59	16.99	18.15	20.17	21.22	21.78	22.22	23.32	23.78	25.78	27.99
High Density	3.31	3.47	3.51	3.85	4.01	4.32	4.51	5.07	5.37	5.95	6.54
General	15.60	17.13	19.20	21.23	21.59	24.31	25.51	27.20	27.61	30.06	32.95
Small Power	41.83	45.34	46.14	48.42	51.70	55.84	56.28	62.25	64.80	70.66	76.74
Large Power											
- SUCOMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Blantyre Water Board	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Portland Cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- David Whitehead	0.00	0.00	0.00	0.00	0.00	0.00	6.35	6.35	12.70	12.70	12.70
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	0.00	0.00	0.00	0.00	0.00	0.00	6.35	6.35	12.70	12.70	12.70
Export	0.27	0.18	0.00	0.00	0.00	0.25	0.26	0.26	0.27	0.28	0.28
INTERCONNECTED SYSTEM											
Total Sales (GWh)	76.60	83.11	87.00	93.67	98.52	106.50	115.13	124.45	134.53	145.43	157.21
Auxilary Consumption (GWh)	0.46	0.50	0.52	0.57	0.60	0.65	0.66	0.71	0.76	0.81	0.88
Tx. & Dbn. Losses (%)	15.8%	16.1%	16.5%	17.5%	17.1%	17.0%	12.6%	11.7%	10.8%	10.0%	10.0%
Losses (GWh)	14.46	16.04	17.30	19.99	20.45	21.95	16.69	16.50	16.38	16.25	17.57
Generated (GWh)	91.52	99.65	104.82	114.23	119.56	129.09	132.48	141.66	151.67	162.49	175.65

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CONSUMER NUMBERS										
Low Density	6578	7184	7833	8530	9278	10019	10812	11659	12564	13532
High Density	5042	5479	5943	6439	6968	7486	8037	8622	9245	9906
kWh/CONSUMER										
Low Density	6662	6370	6272	6228	6199	6210	6206	6198	6189	6181
High Density	1309	1329	1349	1370	1391	1413	1434	1457	1479	1502
SALES (GWh)										
Low Density	27.89	30.42	33.12	36.02	39.13	42.20	45.48	48.98	52.72	56.70
High Density	6.60	7.28	8.02	8.82	9.69	10.58	11.53	12.56	13.67	14.88
General	33.27	36.83	40.74	45.01	49.69	54.46	59.65	65.29	71.42	78.07
Small Power	76.49	83.48	91.00	99.10	107.83	116.50	125.78	135.71	146.35	157.73
Large Power										
- SUCOMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Blantyre Water Board	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Portland Cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- David Whitehead	25.40	25.40	25.40	25.40	25.40	25.40	25.40	25.40	25.40	25.40
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	25.40	25.40	25.40	25.40	25.40	25.40	25.40	25.40	25.40	25.40
Export	0.29	0.30	0.31	0.31	0.32	0.33	0.34	0.35	0.35	0.36
INTERCONNECTED SYSTEM										
Total Sales (GWh)	169.94	183.71	198.59	214.67	232.06	249.47	268.18	288.29	309.91	333.16
Auxilary Consumption (GWh)	0.95	1.03	1.11	1.20	1.30	1.39	1.50	1.61	1.73	1.86
Tx. & Dbn. Losses (%)	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Losses (GWh)	18.99	20.53	22.19	23.99	25.93	27.87	29.96	32.21	34.63	37.22
Generated (GWh)	189.88	205.26	221.89	239.86	259.29	278.74	299.64	322.11	346.27	372.24

TABLE 2.4 (Sheet 2 of 2)
ESCOM Load Forecasting Model
Central Region

		Actual																			
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
DEMAND (MW)																					
Low Density	2.17	2.37	2.53	2.81	2.95	5.29	3.09	3.25	3.31	3.59	3.90	3.88	4.23	4.61	5.01	5.45	5.87	6.33	6.82	7.34	7.89
High Density	0.53	0.56	0.56	0.62	0.64	1.45	0.72	0.82	0.86	0.96	1.05	1.06	1.17	1.29	1.42	1.56	1.70	1.85	2.02	2.20	2.39
General	3.18	3.49	3.91	4.33	4.40	4.96	5.20	5.54	5.63	6.13	6.72	6.78	7.51	8.30	9.18	10.13	11.10	12.16	13.31	14.56	15.92
Small Power	7.96	8.63	8.78	9.21	9.84	6.93	10.71	11.84	12.33	13.44	14.60	14.55	15.88	17.31	18.86	20.52	22.16	23.93	25.82	27.84	30.01
Large Power																					
- SUCOMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Blantyre Water Board	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Portland Cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- David Whitehead	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	2.00	2.00	2.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	2.00	2.00	2.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Export	0.07	0.04	0.00	0.00	0.00	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09
INTERCONNECTED SYSTEM																					
Total (MW)	13.91	15.08	15.78	16.97	17.84	18.69	20.79	22.51	24.20	26.18	28.34	30.35	32.87	35.59	38.54	41.73	44.92	48.36	52.05	56.03	60.30
Auxilary Consumption (MW)	0.08	0.09	0.09	0.10	0.10	0.11	0.12	0.12	0.13	0.14	0.15	0.17	0.18	0.19	0.21	0.23	0.24	0.26	0.28	0.30	0.33
Tx. & Dbn. Losses (%)	20.9%	21.3%	21.9%	23.2%	22.6%	22.5%	16.7%	15.4%	14.3%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%
Losses (MW)	3.70	4.11	4.43	5.14	5.25	5.46	4.18	4.13	4.06	4.02	4.35	4.66	5.04	5.46	5.91	6.40	6.89	7.42	7.98	8.59	9.25
Generated (MW)	17.67	19.26	20.29	22.19	23.16	24.23	25.07	26.75	28.37	30.32	32.82	35.15	38.07	41.22	44.63	48.33	52.02	56.00	60.28	64.88	69.83
Growth rate in maximum demand		9.0%	5.3%	9.4%	4.4%	4.6%	3.5%	6.7%	6.1%	6.9%	8.2%	7.1%	8.3%	8.3%	8.3%	8.3%	7.7%	7.6%	7.6%	7.6%	7.6%
Load Factor (generated)	59.1%	59.1%	59.0%	58.8%	58.9%	60.8%	60.3%	60.5%	61.0%	61.2%	61.1%	61.7%	61.6%	61.4%	61.3%	61.2%	61.2%	61.1%	61.0%	60.9%	60.9%

TABLE 2.5 (Sheet 1 of 2)
ESCOM Load Forecasting Model
(Author: Kennedy & Donkin Power Systems, August 1990)
Northern Region

	1985 (Actual)	1986 (Actual)	1987 (Actual)	1988 (Actual)	1989 (Actual)	1990	1991	1992	1993	1994
CONSUMER NUMBERS										
Low Density	969	1040	1251	1405	1491	1315	1405	1413	1631	1853
High Density	958	997	1136	1196	1204	1049	1105	1101	1266	1435
kWh/CONSUMER										
Low Density	4500	4614	4527	4608	4697	8682	9725	9787	8750	8461
High Density	967	982	965	1034	1098	1113	1212	1230	1249	1269
SALES (GWh)										
Low Density	4.36	4.80	5.66	6.47	7.01	5.88	6.61	6.22	7.00	7.89
High Density	0.93	0.98	1.10	1.24	1.32	1.17	1.34	1.35	1.58	1.82
General	4.36	4.84	5.99	6.81	7.13	6.56	7.58	7.26	8.13	9.20
Small Power	11.70	12.80	14.39	15.54	17.07	15.07	16.73	16.62	19.08	21.63
Large Power										
- SUCOMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Blantyre Water Board	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Portland Cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- David Whitehead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	7.10	7.10	11.83	11.83	11.83
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	0.00	0.00	0.00	0.00	0.00	7.10	7.10	11.83	11.83	11.83
Export	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INTERCONNECTED SYSTEM										
Total Sales (GWh)	21.35	23.42	27.14	30.06	32.52	35.77	39.35	43.28	47.61	52.37
Auxilary Consumption (GWh)	0.13	0.14	0.16	0.18	0.20	0.22	0.23	0.25	0.27	0.29
Tx. & Dbn. Losses (%)	15.8%	16.1%	16.5%	17.5%	17.1%	17.0%	12.6%	11.7%	10.8%	10.0%
Losses (GWh)	4.03	4.52	5.40	6.42	6.75	7.37	5.71	5.74	5.80	5.85
Generated (GWh)	25.51	28.08	32.70	36.66	39.47	43.36	45.28	49.27	53.68	58.52

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CONSUMER NUMBERS											
Low Density	2092	2351	2632	2939	3274	3640	3858	4087	4327	4579	4843
High Density	1612	1802	2007	2230	2471	2734	2883	3038	3200	3369	3545
kWh/CONSUMER											
Low Density	8331	8239	8158	8080	8004	7932	8187	8282	8331	8366	8399
High Density	1289	1309	1329	1349	1370	1391	1413	1434	1457	1479	1502
SALES (GWh)											
Low Density	8.89	9.97	11.14	12.43	13.82	15.35	16.25	17.19	18.18	19.21	20.29
High Density	2.08	2.36	2.67	3.01	3.39	3.80	4.07	4.36	4.66	4.98	5.32
General	10.46	11.89	13.49	15.28	17.28	19.50	20.97	22.55	24.23	26.03	27.94
Small Power	24.36	27.33	30.58	34.14	38.04	42.31	44.86	47.54	50.37	53.33	56.45
Large Power											
- SUCOMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Blantyre Water Board	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Portland Cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- David Whitehead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Viphya Saw Mill	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83	11.83
Export	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INTERCONNECTED SYSTEM											
Total Sales (GWh)	57.61	63.37	69.71	76.68	84.35	92.78	97.98	103.47	109.26	115.38	121.84
Auxilary Consumption (GWh)	0.32	0.35	0.39	0.43	0.47	0.52	0.55	0.58	0.61	0.64	0.68
Tx. & Dbn. Losses (%)	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Losses (GWh)	6.44	7.08	7.79	8.57	9.42	10.37	10.95	11.56	12.21	12.89	13.61
Generated (GWh)	64.37	70.81	77.89	85.68	94.24	103.67	109.47	115.60	122.08	128.91	136.13

TABLE 2.5 (Sheet 2 of 2)
ESCOM Load Forecasting Model
Northern Region

	Actual																				
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
DEMAND (MW)																					
Low Density	0.61	0.67	0.79	0.90	0.98	1.43	0.92	0.87	0.97	1.10	1.24	1.39	1.55	1.73	1.92	2.14	2.26	2.39	2.53	2.67	2.83
High Density	0.15	0.16	0.18	0.20	0.21	0.39	0.22	0.22	0.25	0.29	0.33	0.38	0.43	0.48	0.54	0.61	0.65	0.70	0.75	0.80	0.86
General	0.89	0.99	1.22	1.39	1.45	1.34	1.55	1.48	1.66	1.88	2.13	2.42	2.75	3.12	3.52	3.97	4.28	4.60	4.94	5.31	5.70
Small Power	2.23	2.44	2.74	2.96	3.25	1.87	3.18	3.16	3.63	4.12	4.63	5.20	5.82	6.50	7.24	8.05	8.53	9.05	9.58	10.15	10.74
Large Power																					
- SUCOMA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Blantyre Water Board	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Portland Cement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- David Whitehead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Viphya Saw Mill	0.00	0.00	0.00	0.00	0.00	1.29	1.29	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14
- Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total	0.00	0.00	0.00	0.00	0.00	1.29	1.29	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14
Export	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INTERCONNECTED SYSTEM																					
Total (MW)	3.87	4.25	4.92	5.44	5.89	6.31	7.15	7.87	8.66	9.53	10.48	11.53	12.69	13.97	15.37	16.91	17.87	18.88	19.94	21.07	22.26
Auxilary Consumption (MW)	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.10	0.11	0.11	0.12
Tx. & Dbn. Losses (%)	20.9%	21.3%	21.9%	23.2%	22.6%	22.5%	16.7%	15.4%	14.3%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%	13.2%
Losses (MW)	1.03	1.16	1.38	1.65	1.73	1.84	1.44	1.44	1.45	1.46	1.61	1.77	1.95	2.14	2.36	2.59	2.74	2.90	3.06	3.23	3.41
Generated (MW)	4.92	5.42	6.33	7.12	7.65	8.19	8.62	9.35	10.15	11.03	12.14	13.36	14.70	16.17	17.80	19.59	20.69	21.86	23.10	24.40	25.78
Growth rate in maximum demand		10.3%	16.7%	12.5%	7.4%	7.1%	5.3%	8.4%	8.6%	8.7%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	5.6%	5.6%	5.6%	5.6%	5.6%
Load Factor (generated)	59.2%	59.1%	59.0%	58.8%	58.9%	60.5%	60.0%	60.2%	60.4%	60.6%	60.5%	60.5%	60.5%	60.5%	60.4%	60.4%	60.4%	60.4%	60.3%	60.3%	60.3%

Figure 2.1

Total Demand

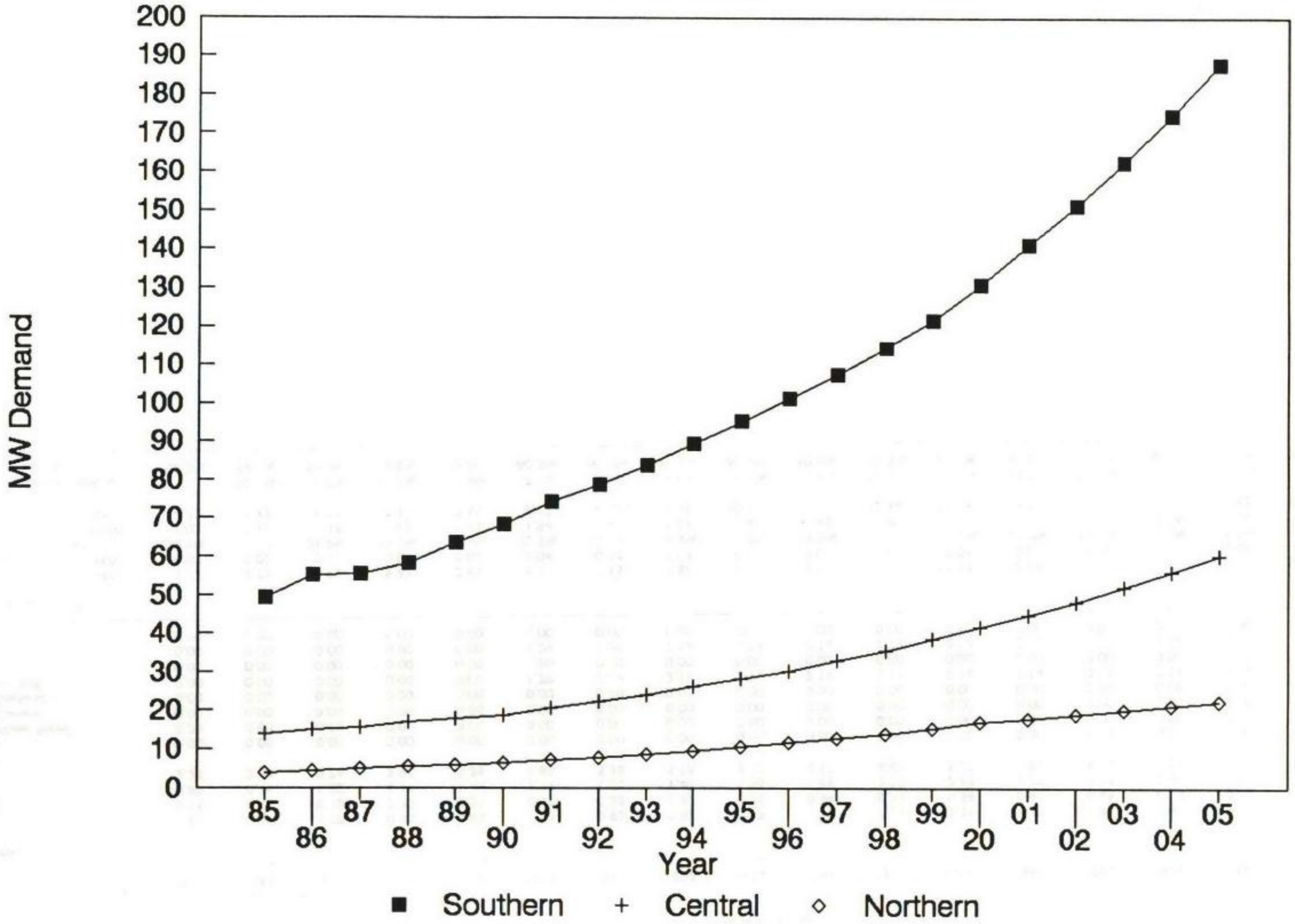
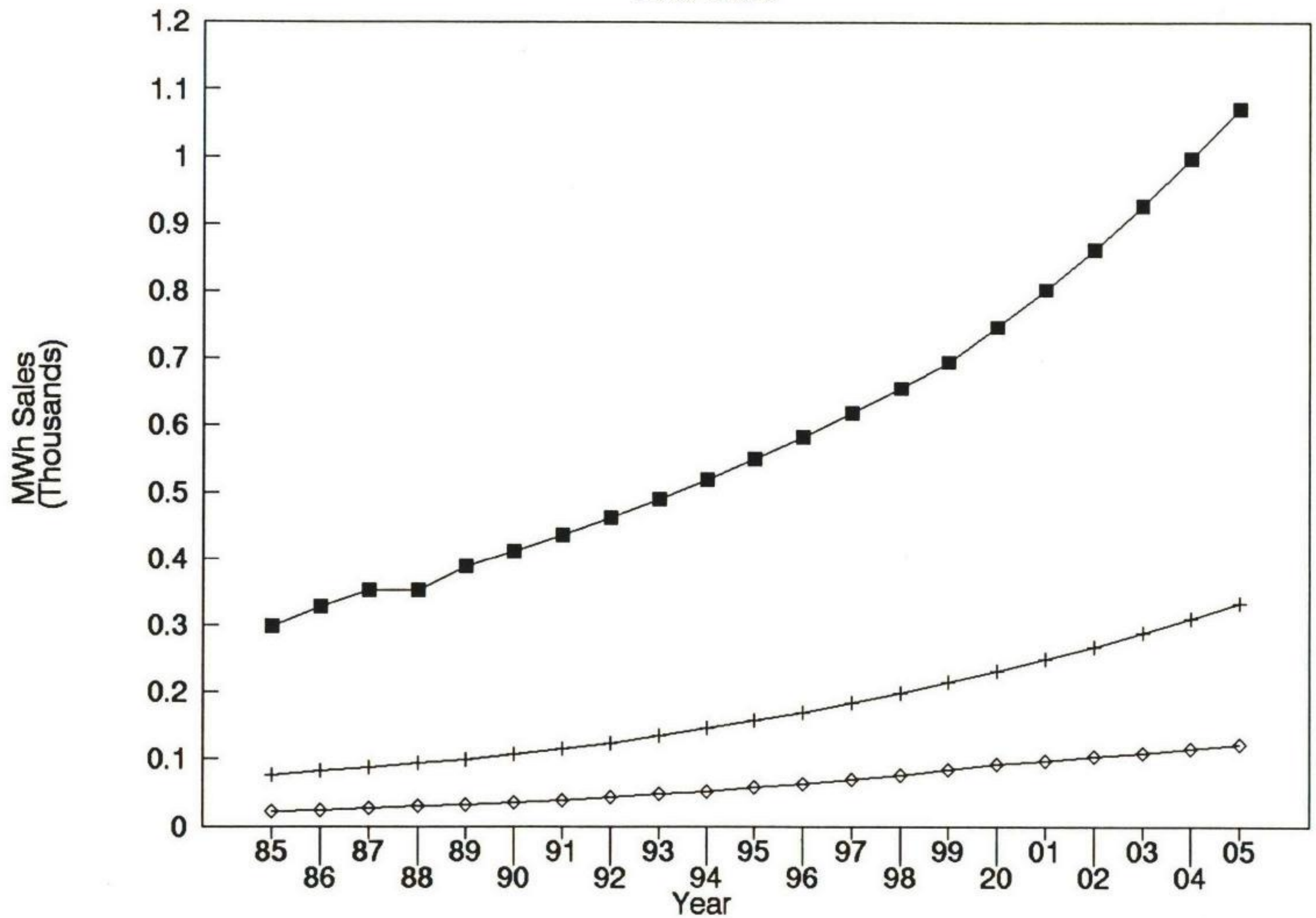


Figure 2.2

Total Sales



SECTION 3

LONG RUN MARGINAL COSTS OF POWER AND ENERGY

3. LONG RUN MARGINAL COSTS OF POWER AND ENERGY

3.1 General

The methodology adopted for estimating long run marginal costs of power and energy follows that of the Coopers & Lybrand Tariff Study of 1985. For the purposes of this study marginal costs can be separated into two types:

(i) capacity costs

(ii) energy costs

Capacity costs are incurred at around the time of system peak, when the system is under strain. Sustained increases in demand at this time would create a need for investment to provide more power. Energy costs may vary with the amount of consumption. Both capacity and energy cost may vary by time of day, by day of week and by season.

In Malawi, the system is largely hydro powered and thus there are relatively high levels of investment and low operation costs. In determining the capacity costs the cost of providing an extra kilowatt in each future project has been determined. The sequence of generation projects is as in the "Least Cost Development Programme", 1988, and the timing is determined by the load forecast in Section 2 of this report as follows.

1991 Nkula B 5

1994 Tedzani III

2000 Kapichira I

2003 Kapichira II

The development programme is optimised to match the type of capacity increment with the energy or power defects on the system. Nkula B Unit 5 is currently being installed to meet a capacity shortfall rather than an energy deficit. Tedanzi III, although it is the third phase at that location, will meet power and energy deficits.

The optimum development programme in Malawi is a function of both the shape of the load and the hydro resources. Malawi has a substantial base-load industrial demand plus a significant commercial load. The combination of these two gives the system a fairly high load factor and a high day-time plateau. This is illustrated in Figure 3.1. The peak generally occurs at around mid-day but the evening peak is close to, and sometimes exceeds, the day peak. The relatively high load factor and the availability of abundant run-of-river resources implies that optimum developments will tend to be new stations in cascade rather than multiple extensions to existing stations.

We set out below our analysis of the long-run costs of supply under the load forecast for the inter-connected system (ICS), presented in Section 2.

3.2 Capacity Costs

Increases in demand at time of system peak will in the long run require:

more generating capacity;

more HV transmission/distribution capacity;

more MV transmission/distribution capacity; and finally,

more LV distribution capacity.

3.2.1 Generation Capacity Costs

The timing of new projects is discussed in Section 3.1, from which it is clear that new hydro investment would be the response to increased demand rather than thermal peaking plant.

The only committed investment in the Least Cost Development Programme is in Nkula B unit 5, on which work is proceeding. The cost of this unit has therefore not been included in the analysis since it can neither be advanced nor delayed in response to incremental demand. All of the other projects are included. Table 3.2 shows for each project the capital cost and the annuitised cost per kW assuming:

(i) a discount rate of 10%

(ii) an exchange rate of MK2.56 = $1

(iii) phasing of expenditure and split between foreign and local cost as given in the Least Cost Development Programme.

(iv) economic lifetime of generating plant of 40 years.

At Kapichira, phase one is considered to provide both capacity and energy, and phase two is for peaking capacity. In general, initial units at a station tend to be used to meet energy requirements whilst later units are for peaking capacity. This assumption may be tested by comparing the loss of energy expectation and the loss of load expectation with and without Kapichira II. This however is beyond the scope of this study. The LRMC of power on the ICS is therefore considered to be 175 MK/kW per annum before adjustment for station use, fixed O&M and incremental reserve margin.

Station use is equivalent to around 0.7% and annual fixed O&M to around 1% of unannuitised capital cost. The required percentage reserve margins which result from the least cost development programme range from 25% to 30%. The annuitised costs are therefore increased overall by 30% to 227.2 MK/kW per annum to give the LRMC of generation for the ICS.

3.2.2 Transmission Capacity Costs

Transmission capacity costs are calculated using an average incremental cost (AIC) methodology. Transmission projects are typically undertaken for the purposes of system extension, replacement and reinforcement and it is difficult to separate these items. The calculations have been based on average incremental cost derived from total planned expenditure over the period 1990 to 2005 at each voltage level and total annual demand growth at each voltage level (ie, demand growth of existing consumers plus that due to demands of new consumers). This may overstate the AIC. However, replacement costs represent only a small proportion of overall expenditure and the overstatement is likely to be modest.

Capital expenditure has been determined on a cost per MW growth basis in the MV and LV categories as follows:

MV 0.23 MK/MW growth
LV 1.15 MK/MW growth

This approach has been made necessary because no investment programme for these categories existed at the time of the study.

In the HV category some investment plans for the 132kV system were available and these are shown in Table 3.1. However no such plans were available for the 66kV and 33kV systems. A cost of 0.23MK/MW growth was therefore assumed.

The HV system is considered to be the 132/66/33 kV system. Changes in HV demand were calculated by taking changes in total demand since all voltage levels has to pass through the HV system. These assumptions yield an average cost of 975.8 MK/kW. Annuitising over the expected life of transmission projects, taken to be 25 years, and adding O&M gives a cost of 110.7 MK/kW per annum for HV transmission and a total cost of 353.8 MK/kW per annum including losses.

The MV system was considered to be the 11 kV system. Changes in the MV demand were calculated from the load forecast by taking total demand and subtracting from it the large power demand which is assumed to be supplied at HV. Applying the same process as for the HV system yields a cost of 786.1 MK/kW and a total cost of 445.3 MK/kW per annum including O&M and losses.

Changes in demand at the LV level are calculated from the low density, high density and general consumer categories in the load forecast. Again applying the same methodology as for the HV system results in a total capacity charge of 527.98 MK/kW per annum including O&M and losses.

Calculation of Transmission AIC is shown in table 3.3.

3.2.3 <u>Summary of Capacity Costs</u>

In order to calculate the long run costs at the HV, MV and LV levels then losses must be included. The following is considered to be an achievable level of power losses in the long run, after the implementation of loss reduction measures:

132/66/33 kV Transmission and transformation	6.5%
11 kV feeder losses	0.7%
11 kV/LV transformer losses	2.6%
LV system losses	2.6%
Non technical losses	0.7%
Total	13.1%

This produces total long run capacity costs at the generation and at each voltage level as follows:

Generation	227.24 MK/kW per annum
HV Transmission	353.77 MK/kW per annum
MV Transmission/distribution	445.28 MK/kW per annum
LV Distribution	527.98 MK/kW per annum

3.3 Marginal Energy Costs

The gas turbine at Blantyre is used only in emergencies or monthly to keep it in running order. The variable cost is not therefore included in the average incremental cost of energy.

In Section 3.2, the marginal cost of capacity at Kapichira II was estimated, however at Tedanzi III and Kapichira I it was decided that the project costs should be allocated to both capacity and energy. In this respect costs should be allocated to the peak period energy made available by those projects, because it is demand for energy within the daytime plateau (0600 to 2030) which causes hydro plant to be the response to incremental demand rather than the cheaper peaking plant. The cost of each project attributable to peak period energy made available is calculated by subtracting from the total annual cost a credit equal to the cost of capacity supplied by the project. For example, the annual cost of capacity at Tedzani III is:

Unit size * LRMC capacity

50,000 * 227.24 = 11.36 m MK

This is then subtracted from the total annual cost of Tedzani III calculated as follows:

Unit size * Annuitised cost per kilowatt

50,000 * 376 MK/kW per annum = 18.8 m MK per annum

The annual cost of energy is therefore 18.8 m MK per annum minus 11.36 m MK per annum, which gives a total figure of 7.44 m MK per annum.

The cost per kilowatt hour at peak is calculated by dividing the annual cost of energy by the peak GWh calculated by assuming the daytime plateau from 0600 to 2030, a load factor of 60% and 92% availability to give 174 GWh per annum in the peak. The cost per kilowatt at Tedzani III is therefore 4.3 tambala/kWh.

The annual cost of energy at Kapichira I is calculated as above giving a cost per kilowatt hour of 13.1 tambala/kWh.

In order to estimate the system energy costs a weighted average of the costs of Kapichira I and Tedzani III has been formed. As the projects will be commissioned approximately five years apart a weight of unity has been applied to Tedzani III and a weight of $1/1.1^5$ to the Kapichira cost, hence weighting more heavily the project which occurs sooner. This yields a cost of 6.2 tambala/kWh for peak period energy.

An average energy charge was also adopted since in the off-peak periods energy is virtually free of charge. We have therefore adopted a weighted average of the calculated long run peak energy charge of 6.2 tambala/kWh and the off peak cost of zero. Thus the long run marginal cost of energy is taken to be 4.1 tambala/kWh on average. Losses are then added at the target level of 10% per annum giving a total LRMC of 4.5 tambala/kWh.

An off peak energy charge of zero has been assumed since Malawi has essentially a run-of river hydro system backed up by duirnal storage. Seasonal storage capacity, other than Lake Malawi is neither required nor contemplated. The cost of providing duirnal storage is a very small portion of the cost of the complete power station. Since water is spilled throughout each day of the year, and has done for several years and is expected to continue to do so, and the cost of pondage is very low, it is reasonable to assume that the off peak LRMC of energy is negligible.

An average LRMC of energy has been adopted since analysis is not carried out on a system basis, but on a feeder by feeder basis. Thus a feeder may peak at a different time from system peal and it would not be appropriate to apply the system peak energy charge to the analysis of that feeder.

Malawi Transmission Projects **Table 3.1**

HV Costs (1990 MK m)

Project	Cost	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Lilongwe - Nkula 132kV line (second circuit)	Foreign $							1.62	6.50								
	Local MK							0.46	1.84								
Blantyre West - Tedzani 132 kV line	Foreign $						2.85	0.87									
	Local MK						0.81	0.27									
Chinteche - Bwengu 132kV line and 132/66k	Foreign $						1.68	6.75									
	Local MK						0.48	1.92									
Golomoti 132/66/33kV substation	Foreign $				0.56	2.28											
	Local MK				0.16	0.65											
Kapichira - Blantyre west (second line)	Foreign $											1.76					
	Local MK											0.45					
Total	Foreign	0.00	0.00	0.00	0.56	2.28	4.53	9.24	6.50	0.00	0.00	1.76	0.00	0.00	0.00	0.00	0.00
Total	Local	0.00	0.00	0.00	0.16	0.65	1.29	2.65	1.84	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00
Total cost $		0.00	0.00	0.00	1.59	6.49	12.89	26.30	18.48	0.00	0.00	4.96	0.00	0.00	0.00	0.00	0.00

CALCULATION OF AVERAGE INCREMENTAL COSTS OF GENERATING CAPACITY

Annuitised Capital Costs of Major Supply Projects (1990 Prices Compounded Forward to Year of Commissioning)

Table 3.2

Project	Capacity (MW)	Year of Commissioning	Costs	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Economic Cost in Year of Commissioning (MK million)	Annuitised Economic Cost MK/kW p.a.
Tedzani III	50	1995	Foreign $	0.99	9.18	22.31	17.06	2.43												183.73	375.8
			Local MK	0.59	7.24	25.51	15.23	2.12													
Kapichira I	50	2000	Foreign $						1.58	6.25	22.78	28.46	23.51	4.26						334.36	683.8
			Local MK						0.95	10.79	35.16	28.60	29.48	7.06							
Kapichira II	75	2003	Foreign $									0.51	1.29	8.28	17.74	14.27	1.58			128.21	174.8
			Local MK									0.31	0.66	1.18	7.13	6.59	0.54				
LRMC																					
Kapichira II	174.80 K/kW pa Plus 30% for station use, O&M, and reserve margin =					227.24 K/kW pa															

CALCULATION OF AVERAGE INCREMENTAL COST OF CAPACITY **Table 3.3**

Transmission/Distribution Costs

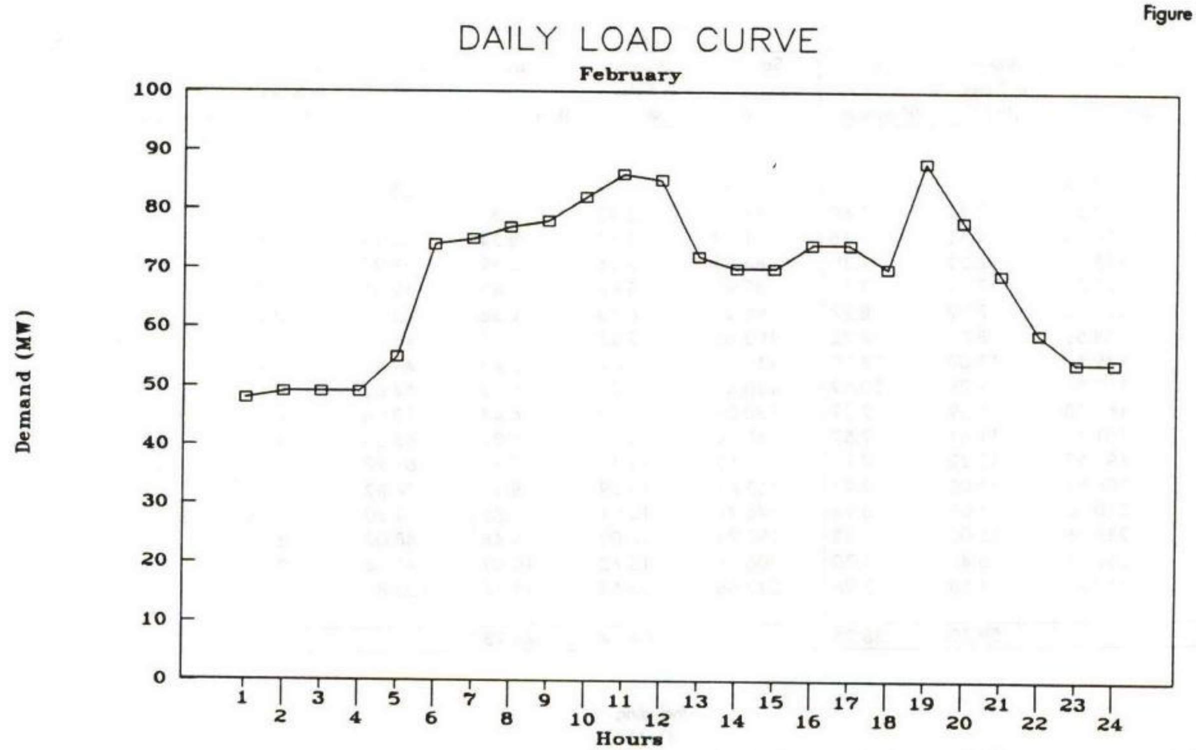
Year	HV			MV			LV		
	Sales (MW)	Growth in Sales (MW)	Costs (K million)	Sales (MW)	Growth in Sales (MW)	Costs (K million)	Sales (MW)	Growth in Sales (MW)	Costs (K million)
1989	87.56			66.77			30.08		
1990	94.68	7.12	1.60	69.10	2.33	1.57	43.34	13.26	15.21
1991	108.80	14.12	3.18	81.29	12.19	8.24	37.16	-6.18	0.00
1992	115.02	6.22	1.40	84.83	3.54	2.39	37.99	0.83	0.95
1993	122.03	7.01	3.17	89.91	5.08	3.43	39.83	1.84	2.11
1994	129.95	7.92	8.27	96.39	6.48	4.38	42.66	2.83	3.25
1995	138.52	8.57	14.82	103.66	7.27	4.91	46.04	3.38	3.88
1996	149.52	11.00	28.78	111.70	8.04	5.43	49.85	3.81	4.37
1997	159.31	9.79	20.69	120.47	8.77	5.93	54.02	4.17	4.78
1998	169.90	10.59	2.39	130.00	9.53	6.44	58.58	4.56	5.23
1999	181.31	11.41	2.57	140.34	10.34	6.99	63.56	4.98	5.71
2000	193.53	12.22	7.71	151.53	11.19	7.56	68.97	5.41	6.20
2001	206.53	13.00	2.93	163.62	12.09	8.17	74.82	5.85	6.71
2002	220.56	14.03	3.16	176.71	13.09	8.85	81.20	6.38	7.32
2003	235.56	15.00	3.38	190.73	14.02	9.48	88.00	6.80	7.80
2004	251.98	16.42	3.70	206.15	15.42	10.42	95.64	7.64	8.76
2005	269.56	17.58	3.96	222.68	16.53	11.17	103.80	8.16	9.36
Present Value (Km)		59.70	58.25		69.44	46.93		21.12	30.66

				Including O+M
Average Incremental HV Costs	975.83	Annuity	107.50	110.73
Average Incremental MV Costs	786.08	Annuity	86.60	89.20
Average Incremental LV Costs	513.59	Annuity	56.58	58.28

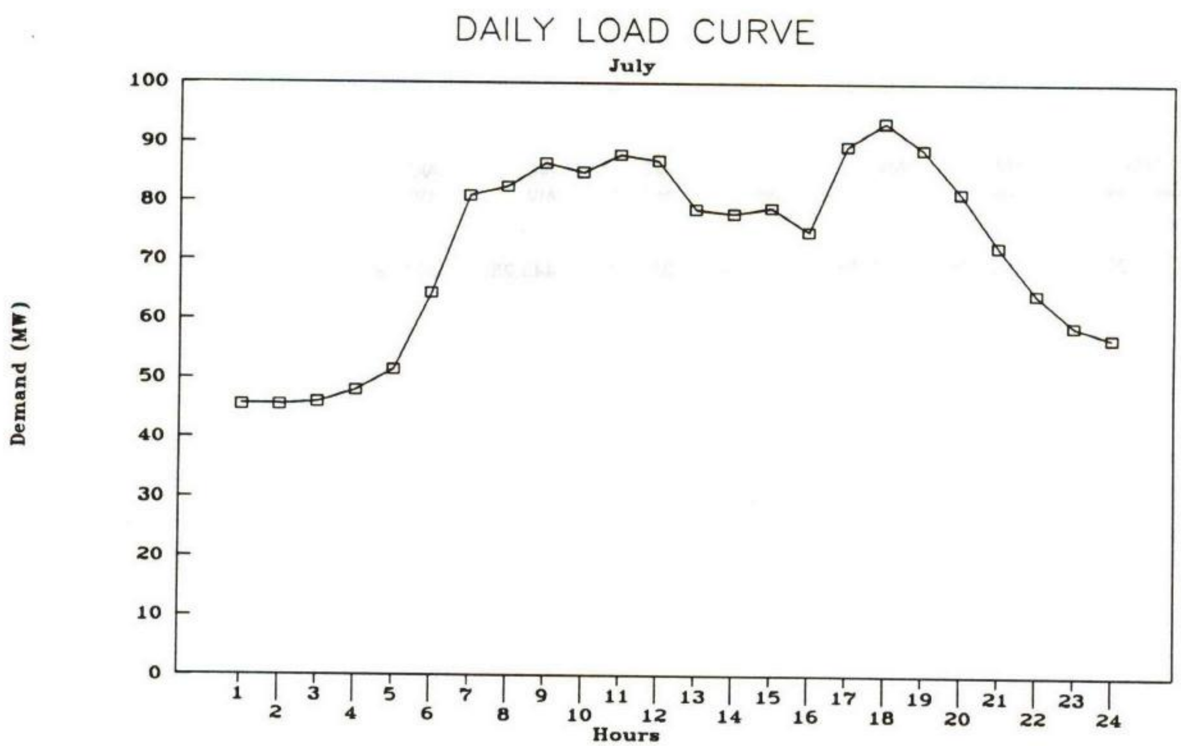
Average Incremantal Costs

	LRMC Generation	HV Losses	MV Losses	LV Losses	AIC HV	AIC MV	AIC LV
Target Year AIC	227.24	6.5%	0.7%	5.2%	353.77	445.28	527.98

Figure 3.1



DAILY LOAD CURVE
February
Demand (MW)
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours



DAILY LOAD CURVE
July
Demand (MW)
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours

SECTION 4

TECHNICAL LOSSES

4. TECHNICAL LOSSES

4.1 Introduction

4.1.1 Technical Analysis

Technical losses may be summarised as those arising from power losses occurring in current carrying conductors, transformers and other items of equipment connected to the transmission and distribution systems. Non-technical losses are those associated with errors in power and energy metering and consumer fraud which result in a mismatch between generated and sold power, and energy which cannot be accounted for by the technical loss component.

The development of strategies for reducing technical losses on the ESCOM system has been based on an exhaustive programme of system measurements associated with the various voltage levels in the system. The analysis was split into three sections, concentrating on the transmission system (132/66/33 kV voltage levels), 11 kV systems in Blantyre and Lilongwe and LV systems in the two cities.

The starting point for the analysis of the 132/66/33 kV transmission and subtransmission systems was the load flow study developed from system records for the 1990 peak demand experienced on 4th July 1990. The analysis performed on 11 kV feeders in Blantyre and Lilongwe, and on LV systems, was carried out on the basis of direct system measurements made with the aid of the Dranetz power demand analysers and clip-on ammeter checks to establish the distribution of loads on these systems. These system measurements were then scaled to produce estimates of the load distribution on the feeders at times of peak demand by a process described in more detail below.

The system measurements were started during the first visit by KDP engineers to Malawi in August 1990. These were then continued by ESCOM engineers until the beginning of November 1990, when the second site visit by KDP took place, during which much of the analysis of present system loss levels and the technical assessment of alternative loss reduction strategies was carried out.

A variety of tools have been used in the assessment of technical loss reduction measures. The KDP LF software package, which has already been widely used by ESCOM and KDP, was utilised for load flow analysis of the 132/66/33 kV systems. For some of the 11 kV feeders analysis has also been performed on the Distribution Plus (DPAS) software package suppied by ESMAP for use in this project. During the period between the two KDP visits, ESCOM engineers were engaged in the preparation of data bases for a number of feeders on DPAS, to facilitate their analysis once the results of feeder loading surveys became available. The LV survey results have been processed using a spreadsheet to perform discrete three phase analysis of voltage drops and losses.

In order to compare the technical viability of alternative loss reduction strategies, load flow analysis has been performed to calculate power losses on the transmission and distribution systems before and after the implementation of loss reduction measures. This enables annual energy losses to be calculated for use in conjunction with the power losses in the economic analysis of alternative projects.

The size of the ESCOM system is such that, particularly at 11 kV and below, it is impossible in a project of this type to carry out an exhaustive analysis of loss reduction measures on each circuit. The emphasis of the work undertaken on technical losses has from the outset stressed the need for a sampled approach covering as much of the system as is practically possible, and ensuring that a representative cross-section of feeders and LV systems are analysed in formulating system-wide loss reduction strategies. To this end, the analysis has concentrated on establishing the viability of specific projects which then form the basis of a wider programme of measures applied across the system, for which resourcing and budgetary requirements have been formulated.

ESCOM engineers in the Central Planning Unit have been fully involved with all stages of the technical loss analysis, from the preparation of system models through to the assessment of alternative loss reduction schemes, to ensure the maximum degree of training and technology transfer in the project.

4.1.2 Economic Analysis

The economic analysis of technical loss reduction measures has been carried out by identifying all of the costs and benefits attributable to a particular project. The methodology for studying the 132/66/33 kV system, the 11 kV system, and the LV systems is the same in all cases, however the Marginal Costs of Capacity vary at each level of transmission and distribution as described in Section 3.

For each feeder under consideration the losses have been calculated over the period 1990 to 2005 assuming firstly that loss reduction measures are implemented and secondly that no loss reduction is carried out. The stream of benefits arises from a saving in generation and transmission costs due to the lower level of losses on the system. In this case no benefits arise from increased revenue to ESCOM since the reduction in technical losses will not have any impact at the consumer end of the system and will not increase demand for power or energy. The value of the benefits of the reduction in losses has been quantified using marginal costs at the appropriate level.

The costs arising from each project are attributable wholly to the capital cost of loss reduction measures for the feeder under examination.

For each project considered an Internal Rate of Return has been calculated, in order to examine the viability of the project in economic terms.

The need to calculate streams of losses for elements of the system both with and without loss reduction over a fifteen year period has necessitated an approach to be adopted to cater for cases where, for example, a circuit or network of circuits is unable to supply the 2005 load without some form of reinforcement. In many cases such reinforcements will inevitably be considered as part of the ESCOM Transmission and Distribution Planning Study, and as such are beyond the scope of the present study, other than in the extent to which they should be based on the planning strategies for loss minimisation which are highlighted in later sections of this report. For the analysis of losses in 2005 to be possible however, all the present ESCOM proposals for transmission system reinforcement have been incorporated as intended system developments, and the minimum additional reinforcement necessary to enable realistic operation of the system in 2005 has been added.

At the distribution level, the effects of limiting growth in existing feeder demand on the viability of loss reduction measures have been examined. This has enabled the assessment of the sensitivity of the proposed measures to demand growth variations and the effects of distribution system enhancement in the form of potential new lines an substations resisting the growth on existing circuits.

The technical and economic analysis of technical loss reduction measures at the various levels of the ESCOM system are discussed in detail below.

4.2 132/66/33 kV System

4.2.1 System Losses Without Loss Reduction

The existing ESCOM load flow model for the present 132/66/33 kV system was used in conjunction with SCADA output to formulate a model of the operation of the system at the peak 1990 demand level of 119 MW, experienced during the evening of 4th July 1990.

The results of this load flow are presented in Table 4.1 and show a peak net power loss of 8.0% based on net generated power. When the power losses associated with transformer core loss are taken into consideration this figure increases to 8.4%. The load forecast gives an annual load factor of 62.3% for the system in 1990, which, using the following formula for calculating loss factor:

$$\text{Loss factor} = 0.7 \times (\text{Load Factor})^2 + 0.3 \times \text{Load Factor}$$

gives a loss factor of 45.8%.

Applying this figure to the load dependent losses, and adding in the transformer core losses, gives an overall annual net energy loss of 6.7% associated with the transmission system, based on the 1990 peak demand.

In order to assess the future variation of losses on the transmission and subtransmission systems, load flow studies were performed for key stages in the planned development of the ESCOM system, reflecting the following modifications:

1990 - 1994:

- first 132 kV Nkula-Lilongwe line;
- uprating of the northern backbone line and substations from 66 kV to 132 kV, including Lilongwe B and Salima;
- Kwacha, Sunnyside and Limbe B substations;
- Zomba 66 kV line;
- uprating Nkhotakota-Mtunthama from 33 kV to 66 kV;
- Golomoti - Monkey Bay 33 kV line;
- Nkula B 5th machine;
- Fundis Cross uprating from 5 MVA to 12.5 MVA;

1994 - 1999:

- second 132 kV Nkula - Lilongwe line;
- Tedanzi III Power Station;

- Tedanzi - Kapichira interconnector;
- Blantyre West 132/66 kV substation;
- Golomoti - Mlangeni 66 kV line;
- Kapichira Phase 1 (2 x 25 MW);
- Blantyre West - Mapanga 66 kV line;

1999 - 2005:

- Kapichira Phase II (3 x 25 MW);
- Blantyre West - Kapichira II;

Table 4.2 shows a summary of the power and energy losses associated with the 132/66/33 kV systems in the years 1990, 1991, 1994 and 2005, which indicates that after an initial increase in losses in 1991, the transmission system improvements proposed by ESCOM control the loss level such that it is back to 6.7% of net energy by 1994. At the end of the planning horizon, in 2005, however, the energy losses have increased to 9.0%. A more detailed analysis, looking first at the 132/66 kV losses, is shown in Table 4.3, and demonstrates that the power and energy losses associated with this section of system continue to reduce until 1999 due to system improvements, but that an increase then occurs over the following five years. There is relatively little impact on losses at 33 kV over the period 1990 - 2005, as shown in Table 4.4, due to the limited 33 kV system enhancements proposed by ESCOM at this stage. As a consequence, the losses on the 33 kV system increase from 2.1% to 3.0% by 2005.

Figure 4.1 shows a breakdown of the power losses occurring on the transmission system at peak demand in 1990. This indicates that the 66 kV system contributes the largest amount to the overall loss level (39%), with the 132 kV system accounting for 26%. Figure 4.2 shows the component of the losses associated with the 132/66/33 kV transmission lines, broken down to indicate those contributing the greatest level of losses to the overall total. This indicates that the 132 kV circuit from Nkula to Salima alone contributes nearly one quarter of the total losses occurring on the transmission system, with the 66 kV circuits from Nkula to Lilongwe, Mapanga and Chichiri contributing the highest losses of the remaining lines.

A number of the measures already proposed by ESCOM for the development of the transmission system will have a direct impact on the losses on these circuits, most notably as a consequence of the introduction of the first 132 kV circuit running directly from Nkula to Lilongwe. The result of introducing the various upgrades indicated above between 1990 and 1994 is to reduce the proportion of transmission system losses associated with the 132 kV and 66 kV lines, with increases in losses, due to the increased system demand, occurring on the 33 kV lines and in the transformer windings, as shown in Figure 4.3.

The above observations indicate a higher loss level at present associated with the ESCOM transmission system than would normally be expected in a 132/66/33 kV system. It is clear, however, that many of the proposed modifications to the present system already programmed for introduction by ESCOM will contribute to an initial reduction in losses, although an overall increase is indicated over the period from 1990 to 2005 from 6.7% of net generated energy lost to 9.0%.

The evaluation of a number of potential methods of reducing losses on the transmission system is considered below.

4.2.2 Loss Reduction Strategies

(a) Reconductoring: 66 kV & 33 kV lines

The potential for reconductoring existing 66 kV circuits has been examined as a possible means of reducing the losses on the ESCOM transmission system. This analysis is based on the principles of conductor optimisation, whereby the cost of losses is evaluated over a number of years for different conductor sizes, and the present values of these costs plus the capital costs associated with the construction of lines of each conductor type are compared to obtain the optimum conductor to be used for a given initial loading condition on the line. This technique gives indicative loading levels for planning purposes; rigorous analysis of individual projects is also performed to ensure the economic viability of the proposals for loss reduction.

Figure 4.4 shows the design loading ranges which apply to the construction of new 66 kV wood pole lines in Malawi, based on the following criteria:

Analysis period: 15 years
Annual Demand Growth Rate: 7.2%
Load Factor: 62.3%
Loss Factor: 45.8%
Marginal Power Cost: 353.8 MK/kW
Marginal Energy Cost: 0.045 MK/kWh
Discount Rate: 10%

The demand growth rate is based on the average figure for the increase in demand in the ESCOM system over the period 1990 to 2005.

The curves shown in the diagram indicate that for peak demand at present in excess of 8 MVA, a 175 sq mm conductor represents the optimum size for the use on 66 kV wood pole single circuit lines. This is based on the following construction costs for 66 kV wood pole lines, obtained from the KDP data base of international transmission costs:

75 sq mm	MK 70,000 per km
100 sq mm	MK 78,000 per km
125 sq mm	MK 85,000 per km
175 sq mm	MK 96,000 per km

Figure 4.5 shows the loading levels which apply for the reconductoring of existing 75,100 and 125 sq mm circuits to become viable, on the basis of upgrading to a 175 sq mm conductor. The capital cost of reconductoring is taken to be 50% of the construction cost of a new line, to reflect the component due to the cost of the conductor itself plus an allowance for the replacement of poles, insulators, etc which may be found necessary. The curves indicate the following thresholds for circuit reconductoring:

From 75 sq mm to 175 sq mm : 9 MVA
From 100 sq mm to 175 sq mm : 12 MVA
From 125 sq mm to 175 sq mm : 16.5 MVA

The load flow results for the peak 1990 system demand were examined in the context of these loading levels, from which two potential reconductoring projects were identified, on circuits using 100 sq mm ACSR conductors at present, with demands in excess of 12 MVA. These projects were then assessed using economic analysis based on the calculation of internal rates of return. This necessitated the calculation of streams of losses with and without reconductoring over a fifteen year analysis period, which was performed on the basis of additional load flow studies to obtain loss levels on the feeders with reconductoring in 1991 (the earliest time by which reconductoring could be achieved) and in 2005, and a 2005 study without reconductoring. The results of this analysis were used together with the capital costs for reconductoring and the marginal costs of power and energy to calculate an internal rate of return for each project.

Table 4.5 summarises the IRR calculation for 66 kV reconductoring on the Nkula A - Chichiri and Nkula B - Mapanga lines. These indicate rates of return of -1.3% for each project, which clearly shows that neither project represents an economically viable loss reduction measure. This is due to the fact that in neither case is the average annual demand increase as great as the 7.2% figure used in deriving the optimisation curves, which are a guide based on system-wide figures. This illustrates the importance of carrying out detailed economic analysis on specific loss reduction projects in parallel with examining trends from system-wide statistics.

A sensitivity analysis was performed to examine the effect of reducing the capital cost of reconditioning from 50% of the new line cost to 30%. This has the effect of decreasing the thresholds for circuit reconditioning to the following levels:

From 75 sq mm to 175 sq mm : 7 MVA
From 100 sq mm to 175 sq mm : 9 MVA
From 125 sq mm to 175 sq mm : 13 MVA

The reduction in reconductoring threshold to these levels does not in practice indicate that any further reconductoring schemes should be considered in the ESCOM transmission system. The effect of reducing the capital costs of reconductoring on the IRR calculations carried out for the Nkula A - Chichiri and Nkula B - Mapanga circuits is to increase the rates of return to 5.2% and 4.4% respectively. These represent marginal levels of return, and these reconductoring projects are not therefore recommended for inclusion in the loss reduction package.

It is recommended that 50% of the new line cost be adapted in considering reconductoring schemes, to ensure that all costs likely to be incurred are represented in the assessment of alternatives.

Figures 4.6 and 4.7 show sets of conductor optimisation curves relating to steel tower lines using the same analysis criteria as for the wood pole cases, except that the capital costs of steel tower construction are somewhat higher than for wood pole, as follows:

75 sq mm	MK 95,000 per km
100 sq mm	MK 105,000 per km
125 sq mm	MK 115,000 per km
175 sq mm	MK 130,000 per km

This results in higher loadings being justifiable at the design stage for new lines and higher reconductoring thresholds, as demonstrated from the diagrams, which show that the 175 sq mm conductor should be used on new lines with demands of over 9.5 MVA and indicate the following reconductoring levels:

From 75 sq mm to 175 sq mm : 10.5 MVA
From 100 sq mm to 175 sq mm : 14 MVA
From 125 sq mm to 175 sq mm : 19.5 MVA

Whilst none of the other 66 kV circuits require reconductoring in terms of these thresholds, the new line loading levels should be utilised by ESCOM in planning transmission system developments. Similarly, the reconductoring levels should be applied as part of a continuing programme of loss monitoring and reduction as the system demand increases.

Figures 4.8 and 4.9 show the new line design loadings and reconductoring loading levels which apply for 33 kV feeders on the ESCOM system. These were calculated using the same economic and financial parameters as for the 66 kV lines, but with the following capital costs for line construction, obtained from the ESCOM data base:

50 sq mm single phase line	:	MK 17,657 per km
50 sq mm three phase line	:	MK 22,970 per km
100 sq mm three phase line	:	MK 32,747 per km
150 sq mm three phase line	:	MK 39,538 per km

The full line construction cost was used in the analysis of reconductoring at 33 kV, to allow for significant pole and insulator replacement as part of the reconductoring exercise.

The new line loadings show that for circuit loads above 2500 kVA a 150 sq mm conductor should be used at 33 kV, as compared with the present ESCOM practice of using a 100 sq mm conductor as the largest size at 33 kV.

The reconductoring loading ranges indicate the following load levels at which transferring to a 150 sq mm conductor is likely to be desirable:

50 sq mm 1-phase to 150 sq mm 3-phase	:	1000 kVA
50 sq mm 3-phase to 150 sq mm 3-phase	:	3000 kVA
75 sq mm 3-phase to 150 sq mm 3-phase	:	4300 kVA
100 sq mm 3-phase to 150 sq mm 3-phase	:	6200 kVA

These reconductoring levels were applied to the 33 kV system in order to identify circuits which would benefit from reconductoring, on the basis of their present peak loading conditions. The circuits from Chichiri to Customs and Fundi's Cross to Thyolo were both found to be close to or exceeding the threshold associated with 75 sq mm conductors, having peak demands in 1990 of 3.82 MVA and 4.92 MVA respectively. (The figure for the Fundi's Cross to Thyolo circuit was obtained assuming that the switching configuration was such as to supply Thyolo B from Chichiri and Thyolo A from Fundi's Cross).

Table 4.6 shows a summary of the loss levels associated with the key years required for the internal rate of return analysis of the two reconductoring schemes, for which 4 km of 150 sq mm reconductoring would be required on the Chichiri - Customs circuit and 35 km on the Fundi's Cross - Thyolo line. The analysis based on the ESCOM capital cost estimates given above is shown in section (a) of Table 4.6, and shows rates of return of 4.3% and 6.9% respectively for the two projects. On this basis, reconductoring of neither would be recommended for inclusion in the loss reduction package.

A further analysis was performed whereby the costs of reconductoring were increased to a level more in line with international budgetary prices than those provided by ESCOM. Whilst it is likely that ESCOM can themselves undertake reconductoring work for the cost levels indicated earlier, it is considered appropriate to assess such projects on the basis of international costings, to ensure that the possible need for contractors from outside ESCOM to carry out some of the projects is fully reflected in the analysis.

The construction cost for a 150 sq mm three phase line, from the KDP data base of international cost estimates, is MK 57,300 per km, which gives the capital costs and IRR figures shown in section (b) of Table 4.6. These indicate rates of return of 0.2% for the reconductoring of the Chichiri - Customs line and 2.3% for the Fundi's Cross - Thyolo line.

From these results, neither project would appear justifiable in financial terms based on international or ESCOM construction costs.

Table 4.7 summarises the technical parameters and construction costs of existing and proposed conductor sizes used in the above analysis of the 132/66/33kV systems.

(b) Voltage Upgrading

Voltage upgrading from 33 kV to 66 kV has been identified by ESCOM as a strategy to reduce the problems of voltage regulation in some of the long rural 33 kV feeders on the system. The extent to which this can be justified as a loss reduction measure has been examined, as detailed below for the case of the Mtunthama 105 feeder. This feeder is at present operating with some 74 km of 75 sq mm AAAC overhead line running at 33 kV from Nkhotakota to Mtunthama, from where a circuit runs to Kasungu and a number of distribution transformers are supplied at both 33 and 11 kV.

Load flow studies were performed for the present operating configuration and then for the situation with the 74 km section of transmission line operating at 66 kV instead of 33 kV. The power losses on the feeder were calculated in each case, and the energy losses were obtained using the load factor and loss factor calculated from Dranetz measurements of the feeder demand.

Internal rate of return calculations were carried out based on these results and using two different approaches to the capital costs involved with the voltage upgrade. In the first case, the fact that this particular line was originally constructed for 66 kV operation but is actually running at 33 kV was taken into consideration. Consequently there is no cost associated with line construction to be considered, but only that of the substation work required at Nkhotakota and Mtunthama. The capital cost associated with this, from ESCOM's cost estimate for the project, is MK 1.05 m. Table 4.8 shows a summary of the calculation, indicating an internal rate of return of 16.8% for the project as a loss reduction measure.

The remainder of the table shows the results of analysis on the basis of costs associated with the substation works and construction of a new 66 kV line, which would be necessary in the case of a line initially constructed for 33 kV operation. This shows an internal rate of return of -2.3%, which is clearly indicative that in this situation the project would not be viable as a loss reduction strategy.

These results indicate that even in the case of a feeder with a relatively high load factor (75.5%), if capital costs of constructing a new 66 kV line are associated with conversion to 66 kV operation, such a project is unlikely to be viable for loss reduction.

In the case of the Mtunthama 105 line, upgrading is justifiable as a loss reduction measure, due to the reduced capital costs involved with the project. This measure has therefore been included in the programme presented at the end of this report.

(c) Compensation

The Least Cost Development Plan for the ESCOM system included in its recommendations the installation of static compensation to be located at Lilongwe in order to improve the power transfer capability of the 132 kV circuits running north from Nkula. Whilst the capital cost associated with SVS equipment is such as to make its introduction an uneconomic proposition when viewed solely from the loss reduction angle, there will clearly be a benefit in terms of reduced losses associated with its introduction as part of the development of the transmission system.

In view of the work currently being carried out in the Transmission and Distribution Study being performed for ESCOM, detailed analysis of the effects of compensation on the losses on the transmission system has not been performed. Any recommendations for the introduction of compensation which are made in the T&D study should however be considered with a view to the potential benefit to be gained by accelerating the timescale for its installation to gain from the effects of loss reduction.

The precise nature of the compensation should also be considered in detail, to ensure, for example, that the appropriate combination of distributed switched capacitors and fully controlled compensation equipment is used to minimise losses on the system whilst maintaining satisfactory reactive power flows and voltage profiles at times of minimum demand.

4.2.3 Comments

It is clear from the work described above that there are very few loss reduction projects which may be economically undertaken on the ESCOM transmission system to reduce losses below the levels which will be achieved following the introduction of the transmission projects already programmed by ESCOM as part of their system development proposals.

The emphasis of such studies as the present Transmission and Distribution Study must be to ensure that losses are maintained at an economic level, which would appear to be in the region of the 6.7%

energy loss level existing on the system at present. Careful monitoring and analysis of losses in the context of the design and reconductoring loadings discussed above will enable ESCOM itself to ensure that its planning policies are developed in line with loss minimisation strategies.

4.3 11 kV Systems

4.3.1 Introduction

In order to assess the scope for loss reduction on the 11 kV sections of the ESCOM system, a sampling approach was adopted whereby as large a number of 11 kV feeders as possible in the study period were analysed to produce results from which a wider programme of loss reduction measures could be developed.

This necessitated detailed measurements of load distributions on the 11 kV systems in Blantyre and Lilongwe, from which load flow models were produced to enable existing feeder loss levels to be calculated.

Loss reduction measures were then applied to these feeders and analysed from both technical and economic viewpoints to establish viable strategies for reducing 11 kV losses. These were then applied at a wider scale over the 11 kV systems as a whole to produce a programme of measures to be included in the final loss reduction package.

4.3.2 11 kV feeder Monitoring

Extensive programmes of feeder monitoring were carried out on the 11 kV systems in Blantyre and Lilongwe to provide the basic data necessary to carry out load flow analysis of individual feeders and groups of feeders to assess loss reduction strategies. The monitoring comprised measurements of power demand, power factor and sending end 11 kV voltage obtained using Dranetz power demand analysers, together with physical surveys of feeder lengths and conductor sizes, and the measurement of transformer LV currents, voltages and power factors. The process whereby these measurements are combined to enable load flow analysis to be performed is described below for a typical feeder.

Figure 4.10 shows the power demand profile obtained for Blantyre Main substation feeder 5L5 over a twenty-four hour period from Thursday 9th to Friday 10th August 1990. The Dranetz averages the power demand on the feeder over a 10 minute interval, so that a smooth demand profile is obtained, rather than the fluctuating profile which would otherwise result from taking instantaneous demand measurements. From this plot it can be seen that the peak demand on 5L5 is just under 2 MW, and that this demand coincides with the system peak at approximately 18:30. The demand gradually decreases through the evening, reaching a steady minimum level during the small hours of the morning, and then builds up from about 05:00 onwards, reaching a morning peak of about 1.6 MW. The load level decreases slightly through the morning until lunchtime, when there is another clearly defined increase in demand to around 1.5 MW, after which the load decreases before building up for the evening peak again.

This feeder demand profile is characteristic of a feeder supplying a predominantly domestic load, with some commercial load contributing to the morning and afternoon demands.

Figure 4.11 shows the corresponding power factor profile for feeder 5L5, once again giving the average power factor over a ten minute period. This shows a steadily increasing power factor up to an average of 0.98 at the peak feeder demand, followed by a gradual decrease towards 0.91 through the evening and into the night. This reflects the gradual disconnection of resistive domestic loads such as electric cookers, lights, water heaters, etc, so that in the middle of the night the comparatively poor power factor results from such loads as air conditioners and refrigerator compressor motors which run throughout the night, together with the low power factor associated with transformer iron losses on the feeder. The power factor builds up again during the early morning as domestic and commercial consumers turn on more resistive loads, and then decreases during the afternoon before the evening peak build up.

The 11 kV voltage variation at Blantyre Main during this period is shown in Figure 4.12, from which the action of manual and automatic tap changers on the system can be clearly observed with sudden increases in voltage during the evening around the peak load period, followed by tapping down during the night and tapping up again in the morning. The voltage level on the 11 kV busbars is generally maintained at a healthy level between 1.01 and 1.05 pu to maintain the system voltage at the remote ends of the 11 kV feeders. The 'peaky' nature of the voltage profile reflects the fact that the Dranetz records instantaneous voltage values as opposed to average values, with the consequence that local load variations will show up more clearly as fluctuations on the overall voltage waveform.

During the period for which the Dranetz was connected to monitor feeder 5L5, measurements of transformer currents and, where possible, voltages and power factor were made at each 11 kV/400 V transformer. The results are summarised in Table 4.9, in which the total demand is calculated from the current measurements and either measured voltages and power factors or assumed values based on the peak load conditions of the transformer. The appropriate factor is then used to multiply the measured load up to what it would be at the feeder peak loading condition, by obtaining the ratio of the monitored feeder load at the time each transformer was measured to the peak load recorded by the Dranetz. This scaling technique is only applied to those transformers for which specific Dranetz measurements have not been made as part of the LV system survey work discussed in Section 4.4, and to those transformers supplying loads which are typical of those supplied by the feeder as a whole. In the case of industrial or pumping loads, together with maize mills, for which the loading is dependent upon specific items of plant being on or off, estimates are based on the likely running condition of the plant at the time of feeder peak.

Using this method it may be observed that the total predicted loading on the transformer peak comes out to 1989.9 kW, which compares favourably with the Dranetz recorded peak demand of just under 2 MW. The resulting transformer loads were then used as the basis for a load flow of the 11 kV feeder.

4.3.3 Present Loss Levels

Load flow studies were performed for a number of the 11 kV feeders in Blantyre and Lilongwe for which load measurements had been obtained, using both the KDP LF software, with which ESCOM engineers were already familiar, and the DPAS package, which was introduced as part of the Loss Reduction Study. The use of both packages enabled as large a number of feeders as possible to be analysed during the study period by both KDP and ESCOM engineers.

Table 4.10 shows a summary of the results of these studies, indicating for each feeder the peak demand, load factor and loss factor, together with the percentage peak power and energy losses. The load factor is calculated from the Dranetz demand measurements as the ratio of the average demand to the peak demand over twenty-four hours. The loss factor is similarly obtained from these results as the ratio of the average of the squares of the demand to the square of the peak demand. The peak percentage power loss is obtained from the feeder load flow results and converted into a percentage energy loss by multiplying by the ratio of the loss factor to the load factor.

The results obtained indicate an average 1.5% energy loss associated with the range of feeders analysed, which included some circuits such as Lilongwe B 3L5, supplying predominantly industrial loads, as well as those supplying more general loads.

The assessment of alternative strategies for reducing the losses on the 11 kV systems is discussed below.

4.3.4 Loss Reduction Strategies

A number of potential loss reduction strategies have been investigated with regard to the losses on the 11 kV system. These have been examined both with regard to their technical viability and their relative economic merits.

The application of capacitors at 11 kV is a strategy which, whilst on many systems being likely to represent an economically attractive proposition due to the relatively low cost of 11 kV capacitor banks, has limited scope for application in the ESCOM system due to the generally good power factors at 11 kV. This is particularly clear when it is borne in mind that it is undesirable to compensate to a level greater than that required to give unity power factor on the feeder at periods of minimum demand, to avoid problems of overvoltages occurring if the capacitors are to remain in service permanently. Switchable capacitors are an option which could be considered if there were significant differences between power factors at maximum and minimum demand levels, although there is a cost penalty associated with this extra degree of sophistication.

Feeder reconductoring is a loss reduction alternative which has far greater scope for application on the 11 kV system, particularly given the existing maximum 11 kV overhead line conductor size utilised by ESCOM of 100 sq mm. It is proposed that a new 150 sq mm conductor size be introduced at 11 kV on feeders which are running at load levels above the optimum for 100 sq mm conductors; detailed technical and economic analysis of this and the other loss reduction measures considered on the 11 kV system are given below.

(a) 11 kV Reconductoring

The starting point for the analysis of reconductoring options at 11 kV is the examination of conductor optimisation curves as in the transmission system analysis described earlier.

A series of curves were produced based on the following data:

Analysis Period: 15 years
Annual Demand Growth Rate: 8.5% - Southern Region
7.6% - Central Region

Load Factor)
Loss Load Factor) Feeder dependent

Marginal Power Cost: 445.28 MK/kW
Marginal Energy Cost: 0.045 MK/kWh

The growth rates shown are average annual values obtained from the load forecast for feeders supplying a mixture of load types, ie, combinations of small industrial, commercial and domestic premises. The load factors and loss factors observed for the feeders which were analysed using Dranetz measurements and load flow analysis varied quite widely,as shown in Table 4.10, and individual optimisation curves were thus generated to examine the sensitivity of reconductoring thresholds to load and loss factors.

The following capital costs for line construction, obtained from the ESCOM cost database, were used in generating the optimisation curves:

50 sq mm	MK 18,924 per km
100 sq mm	MK 28,561 per km
150 sq mm	MK 32,280 per km

Reconductoring costs at 11kV have been taken as 100% of the new line cost, to allow for such contingencies as pole and insulator replacement which may be necessary to accomplish reconductoring successfully.

Table 4.11 shows the results of optimisation studies in terms of the loading on 50 sq mm and 100 sq mm conductors at which it becomes viable to transfer to a 150 sq mm conductor to minimise net present value operating costs. These loading levels are shown for a number of load factors, using the Southern Region average growth rate in section (a) of the table, and for a number of growth rates with the load factor fixed at the overall system value of 62.3% in section (b).

These results show an increase of 18% in the reconductoring thresholds over a range of load factors from 48.4% to 90.1%, the extremes of the sample obtained from Dranetz measurements. This suggests limited sensitivity of the loading levels at which reconductoring should be utilised to load factor variations, particularly in view of the role of this type of optimisation technique as a tool in the preliminary identification of potential loss reduction projects, which are then subjected to more detailed economic analysis to establish their viability.

Section (b) to Table 4.11 shows a difference of some 65% between the load levels at which reconductoring to a 150 sq mm conductor becomes viable over a range of annual growth rates from 8.5% to 2.0% over the fifteen year analysis period. This represents a much more significant sensitivity to growth rate than was the case with load factor, and suggests that great care needs to be taken when applying the regional load growth factors to specific feeders as the basis for conductor optimisation. Figure 4.13 shows in graphical form the implications of these results in terms of the bands in which reconductoring should be performed with regard to both conductor loading and load growth rate, and indicates the lowering of the reconductoring thresholds as the annual load growth varies from 0 to 10%. The impact of growth rate variations on the specific 11 kV reconductoring proposals developed for the ESCOM system is discussed in more detail below.

Further analysis was performed to examine the sensitivity of the reconductoring thresholds to a different form of load growth variation, whereby an 8.5% annual growth was applied over a seven year period, and the feeder load level held constant thereafter for the remainder of the fifteen year analysis. This growth pattern could reflect the possible introduction of other lines and substations due to system enhancement which would tend to limit the growth of demand on an existing circuit.

The results of this analysis are summarised below, with figures from the analysis with full fifteen year growth shown for reference. The thresholds are given in kVA, and percentage of the rating of the line with the smaller cross-sectional area, and are based on an 8.5% annual growth rate at the system load factor of 62.3%.

11kV Reconductoring	7 Year Growth	15 Year Growth
50 sq mm to 150 sq mm	980 (23%)	800 (19%)
100 sq mm to 150 sq mm	1920 (30%)	1580 (25%)

These show an increase in the threshold levels at which reconditioning would become viable to levels which are appropriate for adoption as the starting point for indentification of potential loss reduction projects.

Sample reconductoring projects were initially identified on the basis of the 8.5% and 7.6% growth rates for the Southern and Central regions, and then examined in terms of economic viability. Having performed detailed analysis for the sample projects, a wider programme of reconductoring was prepared based on the same selection criteria that yielded sample projects giving acceptable economic rates of return. This necessitated examination of each feeder to determine its peak demand, from Dranetz measurements, its conductor sizes and lengths from the physical line surveys and its approximate load distribution. The latter factor was assessed from load flows, in the case of the detailed sample analyses, and from an assessment of transformer sizes and locations from single line diagrams for the remaining cases.

As part of this analysis, cable reconductoring has been considered in cases where the thresholds for reconductoring indicated in Figure 4.14 are exceeded. These levels have been prepared on the basis of ESCOM cost estimates for 3 core copper XLPE cables, of which the details are as follows:

240 sq mm	236,200 MK/km
185 sq mm	208,000 MK/km
120 sq mm	150,400 MK/km
70 sq mm	63,000 MK/km
16 sq mm	42,800 MK/km

It may be observed from Figure 4.14 that for the case of replacing existing cables by a 240 sq mm size, the loadings at which this becomes justified are very close to, or in excess of, the cable thermal ratings. In uprating cable capacity for loss reduction purposes, the normal procedure to be adopted would be to install a second cable in parallel with the existing cable to obtain the desired overall cable cross-section. In many of the cases observed on the ESCOM system however, cables that would justify action to reduce losses are already overloaded or will be by the time reconductoring can be implemented.

It is thus proposed that in these cases a single replacement 240 sq mm cable is installed to avoid potential operational problems that may result from continuing to use a cable that has already suffered the stresses associated with operating under overload conditions.

Whilst the replacement of overloaded cables could be viewed as a technical necessity the costs of which should not entirely be borne by loss reduction projects, in practice, as is demonstrated below, the rates of return for most of the proposed projects are sufficiently high not to be affected by the inclusion of the full cable replacement cost where necessary. In one case however a project becomes viable through the apportionment of part of the cable cost to system development.

Table 4.12 shows a summary of internal rate of return calculations which have been performed for reconductoring projects identified on the basis of the techniques described above. The costs used in the IRR calculation have been increased over those provided from the ESCOM data base to allow for international tendering in the event, as discussed earlier, of external agencies being required to undertake the work due to ESCOM resource constraints. Table 4.13 summarises the ESCOM and KDP international budgetary prices for reconductoring, together with the resistance values for the alternative conductor sizes. This gives the following international component costs for reconductoring:

150 sq mm AAAC overhead line: 47,600 MK/km
240 sq mm Cu XLPE cable: 354,000 MK/km

Table 4.12 indicates the generally very good rates of return associated with reconductoring projects identified from optimisation of conductor sizes and confirms the value of undertaking 11kV reconductoring as a loss reduction strategy on the ESCOM system. These have been assessed using quite stringent analysis criteria, whereby the appropriate annual growth rate (7.9% for the Southern Region from 1991 to 2000 and 7.6% for the Central Region over the same period) was applied until the existing feeder under examination reaches its thermal rating. The same amount of growth was then applied to the reconductored line, and the benefits calculated over a fifteen year period assuming no further load growth beyond the thermal rating of the line before reconductoring. This method is somewhat pessimistic, since it takes no account of the ability of the reconductored circuit to supply greater demand levels than the existing line. The rates of return calculated indicate however that from consideration of losses alone the projects are viable.

In the case of Group feeder 202, in which the existing 70 sq mm cable is exceeding its thermal rating at present peak demand levels, benefits have been calculated using a proportion of the capital cost for installation of a 240 sq mm cable equal to the difference between the cost of a 240 sq mm cable and that of a 120 sq mm size, the minimum required to relieve the exisitng cable overhead.

Table 4.14 lists the wider programme of 11 kV reconductoring projects identified for the system as a whole, detailing the feeder names, their peak demands, the length of lines requiring reconductoring, together with details of the sections to be replaced and the total cost for each feeder. From this it may be seen that a total 11 kV reconductoring package of MK 3.9 m is recommended for implementation as part of the loss reduction project.

Examining these projects in the context of the variation of reconductoring thresholds shows that the vast majority of feeders on the list are operating at load levels above those which at 0% growth rate would still show benefits from reconductoring over a fifteen year period. In the following four cases, reconductoring would show marginal benefits if an annual growth rate of below 5% were sustained:

Blantyre Main 5L5
Chileka 3LO
Limbe 5L5
Lilongwe B 4L5

In only one case (that of Lilongwe B feeder 2L5) would reconductoring become unjustified if the forecast annual growth rate of 6.7% were not maintained.

On this basis, it is not considered that the 11 kV reconductoring programme as a whole is significantly influenced by variations in load growth rate, and the package should be implemented in its entirety as part of the loss reduction project.

Figures 4.15 and 4.16 show the conductor optimisation curves based on the ESCOM line costs and using an 8.5% growth rate applied over seven years and a fifteen year evaluation period to determine design loadings for overhead lines and underground cable circuits at 11 kV. These should be used as a guide in the design of future system expansion projects to ensure that these are carried out in accordance with loss minimisation strategies.

(b) Capacitor Placement

Capacitor placement offers limited scope for implementation as a loss reduction strategy on the ESCOM system, due to the generally good power factors occurring across the system. The only feeder likely to benefit from the application of capacitors is Lilongwe B feeder 6L5. This has a power factor at peak of 0.9 at present, and feeds a predominantly industrial load, having a load factor of 84.6%. The existing energy loss level of 1.2% is slightly lower than the average for the 11 kV system. A total of 600 kVAr of capacitance should be applied to the feeder by 2005, with 200 kVAr being installed in 1991. These levels were derived from the results of the Dranetz measurements which indicated that a maximum of 200 kVAr of compensation could be accommodated on the feeder initially to give a unity power factor at minimum feeder demand. This value should be increased to 600 kVAr on a pro-rata basis with the increasing feeder demand, projected from the Central Region annual growth rate of 7.6%.

In general, the benefits of capacitor placement are significantly affected by the positioning of the capacitors on the line; for maximum benefit a distributed approach is necessary to ensure a uniform reduction in the reactive power flow along the feeder and a consequential lowering of the loss level. International experience shows that placing of capacitors at approximately one-third and two-thirds of the total feeder length represents an effective distribution of reactive power support. In the case of Lilongwe B 6L5 these positions coincide with the main tee-offs supplying the industrial loads on the feeder, and these therefore represent optimum positions for the capacitors.

Table 4.15 shows the details of internal rate of return calculations for the reconductoring proposal for 6L5 shown in Table 4.14, the installation of capacitors without reconductoring and the execution of both reconductoring and capacitor placement. The capacitor costs were calculated on the basis of current international budgetary estimates of MK 3,400 per 100 kVAr static capacitor bank. The rates of return for these measures are calculated using seven years' load growth, bringing the feeder loading to its thermal limit, at which stage the feeder demand is held constant for eight further years. In seven years of load growth, only 2 x 100kVAr capacitors would be required, and costs for these are therefore shown in the analysis. The results clearly demonstrate that both the loss reduction projects proposed for this feeder are viable, giving an overall rate of return of 12%. Both are therefore included in the final loss reduction package.

(c) 11 kV System Reconfiguration

Reconfiguration of the 11 kV system to minimise losses will inevitably be influenced to a large extent by the introduction of new bulk supply points, new feeders and the uprating of feeders to higher operating voltages, all of which will undoubtedly form part of the Transmission and Distribution Study currently being performed for the ESCOM system. Until such plans are finalised it is difficult to optimise the configuration of the system in such a way as to ensure that losses are minimised. A case in point is that of Lilongwe B feeder 2L5, which at present has a high loss level of 7.7%, primarily caused by its supplying a relatively remote load which is due to be catered for by a new 33/11 kV substation proposed by ESCOM, which will presumably be viewed in the context of the recommendations of the Transmission and Distribution Study.

Whilst the Loss Reduction Study can strongly recommend that this action should be taken to alleviate an existing high loss situation, such considerations as the sizing of, and possible interconnection of other feeders to, the new substation can only be assessed as part of overall system development plan, which should incorporate loss minimisation as one of its primary objectives. It is thus recommended that such techniques as optimising the open points between feeders by analysis of the power flows occurring on adjacent lines in a closed mode of system operation should be included in the analysis forming the basis of the development plan for the ESCOM system, and that ESCOM should themselves examine the effects of switching operations on losses as part of their normal operational planning procedure.

The use of these techniques coupled with the design guidelines developed in this report will ensure that the loss reduction achieved by the specific projects proposed here is extended in its effectiveness into the planning and operational aspects of the ESCOM system.

4.4 11/0.4 kV Transformation and LV Systems

4.4.1 Introduction

Detailed analysis has been performed for sample 11 kV and LV networks in the ESCOM system, to evaluate existing levels of losses associated with 11/0.4 kV transformers and LV distribution. Methods of reducing these losses have been examined using transformer and conductor optimisation, the latter in terms of conductor size selection on the basis of both loss levels and voltage performance, in order to establish design rules for the planning of the distribution system and to develop cost estimates for programmes of transformer replacement and LV reconductoring across the system.

Whilst all of these measures will reduce losses, and are shown to do so in an economically viable way, it is clear that to fully optimise the performance and development of the existing LV systems and their associated transformers necessitates a coordinated approach to the addition of new transformers and the extension or reconfiguration of the LV systems. The importance of integrating specific loss reduction projects with the planning of the distribution system is such that it can only be fully assessed by means of a detailed study, as part of which a complete data base of all the LV systems supplied from a number of 11 kV feeders is formulated, which can then be used to optimise the positioning of transformers and open points between LV systems.

The magnitude of the task required to achieve this is such that it cannot be fully addressed in a system wide loss reduction study of this type. One of the recommendations detailed below therefore includes for the execution of such a study, which would necessitate a significant exercise in data collection of the type which was very effectively started by ESCOM in formulating the data base for the sample studies carried out in this project. Further details of this and the other loss reduction strategies examined for the LV distribution systems and associated transformation are given below.

4.4.2 11/0.4 kV Transformer Losses

The losses associated with 11 kV/LV transformers were evaluated explicitly for a number of feeders in Blantyre and Lilongwe for which detailed surveys had been performed as part of the 11 kV feeder analysis. The data base used in the calculation of losses for transformers of different ratings is shown in Table 4.16. The core and winding loss figures were obtained from tendered values for transformers supplied to ESCOM, with the exception of those for the 15 kVA and 400 kVA sizes, for which the same percentage impedances were used as for the 25 kVA and 500 kVA sizes respectively.

For each feeder the total transformer core energy losses were calculated as the sum of the core power losses associated with each transformer on the feeder multiplied by twenty-four hours, to obtain a daily core energy loss figure. For the winding losses, the peak loading on each transformer was obtained from the load distribution used as the basis for the 11 kV load flow studies, the associated peak winding power loss was calculated, and then multiplied by the transformer loss load factor and twenty-four hours to obtain a daily winding energy loss figure. The transformer loss load factor was assumed equal to the feeder loss load factor unless the transformer had been specifically monitored with the Dranetz analyser. The total of the two energy loss figures was then compared with the energy supplied to the feeder over twenty-four hours to obtain a percentage transformer loss figure for each feeder.

The results of this analysis for the sample feeders studied are shown in Table 4.17. This indicates an average energy loss level of 1.8% associated with 11/0.4 kV transformation, with an average transformer utilisation factor of 46%. In general it will be observed from the table that as the transformer utilisation factor increases, the balance shifts from core losses to winding losses, reflecting the increasing effect of the load current on the total losses in the transformer.

The optimum utilisation factor for a distribution transformer of a given size may be obtained by calculating the annual cost of losses based on a given peak demand and loss factor, and including a component for the annuitised capital cost of the transformer. Figure 4.17 shows a set of curves indicating the annual operating cost for a variety of transformer sizes in use on the ESCOM 11 kV system, based on the capital costs and percentage losses shown in Table 4.16. The system load factor of 62.3% (with a corresponding loss factor of 45.8%) was used in calculating the cost of losses, together with the marginal power cost of 527.98 MK/kW which applies for losses as far as the LV system. The analysis was performed using a 15 year period for the annuitisation of the transformer capital costs.

These curves show that for each transformer size it is preferable in terms of minimising operational costs to supply loads of up to the transformer rating before switching to a larger size unit. This implies that for loss minimisation it is preferable to replace transformers progressively as loading increases, rather than to use a transformer sized for the maximum projected demand which will be experienced in a number of years' time from the start in a particular location.

The curves indicate that there is in fact nothing to be gained by introducing an intermediate size between 200 kVA and 500 kVA in terms of losses; indeed it is generally advantageous to minimise the number of transformer swaps that are required to cater for load growth, whilst aiming to minimise the annual operating cost of the transformers, so as to avoid unnecessary work being programmed into the utility's operation.

Figures 4.18 and 4.19 show similar curves plotted for the cases of 90% and 40% load factors respectively. These indicate very little variation in the transformer loading levels at which uprating is recommended over this range of load factors. This insensitivity to load factor variation demonstrates that the overall principle of transformer uprating only when the transformer rating is reached is suitable for application on a system wide basis.

A number of sample transformer optimisation studies were carried out in order to alleviate overloads identified from the load distributions used for feeder load flow studies, and to improve utilisation factors by removing over-rated transformers, to be redeployed elsewhere on the feeder, and replacing them with smaller units. In practice, accurate measurements of individual transformer peak demands would be examined prior to replacing them; given the accuracy of the measurement and scaling process used to estimate feeder load distributions however, a reasonable overall trend may be expected to emerge from this sort of analysis, to enable budgetary estimates of transformer replacement costs to be prepared.

Table 4.18 shows transformers which would be replaced on Group Substation Feeder 202, on the basis of the estimated load distribution. This illustrates cases such as that of transformer number 30, which would be uprated to 200 kVA, having reached its 100 kVA rating at peak demand, together with examples such as number 10, where a 200 kVA unit would be replaced by a 100 kVA size, in the presence of a peak demand of 57 kVA. The first of these examples would release a 100 kVA transformer which could be swapped with the 200 kVA released in the second case, thereby avoiding the purchase of an additional unit.

Table 4.19 extends this principle for the remaining transformer replacements identified, from which it is concluded that the twelve changes recommended result in the need for four new transformers, with four units of different ratings being placed in the stores for future use, assuming that their condition is such as to make this a viable option. The capital costs associated with purchasing the new transformers are based on international budgetary figures, and the labour charges for each replacement are based on ESCOM's current rates for the required teams. A total cost of some MK 49,000 is associated with the transformer replacements on Group Feeder 202.

In calculating the internal rate of return associated with this work, streams of losses were calculated based on the use of transformer sizes determined from the optimisation curves, compared with a situation in which transformers are replaced if they are overloaded by more than 20%, and then replaced with the next standard size. No residual value is attached to transformers which are released to go into the store, to take into account the fact that some such units will be beyond the end of their economic lives, or have problems which may present them from being worth re-installing on the system. On the basis of these assumptions an internal rate of return of 17% was calculated for the proposed transformer replacement programme. This represents a worthwhile project to pursue, and validates this approach to transformer sizing as appropriate for application on a system-wide scale.

Table 4.20 shows the results of similar replacement exercises implemented on a sample of 11 kV feeders in Blantyre and Lilongwe, in terms of the number of transformers to be purchased for each feeder and leading to the development of an overall percentage of the installed capacity on the sample feeders which needs to be purchased, split into 50 kVA, 100 kVA, 200 kVA and 500 kVA unit sizes. These percentages are then applied to the total existing 11/0.4 kV transformer capacity on the interconnected system, to produce estimates of the number of units for each size required for budgeting purposes. This results in an estimated MK 2.8 m requirement for new distribution transformers, which is included in the total package summarised at the end of the report.

4.4.3 Capitalisation of Transformer Losses

The transformer capitalisation formula used by ESCOM to assess alternative transformer sizes in terms of losses requires some modification in view of the long run marginal costs of power and energy which have been calculated as part of this study.

The present formula used by ESCOM is as follows:

$a_{po} = C_k + C_w * T_{op}$ (Mk/kW year)

$a_{pl} = (C_k * O + C_w * S * T_{op}) * (M_r)^2$ (Mk/kW year)

$A_{po} = a_{po} * CV$ (Mk/kW)

$A_{pl} = a_{pl} * CV$ (Mk/kW)

where

a = assessment of losses per year

po = no load losses

pl = load losses

C_k = kW demand cost, Mk 333.00/kW

C_w = kWh energy cost, Mk 0.07/kWh

CV = cash value factor, based on 25 years at 15%

T_{op} = operating hours, 8760 per year

O = coincidence factor, 0.95

S = kWh loss factor, 0.33

M_r = capacity factor, 0.65

It is recommended that the following values are used for analysing 11/0.4 kV transformers:

Marginal cost of power: 527.98 MK/kW
Marginal cost of energy: 0.045 MK/kWh

In addition it is felt that for long term analysis the discount rate of 15% presently used is somewhat too high, and that a value of 10% would be more appropriate, as used in the economic analysis performed in this study.

4.4.4 LV Feeder Losses

(a) Present Losses

A number of sample LV systems were monitored in Blantyre and Lilongwe, using Dranetz demand analysers mounted alongside the 11 kV/0.4 kV transformer supplying the system, in order to measure directly the LV phase voltages and currents.

Whilst the Dranetz was connected at each transformer under investigation, measurements of currents and voltages at various points on the LV systems supplied from the transformer were recorded, together with details of feeder lengths and conductor sizes obtained by a line crew carrying out a physical survey. This information was used as the basis of a full three phase load flow, to determine existing loss levels, and to assess loss reduction measures.

Figure 4.20 shows the demand profile obtained for the 315 kVA Browns Road transformer, which is supplied from the Blantyre Main feeder 5L5. The plot shows that the Browns Road transformer is not in fact typical of the 5L5 feeder as a whole, in that it supplies a predominantly commercial load which peaks at about 10:00, with no significant load increase at the time of the overall system peak. The power factor profile of Figure 4.21 shows similar characteristics to those observed for other commercial feeders, with increasing power factor during the evening, but with lower power factors during the day due to air conditioning and other motor loads associated with some very small industrial consumers.

The average phase voltage profile shown in Figure 4.22 shows indications of tap changing further up in the system, coupled with the effects of local load changes. The voltage at the transformer end of the LV system is maintained between 226 and 237 V, which is within the tolerance permitted by ESCOM of plus and minus 6% on the nominal 230 V supply.

Figure 4.23 shows a plot of the demand on each phase of the Browns Road transformer during the monitoring period, and indicates quite significant imbalance between the three phases in terms of loading, particularly around the peak demand periods, when the blue phase is loaded to typically only 60 - 70% of the load on the other two phases. This is reflected in the voltages measured at the ends of the LV feeders, which showed differences of up to 17 V between the voltage on the red and yellow phases and that on the blue phase, resulting in phase voltages to consumers which are outside the ESCOM statutory limit. Detailed three-phase analysis has been performed for four LV systems using a computer spreadsheet model to calculate the power loss in each section of the circuit between services, and to assess the approximate losses occurring in the services themselves. The percentage energy losses calculated from the analysis of two 'average' LV systems and two 'poor' LV systems are shown in Table 4.21. These indicate a range of values from 3.6% to 7.8% losses, together with minimum feeder voltages which are in all cases below the statutory 6% deviation from 230 V permitted by ESCOM.

(b) Loss Reduction

The main loss reduction strategies which have been considered for implementation on the system LV systems comprise the balancing of LV loads to reduce the large differences in currents between the phases, which are observed in many of the LV systems, and the introduction of a new 150 sq mm conductor at low voltage on the overhead line lengths carrying the main feeder currents. In addition, design guides for the selection of LV conductor sizes have been prepared, both in terms of losses and of voltage performance of each conductor against power transfer level and feeder length.

Figures 4.24 and 4.25 show conductor optimisation curves which have been developed for the 400 V systems on the ESCOM network, based on the fifteen year analysis of losses and using the Southern Region average annual demand growth rate of 8.5%, together with the marginal costs of energy and power, the latter being the 527.98 MK/kW figure which applies at LV. These indicate that for new lines, loads above approximately 28 kVA should be supplied using a 150 sq mm conductor. In the case of reconductoring, thresholds are indicated at 27 kVA for replacing 50 sq mm conductors by the 150 sq mm size and 56 kVA for upgrading from 100 sq mm to 150 sq mm. Table 4.22 summarises the conductor parameters and construction costs which apply at LV. The full line construction costs have been assumed for reconductoring, to allow for any pole/insulator replacement that may be necessary in the reconductoring process.

These reconductoring and design loading thresholds are summarised below, together with the results of further analysis which was performed to examine the effect of applying seven years' load growth and then holding the load level constant for a further eight years, to reflect the possible introduction of additional transformers (LV systems which would tend to limit the growth of existing systems.

LV New Lines	7 Year Growth	15 Year Growth
50 mm^2 to 150 mm^2	21 kVA	17 kVA
100 mm^2 to 150 mm^2	33 kVA	20 kVA

LV Reconductoring	7 Year Growth	15 Year Growth
50 mm^2 to 150 mm^2	33 kVA	27 kVA
100 mm^2 to 150 mm^2	68 kVA	56 kVA

It is considered that the 7 year growth figures represent a more realistic load growth scenario, and should therefore be adopted as design thresholds.

Figures 4.26 to 4.28 show power circle diagram plots for 50, 100 and 150 sq mm conductors which represent the maximum load that could be supplied at 0.95 power factor (a typical power factor at peak load associated with the ESCOM LV systems) over 1 km for each conductor size. The levels may be established from the intersection of the 0.95 power factor line and the power circles corresponding to the desired maximum voltage drop which may be tolerated in the line. All of the curves assume a maximum voltage of 105% of nominal at the transformer LV terminals, so that a 10% voltage drop over the length of the line may be accepted whilst ensuring that the 6% statutory limit on undervoltage at the consumers' premises is not infringed.

The following kW - km limits apply from these curves for the three conductors considered assuming a 0.95 power factor and a 10% maximum voltage drop.

50 sq mm : 24 kW - km
100 sq mm : 42 kW - km
150 sq mm : 58 kW - km

These limits may be applied to determine the technical loading limit for conductors in terms of voltage drop, in order to define maximum LV system lengths for specific loadings. For example, a 100 sq mm conductor may be used to supply up to 42 kW over 1 km, or 84 kW over 500 m, 168 kW over 250 m, etc.

It should be noted that these figures represent terminal loading levels, ie. loads lumped at the remote end of a given length of line. In the case of distribution lines these thresholds are usually applied in conjunction with the load moment of the feeder, ie. the sum of the products of loads and distances from the transformer, to produce an equivalent distance at which the total transformer load may be applied to give an indication of the voltage performance of the line.

LV reconductoring analysis has been performed for sample LV systems on the basis of the reconductoring curves and the circle diagrams to identify cases where 150 sq mm could be used to reduce losses and improve technical performance of LV circuits. Table 4.23 shows the detailed results of technical and economical analysis of reconductoring in accordance with the conductor optimisation curves carried out on the Browns Road LV circuit which was analysed in the assessment of existing loss levels. This indicates that 390 m of 100 sq mm conductor should be replaced by the new 150 sq mm size. The table shows the losses and minimum voltages associated with operation in the years 1990, 1991 and 2005. In order to represent a realistic situation, it has been assumed that this

LV feeder would be used to supply a load up to a proportion of the transformer rating equal to the present proportion of the transformer maximum demand which it carries. It is then assumed that future demand growth beyond the transformer rating would be catered for by a separate LV system and transformer. This prevents analysis in 2005 from being carried out on a scenario in which the feeder would not be capable of operation.

These results show an initial reduction in energy losses from 4.7% to 3.1% following reconductoring, with an improvement in the minimum feeder voltage to 202 V. This minimum voltage would be further improved by adjusting the transformer tap to its +5% setting instead of its nominal setting as at present. This is a measure which is recommended for implementation across the whole system, as during the survey work it was discovered that the vast majority of the distribution transformers are operating at nominal tap in situations where low LV voltages are nevertheless a problem and the cause of complaints from consumers.

By 2005 the losses on the Browns Road circuit under investigation will have deteriorated to 4.8%, with a minimum voltage of 188 V. Economic analysis using streams of losses based on these results show an internal rate of return of 19.3% for this reconductoring project, assessed in terms of an international budgetary cost of MK 46,105 per km for the construction of a 150 sq mm LV line. This demonstrates that reconductoring carried out on the basis of the conductor optimisation techniques described above represents an economically viable approach to loss reduction on the LV systems.

Reconductoring requirements have been assessed for a number of sample feeders on the LV systems, in order to establish an approximate percentage of the overall LV feeder lengths which should be reconductored, and to calculate a budgetary allowance for such an undertaking in the loss reduction project. The results of this analysis are shown in Table 4.24, indicating an average figure of 34% of the LV network to be reconductored. The total LV length in the interconnected system in 1990 was 1597 km, reconductoring 34% of which represents a budgetary expenditure of MK 24.9 m, which has been included in the overall budget presented at the end of this report.

A five year programme is proposed for the assessment of the detailed reconductoring requirements of each LV system and carrying out the reconductoring work.

The Dranetz analyser results obtained during the measurements carried out on the Browns Road LV system indicated that at peak transformer loading the current distribution between the red, yellow and blue phases on circuit 1 was 224A, 226A and 155A respectively. This phase imbalance inevitably contributes both to the level of losses on the feeder and to the effect of reduced supply voltage at the remote ends of the system. In order to quantify the reduction in losses and improvement in minimum voltage which could be achieved by balancing the phase currents, the three phases loss calculation which was carried out for the reconductored system in 1991, as summarised above, was repeated assuming an equal sharing of the load current between the phases. The results of this indicate the following:

Additional reduction in energy losses from 3.1% to 2.9%.

Improvement in minimum voltage from 202 V to 207 V.

This clearly demonstrates the degree of improvement which may be obtained by addressing the balancing of loads on the LV system, an exercise which is quite straightforward to implement, as it generally only requires the transfer of consumer services from one phase to another on the overhead LV systems in order to obtain a more equal distribution of load between the phases. It is recommended that ESCOM should address this measure as a high priority, given that it involves minimal capital expenditure and could be effectively implemented by one line crew addressing each of the LV systems in turn.

4.4.5 11/0.4 kV Transformer and LV Loss Optimisation

The measures discussed above all represent technically and economically viable ways of reducing the level of losses associated with 11 kV/LV transformation and LV distribution, which currently account for some 6% of the energy delivered to the 11 kV/LV transformers. The sample studies performed indicate that this loss level can be reduced to nearer 4% by the introduction of 150 sq mm overhead conductors on the existing LV networks, the balancing of LV loads and the replacement of transformers in accordance with optimal loading strategies.

In order to finalise in detail the loss reduction investment programme based on these measures, as well as to obtain further reductions in losses and to fully implement the design criteria which have been presented for the reduction of voltage drops on the LV system, a fully coordinated approach to the reconfiguration of each 11 kV feeder and its associated LV networks is required. This should include the optimisation of distribution transformer placement, LV feeder lengths and the open points between LV systems. It should also include detailed assessment for each LV feeder in terms of how much of the feeder is to be reconductored.

All of the above require the compilation of the comprehensive model of each 11 kV feeder, including 11 kV/LV transformers and LV networks, which can then be examined in the context of a detailed distributed load forecast to establish the technical and economic viability of techniques to be used in planning the development of the system at this level in such a way as to ensure that losses continue to be minimised. The need for this extended detailed investigation of the LV systems was anticipated in the original KDP proposal document for the Loss Reduction Study, in which it was suggested that a review, based on the results of further surveys of the LV networks to be carried out by ESCOM, would be required to finalise the loss reduction investment programme covering all the LV networks on the ESCOM system.

It is envisaged that the most effective way of organising this review would be by means of an initial period of continued data collection which would be carried out by ESCOM in exactly the same way as has been successfully used in obtaining the necessary information for the sample analysis carried out for the Loss Reduction Study. The DPAS software which has already been installed in ESCOM's offices would be used for the analysis, which would be started by means of a detailed examination of the measures required to optimise the LV networks associated with a number of 11 kV feeders supplying different load types. This would be undertaken during a period of approximately one month, during which a distribution planning expert would work with ESCOM's Central Planning Unit in Malawi specifically on this area of system optimisation.

This would establish the process for ensuring that not only are the requirements for each LV system fully defined, but that also these measures are combined with optimal transformer placement and LV system reconfiguration considerations to further reduce losses and define system planning procedures at this level with a view to continued loss minimisation. The level of skill in ESCOM's Central Planning Unit is such that both these areas of work can undoubtedly be completed independently, once procedures for so doing have been established. A brief visit from the distribution planning specialist, eg approximately one week, would then take place to review and summarise the findings of the detailed study in such a way as to enable the details of the LV loss reduction projects to be defined.

A budget allocation of US$ 45,000 is included in the package of loss reduction measures to enable this stage of the project definition to be completed on the basis described above.

Some preliminary analysis has been carried out to examine the comparison between LV reconductoring and the reduction of LV feeder lengths through the placement of additional transformers, in terms of the relative cost effectiveness of the two approaches.

Studies have been performed on the basis of an existing 315kVA 11kV/LV transformer supplying a 145kW load with a load factor of 54% and a loss factor of 37%, supplying two LV systems with 100 sq mm AAC conductors.

Figures 4.29 and 4.30 show the results of a fifteen year analysis with a growth rate of 8.5%. Figure 4.29 shows that the lowest operating costs result from 50% reconductoring on LV feeders with no consideration of additional transformers. Figure 4.30 demonstrates that 50% reconductoring results in the lowest operating costs on LV lines of up to 550 m length, but that at this length it is more economic to introduce a second transformer, with three transformers being the cheapest option for a length of greater than 800 m.

Analysis of the scenario with seven years load growth is shown in Figures 4.31 and 4.32 indicating that 25% is the optimum reconductoring level, and that reconductoring represents the most economic option for LV feeders of up to 750 m in length.

These results show that for LV feeders constructed in accordance with ESCOM's policy of 500 m maximum LV feeder lengths, reconductoring is likely to present the most economic loss reduction measure. For longer feeders the introduction of additional transformers should be considered on a feeder by feeder basis, using length guidelines produced from analysis such as that shown here. It is this type of exercise which it is envisaged should form part of the LV system study recommended above. For the majority of LV feeders on the ESCOM system however, it is likely that reconductoring will prove the optimum loss reduction method.

Table 4.1 : MALAWI TRANSMISSION SYSTEM PEAK LOAD FLOW - 04.07.90

BUSBARS :-

BUSNAME	GEN. TYPE	VOLTS (PU)	ANG. (DEG)	GENERATION (MW)	GENERATION (MVAR)	LOAD (MW)	LOAD (MVAR)
NKULAA11	3	1.017	2.83	24.00	10.91	0.00	0.00
NKULAB11	3	1.005	1.58	40.00	17.90	0.00	0.00
NKULAB66	0	1.095	-0.58	0.00	0.00	5.58	1.61
NKULB211	1	1.050	0.00	25.36	-4.00	0.00	0.00
NKULAA66	0	1.095	-0.58	0.00	0.00	0.00	0.00
NKULA132	0	1.085	-1.57	0.00	0.00	0.00	0.00
TEDZAN11	3	1.015	2.57	30.00	13.26	0.00	0.00
TEDZAN66	0	1.098	-0.41	0.00	0.00	0.06	0.02
FUNDIX66	0	1.043	-2.59	0.00	0.00	0.00	0.00
FUNDIX33	0	1.050	-3.73	0.00	0.00	1.52	0.47
LIWOND66	0	1.034	-3.77	0.00	0.00	0.00	0.00
LIWOND33	0	1.040	-5.04	0.00	0.00	0.43	0.21
DEDZA 66	0	0.963	-7.50	0.00	0.00	0.00	0.00
BALAKA66	0	1.040	-3.52	0.00	0.00	0.00	0.00
NTCHEU66	0	1.002	-5.52	0.00	0.00	0.00	0.00
LILONA66	0	0.924	-9.39	0.00	0.00	0.00	0.00
LILONA11	0	1.047	-10.46	0.00	0.00	5.92	1.90
LILONB66	0	1.011	-14.50	0.00	0.00	0.00	0.00
LILONB33	0	1.033	-16.38	0.00	0.00	3.00	0.90
LILONB11	0	1.038	-15.81	0.00	0.00	15.53	7.46
LILONC66	0	1.008	-14.61	0.00	0.00	0.00	0.00
LILONC11	0	1.040	-17.10	0.00	0.00	3.20	1.00
LILOB132	0	0.952	-11.75	0.00	0.00	0.00	0.00
SALIMA66	0	1.046	-11.03	0.00	0.00	0.00	0.00
SALIM132	0	0.984	-9.94	0.00	0.00	0.00	0.00
MAPANG66	0	1.048	-2.29	0.00	0.00	0.00	0.00
MAPANG33	0	1.053	-3.50	0.00	0.00	0.65	0.15
CHICHI66	0	1.028	-3.02	0.00	0.00	0.00	0.00
CHICHI33	0	1.053	-6.41	0.00	0.00	0.00	0.00
CHICHI11	0	1.030	-9.50	0.00	0.00	21.45	5.60
SUCOM132	0	1.073	-2.58	0.00	0.00	0.00	0.00
NKHOTA66	0	1.007	-15.40	0.00	0.00	0.00	0.00
NKHOTA33	0	1.021	-17.90	0.00	0.00	0.00	0.00
DWANGW66	0	0.992	-16.99	0.00	0.00	0.00	0.00
CHINTH66	0	0.970	-19.39	0.00	0.00	0.00	0.00
TEHILL66	0	0.948	-20.34	0.00	0.00	0.00	0.00
TEHILL33	0	1.008	-22.66	0.00	0.00	0.60	0.08
CHIKAN66	0	0.962	-19.91	0.00	0.00	0.00	0.00
KAPIC132	0	1.079	-2.26	0.00	0.00	0.00	0.00

Table 4.1 (contd) : MALAWI TRANSMISSION SYSTEM PEAK LOAD FLOW - 04.07.90

BUSBARS :-

BUSNAME	GEN. TYPE	VOLTS (PU)	ANG. (DEG)	GENERATION (MW)	GENERATION (MVAR)	LOAD (MW)	LOAD (MVAR)
ZOMBA 33	0	0.974	-5.07	0.00	0.00	0.00	0.00
MANGOC33	0	0.995	-6.42	0.00	0.00	0.60	0.15
MTUNTH33	0	0.979	-19.75	0.00	0.00	0.00	0.00
KASUNG33	0	0.970	-19.89	0.00	0.00	0.00	0.00
THYOLA33	0	0.933	-10.18	0.00	0.00	0.00	0.00
MAKWAS33	0	0.921	-10.31	0.00	0.00	0.00	0.00
THYOLB33	0	0.981	-8.59	0.00	0.00	0.00	0.00
THYOLB11	0	1.025	-9.59	0.00	0.00	1.40	0.38
CUSTOM33	0	1.046	-6.58	0.00	0.00	0.00	0.00
CUSTOM11	0	1.040	-7.40	0.00	0.00	1.55	0.45
MICHIR33	0	1.044	-6.65	0.00	0.00	0.00	0.00
MICHIR11	0	1.033	-8.11	0.00	0.00	2.07	0.60
CHILEK33	0	1.030	-4.18	0.00	0.00	0.00	0.00
CHILEK11	0	1.045	-5.50	0.00	0.00	3.46	1.14
DAVWHS33	0	1.050	-6.49	0.00	0.00	0.00	0.00
DAVWHS11	0	1.046	-8.81	0.00	0.00	5.00	1.60
LIMBEA33	0	1.028	-6.99	0.00	0.00	0.00	0.00
LIMBEA11	0	1.050	-10.10	0.00	0.00	8.90	3.50
KASUNG11	0	1.028	-21.96	0.00	0.00	0.64	0.17
MTUNTH11	0	1.039	-21.74	0.00	0.00	0.63	0.16
CHIKAN11	0	1.031	-20.96	0.00	0.00	1.31	0.41
MAKWAS11	0	0.981	-15.10	0.00	0.00	0.70	0.23
MANGOC11	0	1.033	-9.91	0.00	0.00	1.00	0.33
SUCOMA11	0	1.045	-3.13	0.00	0.00	7.65	3.80
ZOMBA 11	0	1.035	-7.35	0.00	0.00	5.28	1.50
SALIMA11	0	1.013	-10.14	0.00	0.00	1.49	0.49
NKHOTA11	0	1.004	-20.05	0.00	0.00	0.32	0.10
MZUZU 33	0	1.002	-22.95	0.00	0.00	0.00	0.00
MZUZU 11	0	1.045	-24.20	0.00	0.00	1.80	0.55
SUCOMA33	0	1.027	-5.10	0.00	0.00	0.80	0.30
THYOLA11	0	1.039	-12.96	0.00	0.00	3.94	1.10
BALAKA11	0	1.048	-3.85	0.00	0.00	0.44	0.12
NTCHEU11	0	1.052	-5.76	0.00	0.00	0.20	0.06
CHINTH33	0	1.040	-19.76	0.00	0.00	0.30	0.10
CHINTH11	0	1.035	-20.40	0.00	0.00	0.10	0.03
DWANGW11	0	1.035	-19.24	0.00	0.00	1.85	0.68
DEDZA 33	0	1.007	-8.32	0.00	0.00	0.42	0.13
		TOTALS		119.36	38.06	109.79	37.48
		LOSSES		9.57	0.58		

Table 4.1 (contd) : MALAWI TRANSMISSION SYSTEM PEAK LOAD FLOW - 04.07.90

BRANCHES :-

BUSNAMES FROM	TO	NO.	SENDING (MW)	SENDING (MVAR)	RECEIVING (MW)	RECEIVING (MVAR)	(MVA)	TAP (%)
NKULAA11	NKULAA66	1	24.00	10.91	23.84	9.17	25.54	-10.00
NKULAB11	NKULAB66	45	40.00	17.90	39.85	16.05	42.96	-10.00
NKULAB66	NKULA132	48	17.58	7.32	17.55	6.96	18.88	0.00
NKULAB66	MAPANG66	3	13.62	3.45	13.14	3.20	13.52	
NKULAB66	MAPANG66	32	14.76	8.75	14.39	8.49	16.71	
NKULB211	NKULA132	63	25.36	-4.00	25.30	-4.71	25.74	-3.00
NKULAA66	NKULAB66	28	4.62	3.49	4.62	3.49	5.79	
NKULAA66	BALAKA66	37	10.08	2.05	9.69	2.21	9.94	
NKULAA66	CHICHI66	2	15.30	5.10	14.57	4.54	15.26	
NKULA132	SALIM132	66	34.32	3.85	32.10	9.25	33.40	
NKULA132	KAPIC132	64	8.54	-1.60	8.50	2.27	8.80	
TEDZAN11	TEDZAN66	31	30.00	13.26	29.83	11.37	31.92	-10.00
TEDZAN66	NKULAB66	27	7.10	1.57	7.08	1.59	7.26	
TEDZAN66	NKULAA66	26	6.18	1.46	6.17	1.48	6.34	
TEDZAN66	CHICHI66	30	16.49	8.33	15.79	7.39	17.44	
FUNDIX66	FUNDIX33	6	1.52	0.50	1.52	0.47	1.59	-1.50
LIWOND66	LIWOND33	39	2.10	0.65	2.10	0.60	2.18	-1.50
LIWOND33	MANGOC33	40	1.67	0.39	1.61	0.55	1.70	
DEDZA 66	LILONA66	61	6.11	1.86	5.93	2.03	6.27	
DEDZA 66	DEDZA 33	93	0.42	0.14	0.42	0.13	0.44	-5.00
BALAKA66	LIWOND66	38	2.11	0.42	2.10	0.65	2.20	
BALAKA66	NTCHEU66	42	7.13	1.67	6.93	1.88	7.18	
BALAKA66	BALAKA11	83	0.44	0.12	0.44	0.12	0.46	-1.00
NTCHEU66	DEDZA 66	60	6.73	1.82	6.53	2.00	6.83	
NTCHEU66	NTCHEU11	82	0.20	0.06	0.20	0.06	0.21	-5.00
LILONA66	LILONA11	47	5.93	2.03	5.92	1.90	6.22	-12.50
LILONB66	LILONB33	35	3.01	1.01	3.00	0.90	3.13	-3.50
LILONB66	LILONB11	36	15.59	7.93	15.53	7.46	17.23	-4.00
LILONB66	LILONC66	43	3.22	0.99	3.22	1.16	3.42	
LILONC66	LILONC11	44	3.22	1.16	3.20	1.00	3.35	-5.00
LILOB132	LILONB66	34	21.93	11.28	21.82	9.93	23.97	-8.50
SALIMA66	NKHOTA66	51	8.23	-0.65	7.90	-0.20	7.90	
SALIM132	LILOB132	49	22.35	9.25	21.93	11.28	24.66	
SALIM132	SALIMA66	50	8.25	-0.49	8.23	-0.65	8.26	-6.00
SALIM132	SALIMA11	90	1.49	0.50	1.49	0.49	1.57	-3.00
MAPANG66	FUNDIX66	5	1.53	-0.10	1.52	0.50	1.60	
MAPANG66	MAPANG33	33	9.89	3.63	9.86	3.39	10.43	-1.50
MAPANG66	CHICHI66	4	16.10	8.16	15.90	7.85	17.73	
MAPANG33	ZOMBA 33	10	5.68	2.00	5.30	1.74	5.58	
MAPANG33	CHILEK33	11	3.53	1.24	3.47	1.23	3.68	
CHICHI66	CHICHI33	29	46.26	19.78	46.05	16.54	48.93	-5.00

Table 4.1 (contd) : MALAWI TRANSMISSION SYSTEM PEAK LOAD FLOW - 04.07.90

BRANCHES :-

BUSNAMES FROM	TO	NO.	SENDING (MW)	(MVAR)	RECEIVING (MW)	(MVAR)	(MVA)	TAP (%)
CHICHI33	CHICHI11	21	21.59	6.90	21.45	5.60	22.17	0.00
CHICHI33	THYOLB33	22	6.64	2.40	6.27	2.10	6.62	
CHICHI33	LIMBEA33	18	9.13	4.26	8.96	4.10	9.85	
SUCOM132	SUCOMA11	80	8.46	4.24	8.45	4.13	9.41	2.00
NKHOTA66	NKHOTA33	52	1.66	0.32	1.65	0.25	1.67	-2.50
NKHOTA66	DWANGW66	55	6.24	-0.52	6.15	0.31	6.15	
NKHOTA33	MTUNTH33	53	1.33	0.13	1.28	0.31	1.32	
NKHOTA33	NKHOTA11	75	0.32	0.11	0.32	0.10	0.34	0.00
DWANGW66	CHINTH66	56	4.29	-0.46	4.19	0.33	4.20	
DWANGW66	DWANGW11	84	1.86	0.77	1.85	0.68	1.97	-6.00
CHINTH66	TEHILL66	57	2.47	0.54	2.42	0.76	2.54	
CHINTH66	CHIKAN66	62	1.32	-0.34	1.31	0.44	1.38	
CHINTH66	CHINTH33	85	0.40	0.13	0.40	0.13	0.42	-7.00
TEHILL66	TEHILL33	58	2.42	0.76	2.41	0.65	2.50	-7.50
TEHILL33	MZUZU 33	0	1.81	0.57	1.80	0.59	1.90	0.18
CHIKAN66	CHIKAN11	92	1.31	0.44	1.31	0.41	1.37	-7.50
KAPIC132	SUCOM132	65	8.50	2.27	8.46	4.24	9.47	
ZOMBA 33	ZOMBA 11	89	5.30	1.74	5.28	1.50	5.49	-7.50
MANGOC33	MANGOC11	71	1.01	0.40	1.00	0.33	1.05	-6.50
MTUNTH33	KASUNG33	54	0.65	0.13	0.64	0.20	0.67	
MTUNTH33	MTUNTH11	76	0.63	0.18	0.63	0.16	0.65	-7.00
KASUNG33	KASUNG11	77	0.64	0.20	0.64	0.17	0.66	-7.00
THYOLA33	MAKWAS33	25	0.72	0.24	0.71	0.30	0.77	
THYOLA33	THYOLA11	70	3.96	1.32	3.94	1.10	4.09	-12.00
MAKWAS33	MAKWAS11	91	0.71	0.30	0.70	0.23	0.74	-10.00
THYOLB33	THYOLA33	24	4.87	1.69	4.68	1.56	4.93	
THYOLB33	THYOLB11	23	1.40	0.41	1.40	0.38	1.45	-5.00
CUSTOM33	CHICHI33	14	-3.63	-1.13	-3.65	-1.13	3.82	
CUSTOM33	CUSTOM11	69	1.55	0.48	1.55	0.45	1.61	0.00
MICHIR33	CUSTOM33	13	-2.08	-0.66	-2.08	-0.65	2.18	
MICHIR33	MICHIR11	68	2.08	0.66	2.07	0.60	2.16	0.00
CHILEK33	CHILEK11	67	3.47	1.23	3.46	1.14	3.64	-2.50
DAVWHS33	CHICHI33	17	-5.02	-1.83	-5.03	-1.84	5.36	
DAVWHS33	DAVWHS11	16	5.02	1.83	5.00	1.60	5.25	-1.50
LIMBEA33	LIMBEA11	19	8.96	4.10	8.90	3.50	9.56	-5.00
SUCOMA11	SUCOMA33	81	0.80	0.33	0.80	0.30	0.85	0.00
MZUZU 33	MZUZU 11	88	1.80	0.59	1.80	0.55	1.88	-5.00
CHINTH33	CHINTH11	86	0.10	0.03	0.10	0.03	0.10	0.00

Table 4.2 : Summary of 132/66/33kV System Load Flow Results

YEAR	Power Loss %	Energy Loss %
1990	8.4	6.7
1991	9.8	7.8
1994	8.3	6.7
2005	11.6	9.0

Table 4.3 : Summary of 132/66 kV System Load Flow Results

YEAR	Power Loss %	Energy Loss %
1990	6.9	5.6
1991	8.3	6.6
1994	6.2	5.1
1999	5.9	4.7
2005	9.6	7.4

Table 4.4 : Summary of 33 kV System Load Flow Results

YEAR	Power Loss %	Energy Loss %
1990	2.6	2.1
1991	2.5	2.0
1994	3.1	2.5
2005	3.9	3.0

Table 4.5 : Summary of 66kV Reconductoring Analysis

Nkula A - Chichiri

	Demand (MW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Loss Reduction	14.76	4.40	3.24
1991 Post-Loss Reduction	18.08	3.04	2.24
2005 Pre-Loss Reduction	15.34	4.43	3.27
2005 Post-Loss Reduction	19.83	3.03	2.23

Loss Reduction Measures:	Reconductor 46km with 175 sq.mm. conductor
Capital Cost (MK):	46km @ MK 48,000 = MK 2.2m
Internal Rate of Return:	-1.27%

Nkula B - Mapanga

	Demand (MW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Loss Reduction	13.07	3.29	2.42
1991 Post-Loss Reduction	15.96	2.57	1.89
2005 Pre-Loss Reduction	19.28	4.82	3.55
2005 Post-Loss Reduction	21.16	3.17	2.33

Loss Reduction Measures:	Reconductor 44km with 175 sq.mm. conductor
Capital Cost (MK):	44km @ MK 48,000 = MK 2.1m
Internal Rate of Return:	-1.25%

Table 4.6 : Summary of 33kV Reconductoring Analysis

	Chichiri - Customs			Fundi's Cross - Thyolo		
	Demand (MW)	Power Loss (%)	Energy Loss (%)	Demand (MW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Loss Reduction	3.65	0.55	0.40	4.98	6.22	4.57
1991 Post-Loss Reduction	4.09	0.24	0.18	5.41	3.33	2.45
2005 Pre-Loss Reduction	10.38	1.35	0.99	7.79	9.76	7.18
2005 Post-Loss Reduction	10.33	0.87	0.64	7.35	4.49	3.30

(a) Reconductoring based on ESCOM Line Cost Estimates

	Chichiri - Customs	Fundi's Cross - Thyolo
Loss Reduction Measures:	Reconductor 4km with 175 sq.mm. conductor	Reconductor 35km with 175 sq.mm. conductor
Capital Cost (MK):	4 km @ MK 39,538 = MK 158,152	35 km @ MK 39,538 = MK 1.38m
Internal Rate of Return:	4.29%	6.86%

(b) Reconductoring based on International Line Cost Estimates

	Chichiri - Customs	Fundi's Cross - Thyolo
Loss Reduction Measures:	Reconductor 4km with 175 sq.mm. conductor	Reconductor 35km with 175 sq.mm. conductor
Capital Cost (MK):	4 km @ MK 57,300 = MK 229,200	35 km @ MK 57,300 = MK 2.01m
Internal Rate of Return:	0.19%	2.28%

Table 4.7 : Transmission Line Parameters

Line Type	Conductor Size (sq.mm)	Resistance (Ohms/km)	New Line Cost Estimates ESCOM (MK/km)	KDP International (MK/km)
66kV Wood Pole	75 ACSR	0.3623		70000
	100 ACSR	0.2733		78000
	125 ACSR	0.2185		85000
	175 ACSR	0.1576		96000
66kV Steel	75 ACSR	0.3623		95000
	100 ACSR	0.2733		105000
	125 ACSR	0.2185		115000
	175 ACSR	0.1576		130000
33kV Wood Pole	50 AAAC 1-phase	1.0996	17657	
	50 AAAC	0.5498	22970	
	100 AAAC	0.2769	32747	
	150 AAAC	0.1830	39538	57300

Table 4.8 : Summary of 33kV-66kV Voltage Upgrading Analysis

	Mtunthama 105		
	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Loss Reduction	1946	5.24	4.14
1991 Post-Loss Reduction	2032	2.61	2.06
2005 Pre-Loss Reduction	7355	24.45	18.32
2005 Post-Loss Reduction	5944	6.42	5.07

Loss Reduction Measures: Convert 74 km of 33 kV OHL to 66 kV operation

Capital Cost (MK): MK 1,050,000 - Substation costs only; as line constructed for 66 kV operation

Internal Rate of Return: 16.83 %

For the case of the line originally built for 33 kV operation,

Capital Cost (MK): 74 km @ MK 70,000 + 1,050,000 = MK 6,230,000

Internal Rate of Return: - 2.28 %

Table 4.9 : Summary of Transformer Loading Results - Blantyre Main Feeder 5L5

Transformer	Ref.	Size (kVA)	Time Measured	Total Demand (kVA)	Average P.F.	Corrected Demand at 18:30 kW	kVAr	kVA
ALC Workshop	413	100	15:14	47.66	0.98	77.78	15.79	79.37
New BT Market	1363	50	10:47	41.26	0.98	46.43	9.45	47.38
Top Mandala F/Stn.	1951	50	11:00	16.19	0.98	26.03	5.29	26.56
Kufa Road	1709	200	11:50	101.43	0.98	140.99	20.09	142.42
Mbelwa Road	903	200	11:35	104.63	0.98	151.73	30.81	154.83
State House	49	200	11:12	123.76	0.98	195.34	35.88	198.61
Browns Road	305	315	11:15	168.57	0.98	89.92	26.23	93.66
Old Hospital	4	100	16:25	25.04	0.95	48.07	14.40	50.18
St. Andrew's Prim. Sch.	331	100	12:15	27.63	0.98	39.09	7.94	39.89
Mount Pleasant	14	200	15:15	74.77	0.98	205.80	29.33	207.88
Police Camp Sunnyside	354	50	11:50	5.06	0.98	6.92	1.40	7.06
Smythe Road	6	50	15:47	9.78	0.98	41.70	8.47	42.55
Bank Road	75	100	16:00	47.39	0.97	101.48	23.33	104.13
Central Avenue	451	100	09:44	10.33	0.98	16.17	3.28	16.50
Ring Road	8	100	09:17	50.92	0.98	77.08	15.65	78.65
Arnold Road	47	200	16:30	55.43	0.98	110.82	22.50	113.08
Wilson Avenue	352	100	16:40	32.04	0.98	64.49	13.10	65.80
Gatrels	1901	100	16:55	33.37	0.98	64.73	13.14	66.05
Consulate Road	315	400	10:00	106.87	0.99	205.67	29.31	207.75
Namiwawa South	1151	200	10:40	64.81	0.98	100.53	20.41	102.58
Sanjika Stadium	1652	200	11:34	0.60	0.98	0.87	0.18	0.88
Sanjika House	1559	500	10:44	101.89	0.98	158.03	32.09	161.26
Sanjika House	1647	200	10:55	12.56	0.98	20.25	4.11	20.66
TOTALS						**1989.90**	**382.18**	**2027.72**

Table 4.10 : Summary of 11kV Feeder Analysis

Feeder	Peak Demand (kW)	P.F.	Load Factor	Loss Factor	Percentage Losses Power	Percentage Losses Energy
BLANTYRE MAIN 5L5	1987	0.98	54.23%	35.82%	1.51%	1.00%
GROUP 202	3922	0.98	59.34%	37.94%	2.57%	1.65%
CHICHIRI 9L5	2169	0.92	78.97%	63.53%	1.05%	0.84%
CHICHIRI 6L5	2677	0.99	48.35%	26.95%	5.32%	2.97%
LIMBE 1L5	1895	0.97	68.84%	50.55%	0.71%	0.52%
LILONGWE B 3L5	3152	0.94	90.12%	81.71%	2.94%	2.67%
LILONGWE B 6L5	2090	0.90	84.60%	74.50%	1.34%	1.18%
LILONGWE B 1L5/5L5	877	0.99	71.02%	53.26%	2.44%	1.83%
				Averages:	**2.24%**	**1.58%**

Table 4.11 : Sensitivity Analysis of 11kV Reconductoring Load Levels

(a) Variation of Load Factor

Annual Load Growth Rate %	Load Factor %	Reconductoring Thresholds 50 sq mm - 150 sq mm kVA	100 sq mm - 150 sq mm kVA
8.5	48.4	850	1680
8.5	54.2	820	1620
8.5	62.3	800	1580
8.5	90.1	720	1420

(b) Variation of Load Growth Rate

Annual Load Growth Rate %	Load Factor %	Reconductoring Thresholds 50 sq mm - 150 sq mm kVA	100 sq mm - 150 sq mm kVA
10.0	62.3	700	1380
8.5	62.3	800	1580
7.6	62.3	850	1700
5.0	62.3	1050	2100
2.0	62.3	1300	2600
0.0	62.3	1500	2950

Table 4.12 : Summary of 11kV Feeder Reconductoring Analysis

BLANTYRE MAIN 5L5

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Reconductoring	1988	1.51	1.00
1991 Post-Reconductoring	2129	0.38	0.25
2005 Pre-Reconductoring	2321	1.77	1.17
2005 Post-Reconductoring	2298	0.44	0.29

Feeder Length Reconductored (km)	1.9 OHL
Capital Cost (MK)	90440
Internal Rate of Return	**18.1%**

LILONGWE B 3L5

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Reconductoring	3152	2.94	2.67
1991 Post-Reconductoring	3350	2.01	1.82
2005 Pre-Reconductoring	3921	3.59	3.26
2005 Post-Reconductoring	3870	2.32	2.10

Feeder Length Reconductored (km)	2.9 OHL + 0.2 U/G
Capital Cost (MK)	208900
Internal Rate of Return	**15.9%**

GROUP 202

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Pre-Reconductoring	3917	2.57	1.64
1991 Post-Reconductoring	4169	1.22	0.78
2005 Pre-Reconductoring	4571	2.78	1.78
2005 Post-Reconductoring	4503	1.32	0.84

Feeder Length Reconductored (km)	5.4 OHL + 0.5 U/G
Capital Cost (MK)	262460
Internal Rate of Return	**12.6%**

Table 4.13 : 11kV Line and Cable Parameters

Line Type	Conductor Size (sq.mm)	Resistance (Ohms/km)	New Line Cost Estimates ESCOM (MK/km)	KDP International (MK/km)
11kV Wood Pole	50 AAAC 1-phase	1.0996	14619	
	50 AAAC	0.5498	18924	
	100 AAAC	0.2769	28561	
	150 AAAC	0.1830	32280	47600
11kV Cable	16 sq mm Cu	1.334	42800	
	70 sq mm Cu	0.311	63000	
	120 sq mm Cu	0.177	150400	
	185 sq mm Cu	0.115	208000	
	240 sq mm Cu	0.0875	236200	354000

Table 4.14 : ESCOM Loss Reduction Study : Summary of 11kV Reconductoring Proposals

Feeder	Peak Demand (kVA)	Length to Reconductor (km)	Sections to Reconductor	Total Cost (MK)
BLANTYRE				
Blantyre Main 5L5	2028	1.9	BTMain - SL5, SL5 - FUS14	90400
Chichiri 2L5	5019	1.1	Chich11 - Group Hosp. 11	389700
Chichiri 5L5	3445	2.5	ABS1682 - ABS488	119000
		0.4	Chich11 - ABS1682	141700
Chichiri 6L5	2704	13.3	ABS15 - ABS17, SL254 - ABS15, FUS914 - SL254, ABS1742 - FUS2408, SL282 - ABS1742	633100
Chichiri 9L5	2358	4.7	Chich11 - ABS23, ABS23 - ABS1585, ABS2396 - ABS23	223700
Chileka 3L0	1075	6.7	Chil11 - ABS1140, ABS1140 - SL493, SL493 - RM1105	318900
Group 202	4002	5.4	ABS420 - ABS190, SL1587 - ABS420, SL1586 - SL1587, SL1586 - ABS1585, SL1385 - FUS1328	257000
		0.5	Group11 - ABS190	177100
Limbe 3L5	880	1.1	Limbe11 - RMI1351, RMI1351 - RMI1346	52400
Limbe 4L5	1707	1.2	Limbe11 - RMI71, RMI71 - RMI171	425100
Limbe 5L5	2010	3.7	SL467 - SL173	176100
LILONGWE				
Lilongwe A 2L5	1780	3.7	LilA11 - ABS8, ABS8 - ABS32, ABS32 - ABS17, ABS17 - ABS33, ABS17 - ABS40, ABS40 - ABS680	176100
Lilongwe A 3L5	3290	3.8	LilA11 - ABS62, ABS62 - ABS68, ABS68 - SL71, ABS68 - ABS575	180900
Lilongwe B 3L5	3353	2.9	ABS363 - ABS 338, ABS338 - ABS488, ABS488 - FUS408, FUS408 - FUS409, FUS409 - FUS432	138000
		0.2	LilB11 - ABS363	70900
Lilongwe B 4L5	2342	3.5	ABS560 - FUS482, FUS482 - FUS354, FUS354 - FUS522	166600
Lilongwe B 6L5	2322	2.4	ABS363 - ABS412, ABS412 - ABS384, ABS384 - FUS434, FUS434 - FUS854	114200
			TOTAL	**3850900**

Table 4.15 : Summary of Lilongwe B 6L5 Loss Reduction Analysis

LILONGWE B 6L5

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Before Loss Reduction	2091	1.34	1.18
1991 After Loss Reduction	2239	0.89	0.78
2005 Before Loss Reduction	3523	2.24	1.97
2005 After Loss Reduction	3489	1.29	1.14

Loss Reduction Measures :	2.4 km OHL Reconductoring
Capital Cost (MK)	114240
Internal Rate of Return	**13.6%**

LILONGWE B 6L5

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Before Loss Reduction	2091	1.34	1.18
1991 After Loss Reduction	2250	1.38	1.22
2005 Before Loss Reduction	3523	2.24	1.97
2005 After Loss Reduction	3520	2.16	1.90

Loss Reduction Measures :	2 x 100 kVAr Capacitors
Capital Cost (MK)	6800
Internal Rate of Return	**24.9%**

LILONGWE B 6L5

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Before Loss Reduction	2091	1.34	1.18
1991 After Loss Reduction	2239	0.85	0.75
2005 Before Loss Reduction	3523	2.24	1.97
2005 After Loss Reduction	3490	1.32	1.16

Feeder Length Reconductored (km)	2 x 100 kVAr Capacitors + 2.4 km OHL Reconductoring
Capital Cost (MK)	121040
Internal Rate of Return	**12.5%**

Table 4.16 : Transformer Loss Evaluation Data Base

Rating kVA	Core Loss kW	Core Loss %	Winding Loss kW	Winding Loss %	Capital Cost MK	Comments
15	0.07	0.48	0.34	2.28		* ASSUMED LOSSES
25	0.12	0.48	0.57	2.28	4871	
50	0.18	0.36	1.0	2.00	6660	
100	0.3	0.30	1.7	1.70	9228	
200	0.52	0.26	2.7	1.35	14380	
315	0.72	0.23	3.8	1.21	15212	
400	0.88	0.22	4.3	1.08		* ASSUMED LOSSES
500	1.1	0.22	5.4	1.08	21110	
800	1.6	0.20	8.0	1.00		

Marginal Cost of Power	527.98 MK/kW
Marginal Cost of Energy	0.045 MK/kWh
Load Factor :	62.30%
Loss Factor:	45.80%
Peak Load:	250

Table 4.17 : Summary of 11/0.4 kV Transformer Loss Evaluation

11kV Feeder	Peak Demand (kVA)	Transformer Capacity (kVA)	Utilisation Factor (%)	PERCENTAGE TRANSFORMER LOSSES				
				Core		Winding		Total
				Power	Energy	Power	Energy	Energy Loss
CHICHIRI 6L5	2704	5325	50.8	0.57	1.22	1.28	0.74	1.96
CHICHIRI 9L5	2358	5725	41.2	0.60	0.76	0.83	0.67	1.43
GROUP 202	4002	8530	46.9	0.55	0.98	0.97	0.66	1.64
LIMBE 1L5	1954	4275	45.7	0.57	0.55	0.82	0.40	0.95
BLANTYRE MAIN 5L5	2028	3815	53.2	0.50	0.89	1.02	0.65	1.54
LILONGWE B 2L5	3169	9180	34.5	0.77	1.18	0.67	0.54	1.72
LILONGWE B 3L5	3353	6825	49.1	0.40	0.44	0.58	0.52	0.96
LILONGWE B 6L5	2322	6390	36.4	0.70	0.81	0.68	0.59	1.40
LILONGWE A 2L5	1733	2645	65.5	0.48	0.60	3.35	2.89	3.49
LILONGWE A 3L5	3261	6255	52.1	0.50	0.84	1.19	0.82	1.66
LILONGWE A 1L5	1930	6345	30.4	1.27	2.04	1.20	0.80	2.84

Average Utilisation Factor : 46.0 %

Average Total Energy Loss : 1.78 %

Table 4.18 : Sample Transformer Optimisation

Group Substation - Feeder 202

Measured Feeder Peak Demand (MW)	3922	
Time of Feeder Peak Demand	18:38	
Measured Feeder P.F. at Peak	0.98	
Load Factor (Demand in MVA)	59.34%	
Loss Load Factor (Demand in MVA)	37.94%	
Total Transformer Capacity (kVA)	8530	
Total Measured Load (kVA)	2500	
Total Corrected Max. Demand (kVA)	3998	
Total Corrected Max. Demand (kW)	3922	
24 hour Energy Summation (kWh)	52733	100.00%
24 hour Core Energy Loss (kWh)	518	0.98%
24 hour Winding Energy Loss (kWh)	347	0.66%
Total Transformer Loss (kWh)	864	1.64%
Core Power Loss (kW)	21.57	0.55%
Max. Winding Power Loss (kW)	38.07	0.97%
Total Transformer Power Loss (kW)	59.64	1.52%

Transformer	Ref.	Size (kVA)	Peak Demand kW	kVAr	kVA	**Revised Size (kVA)**
1 CHITAWIRA I	308	400	127.15	25.82	129.74	**200**
2 CHITAWIRA II	103	200	103.67	21.05	105.79	
3 NJAMBA I	1721	200	45.49	9.24	46.42	**100**
4 NJAMBA IIB ST COL	1722	100	17.27	3.51	17.62	**50**
5 KWACHA HALL	290	100	76.84	15.60	78.41	
6 CHITAWIRA IND BEHIND OILCOM	2429	50	9.18	1.86	9.37	
7 CHITAWIRA IND(WAYA CO)	2422	50	1.51	0.31	1.54	
8 CHINYONGA PHASE 1	1911	100	49.70	10.09	50.72	
9 CHINYONGA PHASE II	1910	100	63.48	12.89	64.77	
10 CHINYONGA	179	200	56.16	11.40	57.30	**100**
11 CITY GARAGE	1145	100	47.09	9.56	48.05	
12 KANJEDZA ROAD	1604	200	182.02	36.96	185.74	
13 SUNDER FURNITURE	696	315	174.78	35.49	178.35	
14 KANJEDZA NEW HOUSING		100	77.57	15.75	79.15	
15 ADMARC FLATS	1572	200	37.13	7.54	37.89	**50**
16 KANJEDZA NORTH	409	200	119.81	24.33	122.25	
17 KANJEDZA NORTH II	661	200	70.51	14.32	71.95	
18 CENTRAL AUTO SPARES	189	200	335.85	68.20	342.71	**400**
19 RAB PROCESSORS LTD	417	800	311.29	63.21	317.64	
20 KASUNGU CRESCENT	649	100	57.14	11.60	58.31	
21 MULTICOUNTRY	1694	100	92.19	18.72	94.07	
22 CIVIC CENTRE		500	130.66	26.53	133.33	**200**
23 DIGITAL EXCHANGE	1986	200	173.46	35.22	177.00	
24 UTM	160	200	158.01	32.09	161.23	
25 POLY RESIDENCE	624	200	87.30	17.73	89.08	
26 KAMUZU STADIUM	300	100	71.70	14.56	73.16	
27 NKOLOKOSA	1400	200	88.59	17.99	90.40	
28 NKOLOKOSA III	1331	200	108.57	22.05	110.79	
29 NKOLOKOSA II	1330	100	75.15	15.26	76.68	
30 SOCHE EAST II	1195	100	103.00	20.91	105.10	**200**
31 SOCHE EAST	1193	400	71.43	14.51	72.89	**100**
32 KUDYA HOTEL	1367	100	58.57	11.89	59.76	
33 ZINGWANGWA	1940	200	99.54	20.21	101.57	
34 ZINGWANGWA	1939	50	49.47	10.04	50.48	**100**
35 ST PIUS	915	15	6.89	1.40	7.03	
36 NKOLOKOSA I	1329	200	121.64	24.70	124.12	
37 CHIMWANKHUNDA	2106	50	57.43	11.66	58.60	**100**
38 NEW CHIMWANKHUNDA AREA	1499	200	5.69	1.16	5.81	
39 NEW CHIMWANKHUNDA AREA	1500	200	3.09	0.63	3.15	
40 CHICHIRI PRISON	376	100	57.24	11.62	58.41	
41 POLY VILLAGE	2084	50	12.76	2.59	13.02	
42 BWB SOCHE PUMPS	289	400	3.29	0.67	3.36	
43 K.K MILLERS	2316	500	248.90	50.54	253.98	
44 POLICE S DIVISION	421	200	37.44	7.60	38.20	**50**
45 KANJEDZA INDUS SITE	2319	50	36.35	7.38	37.09	

Table 4.19 : Summary of Transformer Replacements - Group Substation, Feeder 202

Transformer Size (kVA)	OPTIMISATION PROGRAMME No. Removed	No. Introduced	No. into Store	No. to be Purchased	Unit Cost (Int. Budgetary) MK	Total Transformer Cost MK
25	0	0	0	0	6500	
50	2	3	0	1	8800	8800
100	2	5	0	3	12200	36600
200	5	3	2	0	19100	
315	0	0	0	0		
400	2	1	1	0		
500	1	0	1	0	28000	
					TOTAL	45400
					Installation : 12 Transformer Replacements @ MK270	3240
					TOTAL COST	**48640**

TRANSFORMER LOSSES

	Demand (kW)	Power Loss (%)	Energy Loss (%)
1990 Pre-optimisation	3922	1.55	1.66
1991 Post-optimisation	4255	1.45	1.50
2005 Pre-optimisation	13959	1.29	1.11
2005 Post-optimisation	13959	0.92	0.92

Capital Cost (MK)	48640
Internal Rate of Return	**17.1%**

Table 4.20 : Summary of Overall 11/0.4 kV Transformer Replacement Programme

Feeder	1990 Installed Capacity (kVA)	Transformers to be Purchased 50 kVA	100 kVA	200 kVA	500 kVA	% of Installed Capacity
Chichiri 6L5	5325	4			1	13
Chichiri 9L5	5725	1	2			4
Group 202	8530	1	3			4
Limbe 1L5	4275	1	5			13
Lilongwe A 2L5	2645	3		3	3	85
Lilongwe A 3L5	6255	2	8		2	30
Lilongwe B 1L5	1965	6				15
Lilongwe B 2L5	9180	7	3			7
Lilongwe B 3L5	6825	1	1			2
Lilongwe B 6L5	6380	4	1			5
Totals	**57105**	**30**	**23**	**3**	**6**	**13**
% of Total Purchased Transformer Capacity		20%	31%	8%	41%	

Total 1990 Interconnected System 11/0.4 kV Transformer Capacity:	203125 kVA
% Additional Capacity to be Purchased (from sample) :	13 %
Additional Capacity to be Purchased :	26322 kVA

Size	% of Total	kVA	No. of Units	Unit Cost (MK)	Installation (per unit)	Total (MK)
50 kVA	20%	5336	107	8800	270	970500
100kVA	31%	8181	82	12200	270	1022500
200 kVA	8%	2134	11	19100	270	213100
500 kVA	41%	10671	21	28000	270	593700
					TOTAL COST	**2799800**

Table 4.21 : Present LV System Loss Levels

Feeder	Load (kW)	Load Factor (%)	Loss Factor (%)	Power Loss (%)	Energy Loss (%)	Minimum Voltage (V)
BANGWE 2	177.3	48.56	28.14	12.5	7.2	162
CHILOBWE BEER HALL 1	43.1	52.43	32.12	5.8	3.6	204
CHILOBWE BEER HALL 2	169.6	52.43	32.12	12.7	7.8	193
BROWNS ROAD 1	145.8	54.37	37.10	6.9	4.7	195

Table 4.22 : LV Line Parameters

Line Type	Conductor Size (sq.mm)	Resistance (Ohms/km)	New Line Cost Estimates ESCOM (MK/km)	KDP International (MK/km)
400 V 4-wire Wood Pole	50 AAC 1-phase	1.0838	12570	
	50 AAC	0.5419	17930	
	100 AAC 1-phase	0.5404	15330	
	100 AAC	0.2702	23380	
	150 AAC	0.1825	30737	46105

Table 4.23 : Summary of Browns Road LV Feeder Reconductoring Analysis

	BROWNS ROAD 1			
	Demand (kW)	Power Loss (%)	Energy Loss (%)	Minimum Voltage (V)
1990 Pre-Reconductoring	145.8	6.90	4.70	195
1991 Post-Reconductoring	158.2	4.50	3.10	202
2005 Pre-Reconductoring	246.7	11.70	8.00	172
2005 Post-Reconductoring	246.7	7.00	4.80	188

Feeder Length Reconductored (km)	0.39
Capital Cost (MK)	18000
Internal Rate of Return	**19.3%**

Table 4.24 : LV System Reconductoring Analysis

Transformer	Total Circuit Length (m)	Circuit Length Reconductored (m)	(%)	Unit Cost (MK/km)	Total Cost (MK)
Chileka 2L0 S/S 1928	852	0	0%	46105	0
Chileka 2L0 Lunzu Trading	2749	432	16%	46105	19900
Limbe 1L5	1956	1602	82%	46105	73900
Blantyre Main 5L5 Browns Road	1518	390	26%	46105	18000
Lilongwe B 4L5 S/S 678	764	363	48%	46105	16700
Lilongwe B 6L5 S/S 444	1328	320	24%	46105	14800
Totals	**9167**	**3107**	**34%**		

Total LV System Length (1990 - Interconnected System) 1597 km

Total Reconductoring 541 km

Total Cost **24,943,000 MK**

Fig. 4.1 : 1990 Peak Load Flow Breakdown of 132/66/33kV Losses

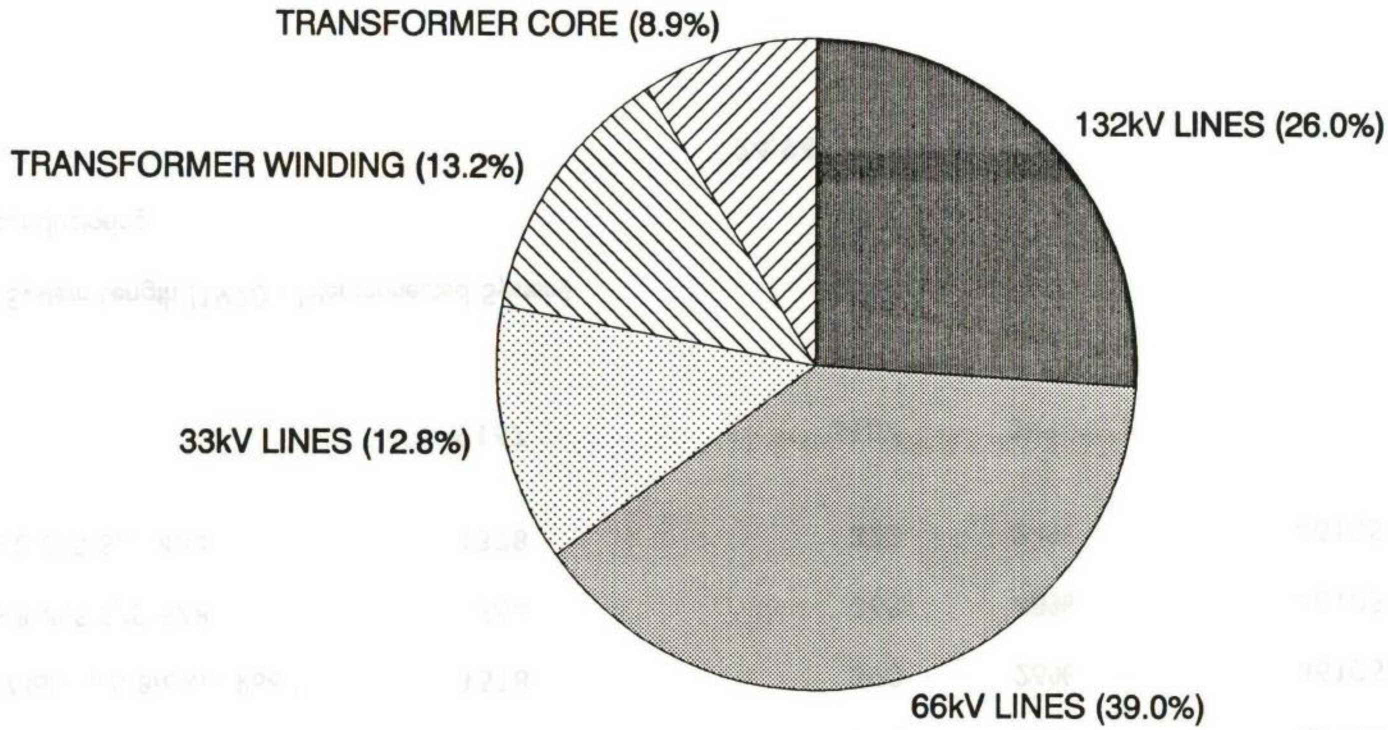


**Fig. 4.2 : 1990 Peak Load Flow
High Loss 132/66/33kV Lines**

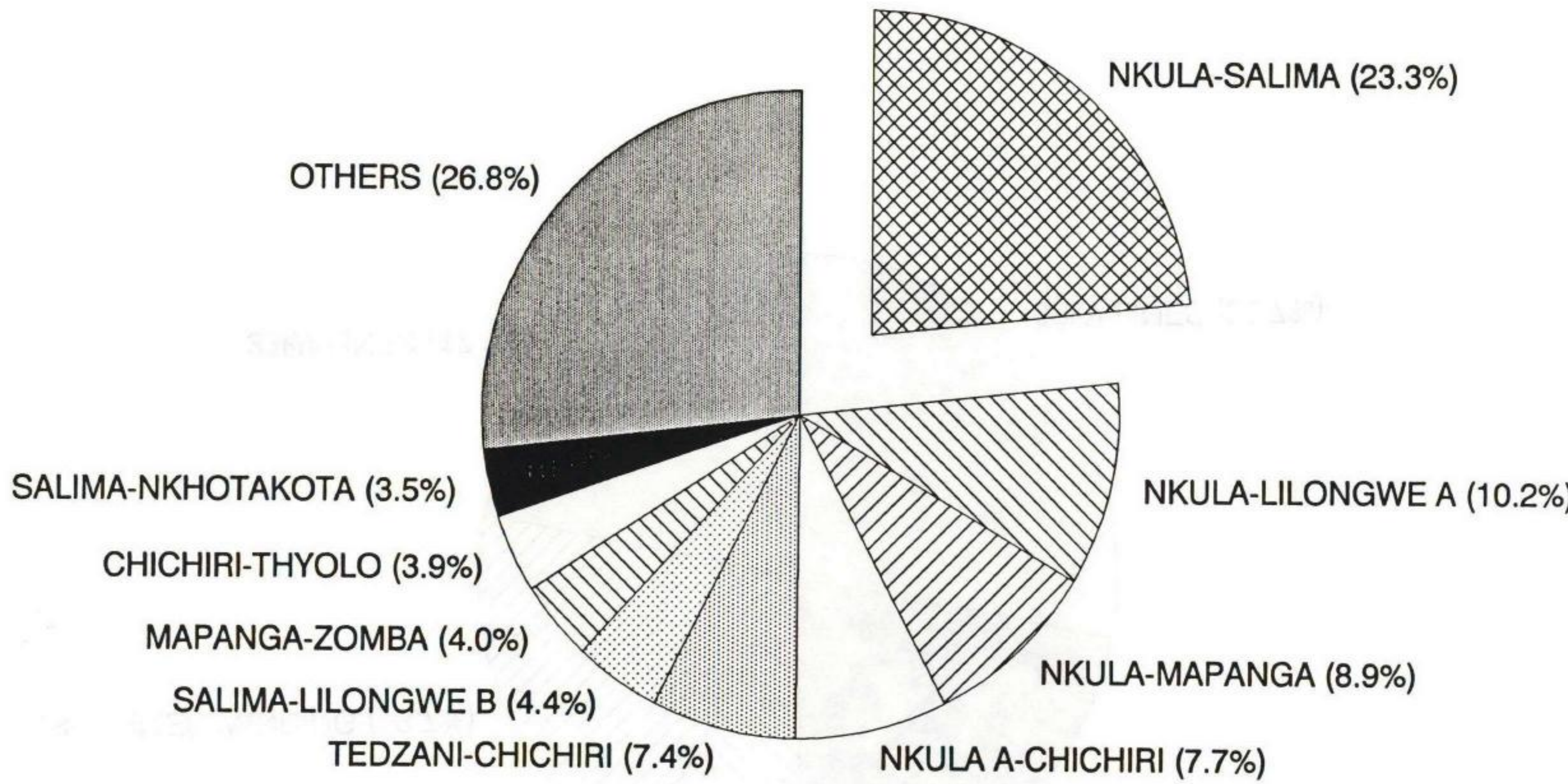


Fig 4.3 : 1994 Peak Load Flow
Breakdown of 132/66/33kV Losses

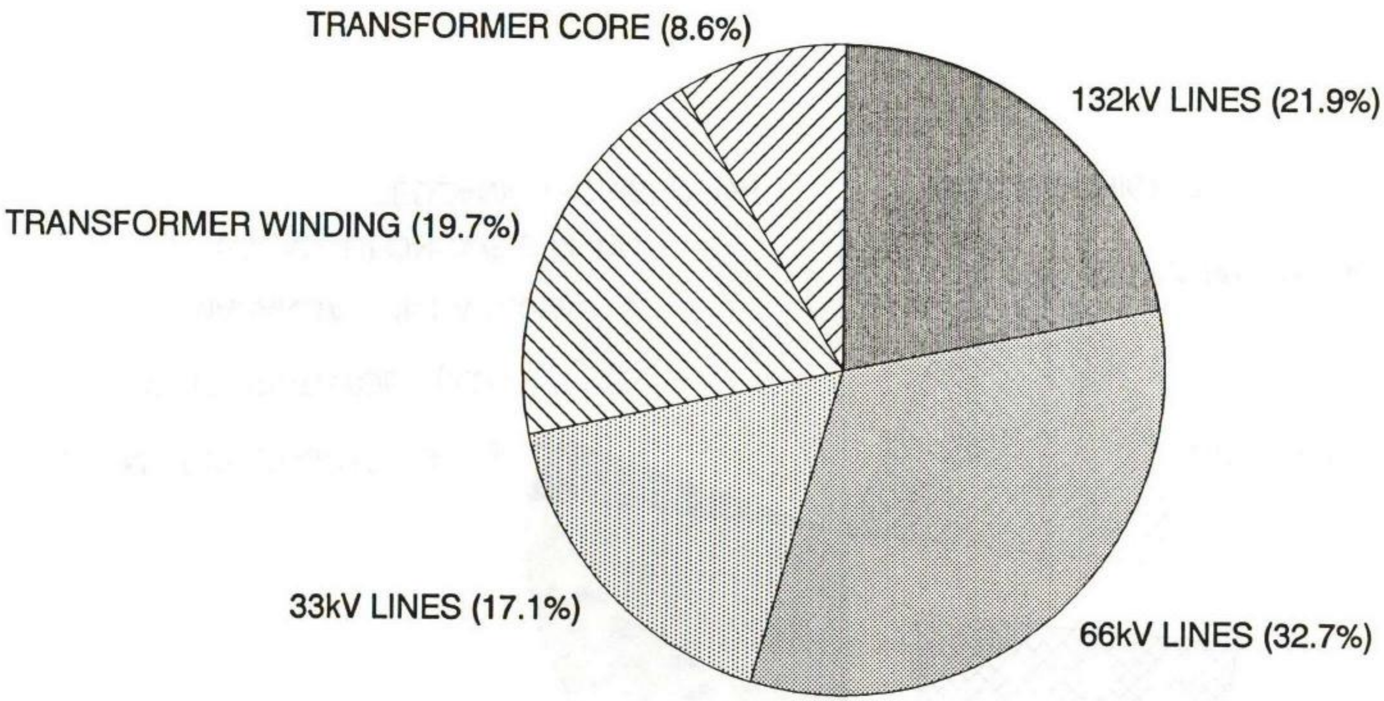


Fig. 4.4 : 66kV New Line Loading Ranges
ACSR Conductors, Wood Pole Lines

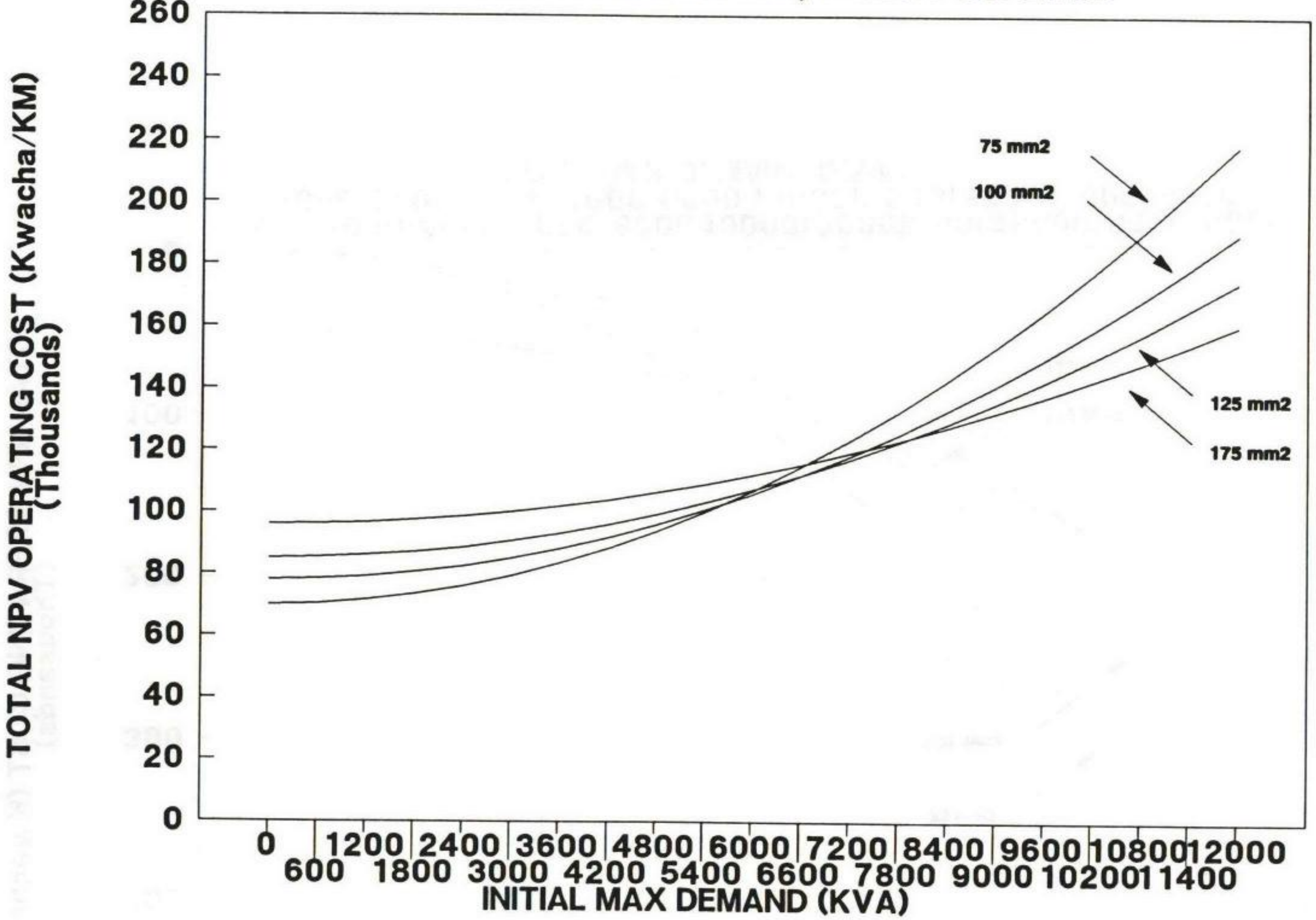


Fig. 4.5 : 66kV Reconductoring Loading Ranges
ACSR Conductors, Wood Pole Lines

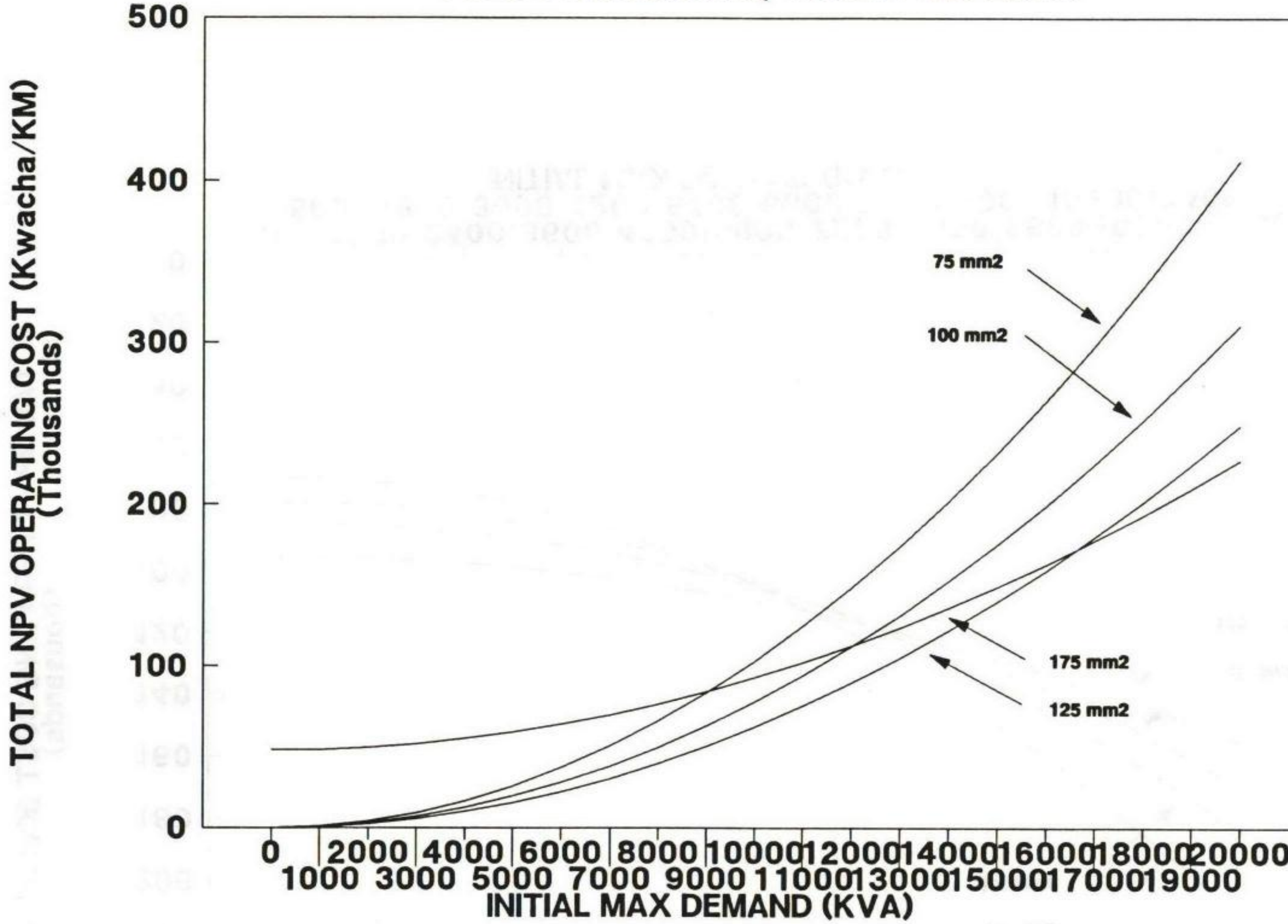


Fig. 4.6 : 66kV New Line Loading Ranges
ACSR Conductors, Steel Tower Lines

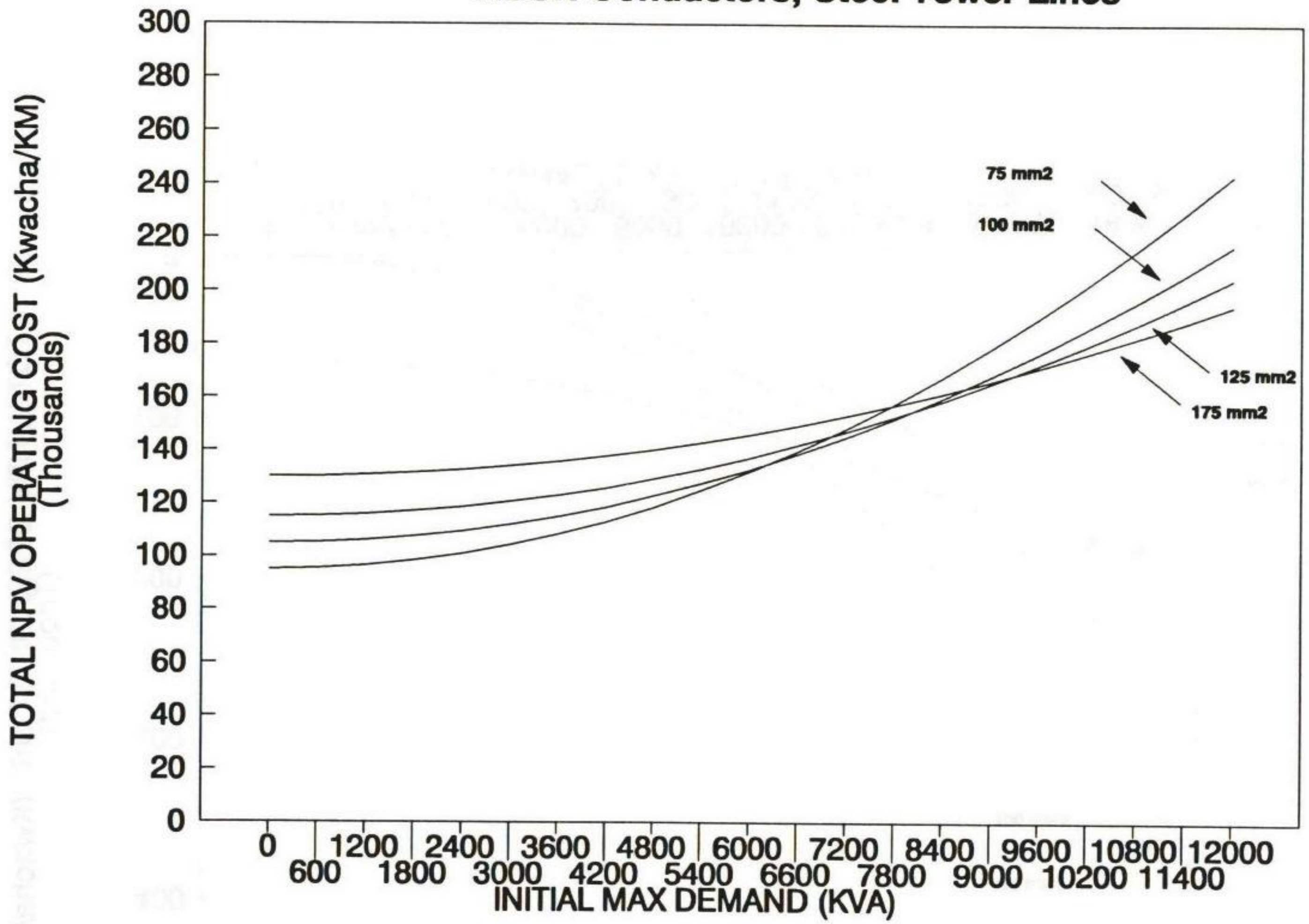


Fig. 4.7 : 66kV Reconductoring Loading Ranges ACSR Conductors, Steel Tower Lines

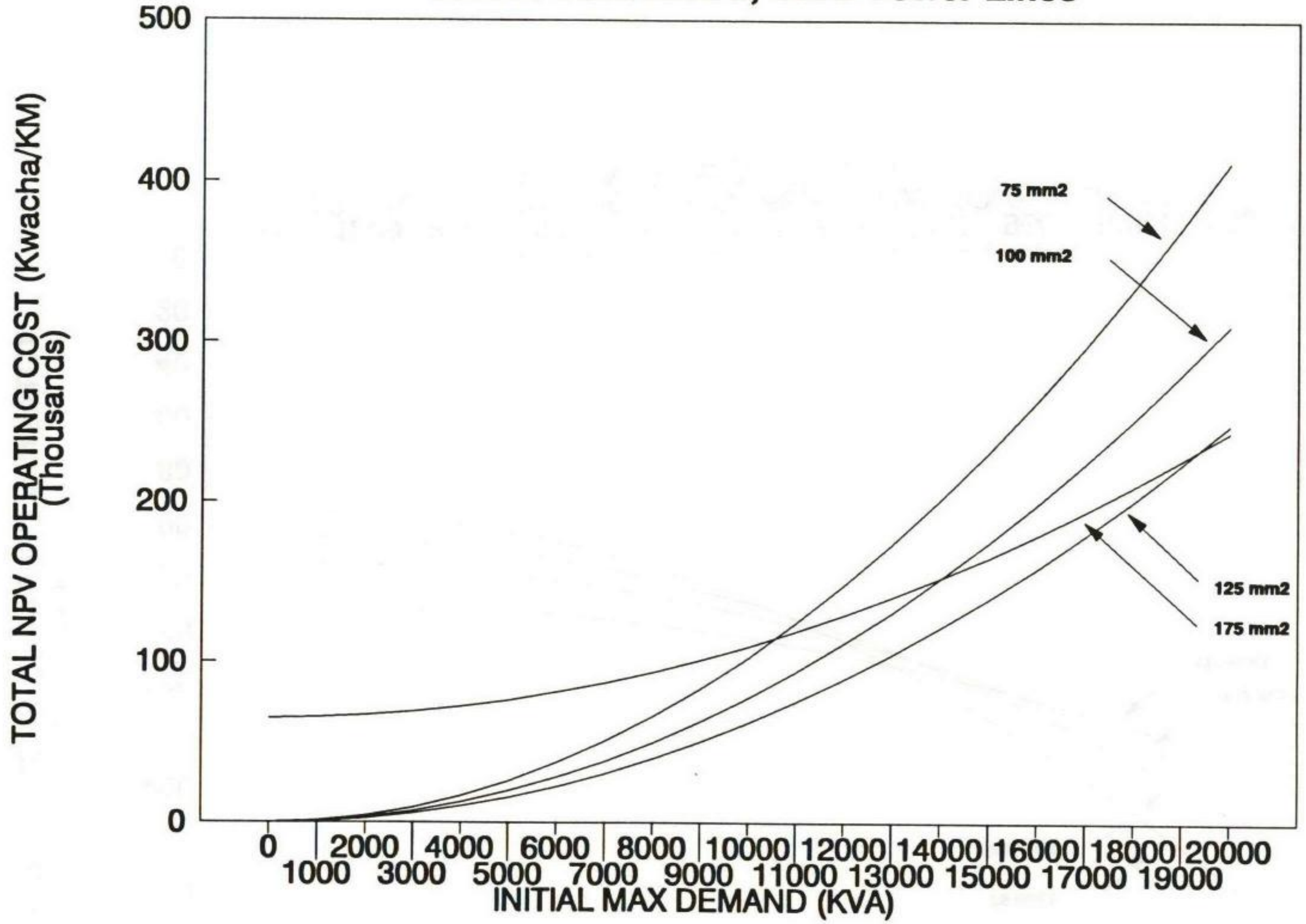


Fig. 4.8 : 33kV New Line Loading Ranges
AAAC Conductors

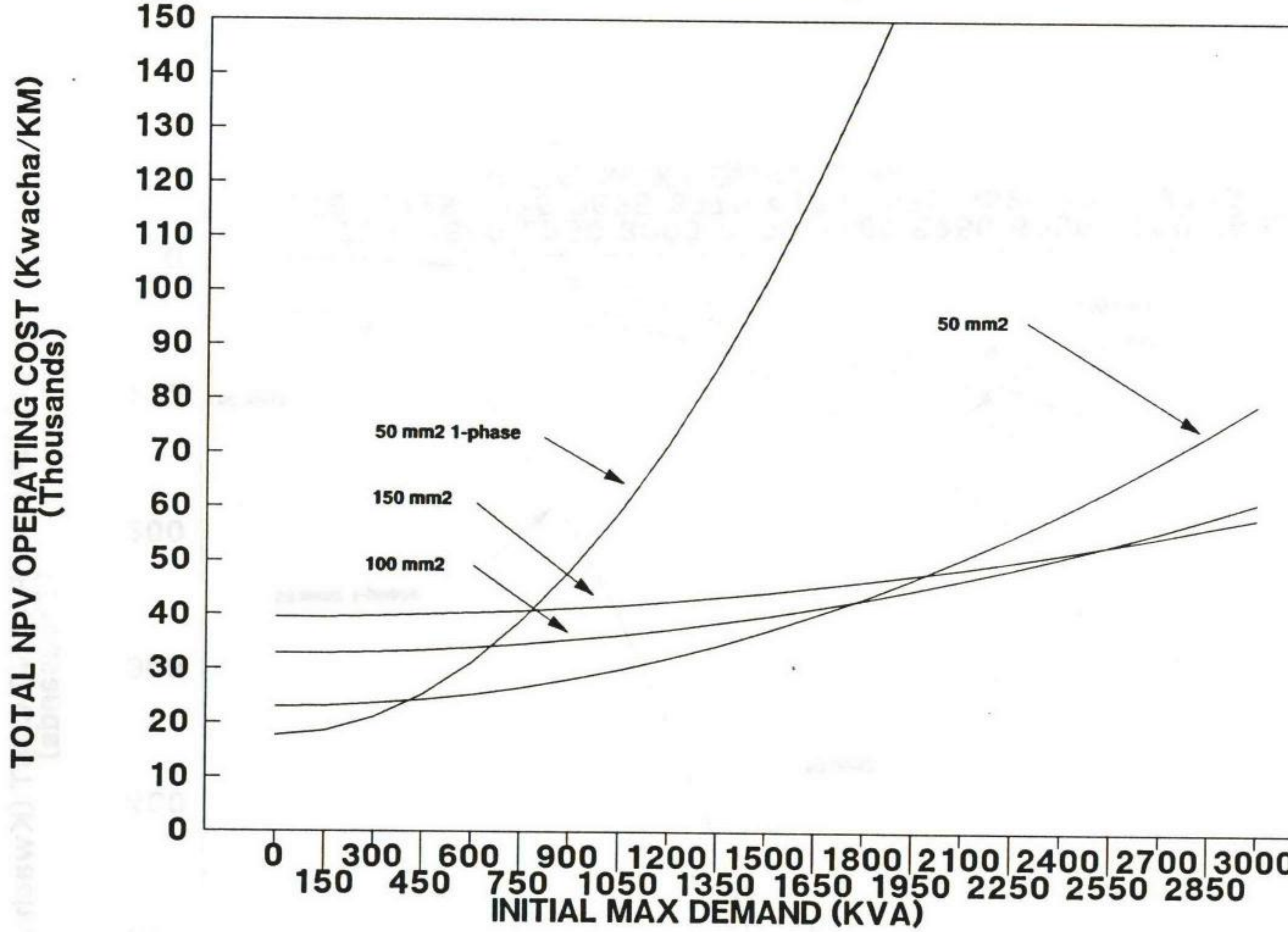


Fig. 4.9 : 33kV Reconductoring Loading Ranges
AAAC Conductors

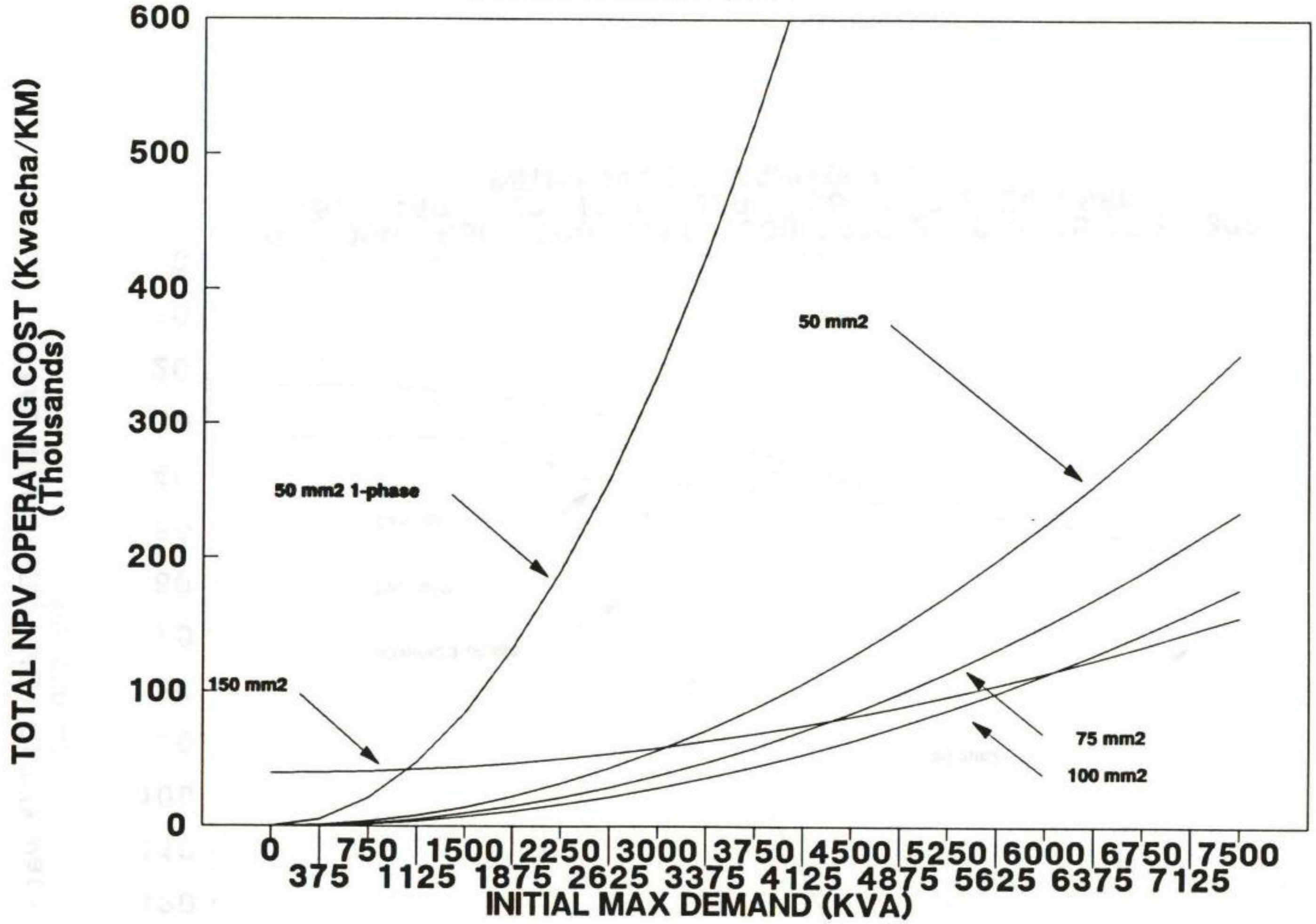
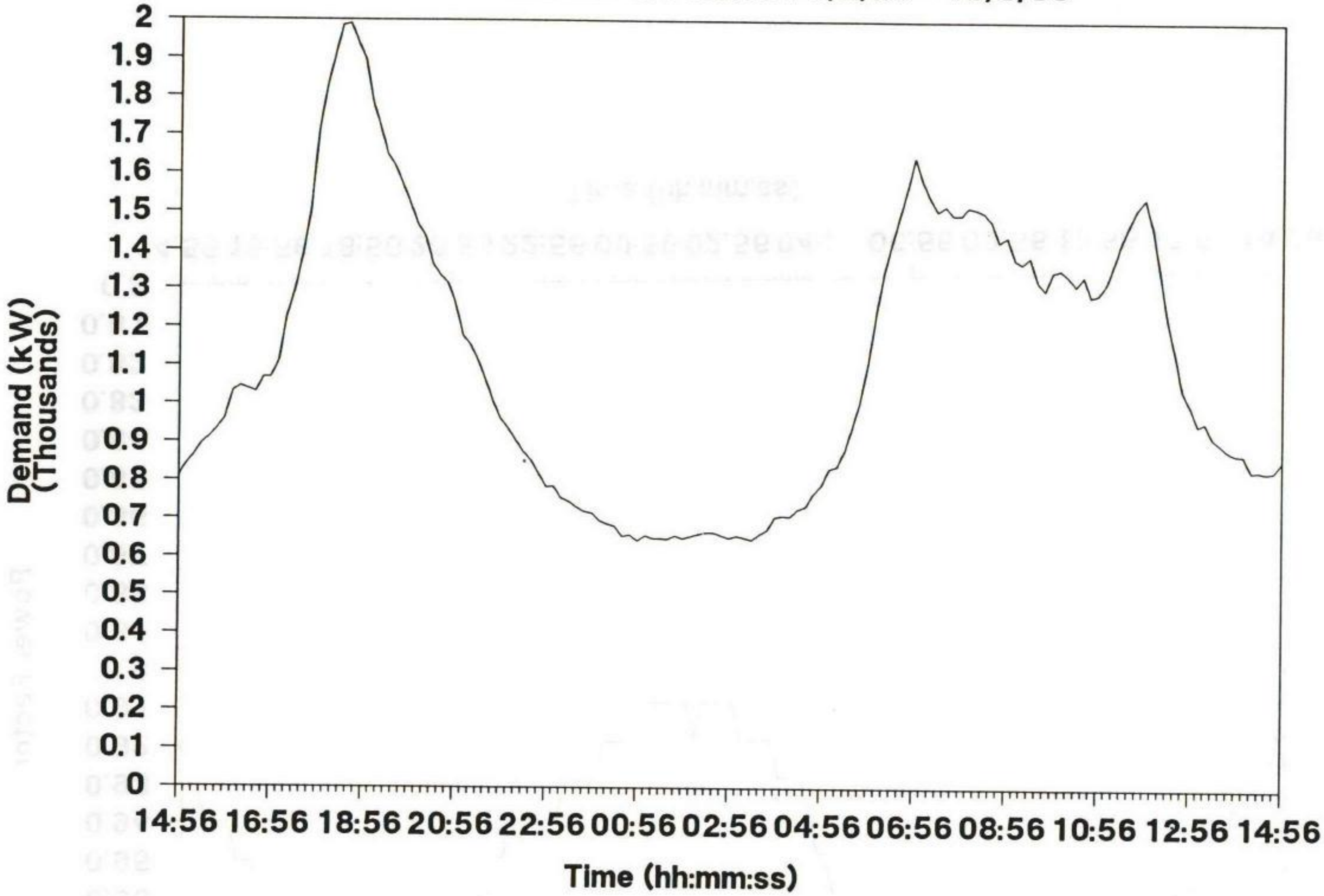
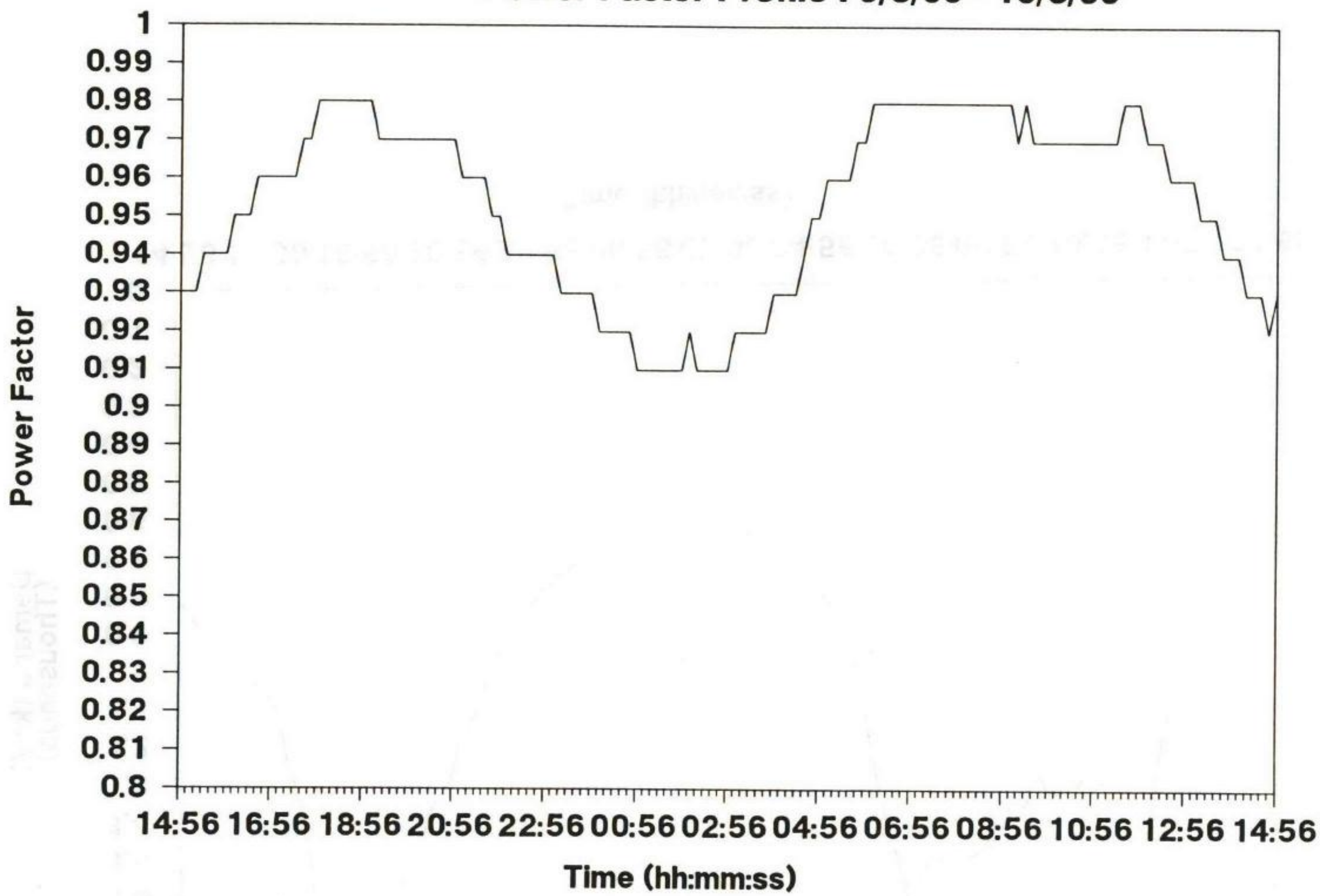


Fig. 4.10 : Blantyre Main : Feeder 5L5
Demand Profile : 9/8/90 - 10/8/90



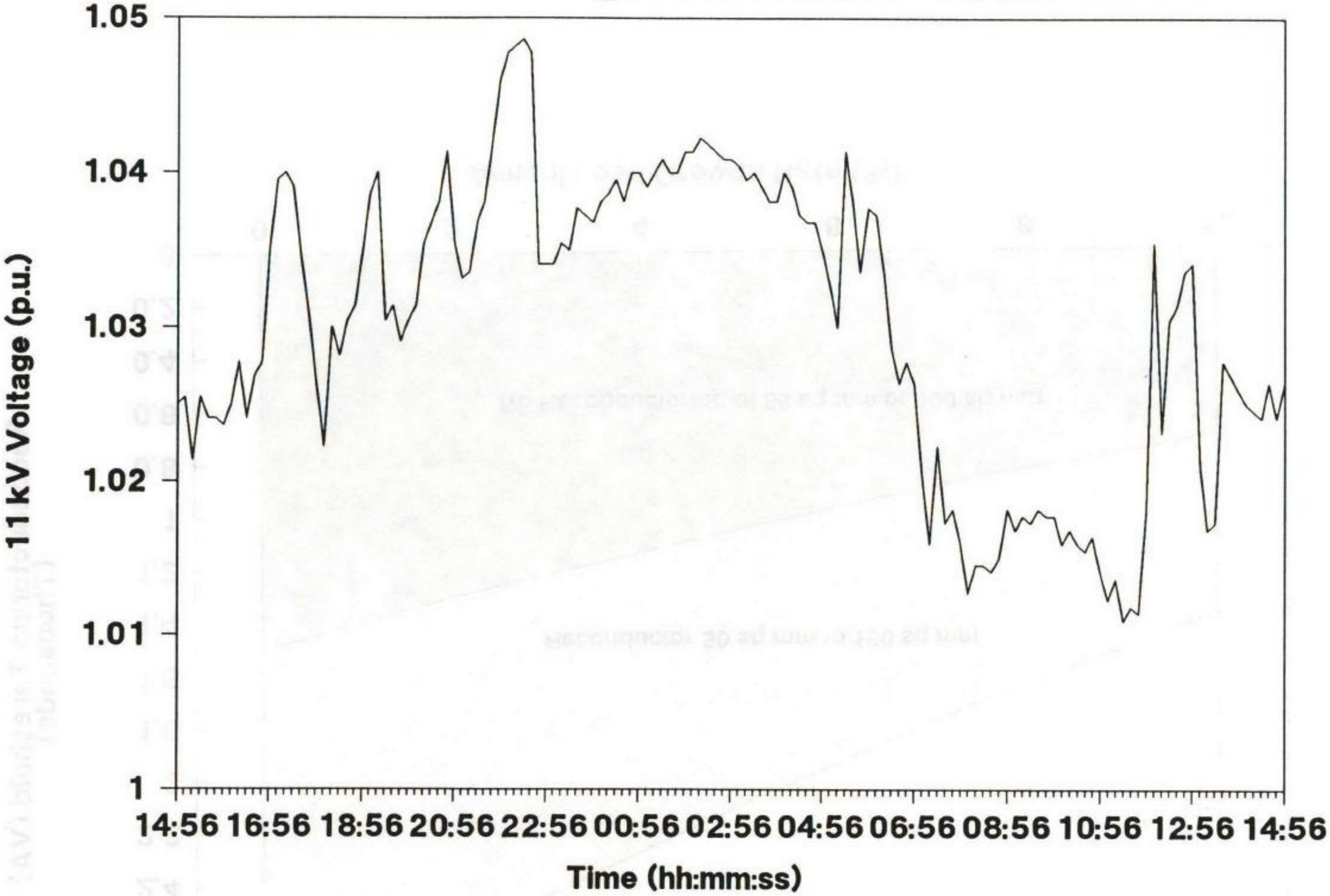
BMAIN5L5.DRW

Fig. 4.11 : Blantyre Main - Feeder 5L5
Power Factor Profile : 9/8/90 - 10/8/90



BM5L5PF.DRW

Fig. 4.12 : Blantyre Main : Feeder 5L5
Voltage Profile : 9/8/90 - 10/8/90



BM5L5V.DRW

Fig. 4.13 : Variation of 11kV Reconductoring Thresholds with Load Growth Rate

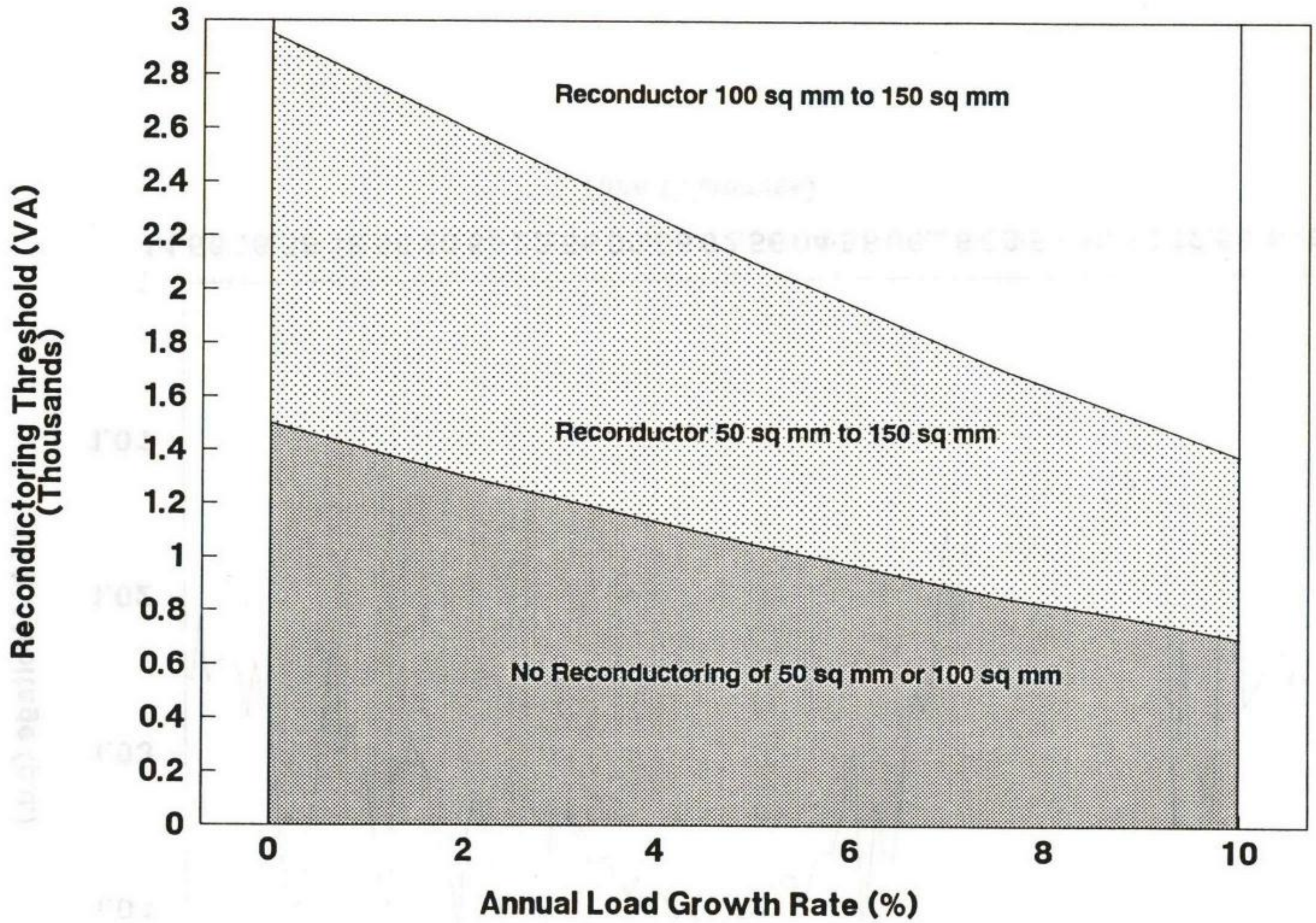


Fig. 4.14 : 11kV Cable Reconductoring Loading Ranges

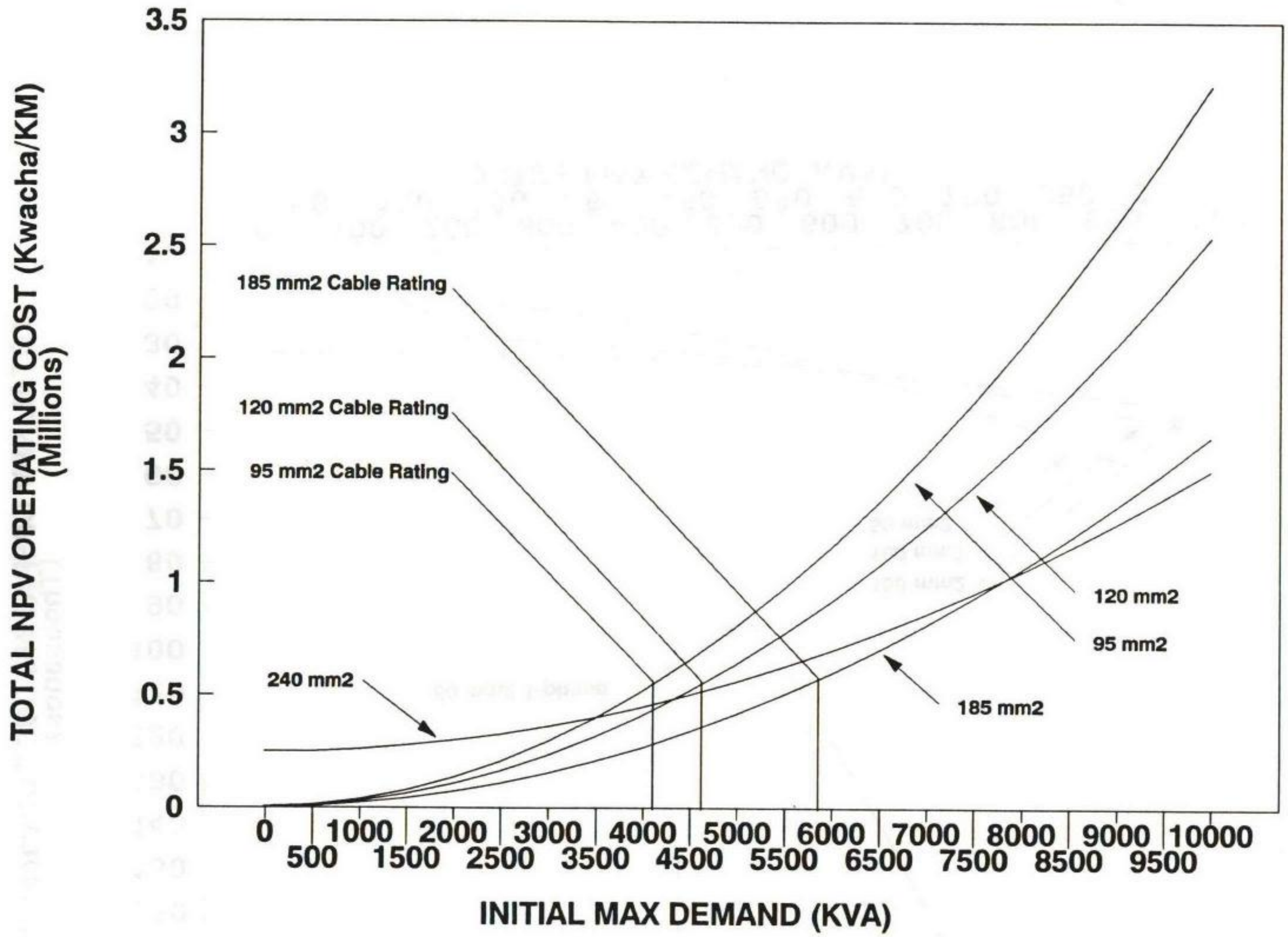


Fig. 4.15 : 11kV New Line Design Loading Ranges
AAAC Conductors

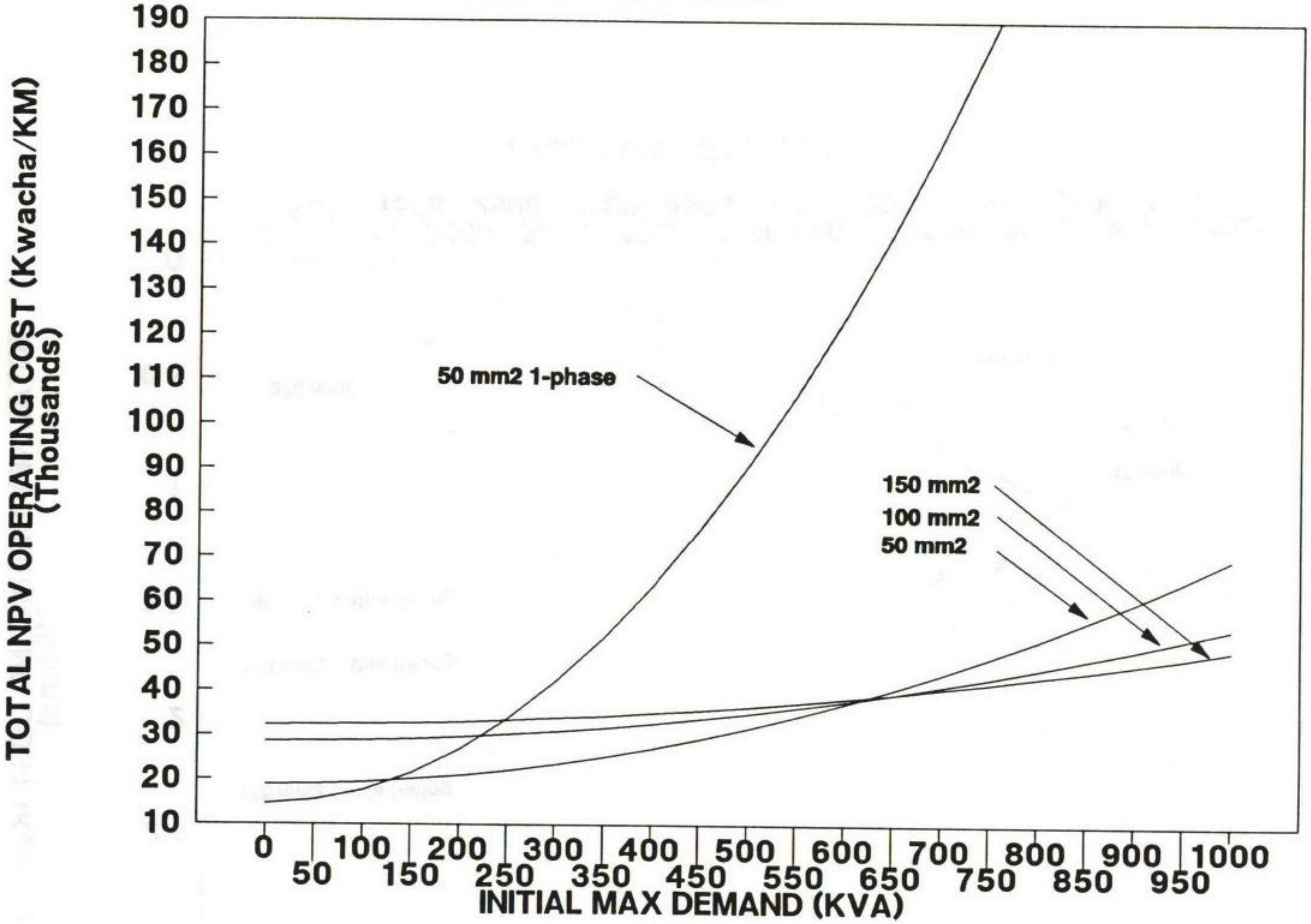


Fig 4.16 : 11kV New Cable Design Loading Ranges
3-core Copper XLPE Cables

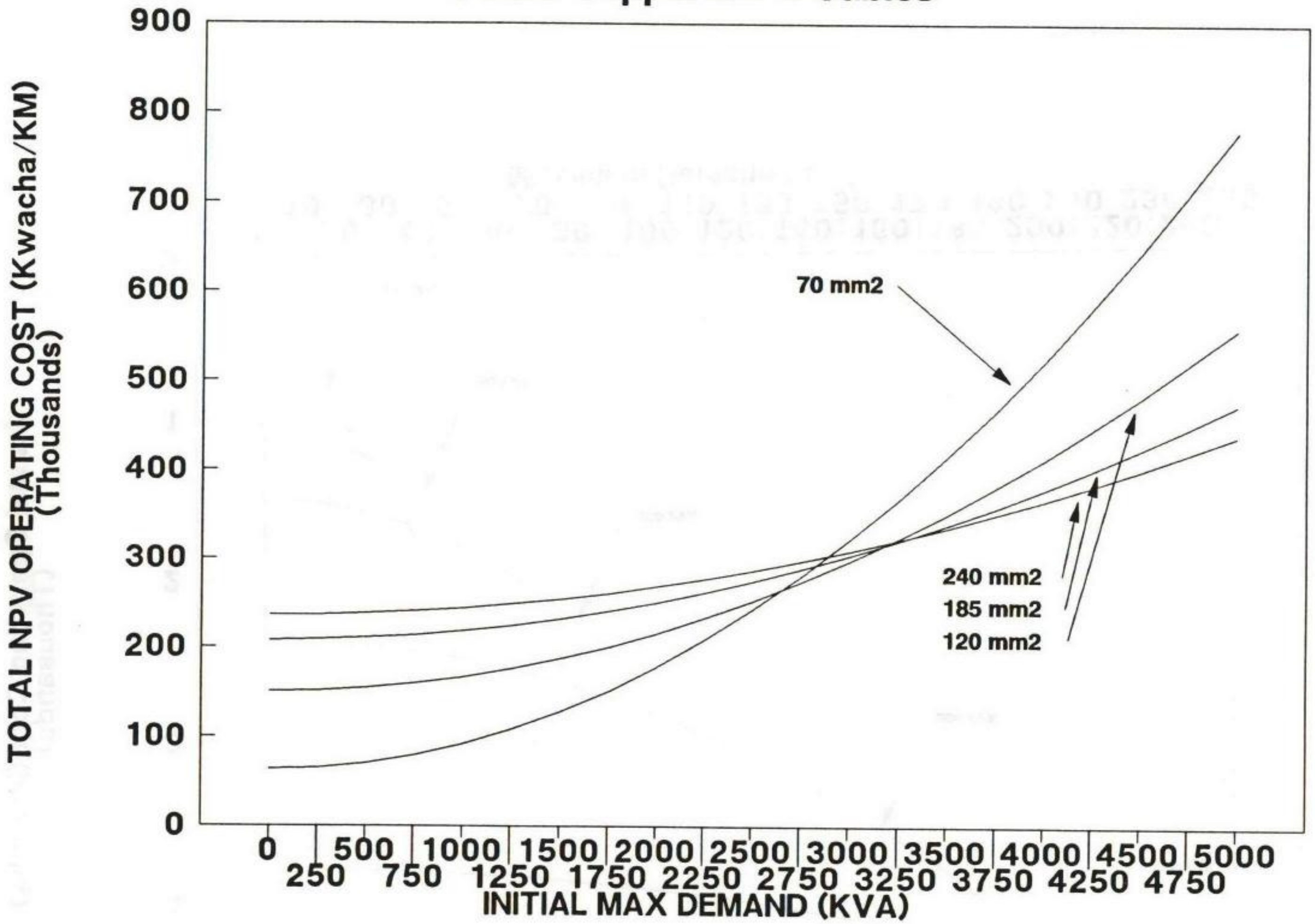


Fig 4.17 : 11 kV/0.4 kV Transformer Optimisation
ESCOM Cost Data - 62.3% Load Factor

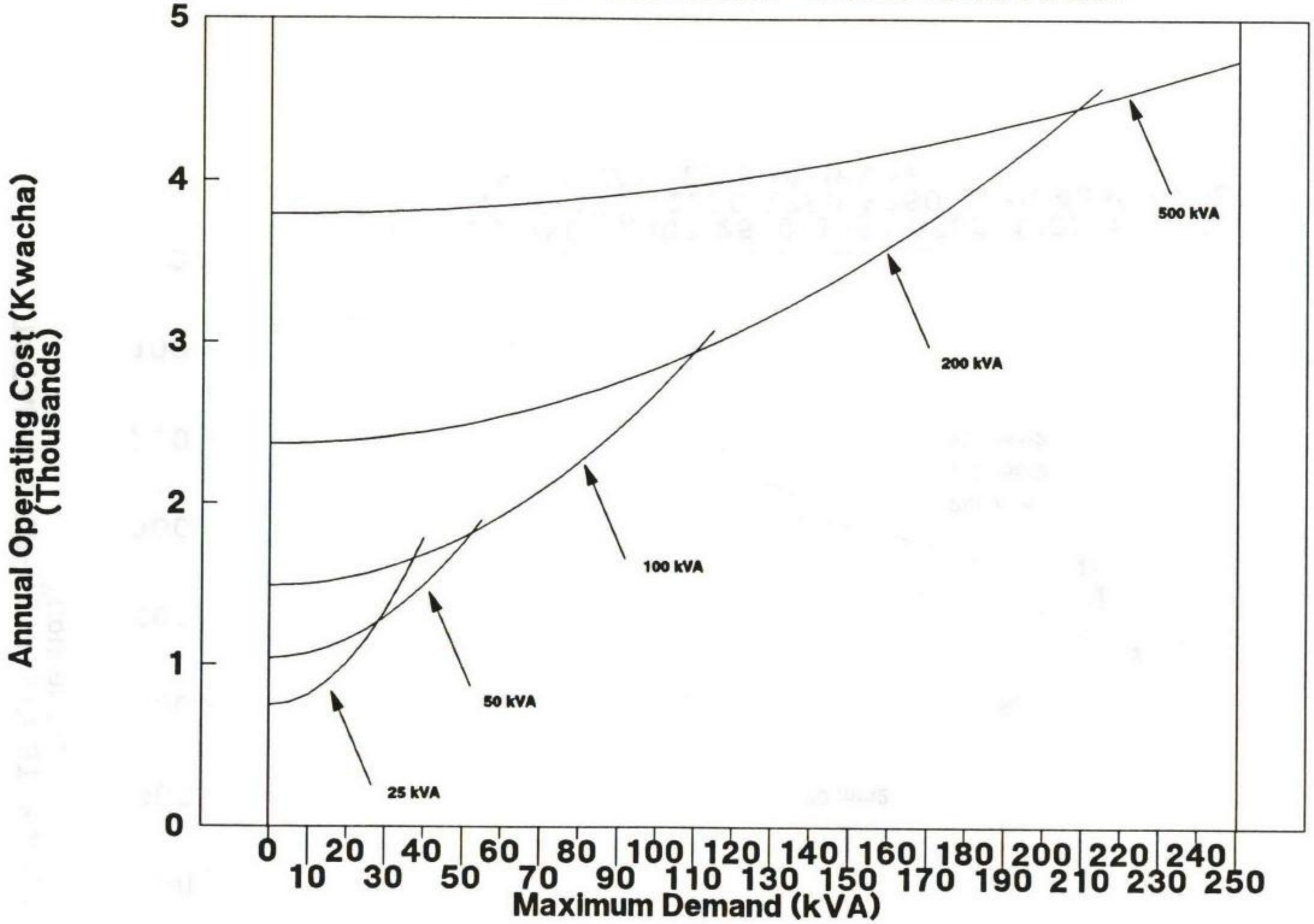


Fig 4.18 : 11 kV/0.4 kV Transformer Optimisation
ESCOM Cost Data - 90% Load Factor

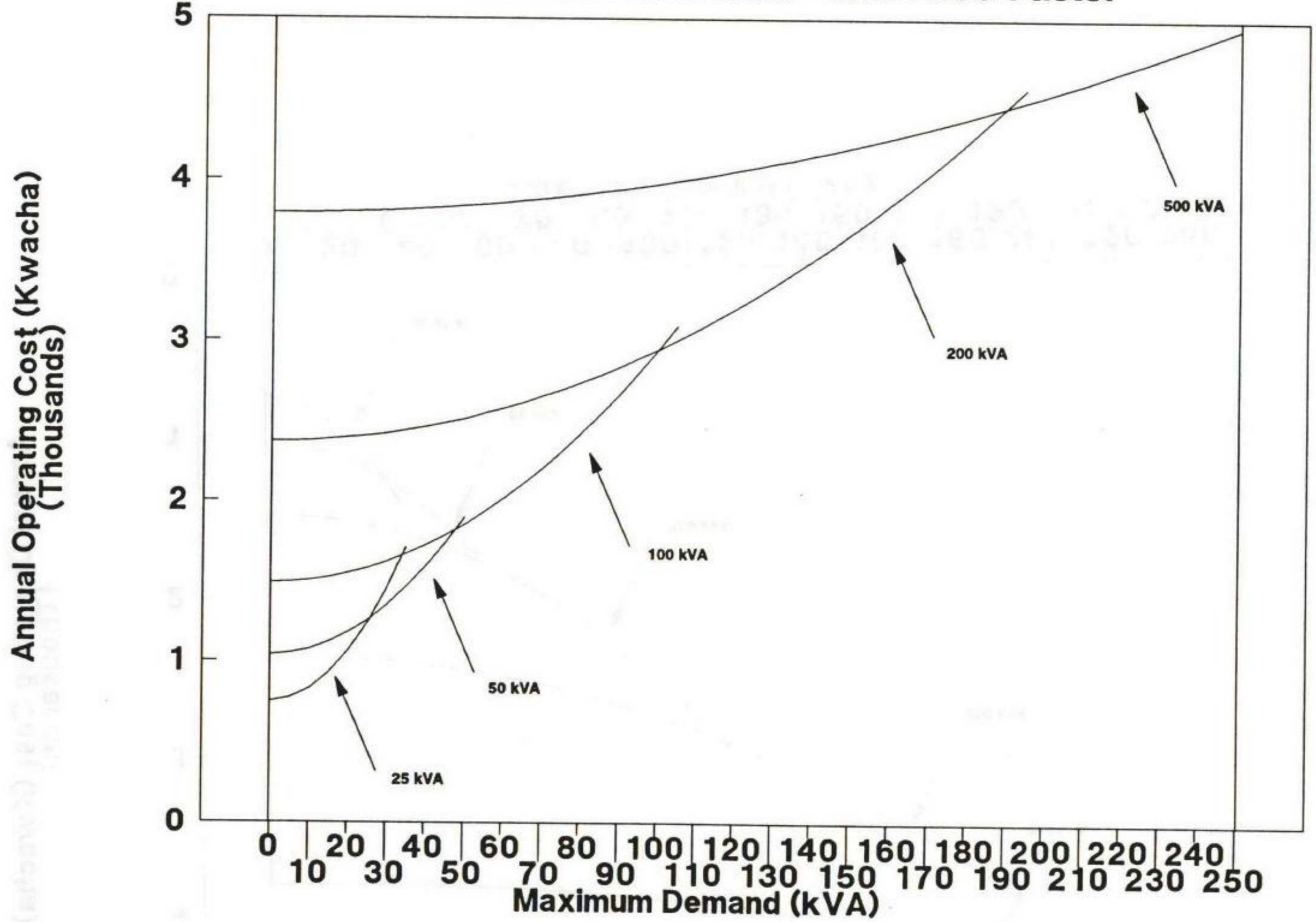


Fig 4.19 : 11 kV/0.4 kV Transformer Optimisation
ESCOM Cost Data - 40% Load Factor

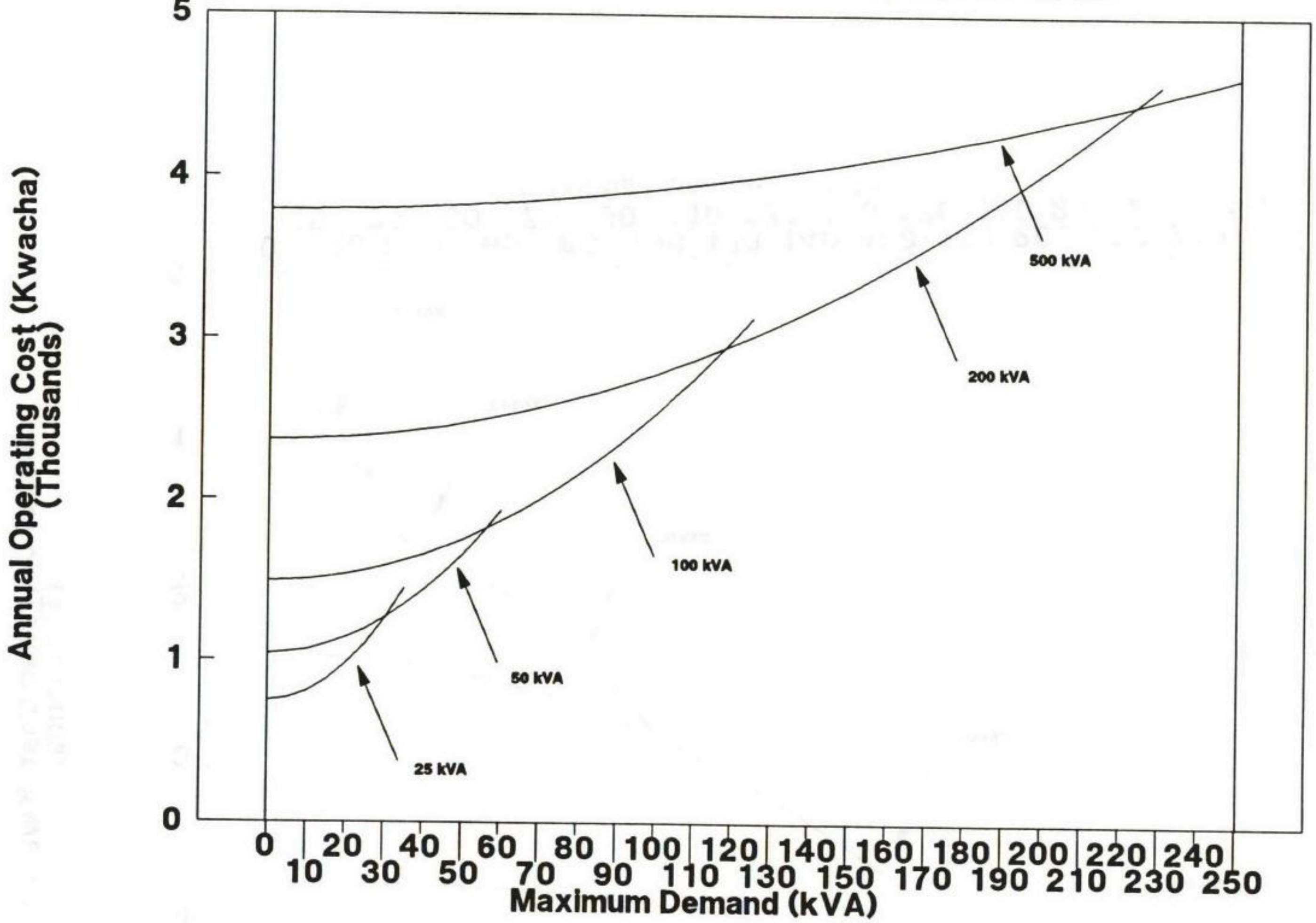


Fig. 4.20 : Browns Road Transformer Demand Profile 14/8/90 - 15/8/90

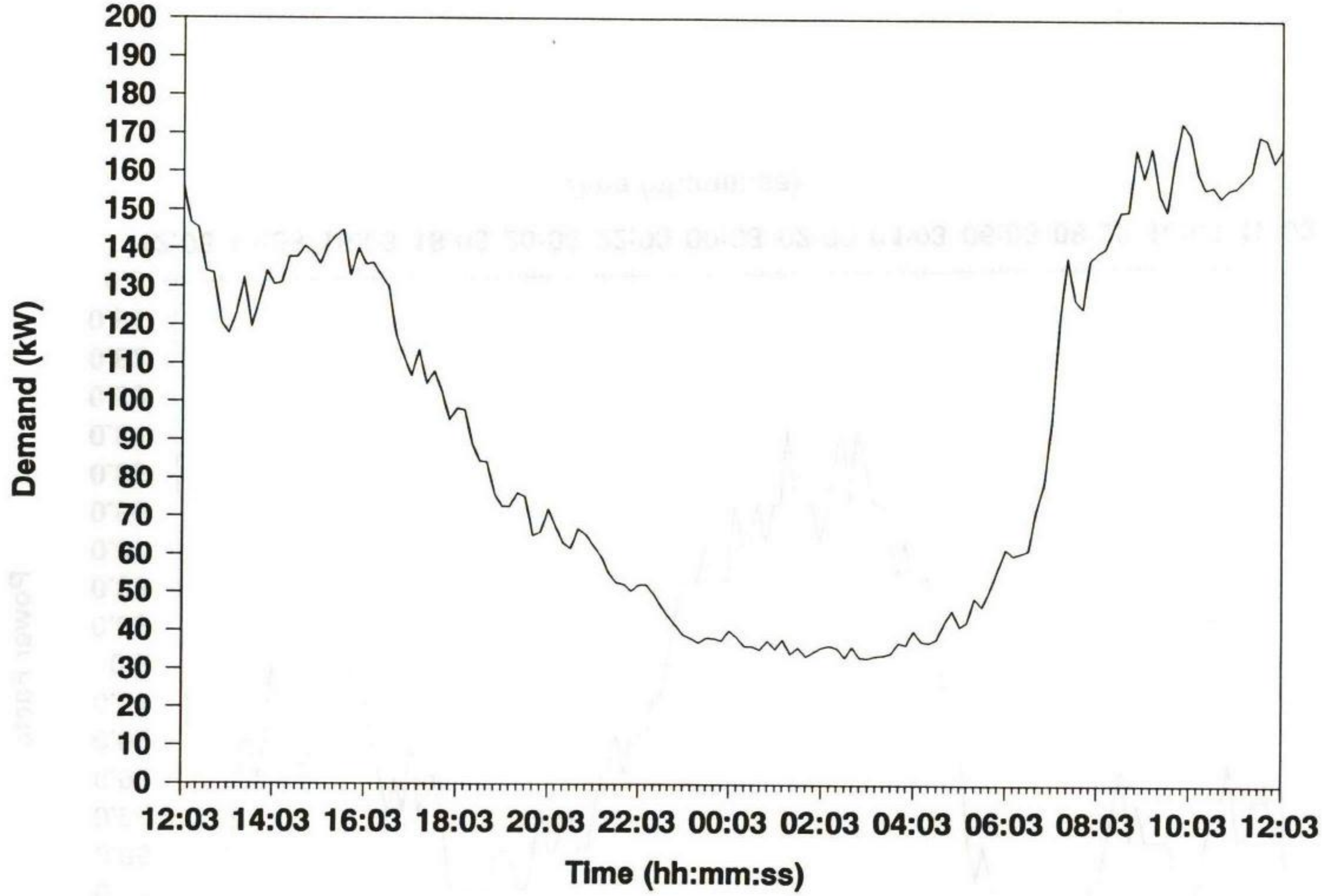


Fig 4.21 : Browns Road Transformer Power Factor Profile 14/8/90 - 15/8/90

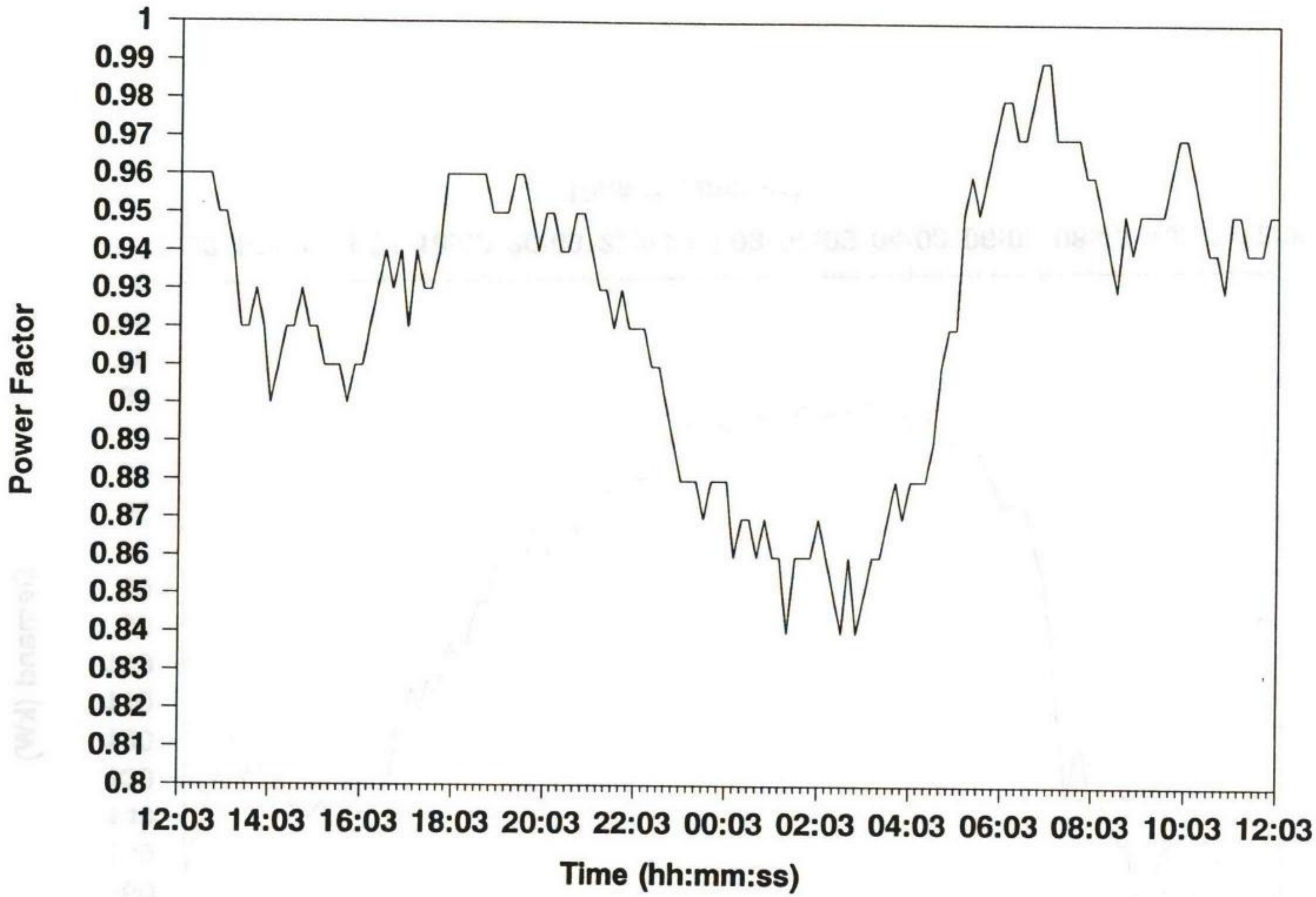


Fig 4.22 : Browns Road Transformer Average Phase Voltage 14/8/90 - 15/8/90

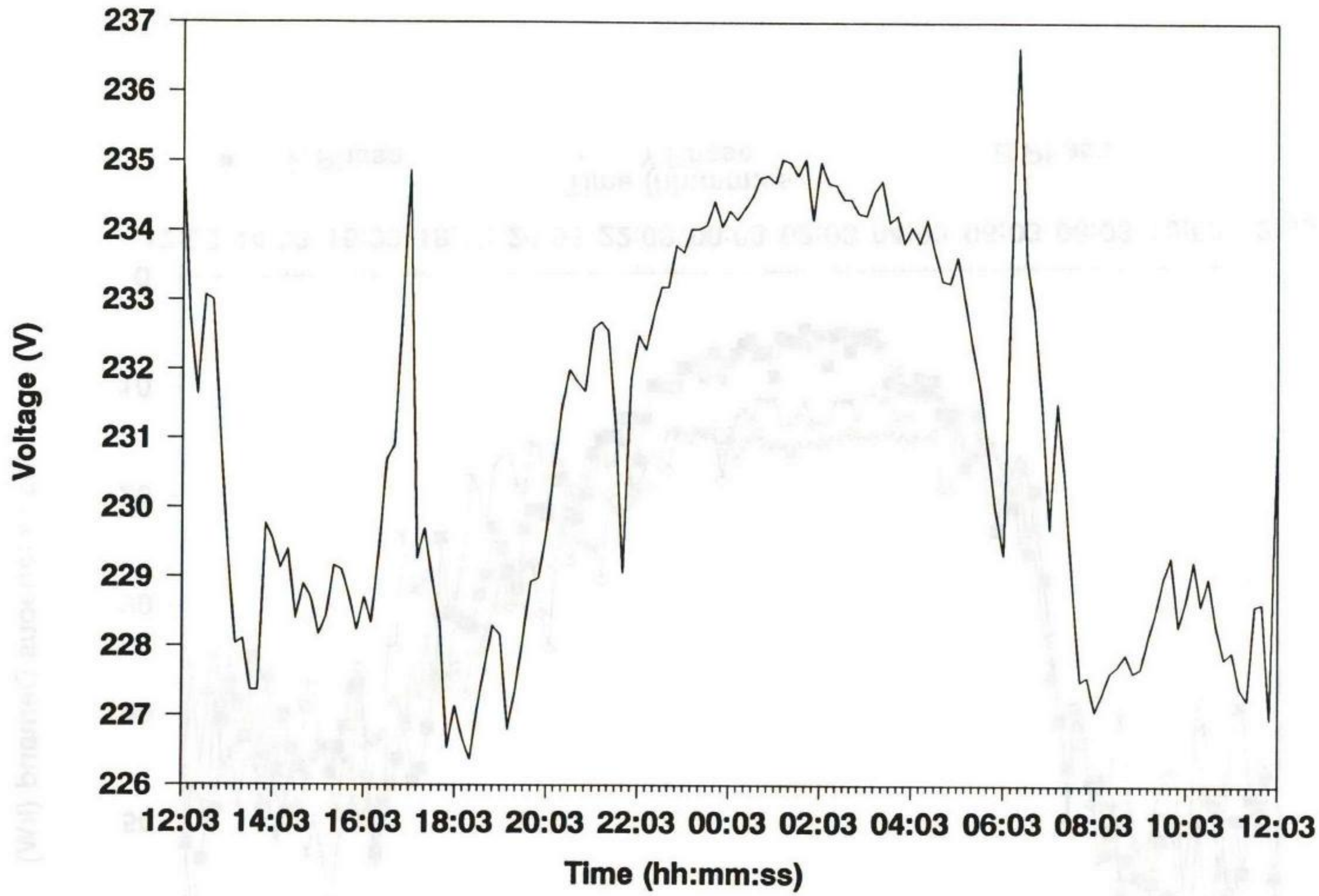


Fig. 4.23 : Browns Road Transformer Instantaneous Demand 14/8/90 - 15/8/90

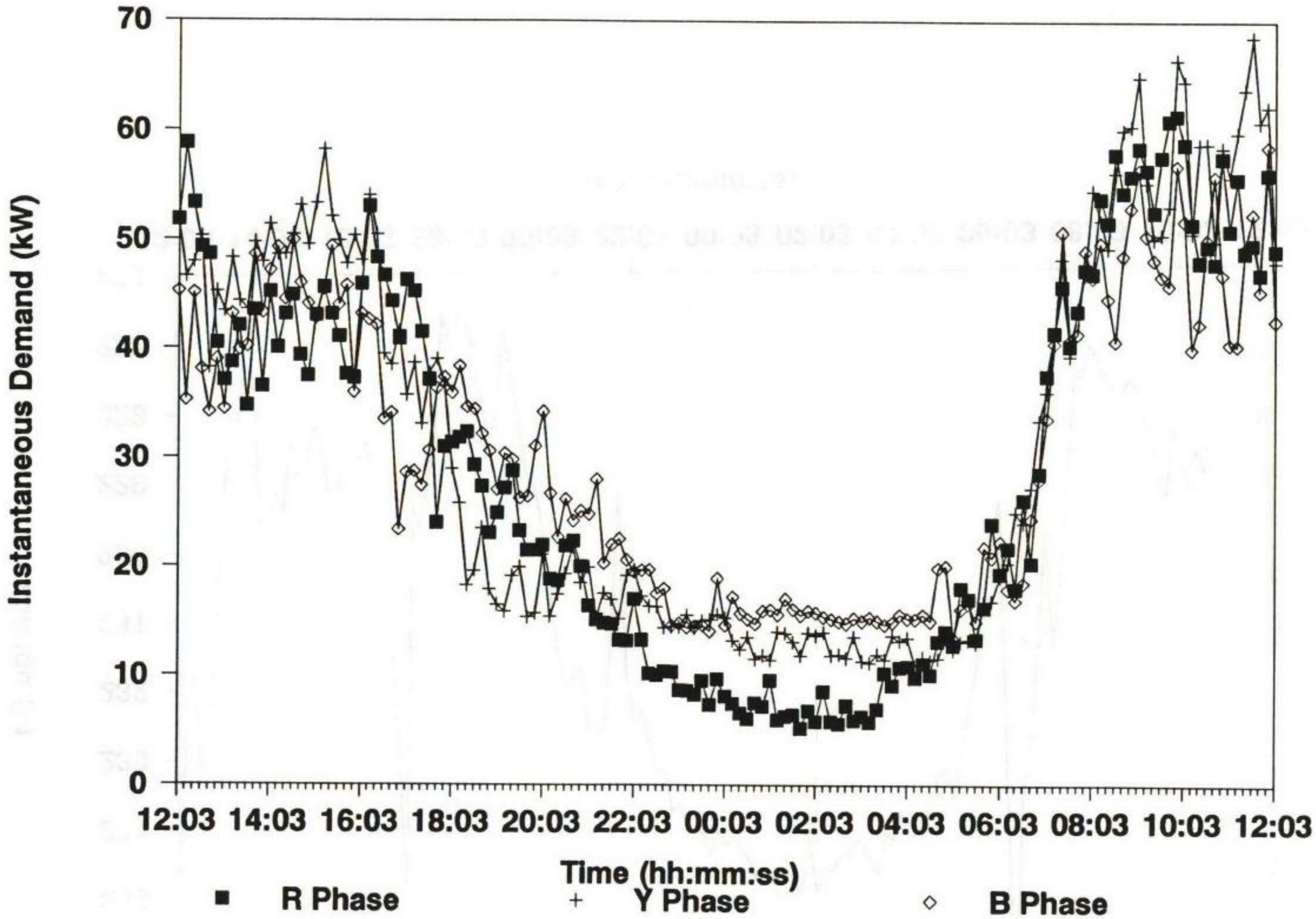


Fig 4.24 : LV New Line Loading Ranges

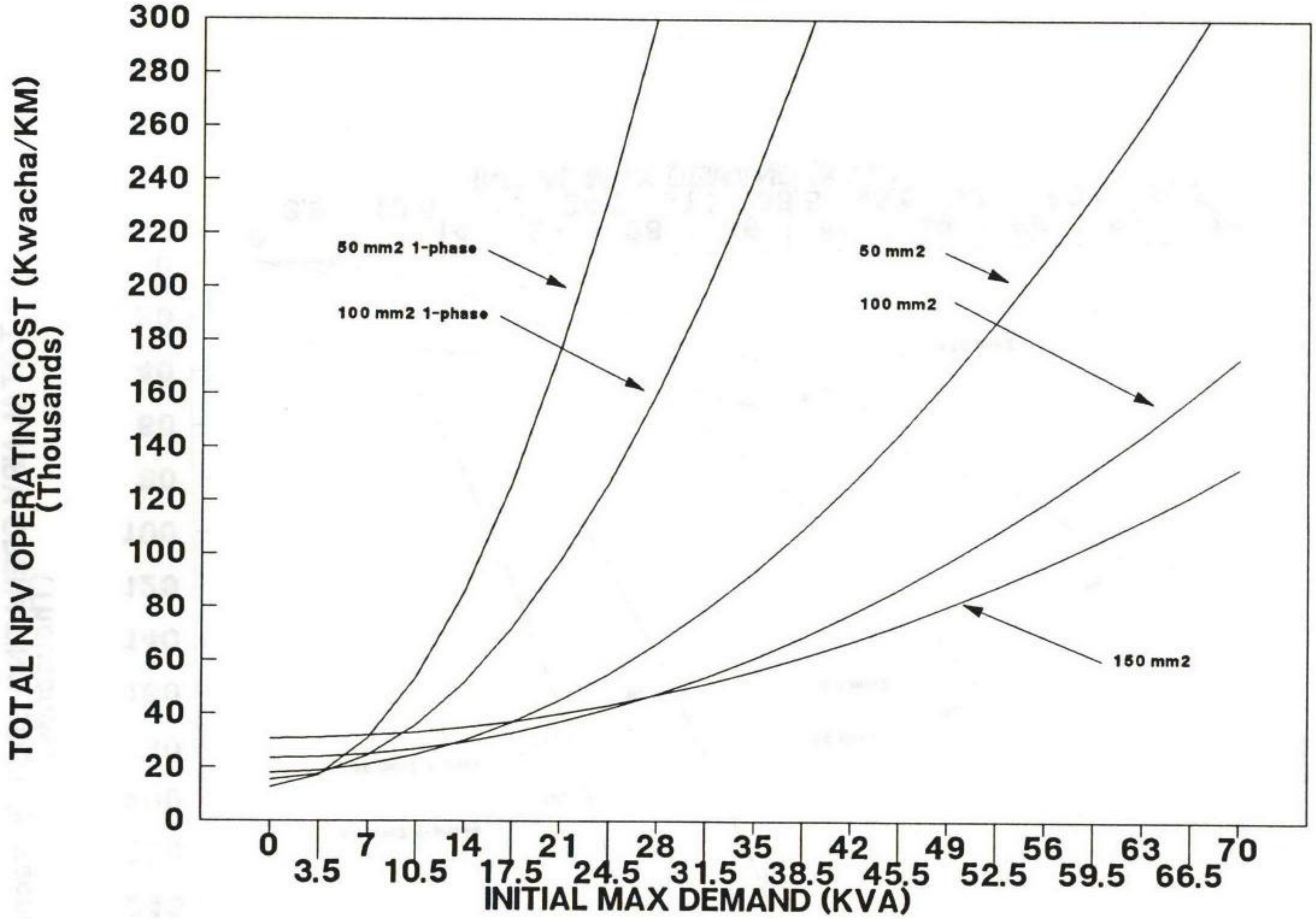


Fig 4.25 : LV Reconductoring Loading Ranges

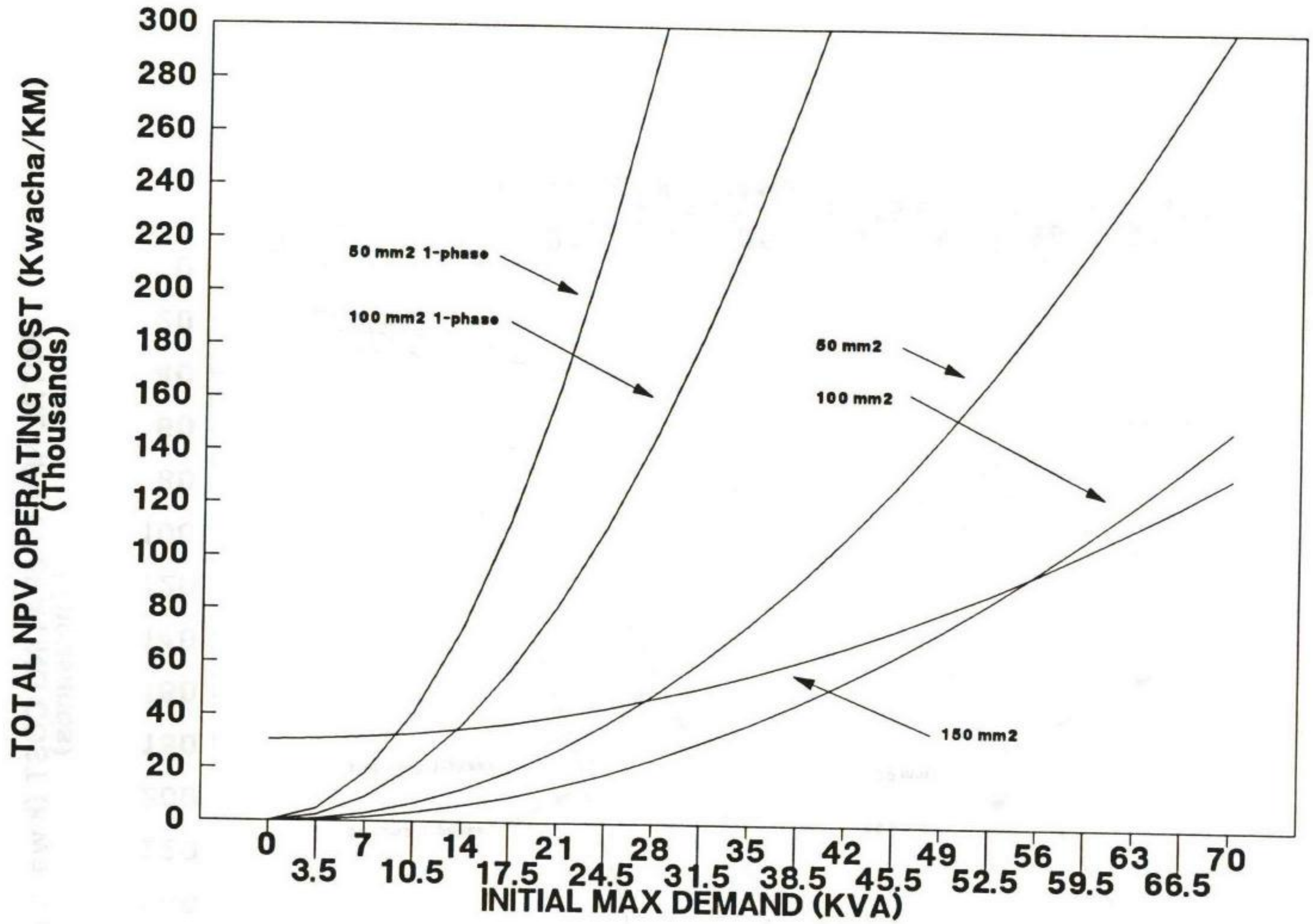


Fig 4.26 : LV Power Circle Diagram

1km 400V 50 sq.mm. Overhead Line

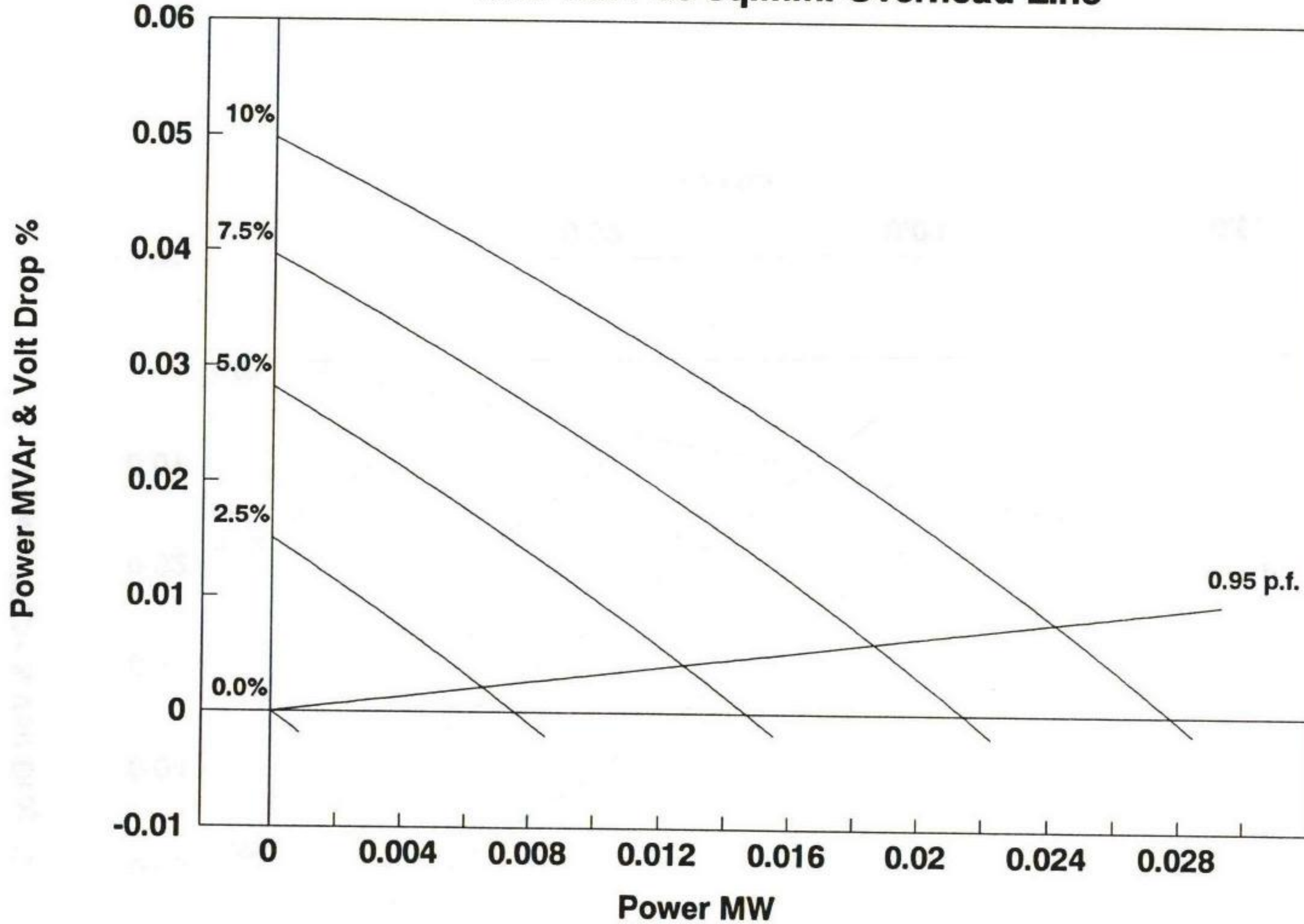


Fig 4.27 : LV Power Circle Diagram
1km 400V 100 sq.mm. Overhead Line

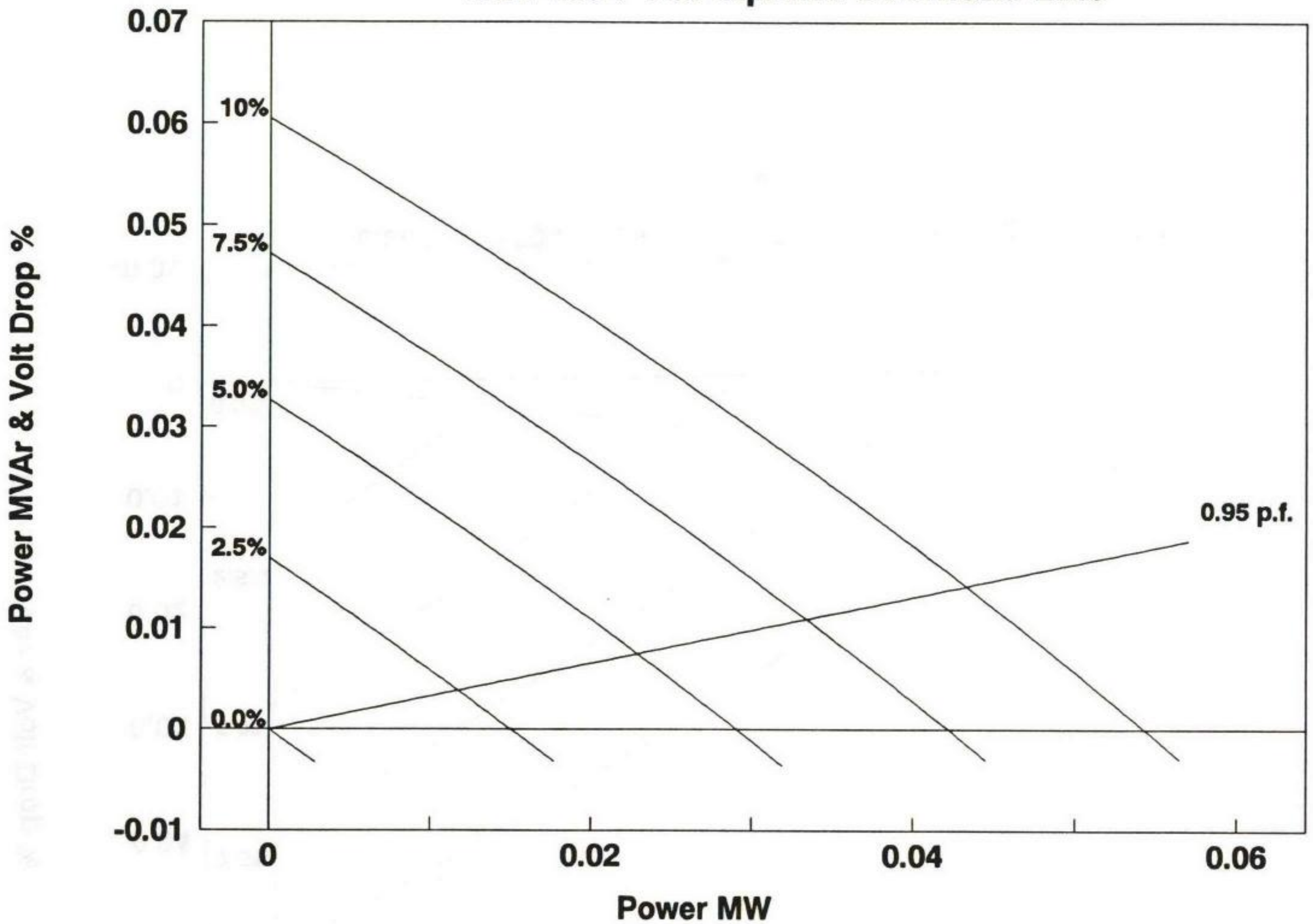


Fig 4.28 : LV Power Circle Diagram
1km 400V 150 sq.mm. Overhead Line

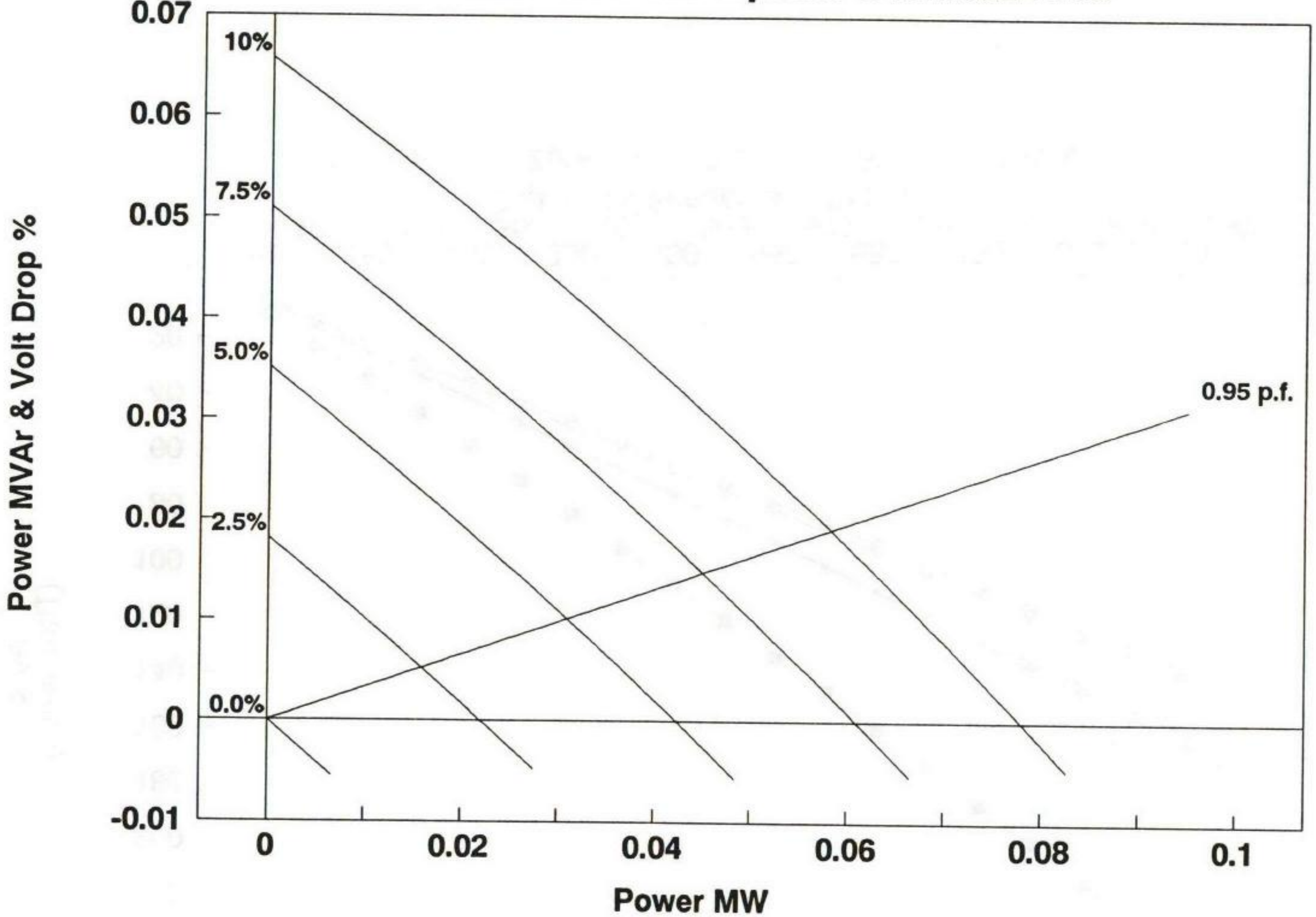


Fig. 4.29 : LV System Operating Costs - 15 year Analysis
Alternative Reconductoring Ratios

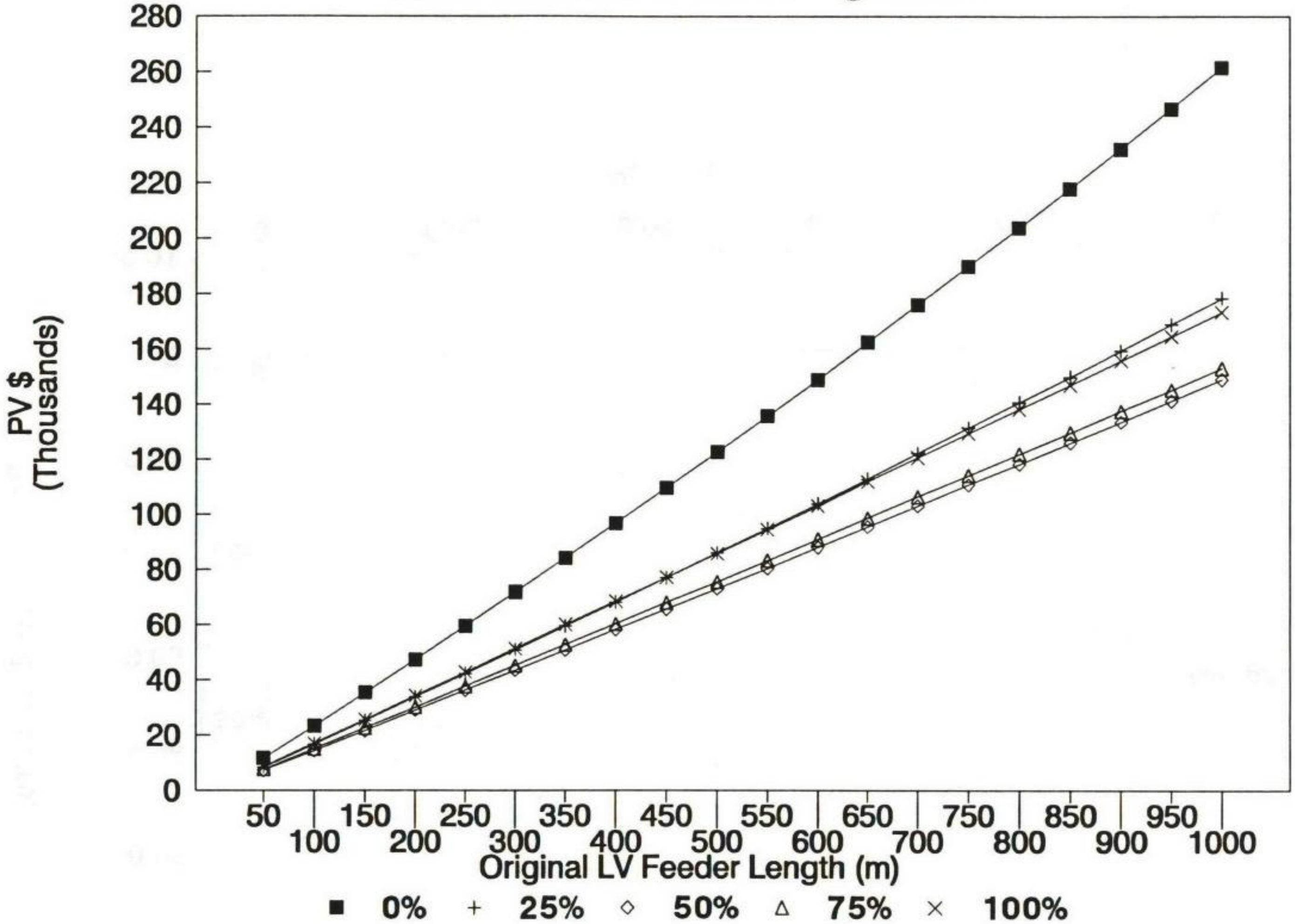


Fig. 4.30 : LV System Operating Costs - 15 year Analysis
Costs of Additional Transformers and Reconductoring

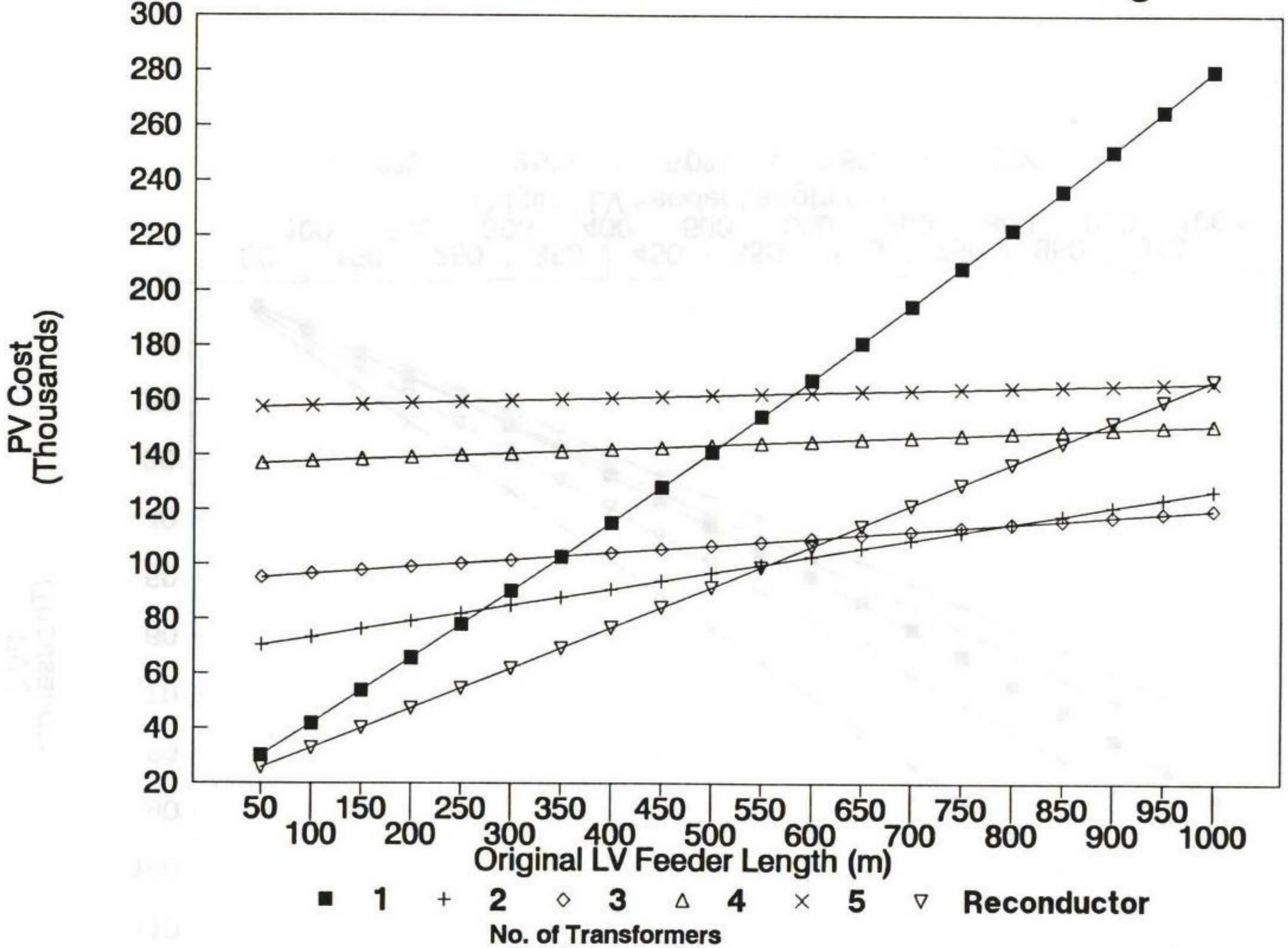


Fig. 4.31 : LV System Operating Costs - 7 year Analysis
Alternative Reconductoring Ratios

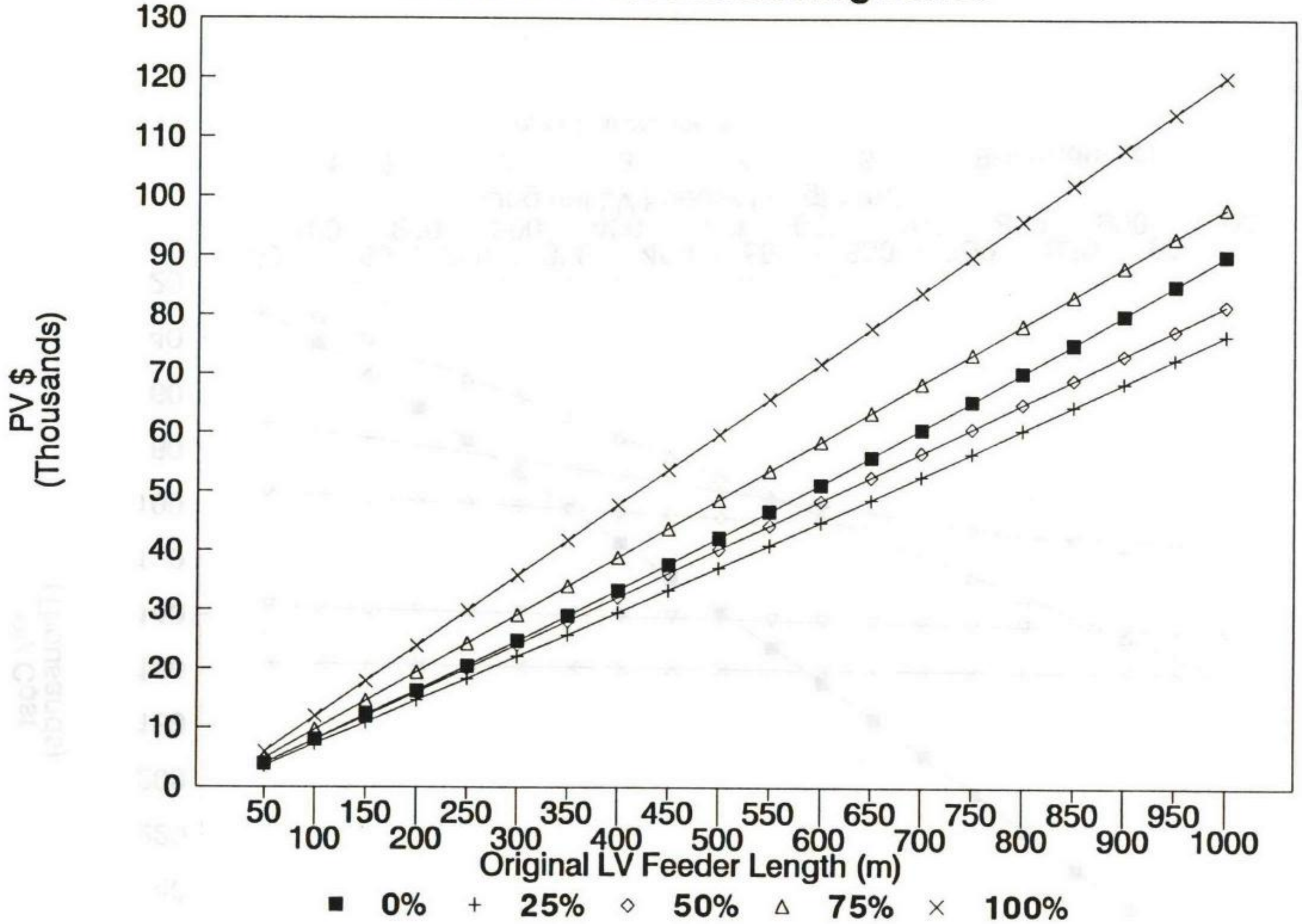
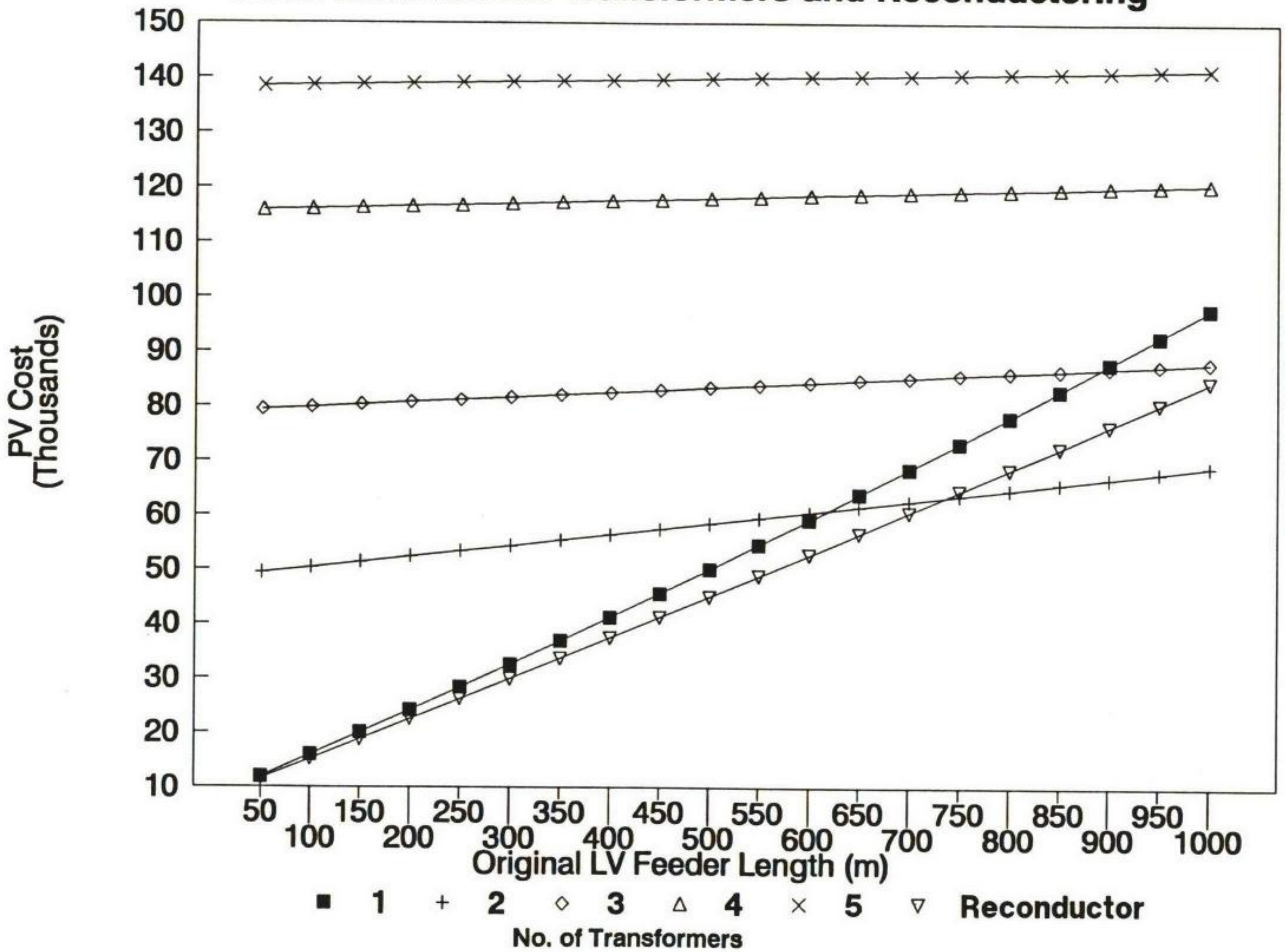


Fig. 4.32 : LV System Operating Costs - 7 year Analysis
Costs of Additional Transformers and Reconductoring



SECTION 5

NON-TECHNICAL LOSSES

5. NON-TECHNICAL LOSSES

5.1 Introduction

The investigation of non-technical losses has concentrated on identifying sources of errors in the ESCOM system which result in incorrect records of generated and sold electrical power and energy being obtained. These can result from straightforward inaccuracies in kWh and kW/kVA metering, problems of incorrect metering installation, or, in some cases, deliberate tampering with connections by consumers. Similarly, in the event of there being any confusion over, for example, the application of meter factors by meter readers or within the billing system, this could introduce potential sources of billing inaccuracy.

The investigations of non-technical losses incorporated in this project commenced with a comprehensive series of checks on the metering installations at the major consumers in Blantyre and Lilongwe carried out by a KDP metering specialist and his ESCOM counterpart during the first four week KDP site visit. This work was then continued by ESCOM during the period prior to the second site visit, to enable a larger sample of consumer installations to be checked. Each major consumer's premises was visited and a Dranetz power demand analyser was connected to the incoming voltage and current supplies to the kWh meter. The Dranetz was able to record accurately the energy supplied over a given period to the consumer, taking due cognisance of current and voltage transformer ratios, if applicable. This measurement was then compared with the energy recorded by the consumer's meter.

Each test was carried out over a period of typically several hours, to ensure that any slight error in the physical reading of the kWh meter would not have a significant effect on the calculation of the meter accuracy. Whilst the Dranetz monitoring was in progress, a number of checks relating to the consumer's meter installation were carried out, to identify any obvious signs of tampering, connection errors etc. which would indicate potential non-technical losses. Where possible, the Dranetz connections at each metering installation were made in such a way as to give a metering check which was independent of current transformer accuracy, so that as much of the installation as possible was tested for sources of error.

The results of the Dranetz checks were used to calculate an overall percentage accuracy for the kWh meter, which was compared with the statutory accuracy limits of plus and minus 2.5% permitted by ESCOM.

Similar accuracy checks were carried out on the energy meters at the Nkula and Tedzani power stations, to audit the figures for total annual generated MWh and auxiliary energy consumption which are used as the basis for the annual energy loss calculation.

Details of the results of the investigations of both consumer and generator metering accuracy are given below.

Tests were also carried out on the accuracy of the meter test and calibration facilities used by ESCOM, as these are clearly of critical importance in determining the accuracy of meters which are installed in the power stations and at consumers' premises throughout the system.

In parallel with the metering checks which were performed, the investigation and detection procedures employed by ESCOM in looking for sources of non-technical losses in the system have been examined. The results of this analysis are described below, together with recommendations for reducing non-technical losses and the associated financial and economic analysis of the measures proposed.

5.2 Metering Accuracy

5.2.1 Generator Meters

Table 5.1 shows the results of generator metering accuracy checks which were carried out during the course of the project. It will be observed from this that the accuracy of the meters on a number of the generator units was found to be outside the statutory 2.5% tolerance. The overall error on generator metering at Nkula and Tedzani was found to be an over-read of 2.7%, i.e. the generator metering is indicating that more energy is being generated than is in fact the case. This will lead to an artificially high estimate of the losses associated with the rest of the system when the generator metering figures are used as the basis for comparing generated energy with sold energy.

It is recommended that those meters which are outside the statutory accuracy limits be replaced and recalibrated in the metering section prior to being placed elsewhere on the system, and that for the other meters readings are corrected before being used as the input to loss calculations. All the generator kWh meters should be checked and recalibrated frequently, to ensure that correct metered energy figures are included in the system statistics.

5.2.2 Metering at Industrial Consumers

The results of the summary of metering at industrial consumers' premises are shown in Table 5.2.

The results may be considered both in terms of the accuracy of the meter and the overall metering system accuracy, which includes current transformers, interposing transformers and voltage transformers. The general philosophy of the meter accuracy tests was to monitor the complete metering system of the installation wherever possible and to establish correct CT and VT ratios wherever access is limited.

The industrial consumer meters were generally found to be operating within statutory accuracy limits, as can be seen from Table 5.2. The large errors shown were due to other reasons, as discussed below for the individual cases. The discussion is intended to point out some of the problems in metering and help to eliminate such occurrences in metering systems in future installations.

Agriculture Research Office (LV metering)

The metering system was found to be operating with one of the voltage leads disconnected from the fuse holder which was sealed. Loose connections were also found in other installations but the voltage leads were in position. For an LV installation this could result in an error in the region of 1/3 under-read. For an 11kV installation the discrepancy would depend on the disconnected phase, as the power factors could vary widely between phases.

Pipe Extruders Ltd (LV metering)

The metering error was due to a reversed CT connection. This would normally result in the metering system recording about 1/3 of the true energy for a balanced load. If the load is unbalanced the error could be more or less than this depending on the relative phase loading.

The Stage Coach (LV metering)

At this installation it was found that the blue phase was by-passing the meter. The figure of 19.3% under-read indicates that this phase was carrying less load than the other phases.

Kamuzu International Airport (HV metering)

There were two metering sets for this installation, one for each side of the sectionalised busbar. One side of the busbar was comparatively heavily loaded while the other was carrying a fraction of the load. Meter No. 1 was monitoring the majority of the load while the disk of meter No. 2 was just creeping. It is understood that this is the normal operating mode of the airport system.

Tests carried out on Meter No.1 revealed a 47.5% metering system under-read error. The true energy units were therefore 1.89 times the metered values.

A possible reason for this could be a wrong CT ratio or tap position inside the meter. The kVAh meter was within accuracy.

Tests on meter No.2 under full airport load revealed a metering error of 46.14% comparable to that of meter No.1. The kVA meter error was within limits.

During normal operating conditions however Meter No.2 is supplied with very little CT secondary current, operating outside guaranteed accuracy limits. This results in further accuracy errors.

For clarification consider the energy recorded between August 1989 and August 1990.

	kWh	kVAh	kWh/kVAh
Meter No. 1	2005900	4685300	0.43
Meter No.2	0104100	788500	0.13

The power factor of the load according to measurements was 0.99 and for the purposes of this exercise we will consider it as 1.

As can be seen, while for Meter No. 1 the kWh meter recorded approximately half of the kVAh figure, Meter No. 2 recorded 0.13 times the kVAh figure. This translates into an even higher under-reading error during normal operating procedures.

It is recommended that the metering system should be changed to a one meter system with a summation CT.

Limbe Leaf Tobacco Company (HV metering)

The initial meter monitoring tests, which included the Meter and the interposing CT, revealed a meter accuracy of 1.1% over-read.

Following investigations into primary transformer and secondary CT current it was considered necessary to monitor the supply at the 11 kV side of the transformers in order to eliminate any errors introduced by the CTs.

The overall meter testing revealed that the metering system was under - reading by 24.5%. The correct reading was therefore 1.32 times the metered value.

A plausible reason for this could be that the CTs in one of the phases is 150/5 A as opposed to 100/5 A as per the declared CT nameplate inside the relay panel.

It is recommended that the CTs be changed as the present accuracy of the calculated correction factor is dependent on load balance.

Mount Soche Hotel and Blantyre Netting

Both of these installations have meter under-reads of the order of 50%, which are suspected to be due to incorrect connections between the current transformers and the meters. It is recommended that both of these installations be thoroughly examined as a matter of high priority.

Table 5.3 summarises the results of both the generator and consumer metering checks, indicating that the total non-technical losses measured by the end of the second site visit accounted for nearly 4% of the 1989-90 metered energy generation. The revenue which would have been recovered in 1989-90 by the correction of the major consumer metering errors shown in Table 5.2 amounts to some MK413,000. This clearly demonstrates the value of the meter checking exercise which was carried out during the loss reduction study, together with the importance to ESCOM of maintaining such a programme of checks in conjunction with the analysis of billing information.

After discussions with ESCOM concerning the levels of consumer fraud occurring on the system, it was concluded that one method of reducing the scope for making illegal connections to the meter terminals or tampering with the meter itself would be to introduce meter boxes at each consumer's premises in the domestic, general and small power categories. These would be sealed, with a perspex front to enable the meters to be read without opening the box, and would make tampering in the vicinity of the meter extremely difficult. In this respect the application of meter boxes represents a more effective strategy than that of using, for example, socket type meters, since although the latter avoid the ease of access to terminals which is a problem with conventional meters, it is still possible to interfere with the meter itself.

Details of the costs associated with meter boxes and the proposed method for their introduction are given in section 5.5 below. In summary however, the estimated costs of meter boxes and socket type meters, including the sockets, are:

Meter Box (single phase)	Mk 60	(Local Malawi)
Meter Box (three phase)	Mk 140	(Local Malawi)
Socket Type Meter (single phase)	Mk 100	(FOB USA)
Socket Type Meter (three phase)	Mk 650	(FOB USA)

There is likely to be an additional cost penalty in the case of socket type meters resulting from increased installation time as compared with the meter boxes, especially given the intention that new consumers should install their own boxes prior to having a supply connected by ESCOM.

It is considered that a more immediate and cost effective reduction in non-technical losses will be achieved using the meter box approach, which will provide a visible deterrent as well as a reasonable degree of security at the most vulnerable point of the metering process. In addition it offers the attraction of using local materials and labour in the production of the boxes, which will be required in considerable quantity.

Financial rates of return for the alternative schemes are given in section 5.5.

5.2.3 <u>Meter Test Bench Accuracy</u>

The results of tests carried out to investigate the accuracy of the two meter test benches in Blantyre are shown in Tables 5.4 (a) and (b). Tests were carried out on the Foster test bench by connecting the Dranetz to the bench output and requesting the operators to set the bench to give outputs of specified currents, voltages and power factors over a range that would normally be used in meter testing. This bench is used for checking energy meters by setting known values of power as input to the meters under test, and then timing the duration of the test using a stop watch. The time and power figures are then used to calculate the energy supplied, which is compared with the reading on each meter.

The accuracy of this procedure is critically dependent on the operator's skill in setting the power levels, and the accuracy of the wattmeters and the timing device. With regard to setting the power factor of the bench output, the power factor meter on the bench does not function correctly, so that the operator has to calculate the power factor from readings on voltmeters an ammeters, to establish the power factor being used.

The results of tests carried out on this bench are shown in Table 5.4 (a). They indicate accuracies of between 0.4% and 1.6% on the individual meters on the bench, together with a range of accuracies from +1.12% to -2.74% in the accuracy of the stated power output of the bench in the various test modes. This represents an unacceptably wide range of accuracies for testing purposes, since the permitted meter tolerance of plus or minus 2.5% could potentially be added onto these figures and considered acceptable for placing of the meter on the system. The skill of the operators in obtaining this range of accuracies is to be commended however, given the range of accuracies of the instruments with which they are working.

The normal accuracies expected of test bench equipment are as follows:

Active Energy Measurements:	0.2%,	i.e. class 0.2
Reactive Energy Measurements:	0.5%,	i.e. class 0.5
Currents, Voltages, etc. :	1.0%,	i.e. class 1.0

It will be observed that most of the results listed in Table 5.4(a) exceed these limits.

These factors coupled with the fact that the bench was purchased secondhand in 1954 and is no longer supported by the manufacturer indicate that a replacement bench should be purchased in the loss reduction project.

The second meter test bench is a Landis and Gyr model manufactured in 1972, and is used in conjunction with a rotating substandard kilowatt-hour meter for carrying out meter checks. The accuracy of this standard instrument was checked using the Dranetz analyser over a range of test loadings. The results of these checks are shown in Table 5.4 (b), indicating a range of accuracies between 1.19% and 2.66% over-reading on the standard meter. Whilst consistent over-reading will not result in increased non-technical losses, it does represent potential use of meters which are outside the statutory accuracy limits. It is therefore recommended that this test bench also be replaced.

The new test benches should be located in a new meter test room with carefully controlled environmental conditions so that the equipment is not subjected to wide temperature ranges, vibrations, dust etc., thereby ensuring that its accuracy is maintained. Full training in the use of the equipment by its manufacturer should also be included when it is installed.

It is proposed that the existing portable test meters which are used by the metering section be replaced by electronic units, which will have a stronger resistance to the effects of being transported to consumer installations than is the case with the existing rotary units. Inclusion of fifteen meters is recommended, to be split between bases in Blantyre, Lilongwe and Mzuzu.

The meter test benches which should be purchased as part of the loss reduction package should each be capable of handling up to ten single phase or polyphase meters, and should incorporate a solid state reference standard meter which meets the active and reactive energy classes detailed above. The reference standard should be capable of running meter checks either by measuring impulses detected by a photoelectric head from the disc of a single meter, or by supplying a pre-determined amount of energy to a batch of up to ten meters. The bench should incorporate a console on which phase currents and voltages are displayed, together with the necessary controls to obtain the full range of test currents, voltages and power factors required for carrying out meter tests.

The solid state test meters should be sufficiently rugged to enable frequent transportation, and should be suitable for testing both single phase and three phase meters. They should be supplied with suitable current clamps and voltage connectors to enable them to be conveniently connected to the range of meters used by ESCOM.

The emphasis of these and the test benches should be on the provision of reliable, rugged instrumentation which performs the basic functions required, rather than incorporating large numbers of unnecessary optional extras. Manual test benches rather than fully automatic computerised units are recommended, to avoid unnecessary complication of the meter testing procedure.

Budgetary amounts have been included in the loss reduction package to cover the above equipment, as follows:-

2 Meter Test Benches :	MK 333,000
Meter Test Room	MK 80,000
15 Solid State Meters :	MK 75,000

An additional MK 30,000 has been included to cover a one week period of training to be provided by the test bench manufacturer, to ensure that the ESCOM metering technicians are fully versed in the operational procedures required to obtain accurate results from the benches.

5.3 Billing System

The mainframe ICL ME29 computer used for billing is located in ESCOM House, Blantyre and was introduced here in 1983. It has 1MB of RAM memory, two fixed disks of 120 MB each and two exchangeable disk drives with a disk capacity of 80 MB each.

A direct data entry and verification system is in operation through terminals in Blantyre. In Lilongwe data is entered to the Blantyre mainframe via a modem link. Elsewhere data forms are completed by the District offices and sent to Blantyre Data Processing Section.

The computer billing system is designed by a South African company called Jack Curtis Computer Systems. It was installed in 1983 and covers all billing activities from the entry and verification of meter consumption data to the printing of invoices and the provision of management information reports.

The main file used for the billing system is the Customer Master File containing records for nearly 40,000 consumers. This alone accounts for between 60 MB and 70 MB of disk space.

Since the Draft Final Report it is understood that ESCOM has purchased two ICL DRS 3000. One is sited in Lilongwe and the other in Blantyre to replace the ME29. They are to be used for billing, stock control, transport management and payroll. Further to this a number of PC's have been purchased of which nine are believed to be for billing. Given the recent hardware purchases it is not thought necessary that any further hardware will be necessary to carry out the billing function of ESCOM, and no cost for hardware has therefore been incorporated into the financial and economic analysis at this stage.

Remote data entry stations in the regions would speed the processing of billing considerably and would also avoid the need to complete data entry forms thus possibly avoiding errors in transcribing the data. The suitability of remote data entry stations would depend on the availability of a reliable telephone network and before proceeding with this programme ESCOM should ensure that an adequate communciations infrastructure for the transfer of data is in place.

New billing software is also required to carry out both the functions of the current software together with some additional functions that have been identified to be necessary, in connection with the detection and investigation of non-technical losses. Firstly the ability to enter kVAh as well as kWh is essential so that the billing system may also calculate power factor. This would act as a check on the metering accuracy of large consumers, identifying potential problems with either the kVAh meter or with the kWh meter. Secondly, simple enquiry functions need to be improved. At the moment, for example, it is only possible to trace a consumer's account on the computer with the account number. Tracing a consumer by name is carried out by searching through printed records in order to find the account number. New billing software can provide all of the facilities currently available to ESCOM and in addition to this can provide all of the functions necessary to a modern billing system. It is recommended that a detailed specification of the billing software be carried out, however, a budget price of MK 1,082,005 has been obtained and has been incorporated into the economic and financial analysis. This price is based on an established billing package being tailored to the specific needs of ESCOM and would be undertaken as a consultancy project including program development, installation, testing, support and staff training.

Off-the-shelf billing packages are available at a basic cost of approximately MK 65,000. However, these are not likely to meet all of ESCOM's requirements and bespoke software would need to be written. In addition to this ESCOM would require installation, testing, data conversion, support and training. The total cost is likely to approach that given above. The cost of the consultancy project has therefore been included in the economic and financial analysis although it may be a little pessimistic.

5.4 Organisation of Investigation and Detection

5.4.1 General ESCOM Organisation

The organisation of ESCOM in so far as it affects the detection and correction of non-technical losses, broadly cuts across four sections.

Meter reading falls under the Revenue section. Readings are passed to the Data Processing section where customer records are updated and invoices produced. Meter readers also note any problem meters or suspicious supplies and reports are passed to engineers for investigation. In Blantyre the Metering section under the Commercial Manager investigates these cases. Elsewhere they are investigated by the Consumers Engineer, the District Engineer or Officer-in-Charge. In cases where supplies have been obtained illegally, the Area Manager, District Engineer or Officer-in-Charge estimates the value of that theft. The consumer engineers are responsible for installing new meters and passing the documentation back to the Revenue section. Meter readers disconnect supplies. The Data processing section produces exception reports, which are passed to the Revenue section, and other statistics for ESCOM management.

For operational and administrative purposes Malawi is divided into three 'Areas' comprising the South (Blantyre), Centre (Lilongwe) and North (Mzuzu), each under an Area Manager. In the Southern Area there are currently two smaller administrative 'Districts' under a District Engineer. These are the Thyolo District and the Zomba District. The lowest organisational level is that of the 'Office' under the control of an 'Officer-in-Charge'. There are currently sixteen Offices with three more planned. Two of these Offices (Liwonde and Mangochi) report to the Zomba District and one (Mulanje) to the Thyolo District. The other Offices report directly to the Area.

The staffing of the Offices varies depending on their size. The Officer-in-Charge is generally technically well qualified but may not be qualified or experienced at the administrative or managerial level. As a minimum the Office will include a cashier/meter reader, linesmen and support staff. The cashier/meter readers report to the Officer-in-Charge for administrative purposes but to the Area Branch Accountant for functional purposes.

The District organisation includes a District Accountant who again reports to the District Officer for administrative matters and to the Area Branch Accountant on functional matters.

5.4.2 Revenue Section

There are currently 62 meter readers in ESCOM as shown in Table 5.4.1. The majority of these are centred in Blantyre (25) and in Lilongwe (15). Zomba has a further four and Mzuzu another three. The remaining fifteen operate in isolation outside the main centres.

In Blantyre and Lilongwe the meter readers are divided into sections with four or five in each. One of these sections comprises 'Special Meter Readers' who have motorised transport in the form of cars or motorbikes. These readers operate on the outskirts of the city; they read the meters of the 'Small Power' and 'Large Power' consumers and they undertake disconnections and reconnections. The sections additionally have 'Section Leaders'. In the smaller areas, outside of the main centres, the meter readers may double as cashiers.

There are no vacancies for meter readers at present. In the near future there are plans to recruit full time staff for Mzimba, Nkhata Bay and Chinteche. At Mzuzu the numbers are planned to increase by one, bringing the complement to four. At Nchalo the duties of the cashier/meter reader are to be split between two people.

During periods of annual leave or sickness for meter readers in the more isolated areas it is ESCOM policy to use relief meter readers. These are taken from among the normal readers in Blantyre and Lilongwe. In some cases, monthly consumption during these periods is estimated.

ESCOM policy is currently to recruit meter readers with a grade 4 Malawi Certificate of Education with a credit in mathematics.

The procedures for meter readers are not formally documented in a single procedural guide. Nevertheless, a brief job description together with various memoranda describes the duties and tasks expected of meter readers. New meter readers learn the job by shadowing the older, more experienced readers for a period of one month. New meter readers are confirmed in their jobs after a satisfactory six month probationary period. A seminar for meter readers and metering technicians was last held in 1988. A three day seminar was scheduled to be held at the end of August 1990. Special meter readers would benefit greatly from more specialised training.

The turnover of meter readers is said to be high with a stay of above three years regarded as very good. In Blantyre the majority of readers have been in the job for less than two years. Two or three have been with ESCOM for about ten years. The starting pay for a new meter reader is K2208 ($800)/year.

Disciplinary action takes the form of denial of annual increments in pay, suspension or dismissal. Over the one year period, July 1989 to June 1990, some six disciplinary actions were taken against meter readers throughout the country. Four of these were related to the use of ESCOM vehicles, one to poor work performance and one relating to missing cash for a meter reader/cashier.

(i) Meter Reading and Recording

Meter readers carry a 'meter book' together with a notebook. The meter book contains a double page entry for each meter. He enters the new meter reading and subtracts the old reading from the new to give a monthly consumption. These entries are repeated in the house card which accompanies the meter. The meter reader does not adjust the reading to take account of any multiplying factors.

Meters are supposed to be read fairly close to an interval of one month. A memo dated March 1988 to section leaders asks them to ensure that readings are taken monthly within plus or minus four days. This practice is not generally adhered to. For the very large consumers, meters are read on the last working day of the month. The adoption of a consistent pattern for meter reading would have the unfortunate disadvantage that tamperers may easily anticipate these visits, thus making the task of detection more difficult. The element of randomness has an advantage in this respect, although it is recognised that it may cause payment difficulties for some customers.

The meter books are passed to the section leaders (in Blantyre, Lilongwe, Mzuzu and Zomba). The section leader checks the meter books to ensure that the reader has not skipped properties and to estimate the consumption of those meters where the reader was unable to gain entry. This estimate is based on the average of the last three months consumption. (Where a meter reader fails to gain entry for three consecutive months then the householder is notified that failure to permit entry on the next visit by the meter reader will result in disconnection).

In Blantyre, the meter books are passed to the data-processing section. Outside Blantyre slightly different procedures operate. In Lilongwe the metering records are entered into the computer (in Blantyre) directly via a modern link. Elsewhere, the metering records are transcribed onto a form which is then sent to Blantyre for data entry.

The billing system reports all 'rotas' which remain unprocessed.

The 'Special Meter Readers' undertake the readings for the 'Small Power' consumers. The kVAh are recorded for most of these consumers but the information is not transcribed onto the computer and is not therefore reported to the Commercial Manager. The kVAh readings, in conjunction with kWh, will enable power factors to be calculated. This will act as a cross check on the accuracy of the two meters. Should the power factor fall below, say 80%, the computer should issue a warning which will trigger an investigation by the Commercial Manager.

(ii) Defective Meters and Theft

The meter readers are also required to note any problems with the meters or supplies in their notebook. This will include broken seals, broken meters, tampering, meters not operating and signs of the meter being by-passed. They are instructed to pay attention to the appliance ownership in a property in relation to the monthly consumption levels.

The notebooks in Blantyre and Lilongwe are passed to the section leaders who writes a memo to the Branch Accountant noting any problem meters. In Blantyre the Branch Accountant writes a further memo to the Commercial Manager asking him to investigate. In Lilongwe these cases are reported to the Consumer Engineer for investigation. Outside the main cities, reports of meter problems are reported to the District Engineer or Officer-in-Charge who may refer the matter to the Area Engineer. If it is confirmed that an illegal connection has taken place then the meter reader receives a K5 reward.

Memoranda to the Commercial Manager are relatively infrequent. In the two month period in February and March 1990 there were 13 cases reported for Section III in Blantyre and 43 cases for Section II. Payments to meter readers under the reward scheme are relatively rare, approximately two per reader per year.

The reward appears to be on the low side. At two findings per year it amounts to less than 0.5% of the annual pay of the new starter (K2208/year). Moreover, it is a small sum compared with the 'fine' facing the tamperer (K110 to K130 plus estimated lost units). For the Special meter readers the divergence between the value of the reward and the value of the theft is even greater. The incentive to enter into collusion, either through casual favours from customers or through bribery, is great. An increase in the reward to correct this imbalance would seem to be in order. However, there is a danger that the balance could swing too far in favour of reporting incidences such that the metering section or consumers engineers are inundated with cases to investigate. If the reward is too great there is also the danger that the meter reader will fabricate evidence. An increment to, say, K20 for ordinary meter readers per proven illegal customers would seem reasonable and could easily be recovered in the customer's 'fine'. For the Special meter readers operating in the Small Power category, an automatic figure of K50 might be appropriate with a discretionary additional reward for catching the extra big and sophisticated tamperers. All of these payments could be recovered in the 'fine'. The rewards should be indexed against annual average pay rises.

Approximately 20% of supplies investigated are generally shown to be illegal and an unknown proportion of those reported are investigated. The meter readers may report fifty consumers per year, of whom only two may be found to be pilfering. This does not seem unreasonable and the system of rewarding readers only for successful investigations appears to work well.

No record is maintained with the customer file of reports made by meter readers nor of cases where the consumer was found to have been acting illegally. In order to check a consumer's past history the Revenue or Branch Accountant would need to read through the book of memos. A record should be kept in the customer file thus permitting easy access to both past consumption and to past reports.

Meter readers are required to check all meters, including those of properties where the supply has been disconnected. They also look out for properties which have a supply but no account.

(iii) Procedures for New Connections

New consumers pass through three stages before they are connected. First of these is the connection application and connection fee, second is the inspection and inspection fee, and the third is the payment of a deposit and connection. Consumers may, however, pay all three fees in one go. Upon payment of the deposit they are issued with a receipt and allocated an account number by the Revenue section, both of which are entered in a 'new connections' book. The Consumers section informs the Revenue section of the connection and the opening meter reading. The date at which this occurs is noted in the New Connections book. The Revenue section then completes a form which they submit to data processing to open a new record for this customer. A new entry is also made in the meter book.

There is no systematic check that all customers who have been provided with a supply ever have their meters read and are billed. This is discussed further in Section 5.4.7 below.

(iv) Procedures for Disconnections/Reconnections

A consumer wishing to discontinue his supply completes a form indicating the date and time at which he wishes the supply to be disconnected. ESCOM then sends a meter reader to the property at that time to read the meter. In Blantyre and Lilongwe only the special meter readers were, at one stage, selected for this task. This precaution would appear to have been discontinued at the present time and normal meter readers also undertake disconnections and reconnections. Special meter readers are routinely issued with sealing pliers.

Normal meter readers are issued with pliers on an as-needed and as-available basis. A shortage of pliers has existed and pliers have been lost or mislaid. This has meant that supplies have been disconnected or reconnected without the fuse being resealed. This in turn has brought into question the value of evidence provided by a broken seal.

Outside of Blantyre and Lilongwe, normal meter readers are supposed to be issued with sealing pliers. The shortage of pliers has again meant that meters and fuses have not always been sealed. This situation may be rectified with the purchase of fifty new pliers.

The practice of allowing supplies to remain unsealed should be strongly discouraged. Pliers should ideally be issued only to Special meter readers in Blantyre and Lilongwe. Pliers issued in the outstations should always be signed out.

The Revenue section submits a closedown form to the Data Processing section when the supply has been disconnected.

A customer who wishes the supply to be restored to a property to which he has just moved will again complete a form and the meter reader will visit to read the meter and reconnect supply. He will at this time note any discrepancy between this and the closing reading prior to disconnection. A form is then submitted to the Data Processing section to open a new account. The form will include the opening meter reading (as noted below there is no cross-check to ensure that closing readings are equal to opening readings).

There is no systematic reporting of numbers, names and addresses of premises which have been disconnected and not reconnected. A quarterly management information report showing the addresses of those properties which have not been reconnected after six, nine and twelve months should serve to warn ESCOM of potential problem supplies. It would also be useful information for other purposes.

5.4.3 Procedures Designed to Prevent Fraud by Meter Readers

The rotas for meter readers are allocated by the section leaders. In Blantyre, Lilongwe, Mzuzu and Zomba the meter readers are, in principle, not supposed to be allocated to the same area for two months in succession. In practice they may take the same rota for several months consecutively. However, the meter readers do generally rotate frequently within each section. Moreover, there is no evidence of systematic patterns involving combinations of two readers always visiting the same areas.

Rotation of meter readers between sections is said to be practised in Blantyre but this is not borne out by the evidence. In Blantyre, for example, four readers stayed in Section I for over five years between 1982 and 1987. One of these four still remains in that Section whilst none of the new readers who joined ESCOM over a year ago have been rotated.

Notwithstanding the above, there is no evidence of any collusion between meter readers and customers to defraud ESCOM. Moreover, given the relatively high turnover rate amongst meter readers the need for rotation between sections in Blantyre and Lilongwe is less pressing. Outside of the main centres, where there is only one meter reader there is a need for some form of checking. It is important that during periods of annual leave, consumption should not be estimated but a relief meter reader be called in to act as an auditor of the primary reader.

5.4.4 Daily Information Report

The daily information report is received by the Revenue Accountant and contains information relating to:

- deleted accounts
- accounts where consumption is +/- 50% of the previous month
- negative consumption

The bulk of the reports relate to accounts where consumption exceeds +/- 50% of the previous month. The 'deleted accounts' are ignored by the Revenue section. These refer to accounts which have been closed and the final invoice settled. Since no action is taken this report serves no purpose and adds to the volume of information passed to the Revenue section.

Negative consumption relates to accounts where an adjustment has been applied to compensate for erroneous entries in previous months. These reports are relatively infrequent and no action generally appears to be taken.

The Assistant Accountant (Revenue) scans the report and places a tick against those accounts which either show gross variation over the previous month (eg, a factor of 10 greater or less). Additionally he marks with a tick those accounts for which the minimum charge has been applied (ie, K10.25). The invoices for these are then extracted and passed to the Revenue Accountant. For Blantyre the invoices may be passed to the Section Leaders to be checked and adjusted if necessary. For other accounts the Revenue Accountant adjusts the invoices. A cross is marked on the daily information report against those accounts where the invoice has been extracted.

The daily information report of the 11th August 1990 contained 15 pages and approximately 750 records to be scanned. This was, apparently an exceptionally large report but nevertheless indicates the volume of information facing the Revenue section. On this occasion 90 invoices were extracted for closer examination. The information contained in this report is not passed to the Commercial Manager or Consumer Engineers and is not used to detect tamperers. It is recommended that the Daily Information Report also be passed to the appropriate investigation personnel.

The volume of information is generally too great to enable the Revenue section to adequately monitor records. At the same time the quality of information could be improved to target problem accounts more usefully. The problem is compounded by the absence of a system for the maintenance and easy retrieval of information on a consumer's past. This is discussed further in Sections 5.4.5 (iii) and 5.4.7 below.

5.4.5 Consumers Engineer and Meter Engineer

(i) Organisation

In the past year the smaller isolated Offices and District Offices have taken responsibility for the connection and meter investigation for the domestic and general consumers. However, resources and skills are generally lacking in these offices and more complicated tasks are passed to the Area Consumer Engineers or to the Metering section in Blantyre. The Offices are responsible for imposing 'fines' on consumers found to be illegally taking supplies. The District offices and the outstations do not read meters for the 'Small Power' consumers. It is currently ESCOM policy to train staff in these offices and to provide equipment (including check meters) in order to devolve as much of the connection and investigation work as possible.

The Commercial Manager has responsibility for all consumer matters and is also responsible for consumers above 500 kVA or involving large capital costs (above K100,000) or those metered at HV.

The metering section under the Commercial Manager undertakes a form of trouble-shooting. They undertake ad-hoc meter investigations, extensive investigations of meters over given areas and meter testing. The meter test bench in Blantyre is under the control of this section. In Blantyre, the task of investigating suspect meter tamperers is undertaken by the Commercial Manager. Elsewhere, it is undertaken by Consumers Engineer.

The organisation of the Metering section is currently under review. It is headed by a Meter Superintendent under whom is nominally a Meter Technician Engineer (vacant) with a Senior Meter Technician below this. The latter post is also vacant. There are two meter technicians who now undertake the meter investigations and three 'artisans' or meter mechanics who test, repair and overhaul meters. One of the latter posts is vacant. In the near future, with the retirement of the current occupant, the post of Meter Superintendent will disappear.

The Consumer Engineer under the Area Manager undertakes the largest proportion of the connection work. In Blantyre the section is headed by the Consumer Engineer followed by an Assistant Consumer Engineer. Under him is a Senior Installation Inspector and two Installation Inspectors. Below these are Consumers clerks, etc. The section is responsible for connecting consumers, inspecting installations, investigating suspected cases of tampering, imposing 'fines' and estimating adjustments to accounts.

(ii) Equipment and Resources

The meter test bench facilities and the other equipment to enable meters and supplies to be investigated are discussed elsewhere in the main text.

The Commercial Manager has identified transport as one of the major constraints on the Metering section. This is also the case with the Consumers section where three inspectors have the use of only two vehicles.

(iii) Procedures

The Commercial Manager checks the readings taken for all Small Power consumers. Investigation of problem meters in this category is always undertaken by the Metering section under the Commercial Manager.

All meters which are new or have been overhauled or tested have shellac applied to the voltage terminals. The use of seals for the meter and fuse is discussed in Section 5.4.2 above. Shellac has not always been applied. Only where it has been applied and the voltage terminals are found to be loose is it taken to be evidence of tampering.

When meters are replaced a meter order form is completed and a new meter drawn from stores. The reading of the old meter taken out is noted on the form as is the initial reading on the new meter. These readings are entered in the meter books by a clerk.

(iv) Imposition of 'Fines' and the Deterrence of Offenders

Consumers found to have faulty or broken meters are charged a MK10 meter testing charge. In cases where meters have been by-passed or tampering is proven then the consumer is 'fined' an amount which is calculated according to an estimate of the costs of the investigation including transport, administration, overheads, meter investigation, staff time, revenue staff time and a meter testing fee. This is estimated to be MK100 for labour, MK10 per inspection visit (normally x2) and, if the meter is faulty, MK10 for recalibration.

Additionally an estimate is made by the Officer-in-Charge, the District Engineer or the Consumers Engineer of the amount of units which ESCOM has lost as a result of the illegal abstractions. In theory consumers may also be charged with the cost of a new meter, which could be of the order of K100. Consumers in financial difficulties may be given the chance to pay the 'fine' in instalments.

Consumers are sent a standard letter which brings to their attention Section 36 of the Electricity Act and Rule 4 of the ESCOM By-laws under which "... if any person without lawful justification or excuse injures or interferes with or damages or permits or suffers to be injured, interfered with or damaged any ESCOM electric apparatus or installation of any kind whatsoever, he shall be guilty of an offence". No mention is made of theft. In the event that a consumer commits an offence twice it is ESCOM policy to take that person to court. The one instance noted by the team in which two offences were committed did not involve court action.

It would appear that ESCOM have only taken a very limited number of cases to court and that these involved a lot of time and effort and were not successful. Consequently, ESCOM decided to adopt the approach outlined above of charging tamperers and illegal abstractors with the cost of detection and investigation. ESCOM has no legal powers to impose fines and is therefore constrained to asking consumers to reimburse these costs. They cannot set the 'fine' at any arbitrary level. The imposition of the charge has not been tested in the courts.

For the smaller consumers in the high density areas the 'fine' may appear to be punitive, equivalent to the cost of units for up to two years for a normal household. However, of the 42 illegal cases in the high density area of Bangwe in May/June, only three of the 'fines' remain unpaid at this date (August). For the consumers in low density areas or for 'General' consumers the size of the fine is negligible. This may be equivalent to only one to three months supply.

As a general legal principle the fine for a misdeed is tailored to the income of the miscreant and to the size of the misdeed. The size of the 'fine' should ideally be increased substantially for the larger consumers. An argument could easily be made that the detection and investigation systems are designed to catch and deter the larger culprits and that the costs should be shared in proportion to the scale of the abstraction. This is similar to the principle of marginal cost pricing. A different scale should be charged for each of the low density and high density areas and for the 'General' consumer category. 'Small Power' consumers could be charged on a per kVA basis.

The average cost of detection and investigation is also thought to be somewhat understated. Account should be taken of all costs including part of the capital costs of vehicles, part of the capital cost of the meter testing bench and other testing equipment, training costs, the meter readers' reward, part of the cost of the billing system and a more substantial part of the cost of supervisory and management staff.

It should also be remembered that one of the principle purposes of a system of penalties is not justice but deterrence. Maximum publicity should be given to programmes designed to catch illegal tapping. In this respect the Commercial Manager's preferred approach involving high profile sweeps of an area may be more effective than occasional ad-hoc visits to suspect properties.

(v) Records of Offences

Correspondence relating to reports of broken seals, broken meters or consumers for meter tampering or by-passing supplies is maintained in a file with the Commercial Manager in Blantyre. The current file contains correspondence since the beginning of 1989. The correspondence file does not contain records of all cases reported. Separate files are maintained by the Consumers Engineer, District Engineers and Officer-in-Charge. A rather haphazard system of recording pertains in the outstations.

Meter readers' reports or records of mis-deeds are not kept in the consumer's file in the Revenue section.

In the event that the Commercial Manager or Area Manager should wish to check the past consumption behaviour of a consumer he would need to search the correspondence file and also go to the consumer file (held by the Revenue section) or meter books to find the past pattern of consumption. As discussed above in Section 5.4.2 above and in Section 5.4.7 below there is a very strong case to be made for keeping a record with the customer file and on computer of any previous reports and findings.

5.4.6 Results of Meter Investigations

The monthly reporting to the Commercial Manager of meter investigations, meter replacements and cases of illegal supplies has recently been introduced. At the same time a report on the same topic has been requested covering the period 1986 to 1989. The statistics have been compiled for Blantyre but not for Lilongwe. The Blantyre results are shown below:

	1986	1987	1988	1989	1990
Investigations	1162	1472	359	563	578
Illegal	-	63	85	47	106

(Note: In 1986 ESCOM was only concerned with the condition of the meters and the meter seals, hence no action was taken against suspected consumers).

In 1990 the following monthly statistics have been compiled:

	Investigations	Illegal	Meters Changed
March	186	42	33
April	56	10	7
May	132	32	24
June	109	13	

(Note: Not all those with illegal supplies required new meters).

In those cases where meter seals are found to be broken or the meter is broken but there is no evidence of meter tampering or by-pass then a warning sticker is placed on the meter which is then resealed. In most all of the cases found to be illegal the meter had been by-passed. In the remainder the voltage link had been opened. The large number of cases in March were due to the sweep of Bangwe (discussed below). The low number of cases in April were due to problems of sickness in the meter investigation team.

Some four major investigation exercises or meter resealing programmes have been undertaken to date. The two most recently were for Bangwe and Chilomoni. Both of these are high density areas in Blantyre. The Chilomoni operation took place in July 1990 and netted approximately 35 cases of meter by-pass. The Bangwe operation took place over a one week period in late May and early June and netted approximately 42 meter by-passers. The latter operation was co-ordinated by the Metering section under the Commercial Manager but involved staff from the Consumers section. The premises were targeted in advance by the Commercial Manager from the reports by meter readers. The success rate in finding by-passers was 23% of those investigated.

Other areas in Blantyre which are likely to have similar problems include Ndirande, Chilombwe, Zingwangwa, Soche, Chitawira, Chinyonga, Njamba and Kanjedza. Nkolokosa was also investigated in 1986 solely for the purpose of resealing meters. Of these areas, Ndirande is the largest. The last three are relatively small and of medium to high density.

5.4.7 Data Processing Section

Procedures

Meter consumption is entered and verified as described in Section 5.4.2 and 5.4.7(i) above. An initial vetting run further checks the validity of the entries and reports errors. These are passed back to the Revenue section for correction.

The data entered includes the old meter reading, the new reading and the consumption. The old meter reading entered in the transaction is compared with the meter reading on the file. Discrepancies are reported. The meter readers' calculations are also checked by the system. The master customer records are updated upon receipt of approval by the Revenue section. Corrected transactions are re-entered at a later time.

Management reports and invoices are produced daily. The distribution and content of management information reports is described in Section 5.4.4 above. Suggestions for the improvement in the reporting system are given below.

Accounts are closed at month end, which, for the Data processing section, occurs at the end of the 9th day of the following month. Thus the sales recorded for the month of July are closed on the 9th of August.

Accounts for which a closing transaction has been entered are not deleted until the final invoice has been settled. Until this happens this becomes a suspense account.

The meter readers' Section Leaders generally estimate the consumption for unread meters as described in Section 5.4.2(i) above. Accounts where this has not happened and for which no consumption has therefore been entered are known as 'presumptive'. The consumption is estimated by the computer as equal to the last months consumption. This practice differs from that of the Section Leaders who base their estimate on the average of the past three months consumption. Presumptive bills are reported in an Exceptions Report.

At month end a list is compiled of all books for which no transactions have been received.

Account numbers are generated by the Data processing section and passed to the Areas and Districts in batches.

Suggested Improvements in Computerised Systems

New Connections

The procedures for the recording of the connection of new consumers before a supply is given, as described in Section 5.4.2(i) above, are manual. No checks exist, outside the observation of the meter readers, to prevent consumers being connected and not billed. This could be by oversight or deliberate. It will be a relatively minor procedural change to open a master customer record as soon as a form is completed by a customer requesting a connection. Upon completion of the connection the record would be updated and bills sent. The system should report those instances where delays of three, six, nine and twelve months occur between the request and connection. The report would add valuable management information in addition to its role in reducing the risk of losses.

5.5 Economic and Financial Analysis

5.5.1 Financial Analysis

The financial analysis of non-technical losses is based on determining the internal financial rate of return. To this end, all of the financial costs and benefits attributable to the reduction of non-technical losses were calculated.

It was first necessary to estimate the level of non-technical losses on the system. As was detailed in Section 5.2 losses that were found as a result of measurement and meter checking are as follows:

Metering errors at power stations	2.7%
Metering errors in the small and large power categories	1.3%

Further to this it is estimated that some 2.9% of non-technical losses still exist on the system these may be split into categories as follows:

Small power losses	1.3%
Domestic	0.6%
General	1.0%

In the small power category, losses were calculated from the Industrial Consumer Meter Accuracy Results Table 5.2.2 from which all those consumers that could be considered to be large power were eliminated (ie, SUCOMA, David Whitehead). The loss in this category is calculated from the remaining consumers, which was considered to be a reasonable sample of some 8% of the small power consumers selected at random.

In the domestic category analysis of the bills of those consumers found to be taking illegal supply was undertaken. This showed that where a consumer was found to be taking illegal supply in the high density and low density categories some 202 kWh were stolen on average. This represents some 75% of average consumption per consumer in the domestic category. It is assumed that 5% of domestic consumers are taking illegal supply, which is considered a reasonable estimate since it is known that fraud is fairly common in the domestic sector. In total some 3.9% of the energy in this category is estimated to be lost through non-technical losses, giving an overall system loss of 0.6%.

In the general category it is assumed that a consumer who is stealing electricity will only pay for 25% of his actual consumption. It is further assumed, in the absence of any other data, that some 10% of consumers in this category are stealing energy. This is considered a reasonable estimate since the general category and in particular the maize mills and garages are notorious for this kind of theft. Losses in this category are therefore estimated to be 7.5% of consumption, representing 6 GWh and 1.0% losses on the system.

In calculating streams of non-technical losses it is assumed that the overall non-technical losses in the small power domestic and general categories will fall to 0.5% by the end of 1995, which is considered a reasonable target for the measures proposed, and will be maintained at this level thereafter. Losses are valued using the current average tariff in each category and the benefits are determined in the loss reduction by assuming the reduction to 0.5% by 1995, and in the case with no loss reduction by assuming that the current losses remain constant over time. This in reality represents a somewhat pessimistic view in calculating rates of return, as in general if no action were taken against non-technical losses they would increase over time (in terms of KWh) rather than remaining constant.

The costs of reducing non-technical losses include a billing system software, meter boxes socket or type meters, meter pliers, two meter test benches in Blantyre and a meter test room.

The requirements of the billing system are detailed in Section 5.3. The cost of the billing system software is estimated to be MK1,082,005 plus an annual software rental and maintenance charge of MK166,740.

Software	MK 1,082,005
Quarterly Software rental/maintenance	MK 166,740

With regard to meter boxes there are a number of options. Firstly it is envisaged that in the long term all meters should be placed in sealed boxes, and that these should have a transparent front so that the meter may be read without having to open the box. In this way any person wishing to access the meter box would have to first break the seal. It is, however, difficult to establish the benefits that are directly attributable to installing meter boxes since whilst meter tampering would be immediately evident, meter by-passes would still be possible. A crucial requirement to prevent tampering is that meter pliers are under strictly controlled issue, and are only available to those people who are empowered to seal both meters and boxes. It is therefore recommended that fifty pairs of meter pliers are purchased at MK 173 per pair.

It is assumed that all new connections would be carried out using the meter boxes and that this would be at the expense of the consumer and would be installed by the consumer. ESCOM would install and seal the meter in the normal way. The meter box would also be sealed by ESCOM. There would therefore be negligible additional cost to ESCOM.

In the case of existing consumers it is envisaged that all meters in the Small Power, High Density, Low Density and General categories could be placed in sealed boxes within a period of fifteen years. The entire cost of this would be borne by ESCOM. The cost of meter boxes is estimated to be MK 60 for a single phase box and MK 140 for a three phase box. The cost of labour to install these is estimated to be MK 100 per day for a three man team comprising a meter fitter, an assistant and a driver. It is estimated that a single phase box would require one day to fit and that a three-phase box would require two days to fit. The level of commitment required to complete this project would be eight teams for fifteen years. The cost of eight vehicles has also been included.

A second approach, in the light of the difficulty in assigning benefits to the installation of meter boxes, would be a three stage project.

(i) require that all new meters are placed in sealed boxes.

(ii) force all consumers found stealing to have sealed boxes. This could be added to the 'fine' imposed on meter tamperers by ESCOM as follows:

Box	MK 60
Fitting	MK 100.

It could therefore increase the penalty for meter fraud by MK 160 for single phase consumers.

(iii) assess the level of benefits to be obtained by installing meter boxes by replacing all of the boxes in a particular area and accurately monitoring the results.

Even though the level of benefits arising from installing meter boxes is somewhat indeterminate, it is expected that trials will show that the full programme of installation is financially viable and it is this programme that has therefore been included in the financial analysis.

As alternative analysis has also been considered for the installation of socket-type meters, a similar programme of installation should be carried out as detailed above for meter boxes. Thus the benefits can be assessed. For the purposes of this analysis the benefits obtained from installing socket-type meters are considered to be the same as from installing meter boxes. Whilst socket-type meters prevent tampering with the connections to the meter, they do not prevent tampering with the meter itself. Conversely sealed meter boxes will prevent tampering with the meter but not the connections to it.

The cost of socket type meters is as follows:

Single Phase	MK100
Three Phase	MK650

Plus installation as detailed for the meter boxes, giving a total installed cost as follows:

Single Phase	MK200
Three Phase	MK850

Whilst analysis was carried out on this basis, it was considered likely that installation costs for socket-type meters would be higher than for meter boxes. A further study was therefore carried out with installation cost multiplied by a factor of 1.75.

The cost of two meter test benches and a meter test room have been included to replace the two meter test benches in Blantyre. These are at an estimated cost of MK 170,000 each for the test benches and MK 80,000 for the test room. The cost of fifteen solid state test meters has also been included at MK 5,000 each.

All of the above costs are based on budget prices obtained from recognised suppliers of the products. The results of the analysis are presented in Tables 5.6 to 5.8. Table 5.6 shows the analysis including meter boxes, giving an Internal Financial Rate of Return (IFRR) of 37.6%. Table 5.7 shows the analysis including socket type meters with the lower installation cost, giving an IFRR of 31.3%. Finally Table 5.8 shows analysis with socket type meters and the higher installation cost, giving an IFRR of 24.76%. Thus whilst all three options are viable the installation of meter boxes represents the most favourable IFRR.

5.5.2 Economic Analysis

The economic analysis is carried out using the same methodology as for the financial analysis. The costs and benefits detailed above are all relevant to the economic analysis with the exception that only 30% of the cost of the billing system has been included. This reflects the loss reduction purpose of the billing system. There is also an additional benefit in the form of resource cost savings.

Resource cost savings arise from the fact that the consumer will use more electricity if he is not being charged for it than he will if he has to pay the full price for every unit consumed. This may be represented as the area BCD in Figure 5.1.

The resource cost saving is simply calculated in the domestic categories by assuming that each consumer has two circuits - lighting and sockets and that where the meter is by-passed it will be to avoid paying for the consumption on the sockets. The average domestic consumer in Malawi consumes 2918 kWh per year. Analysis of the bills of those consumers caught with meter by-passes reveals the following information:

(i) assuming that all units consumed for the purposes of lighting are metered, the annual consumption per consumer for lighting is 1284 kWh.

(ii) on average, a consumer caught with a meter by-pass consumes 3660 kWh per annum.

In Figure 5.1 consumption on the socket when the consumer is paying for all the energy he consumes, is represented by point A. This is calculated as follows.

Average consumption by consumer not by-passing meter - consumption for lighting:

= 2918 - 1284
= 1635 kWh

Point B is the consumption on the socket when the consumer is by-passing the meter. This is calculated as follows:

Average consumption by consumer by-passing meter - consumption for lighting:

= 3660 - 1284
= 2376 kWh

The resource cost savings in this category are shown in Figure 5.1 and assuming an average tariff of 0.15 MK/kWh these are equal to 0.075 MK/KWh. This implies that the average meter bypasser in the domestic sector is stealing electricity to the value of 55.6 MK per annum.

Resource cost savings in the small power and general category have not been calculated due to insufficient data, however, it has been assumed that the Resource Cost Savings in these sectors are 0.075 MK/kWh. It is not expected that this will have any substantial effect on the economic viability of the project. In the general category it is well known and accepted that theft is high, especially among the maize mills and garages. In the small power category it appears that fraud is not so high, however there are still metering errors to be detected. Incorrect meter readings and lower bills may encourage consumers in this sector to be more profligate than they otherwise would be and thus resource cost savings have been included.

The costs for the economic analysis are the same as for the financial analysis except that only 30% of the billing system cost has been taken to be attributable to loss reduction. The billing system has a variety of purposes other than loss reduction. For example, it will speed and ease the billing process and the hardware will need to be specified not only to run the billing system, but also programme such stock control and payroll.

The results of the analysis are indicative only of the economic rate of return. Tables 5.6, 5.7 and 5.8 show Economic Rates of Return for meter boxes, socket-type meters and socket-type meters with a higher installation cost of 16.4%, 8.78% and 0.19% respectively. It is therefore indicative that only the installation of meter boxes is economically viable.

Table 5.1 : Power Stations Meter Accuracy Results as at 14/12/90

Power Station Unit Tested	Accuracy (%)	Units Metered (MWh) 1989-90	Units Over-read (MWh) 1989-90
NKULA A			
Generator Transformer 1			
Generator Transformer 2	2.0		
Generator Transformer 3	1.8		
NKULA B			
Generator Transformer 4	0.6		
Generator Transformer 5	0.5		
Generator Transformer 6	0.1		
Generator Transformer 7	3.6		
TEDZANI			
Generator Transformer 1	0.8		
Generator Transformer 2	1.1		
Generator Transformer 3	-3.7		
Generator Transformer 4	-3.0		
Station Transformer	-0.2		
NKULA A			
Generator 1	2.7	49254	-1304
Generator 2	-2.0		
Generator 3	3.8	52725	-1944
NKULA B			
Generator 4	2.7	112275	-2998
Generator 5	3.4	113622	-3748
Generator 6	2.1	44210	-926
Generator 7	2.8	78210	-2115
TEDZANI			
Generator 1	2.5	41850	-1004
Generator 2	1.1	43431	-479
Generator 3	3.9	46915	-1754
Generator 4	1.2	45097	-533
TOTALS		627589	-16805
Error			2.68%

Table 5.2 : Industrial Consumers Meter Accuracy Results as at 14/12/1990

Customer Name INDUSTRIAL CONSUMERS	Peak Demand (KVA) 1989-90	Accuracy (%)	Units Metered (MWh) 1989-90	Units Lost (MWh) 1989-90	Monthly Average MD (KVA) Error	Energy Revenue Lost 1989 -90 (Kwacha)	Power Revenue Lost 1989 -90 (Kwacha)	Total Revenue Lost 1989 -90 (Kwacha)
SUCOMA	15000	-1.23	51670	645	0	0	0	0
David Whitehead & Sons	5750	1.26	31739	(396)	0	0	0	0
Limbe Leaf Tobacco Co	1490	0.63	5305	(33)	0	0	0	0
Portland Cement Blantyre	1300	0.80	4241	(33)	0	0	0	0
Timber Products	760	2.00	2903	(57)	0	0	0	0
Lever Brothers	710	0.44	3165	(14)	0	0	0	0
Grain & Milling Co	690	0.63	1878	(12)	0	0	0	0
Carlsberg Malawi Ltd	640	1.06	2692	(28)	0	0	0	0
Universal Industries	465	1.05	1658	(17)	0	0	0	0
ENCOR Products	375	0.06	990	(1)	0	0	0	0
Enterprise Container	330	0.10	1510	(1)	0	0	0	0
BWB Chileka Pumping No 2	3650	-0.69	22046	154	0	0	0	0
BWB Chileka Pumping No 1	3650	1.95			0	0	0	0
BWB Walker's Ferry - Nkula	5800	0.72			0	0	0	0
Plastic Products LTD	325	0.09			0	0	0	0
Blantyre Netting (DWS)	370	-49.05	1625	1,564	303	54,741	6,080	60,821
Mount Soche Hotel	310	-50.48	1091	1,112	256	38,931	5,135	44,067
Namin'gomba Tea Factory-Thyolo	615	-0.78	7	0				
LILONGWE								
Agricult Research Off. present	114	-25.23	236	80	44	2,784	880	3,663
Agricult Research Off. correct	114	-2.08						0
Limbe Leaf Tobacco Meter only	1490	1.13						0
Limbe Leaf Tobacco Overall	1490	-24.45	6507	2,106	404	73,713	97,279	170,992
Stancom Tobacco Packers LTD	1240	1.13	525	(6)	0	0	0	0
Lilongwe Water Board	1200	0.45	7256	(32)	0	0		0
Lilongwe Hotel	363	1.13	1328	(15)	0	0	0	0
Min of Transport KIA No1 meter	1200	-47.05	2332	2,072	0	72,535	6,480	79,015
Min of Transport KIA No2 meter		-85.70	105	629	0	22,003	6,480	28,483
Reserve Bank of Malawi	620	1.97	1885	(36)	0	0	0	0
Capital Hotel	488	0.46	2716	(9)	0	0	0	0
Pipe Extruders LTD	209	-65.75	265	508	303	17,793	6,077	23,870
SMS Kamuzu Central Hospital	209	1.81	895	(16)	0	0	0	0
Southern Botllers LTD	202	0.81	633	(5)	0	0	0	0
Kamuzu College of Nursing	195	0.88	580	(5)	0	0	0	0
Shore Rubber LTD	180	1.46	405	(6)	0	0	0	0
Lilongwe Water Board No 2	400	0.18	484	(1)		0	0	0
Kamuzu Barracks	360	1.20	1205			0	0	0
Stage Coach	37	-19.3	176	42	14	1,476	286	1,762
TOTALS			**160,052**	**8,189**	**0**	**283,976**	**128,697**	**412,673**

Table 5.3 : Summary of Meter Accuracy Results as at 14/12/1990

Total metered generation at Nkula A & B and Tedzani	627589 MWh
Meters over-read at above power stations by	16805 MWh
True generation	610784 MWh
Total generator metering error	2.68 %
Energy lost due to consumer meter undereading	8189 MWh
Percentage of lost energy	1.34 %
Energy Lost + Power station meter over read	24994 MWh
Total loss figure as a percentage of true generation	**3.98 %**

Table 5.4 (a) : Results of Meter Test Bench Checks

FOSTER BENCH

Test Bench Readings		Dranetz Readings	Percentage Error
Test 1 : 20A, Unity P.F.			
VA-N	230	231.8	+0.78
VB-N	230	231	+0.43
VC-N	230	231.1	+0.48
IA	20	19.82	-0.90
IB	20	19.79	-1.05
IC	20	19.68	-1.60
WA	4600	4596	+0.09
WB	4600	4573	+0.59
WC	4600	4546	+1.19
Total	13800	13715	+0.62
PF	0.99	0.99	0
Test 2 : 20A, 0.5 P.F.			
Total W	6950	7146	-2.74
PF	0.5	0.52	-4.00
Test 3 : 100A, 1.0 P.F.			
Total W	69000	68230	+1.12
Test 4 : 100A, 0.5 P.F.			
Total W	34500	34750	-0.72
Test 5 : 400A, 1.0 P.F.			
Total W	276000	275500	+0.18

Table 5.4 (b) : Results of Meter Test Bench Checks

LANDIS & GYR SUBSTANDARD METER

Test Period (h)	Load (A)	Substandard Reading (kWH)	Dranetz Reading (kWH)	Percentage Error (%)
1.00	100	78.00	75.98	+2.66
2.00	50	79.57	78.64	+1.19
1.00	5	3.60	3.55	+1.49

TABLE 5.5

NUMBERS OF METER READERS

SOUTHERN Region		
Blantyre	Special meter readers	6
	Ordinary meter readers	19
	Total	25
Thyolo		1
Mulanje		1
Nchalo		1
Bangula		1
Zomba		4
Mangochi		1
Liwonde		1
Total Southern region		35
CENTRAL Region		
Lilongwe	Special meter readers	3
	Ordinary meter readers	12
	Total	15
Kasungu		1
Mchinji		1
Salima		1
Dedza		1
Nkhota-Kota		1
Dowa		1
Total Central region		21
NORTHERN Region		
Mzuzu		3
Rumphi		1
Karonga		1
Chitipa		1
Total Northern region		6
GRAND TOTAL		**62**

FINANCIAL AND ECONOMIC ANALYSIS OF NON-TECHNICAL LOSSES - Meter Boox Option

Table 5.6

	COSTS							FINANCIAL BENEFITS				ECONOMIC BENEFITS	
Year	Meter Boxes	Billing System	Meter Test Benches	Meter Pliers	Meter Test Room	Solid State Meters	Total Cost	Small Power Benefit	Domestic & General Benefit	Total Benefit	Net Financial Benefit	Resource Cost Savings	Net Economic Benefit
1990								0	0	0	0	0	0
1991	751960	1082005	332850	8650	80000	75000	2330465	195474	142017	337490	-1992975	142430	-1430631
1992	431960	166740					598700	354931	284033	638964	40264	269854	-212128
1993	431960	166740					598700	541106	426050	967156	368456	408410	-73572
1994	431960	166740					598700	731499	568067	1299566	700866	548723	66741
1995	431960	166740					598700	949199	710083	1659282	1060582	700414	218432
1996	431960	166740					598700	1060172	793969	1854141	1255441	783538	301556
1997	431960	166740					598700	1150869	877855	2028724	1430024	858214	376232
1998	431960	166740					598700	1250865	961741	2212605	1613905	936764	454782
1999	431960	166740					598700	1362586	1045626	2408213	1809513	1020199	538217
2000	431960	166740					598700	1487280	1129512	2616793	2018093	1109040	627058
2001	431960	166740					598700	1622181	1213398	2835579	2236879	1202134	720152
2002	431960	166740					598700	1771052	1297284	3068336	2469636	1301049	819067
2003	431960	166740					598700	1932783	1381170	3313952	2715252	1405322	923340
2004	431960	166740					598700	2110616	1465055	3575672	2976972	1516304	1034322
2005	431960	166740					598700	2305777	1548941	3854719	3256019	1634507	1152525
										IFRR	37.57%	IERR	16.44%

FINANCIAL AND ECONOMIC ANALYSIS OF NON-TECHNICAL LOSSES -Socket Type Meters

Table 5.7

	COSTS							FINANCIAL BENEFITS				ECONOMIC BENEFITS	
Year	Socket Meters	Billing System Software	Meter Test Benches	Meter Pliers	Meter Test Room	Solid State Meters	Total Cost	Small Power Benefit	Domestic & General Benefit	Total Benefit	Net Financial Benefit	Resource Cost Savings	Net Economic Benefit
1990								0	0	0	0	0	0
1991	913945	1082005	332850	8650	80000	75000	2492450	195474	142017	337490	-2154960	142430	-1592616
1992	593945	166740					760685	354931	284033	638964	-121721	269854	-374113
1993	593945	166740					760685	541106	426050	967156	206471	408410	-235557
1994	593945	166740					760685	731499	568067	1299566	538881	548723	-95244
1995	593945	166740					760685	949199	710083	1659282	898597	700414	56447
1996	593945	166740					760685	1060172	793969	1854141	1093456	783538	139571
1997	593945	166740					760685	1150869	877855	2028724	1268039	858214	214247
1998	593945	166740					760685	1250865	961741	2212605	1451920	936764	292797
1999	593945	166740					760685	1362586	1045626	2408213	1647528	1020199	376232
2000	593945	166740					760685	1487280	1129512	2616793	1856108	1109040	465073
2001	593945	166740					760685	1622181	1213398	2835579	2074894	1202134	558167
2002	593945	166740					760685	1771052	1297284	3068336	2307651	1301049	657082
2003	593945	166740					760685	1932783	1381170	3313952	2553267	1405322	761355
2004	593945	166740					760685	2110616	1465055	3575672	2814987	1516304	872337
2005	593945	166740					760685	2305777	1548941	3854719	3094034	1634507	990540
										IFRR	31.31%	IERR	8.78%

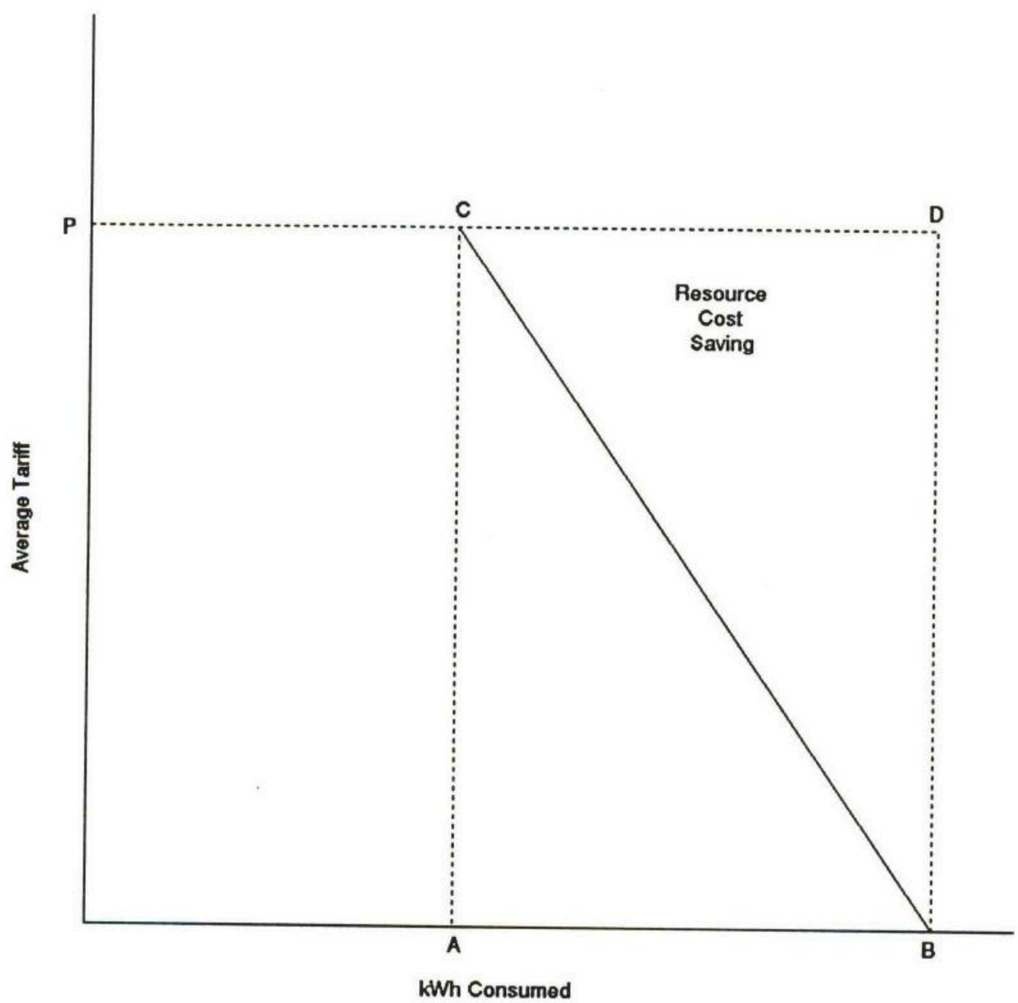
FINANCIAL AND ECONOMIC ANALYSIS OF NON-TECHNICAL LOSSES -Socket Type Meters - Increased Installation Costs

Table 5.8

	COSTS							FINANCIAL BENEFITS				ECONOMIC BENEFITS	
Year	Socket Meters	Billing System Software	Meter Test Benches	Meter Pliers	Meter Test Room	Solid State Meters	Total Cost	Small Power Benefit	Domestic & General Benefit	Total Benefit	Net Financial Benefit	Resource Cost Savings	Net Economic Benefit
1990								0	0	0	0	0	0
1991	1115235	1082005	332850	8650	80000	75000	2693740.	195474	142017	337490	-2356250	142430	-1793906
1992	795235	166740					961975.1	354931	284033	638964	-323011	269854	-575403
1993	795235	166740					961975.1	541106	426050	967156	5181	408410	-436848
1994	795235	166740					961975.1	731499	568067	1299566	337590	548723	-296534
1995	795235	166740					961975.1	949199	710083	1659282	697307	700414	-144843
1996	795235	166740					961975.1	1060172	793969	1854141	892166	783538	-61719
1997	795235	166740					961975.1	1150869	877855	2028724	1066749	858214	12956
1998	795235	166740					961975.1	1250865	961741	2212605	1250630	936764	91506
1999	795235	166740					961975.1	1362586	1045626	2408213	1446237	1020199	174942
2000	795235	166740					961975.1	1487280	1129512	2616793	1654817	1109040	263783
2001	795235	166740					961975.1	1622181	1213398	2835579	1873604	1202134	356877
2002	795235	166740					961975.1	1771052	1297284	3068336	2106361	1301049	455792
2003	795235	166740					961975.1	1932783	1381170	3313952	2351977	1405322	560065
2004	795235	166740					961975.1	2110616	1465055	3575672	2613697	1516304	671047
2005	795235	166740					961975.1	2305777	1548941	3854719	2892743	1634507	789249
										IFRR	24.76%	IERR	0.19%

Figure 5.1

RESOURCE COST SAVINGS



SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Existing System Losses

The measurement and analysis work described above has enabled an estimate to be produced of the existing technical losses associated with the various voltage levels on the ESCOM system, together with the non-technical losses which have been accounted for to date, and those which are estimated to be remaining on the system.

In producing the technical loss estimate, it is important to take due cognisance of loads which are supplied from each voltage level and the losses associated with each level and to subtract these from the energy which is supplied through the lower levels, in order to avoid calculating an unduly pessimistic loss estimate. Figure 6.1 shows the assessment of technical losses performed in this way, working on the assumption that large power consumers are supplied from the 132/66/33 kV system, small power from the 11 kV system and domestic and general consumers from the LV network. The technical energy loss percentages used are taken from the results of the analysis described in Section 4 for each of the elements of the transmission and distribution systems. For the case of the small power consumers, half of the load is shown supplied from the 11 kV system directly and half through 11 kV/LV transformers. This makes an allowance for the fact that some of the largest small power consumers are HV metered, and the losses associated with their transformers do not therefore appear as a loss to ESCOM.

The results of this analysis indicate technical losses of 10.1% and initial non-technical losses of 6.9%, giving an estimated total energy loss figure of 17% of net generated energy for the system at the start of the study. This compares quite favourably with the ESCOM figure of 16.3% which applied for 1989.

The non-technical losses found during the period of this study account for 4% of the net generated energy, suggesting that overall the remaining system loss level is running at approximately 13%.

6.2 Losses After Loss Reduction

Indicative levels of losses after the introduction of the various loss reduction measures which have been discussed above have been calculated to give an estimate of the target loss level which should be obtainable following the implementation of the recommendations contained in this report.

Figure 6.2 summarises the predicted levels of losses after the introduction of loss reduction measures, based on the reduction in losses observed from the sample studies performed at each voltage level. It is assumed that the percentage loss levels calculated after the introduction of loss reduction measures on the system in 1991 are maintained as target levels during the development of the system, and that the goal of achieving 0.5% non-technical losses by 1995 is maintained as the target level for non-technical losses thereafter. The results of this analysis show a target technical energy loss level of 9.1% of net generation, which, when combined with 0.5% non-technical losses, gives an overall figure of 9.6%. This is considered a realistic target level on the basis of foregoing analysis, and is in line with the initial estimate used in preparing the load forecast at the outset of the study.

6.3 Recommendations

The recommendations for loss reduction projects which have been described in the main body of the report are summarised below.

6.3.1 132/66/33 kV System

The results of the work carried out on the transmission system indicate that there is very little work which can be justified in addition to the developments which are already programmed by ESCOM in order to reduce losses. Upgrading of the Mtunthama 105 33 kV circuit to 66 kV operation is a justifiable loss reduction measure due to the fact that the line is already constructed for 66 kV operation (section 4.2.2).

The Least Cost Development Plan for the ESCOM system included recommendations for the installation of static compensation equipment on the 132 kV system. Whilst the capital cost of such equipment is such as to make it unattractive when viewed solely from the angle of loss reduction, benefits in terms of reduced losses should be examined if the current work being carried out in the Transmission and Distribution Study recommends its introduction as part of the optimal development of the system.

It is recommended that the design loading levels for conductors which have been developed in this report are used as the basis for planning the transmission system with a view to minimising losses at all stages of system development (section 4.2.2).

6.3.2 11 kV System

A substantial programme of feeder reconductoring at 11 kV is proposed, together with limited application of capacitors, on account of the generally good system power factors. Reconductoring generally takes the form of introducing a new 150 sq mm conductor size at 11 kV, together with some cable replacement (section 4.3.4).

It is recommended that the overall configuration of the 11 kV system be optimised in terms of loss minimisation once the basic system plan has been established in the Transmission and Distribution Study. It is anticipated that the study should include consideration of losses as a matter of course, but it is emphasised that for full benefit to be derived from the design criteria presented in this report a coordinated approach to the optimisation of the 11 kV system should be adopted. It is also recommended that at an operational level ESCOM should examine the effects of switching operations and consequent local system reconfiguration in terms of losses as part of their normal procedures.

6.3.3 LV Systems

Proposals have been developed for the purchase of 11/0.4 kV transformers (section 4.4.2) and the execution of LV reconductoring projects (section 4.4.4) with a view to reducing losses associated with distribution transformers and LV systems.

The magnitude of the task of optimising the detailed investment programme based on these measures is such that it can only effectively be finalised by means of a detailed LV study whereby transformer placement and LV feeder lengths can be coordinated to minimise losses overall.

It is envisaged that this work could be carried out with considerable input from ESCOM's Central Planning Unit in conjunction with a distribution planning specialist, and a proposal based on this approach has been included in the loss reduction package and is discussed in more detail in the earlier sections of this report (section 4.4.5).

Load balancing on the LV systems has been shown to play an important role both in reducing loss levels and in improving voltages at remote ends of the feeders. This measure involves minimal capital cost, and is therefore strongly recommended as a loss reduction measure (section 4.4.4).

The voltage profile across the LV networks in general would be substantially improved by changing the tap settings on all of the 11 kV/LV and 33 kV/LV transformers to their +5% levels. Most of the distribution transformers are currently operating on nominal tap, and not therefore utilising the opportunity to improve voltages at consumer's premises.

6.3.4 Non-technical Losses

The key recommendations relating to non-technical loss reduction involve a number of capital purchases and measures to improve organisational aspects of the detection and investigation of losses arising from metering errors and fraud. In summary, these recommendations are as follows:

- Implementation of a new computer billing system (section 5.3).
- Installation of meter boxes at all new consumers' premises and retrospectively at all small power, high density, low density and general consumers (sections 5.2, 5.5).
- Purchase of two meter test benches and construction of a new meter test room in Blantyre (section 5.2).
- Purchase of fifty pairs of meter pliers.
- Purchase of fifteen solid state kWh meters for use by the ESCOM metering department in carrying out on-site meter accuracy checks.

The organisational recommendations relating to non-technical loss reduction may be summarised as follows and are detailed in section 5.4 of the report:

- The incentive for collusion between meter readers and tamperers is considerable. The reward for ordinary meter readers should be raised to, say, K20 per proven illegal customer. For special meter readers (dealing with Small Power customers) the reward should be considerably more at, say, K50. Additionally, a discretionary payment could be made for big discoveries or offences which are cleverly disguised. The cost of this could be recovered in the customer's 'fine'. Rewards should be index-linked to annual average pay increases;

- Meter readers in outstations should always be replaced by outside relief readers during periods of leave to act as auditors of the primary reader;

- The meter readers reports and details of any investigations carried out against a particular customer should be systematically maintained and circulated to all staff charged with detecting and investigating illegal abstractions (ie, Commercial Manager, Consumers Engineer, District Engineers and Officers-in-Charge). The filing should be such as to enable staff to quickly and easily check on a customer's past mis-deeds and past consumption history;

- An account number should be allocated and a record entered on the computer as soon as a request is made for a new connection. The system should report accounts which are experiencing long delays in connection. These should then be investigated;

- Sealing pliers should only be issued to Special Meter Readers in Blantyre and Lilongwe. No disconnections or reconnections should be made without sealing pliers. All pliers should be fully accounted for and signed for when they are issued;

- Special meter readers should be given more specialised training to reflect the sophistication of the meters and customers in the Small Power category. Specific training should be included on current transformer metering methods and the potential errors which can result from incorrect connections in three phase metering.

- Meter readings should continue to be undertaken at random intervals to prevent consumers becoming familiar with a routine and anticipating visits;

- Opening meter readings should be checked by the billing system against the previous closing reading for disconnections/reconnections.

- Premises which have been disconnected but fail to be reconnected within a reasonable period of time should be reported by the billing system and investigated;

- The 'fine' for illegal abstractors should be tailored to the size of the consumer. A little creativity could be used to easily justify the raising of the 'fine' to a level which might act as a real deterrent;

- The ESCOM policy of high profile and concentrated investigations of areas should be continued to reap the maximum publicity and deterrence value;

- The Abnormal Consumption Variations report should be made more informative and should be circulated to all persons responsible for detecting and investigating non-technical losses. The report should look for both changes in trend and monthly dips or spikes relative to 'normal' variations. Seasonal variations should also be taken into account. Abnormal variations in kVA readings should also be reported;

- Customer master records should include a record of past misbehaviour. This should also be reported in the event of an Abnormal Variation;

- The Abnormal Variation Report should include the customer's consumption history over the past 14 months;

- The kVAh readings taken for Small Power consumers should be entered on the customer master record on the computer. The power factor should be calculated to act as a cross-check on the accuracy of the kWh and kVA meters. If the power factor falls below, say, 0.8 a warning report should be sent to the Commercial Manager for further investigation.

6.3.5 <u>General</u>

Continued monitoring of both technical and non-technical losses is important both in terms of enabling the finalisation of the LV loss reduction programme and in terms of tracing sources of meter errors and consumer fraud. In order to facilitate this it is strongly recommended that two Dranetz power demand analysers and accompanying personal computers and software be purchased for ESCOM aa part of the loss reduction package, particularly in view of the experience which has been gained in effectively using this equipment by engineers in both the metering and planning functions of ESCOM.

6.4 Budgetary Requirements

Budgetary requirements for each loss reduction project have been given in the main text expressed in Malawi Kwacha. These are now summarised in Table 6.1, split into foreign and local cost components, based on constant 1990 costs.

The overall budgetary requirements identified including contingencies, amount to US$ 13.8 m of foreign costs, with an associated MK 13.2 m local component. The overall package is equivalent to US$ 19.1 m. The significance of the LV system component in the overall budget, together with the sum for distribution transformer replacement, reinforces the need for further attention to be paid to the overall optimisation of the LV systems prior to the implementation of a large scale reconductoring and transformer replacement programme at this level.

The fact that overall the loss reduction budget is lower than would be expected in some situations reflects the findings of the study with regard to economic loss levels, particularly relating to the transmission system. It is also indicative of the relatively small investment required to attach non-technical losses, which form a significant component of the existing loss level on the ESCOM system and which have already been substantially reduced simply by monitoring consumers' installations and making straightforward corrections of metering errors. Through this process alone, over MK 0.4 m of annual revenue has already been recovered.

Subject to the observations made regarding the need for further work on the LV systems, these investment levels may be viewed as adequate to bring losses on the ESCOM system down to an economic level.

6.5 Programme

The programme proposed for the execution of the various loss reduction projects is designed to enable the various recommendations to be implemented within five years. This is considered a reasonable timescale in which to attain the target loss level of 10% for the system as a whole. The exception to the five year implementation period is the scheme for installing meter boxes, which is intended to run through a fifteen year prior due to the number of consumer installations requiring modification.

The rates of return associated with 11kV reconductoring and non-technical loss reduction are such that they represent the projects which should be undertaken as the highest priority. They are also quite self-contained, as substantial changes to reconductoring recommendations are unlikely to result from optimisation of the 11kV distribution systems.

On the assumption that one gang is dedicated to the task of reconductoring the 59km of 11kV feeders identified for inclusion in the project, a time allocation of approximately six months is included in the programme for this activity. This allows some contingency for such items as pole replacement which may be found necessary during the course of the project.

With regard to non-technical losses, the most time consuming activity is likely to be the introduction of a new billing system. This will necessitate periods of specification, software preparation, testing and training prior to handing over, and is thus likely to take up to eighteen months for completion. Shorter periods are envisaged for the procurement of the meter test benches and the other items; clearly the new meter test room would need to be complete before the test benches arrive, but since a period of some twelve months is likely to be required for the benches to be specified, tenders to be received and the benches to be supplied, the building should easily be complete within this period.

Before work can be carried out on LV system reconductoring and transformer replacement, further study will be needed to optimise the positioning of distribution transformers and the configuration of LV circuits. It is envisaged that this would be performed at the start of the five year programme, and would comprise a one month period of works undertaken by a distribution planning specialist working with the ESCOM central planning unit, followed by a period of approximately six months during which ESCOM would apply the techniques established in the first visit to optimise the LV systems across the network. The results of this analysis would thus be combined into a revised statement of the LV distribution system requirements and budget assessment.

On the basis of the work carried out to date, it is likely that some 500km of the LV system would require reconductoring, with over two hundred new transformers to be purchased and three times that number of replacements and swaps. This amount of work, coupled with the balancing of LV loads, would require the resources of at least three gangs of linesmen, with one over to carry out the transformer replacements simultaneously with the reconductoring work on each feeder, to minimise load interruptions, if it is to be achieved within the four years remaining after the LV optimisation study.

The 33kV to 66kV upgrading of Mtunthama 105 feeder is the last project to be implemented on the basis of loss reduction, and is programmed for inclusion in the final year of the five year period.

Figure 6.3 summarises the above programme in the form of a bar chart indicating the relationship between the projects in terms of their execution times.

Table 6.1 : Summary of Loss Reduction Budget Requirements

Project	Local Cost MK m	Foreign Cost US$ m
33kV-66kV Line Upgrading Mtunthama 105	0.157	0.357
11kV Reconductoring and Capacitor Placement	0.581	1.316
11kV/0.4kV Transformer Replacement	0.420	0.952
LV System Reconductoring	3.741	8.481
11kV/LV System Optimisation Study	0.000	0.045
Billing System	0.000	0.433
Meter Test Room	0.080	0.000
2 x Meter Test Benches	0.000	0.133
Meter Test Bench Installation/Training	0.000	0.012
15 Solid State Meters	0.000	0.075
Installation of Meter Boxes	6.479	0.128
50 Pairs of Meter Pliers	0.000	0.003
2 x Demand Analysers (incl. PC's)	0.000	0.020
Sub-Total	11.46	11.95
Physical Contingencies (10 %)	1.15	1.20
Engineering Contingencies (5 %)	0.57	0.60
TOTAL	**13.18**	**13.75**

Exchange Rate : MK 2.5 = US$ 1.0

Fig. 6.1 : Summary of Existing Loss Levels

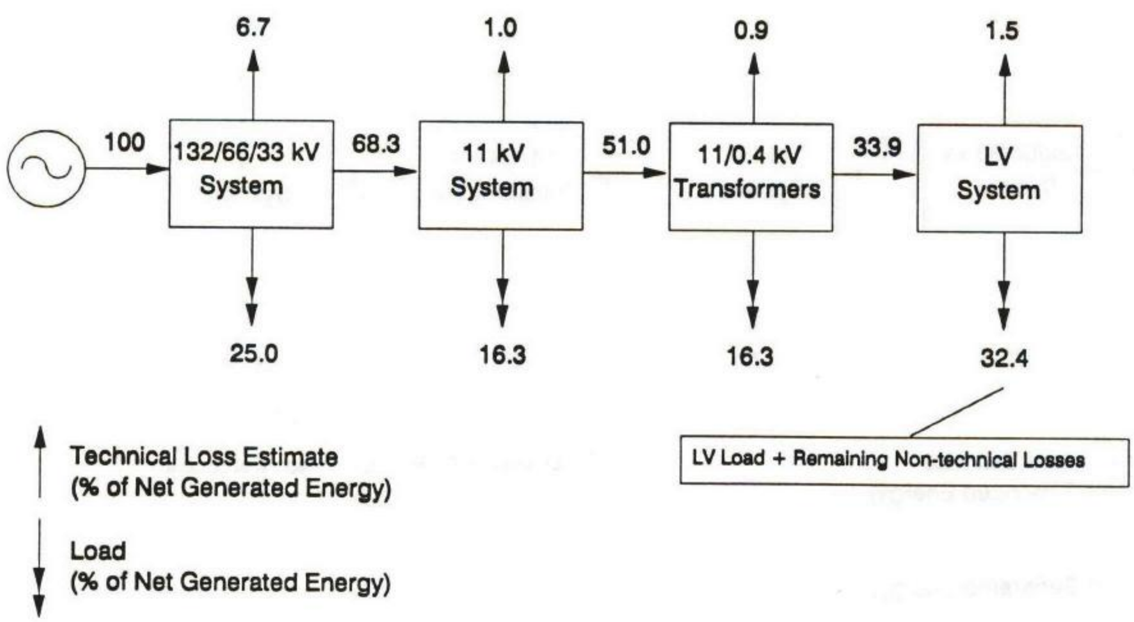
Load Breakdown

Class	Consumption - % of 1989 Net Generated Energy, corrected for metering errors found	Voltage Level
Large Power	25.0 %	>= 33 kV
Small Power	32.5 %	11 kV
Domestic / General	29.5%	0.4 kV

Breakdown of Loss Estimates

Level	Energy Loss Estimate	
132/66/33 kV Transmission	6.7 %	Percentage of energy entering each level
11 kV Distribution	1.5 %	
11/0.4 kV Transformation	1.8 %	
LV Distribution	4.2 %	
Non-Technical Losses Found	4.0 %	Percentage of net generated energy
Non-Technical Losses Remaining	2.9 %	

Energy Flow Diagram



TOTAL LOSS ESTIMATE AT START OF STUDY : 17.0 %

ESTIMATE OF REMAINING LOSSES : 13.0 %

Fig. 6.2 : Summary of Target Loss Levels

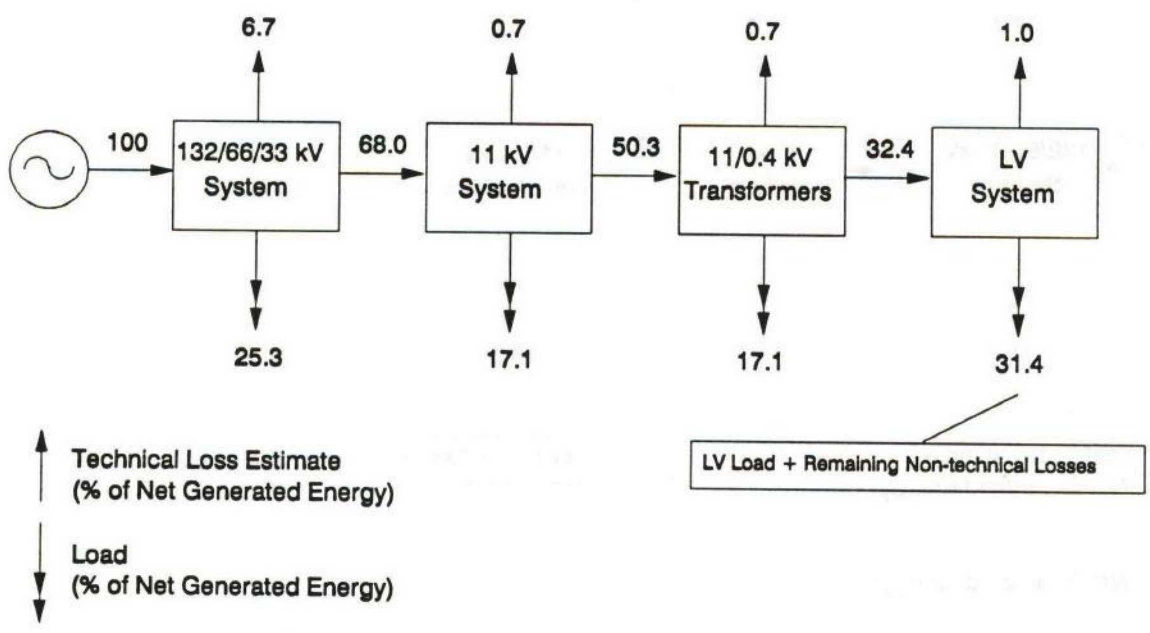
Load Breakdown

Class	Consumption corrected for Non-Technical Loss Reduction	Voltage Level
Large Power	25.3 %	>= 33 kV
Small Power	34.2 %	11 kV
Domestic / General	30.9 %	0.4 kV

Breakdown of Loss Estimates

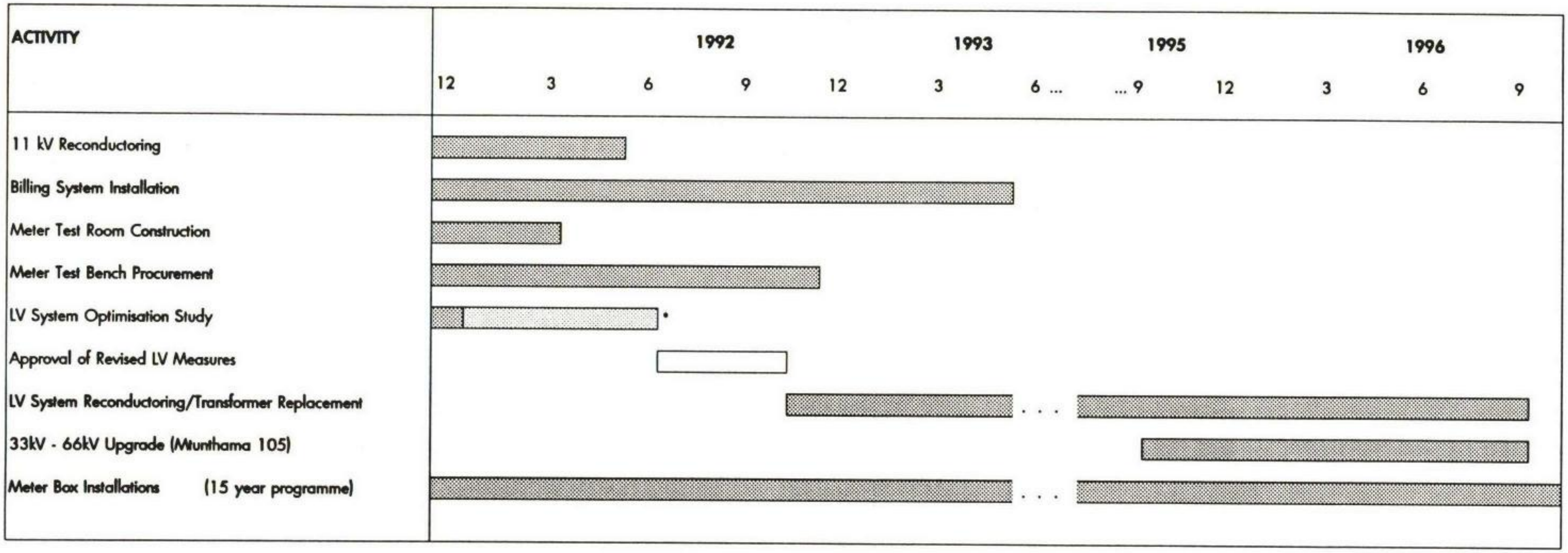
Level	Energy Loss Estimate	
132/66/33 kV Transmission	6.7 %	Percentage of energy entering each level
11 kV Distribution	1.0 %	
11/0.4 kV Transformation	1.5 %	
LV Distribution	3.0 %	
Non-Technical Losses	0.5 %	Percentage of net generated energy

Energy Flow Diagram



TARGET LOSS ESTIMATE AFTER LOSS REDUCTION : 9.6 %

Fig. 6.3 : Programme for Implementation of Loss Reduction Measures



SECTION 7

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7. REFERENCES

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Study to update ESCOM's Least Cost Development Programme - Final Report (KDP/WLPU April 1988).

Load Representation in Power System Stability Studies, Concordia & Ihara, IEEE PAS-101 No. 4, 1982.

APPENDIX A

EFFECT OF VOLTAGE ON DOMESTIC ELECTRICITY CONSUMPTION

EFFECT OF CHANGES IN VOLTAGE ON ELECTRICITY CONSUMPTION

Change in Voltage from 219 to 230 Volts ie 5.0%

APPLIANCE TYPE	% OF TOTAL	SHORT TERM Power	SHORT TERM Energy	LONG TERM Power	LONG TERM Energy
Incandescent Lighting	15%	8%	8%	4%	4%
Fluorescent Lighting	15%	3%	3%	12%	12%
Water Heaters	15%	10%	0%	5%	0%
Refrigerators & Freezers	40%	4%	0%	12%	0%
Fans & Air Conditioners	10%	0%	0%	10%	0%
Televisions	5%	10%	10%	20%	20%
Induction Motors	0%	-0%	-0%	10%	10%
Computers & Electronics	0%	0%	0%	10%	10%
OVERALL EFFECT		5%	2%	10%	3%

Notes:

	Short Term Variation (dP%/dV%)	Thermostatic Control	Failure if Voltage Low	Consumer Compensation
Incandescent Lighting	1.6	No	No	Yes
Fluorescent Lighting	0.7	No	Yes	Yes
Water Heaters	2.0	Yes	No	No
Refrigerators & Freezers	0.8	Yes	Yes	No
Fans & Air Conditioners	0.0	Yes	Yes	No
Televisions	2.0	No	Yes	No
Induction Motors	-0.1	No	Yes	No
Computers & Electronics	0.0	No	Yes	No

Reference : Load Representation in Power System Stability Studies
Concordia & Ihara, IEEE PAS-101 No.4 1982 **(56 refs)**

TJW / 28-Mar-91

EFFECT OF CHANGES IN VOLTAGE ON ELECTRICITY CONSUMPTION

Change in Voltage from 190 to 230 Volts ie 21.1%

APPLIANCE TYPE	% OF TOTAL	SHORT TERM Power	SHORT TERM Energy	LONG TERM Power	LONG TERM Energy
Incandescent Lighting	15%	36%	36%	18%	18%
Fluorescent Lighting	15%	14%	14%	17%	17%
Water Heaters	15%	47%	0%	23%	0%
Refrigerators & Freezers	40%	17%	0%	18%	0%
Fans & Air Conditioners	10%	0%	0%	10%	0%
Televisions	5%	47%	47%	57%	57%
Induction Motors	0%	-2%	-2%	8%	8%
Computers & Electronics	0%	0%	0%	10%	10%
OVERALL EFFECT		23%	10%	20%	8%

Notes:	Short Term Variation (dP%/dV%)	Thermostatic Control	Failure if Voltage Low	Consumer Compensation
Incandescent Lighting	1.6	No	No	Yes
Fluorescent Lighting	0.7	No	Yes	Yes
Water Heaters	2.0	Yes	No	No
Refrigerators & Freezers	0.8	Yes	Yes	No
Fans & Air Conditioners	0.0	Yes	Yes	No
Televisions	2.0	No	Yes	No
Induction Motors	-0.1	No	Yes	No
Computers & Electronics	0.0	No	Yes	No

Reference : Load Representation in Power System Stability Studies
Concordia & Ihara, IEEE PAS-101 No.4 1982 **(56 refs)**

TJW / 28-Mar-91

The World Bank
INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
INTERNATIONAL DEVELOPMENT ASSOCIATION

1818 H Street, N.W.
Washington, D.C. 20433
U.S.A.

(202) 477-1234
Cable Address: INTBAFRAD
Cable Address: INDEVAS

November 7, 1991

Mr Martin Kazembe
Assistant Project Coordinator
Department of Forestry
P.O. Box 30048
Lilongwe
Malawi

Dear Martin:

Enclosed are copies of some papers on the use of nitrogen fixing trees (NFTs) to promote the production of woody biomass in eucalypt plantations plus a copy of a paper on estimating woody biomass in eucalypt stands.

I promised some of the people at FRIM that I would send these after we discussed the introduction and use of NFTs to promote the growth of other species in both Government plantations and private woodlots. The paper on predicting biomass might be useful given the work FRIM and FD should be doing in determining woody biomass at Mulanje and other sites. I would appreciate it if you could forward the papers on to the right persons at FRIM.

Can you let me know how the contract arrangements are progressing with Mitshubishi and the other suppliers of vehicles and equipment you are in the process of procuring. Don't forget to send us a copy of the contract.

How are the arrangements going to get that Financial Controller on board as per our discussions with the Deputy Accountant General and the Deputy P.S. of MFNR?

All the best.

Yours faithfully,

Paul Ryan

The World Bank
INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
INTERNATIONAL DEVELOPMENT ASSOCIATION

Esmap Operations Division
Industry and Energy Department

1818 H Street, N.W.
Washington, D.C.
20433
U.S.A.

Tel.: (202) 473-7070
Fax: (202) 676-0436

October 25, 1991

Professor J.A.C. Kandawire
Department of Sociology
Chancellor College
University of Malawi
Zamba, Malawi

Dear Prof. Kandawire,

This letter is to thank you and your team for the excellent work you have done thus far. The amount of information you have been able to collect and the insights you have offered are indeed impressive. This is, by the way, not just my opinion but also the opinion of my colleagues.

In addition to your research skills, your diplomatic skills are also exceptional - and given my limited diplomatic skills, very much needed. Although you probably told us only a small part of what you have done in this sense, I have no doubt that your quiet work is the main reason why things have gone so smoothly and so well.

Please tell your whole team, including the Research Assistants, how much we appreciate your work. I am confident your final report will be of top quality and I am looking forward to reading it.

Best wishes

Maurizia Tovo

P.S. Should there be any problems or any queries, please do not hesitate to contact me.

MT:peb

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THE WORLD BANK / IFC / M.I.G.A.

Headquarters: WASHINGTON, D.C. 20433 U.S.A.

Tel. No. (202) 477-1234 // Fax Tel. No. (202) 477-6391 // Telex No. RCA 248423

FACSIMILE COVER SHEET AND MESSAGE

October 21, 1991	NO. OF PAGES (including this sheet) 2	MESSAGE NO. 2111

TO:
Name Mr G. P. Sakanda, Acting Chief Forestry Officer
Fax Tel. No. (265) 733-245
Company/ Organization The Ministry of Forestry
City & Country Lilongwe, Malawi

FROM:
Name Paul Ryan
Fax Tel. No. (202) 4770542
Dept./Div. Name IENOD
Dept./Div. No. 65732
Room No. S 4043
Telephone No. (202)4771038

SUBJECT/REFERENCE: Malawi Energy I: Procurement of Motor Cycles

MESSAGE:

Copy to Mr Martin Kasembe, Assistant Project Coordinator.

Further to my fax of September 4, and based on the additional information provided in Mr Kaseme's letter of October 14 that spares and back-up service would not be adequately provided by Export Survellance and Mreridien, the Bank has no objection to the awarding of the contract for LOt 6, motor cycles, to Standsfield Motors. The amount specified is MK628,452. Please let me know when you have finalised the contracts and send two copies of the signed contracts to Washington.

On another matter, my colleague, Mr Robert van der Plas, is anxious to hear from Mr Kasembe regarding the proposed visit of the Projecxt Coordinator from the Charcoal Project in Rwanda, Mr Evode Safali. By aletter dated July 15, Mr van der Plas wanted to know the optimal time for mr Safali's visit to inspect the charcoal operations at Viphya and to discuss the marketing of softwood charcoal. October or November this year is preferred. I am attaching a copy of Mr van der Plas' letter.

cc : McNamara (AF6AG); Gopalkrishna (AFTOS)
Telahun (AF6IE); Pohland (Field Office, Lilongwe)

Transmission authorized by Paul Ryan (IENOD)

If you experience any problem in receiving this transmission, inform the sender at the telephone or fax number listed above in the box.

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Mr. Martin Cazembe
Dep. Project Director
Forestry Department
Wood Energy Component, Energy I Project
Lilongwe
Malawi

July 15, 1991

Dear Mr Cazembe,

This is to request your cooperation for organizing a short visit to Malawi (re: Wood Energy Component of the Energy I project) for the Rwandan coordinator of the 'Assistance to the Charcoaling Sector, Phase II' project.

The joint UNDP/World Bank ESMAP program has launched a charcoal training program in Rwanda in 1987, which until now has focussed on training of traditional charcoalers in the use of more efficient (improved traditional) charcoaling methods (particularly the Casamance method). Wood used for charcoal making stems from village or private eucalyptus plantations, although the project intends to start an important activity in domanial plantations in the near future because of the availability of pinewood in large quantities. The project has recently created an association of professional charcoalers and started a research component to identify other charcoaling methods (than earthen mound and pit kilns) which could be feasible under Rwandan conditions.

I have attached a copy of a draft document outlining the status of the project (which also included a component on commercialization of improved charcoal stoves) to give you an idea what has been done during the project 's Phase I. Now that the activities begin to concentrate more on charcoaling in pinewood plantations, we thought it useful when the Rwandan project coordinator, Mr. Evode Safali, visits the Malawi Viphya charcoal project for the duration of not more than one week later this year. In this way, there can be some important cross-fertilization between the two projects.

Grateful if you could inform me about the most optimal timing for such a visit, preferably in October or November 1991 so that we can make the arrangements for Mr. Safali to visit you. If you have any questions, please do not hesitate to contact me, or Mr. Safali whom you can reach through the World Bank's office in Rwanda.

Sincerely,

Robert van der Plas
ESMAP Operations Division
Industry and Energy Department
Rm S4-027

Encl:

cc: McNamara (AF6AG); Safali (c/o AF3RW)

THE WORLD BANK / IFC / M.I.G.A.

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ESMAP Operations Division
Industry and Energy Department
Rm S4-027

Encl:

cc: McNamara (AF6AG); Safali (c/o AF3RW)

THE WORLD BANK/IFC/MIGA

Office Memorandum

DATE: October 3, 1991

TO: Ms. Maurizia Tovo, IENOD

FROM: Hossein Razavi, IENOD, and Robert Saunders, IENED

EXT.: 33695

SUBJECT: MALAWI: Workshop on "Beneficiary Assessment in the Power Sector" Terms of Reference

---

1. A workshop on "Beneficiary Assessment in the Power Sector" will take place in Malawi on October 16-19, 1991. As agreed during the Steering Committee meeting held in Amsterdam on September 17, 1991, it will be divided into three parts as follows:

Part 1 (two days): to review the data obtained from the field work and discuss preliminary findings, as well as to prepare a final agenda for Part 2, with the participation of the researchers, the Project Coordinator (i.e., yourself) and Project Adviser (Mr. Salmen, AFTSP) and the Steering Committee members;

Part 2 (one day): to present preliminary findings and recommendations, and to discuss them with representatives of the Energy Planning Unit, the Department of Research and Environment, the Ministry of Community Services, the utility and donors;

Part 3 (one day): to review the outcome of Part 2 and prepare a detailed work plan for the completion of the Malawi component with the same participants as in Part 1.

The workshop should keep in view the need to provide guidelines covering Policy Recommendations, Project Design and Political/Institutional Aspects to complement the draft EPUES guidelines. To this end, it was agreed that representatives of DANIDA and GTZ should be invited to participate.

2. As the Project Coordinator, you will participate in the workshop and ensure that the event unfolds as smoothly as possible, both from a logistical and a productive point of view. Upon returning to headquartes, you will circulate a report summarizing the outcome of the workshop.

cc: Churchill (IENDR), Kalim (PRSCG); Gilling, Mostefai (IENPD), Menke (IENED), Telahun (AF6IE), Jovanovic (AF6CO), Malone (AF6ML), Africa ISC files; PRE IISC files

MT:peb

Ko Chun

THE WORLD BANK / INTERNATIONAL FINANCE CORPORATION

OFFICE MEMORANDUM

DATE: January 4, 1990

TO: Mr. Ernesto Terrado, Acting Chief, IENHE

FROM: Keith Openshaw, IENHE Keith Openshaw

EXTENSION: 31042

SUBJECT: Forestry Statistics in Africa - Seminar, Blantyre, Malawi 12 - 25 November 1989 - Back-to-Office Report

1. In accordance with my terms of reference dated 25 October 1989, I attended the above seminar from November 12 - 18, 1989 and presented two papers, one on measuring biomass supply and the other on demand surveys, with particular reference to the recent work done in Botswana and Zambia. I also took an active part in the discussions on methods of measuring and recording non-industrial wood products namely, fuelwood, charcoal and poles. Meetings were held with various government representatives and a note was left behind on the work of IEN.

2. FAO organized a seminar on Forestry Statistics and representatives of 13 countries attended namely Ghana, Kenya, Lesotho, Liberia, Malawi, Mozambique, Nigeria, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. The first week of the seminar was concerned with country reports and the problems of measuring non-industrial wood products.

3. I presented two papers on the recent work done in Botswana and Zambia. The first one concerned the measuring of biomass supply entitled Biomass Assessment with particular reference to recent work done in Zambia and Botswana by the World Bank Urban Household Energy projects and the second one was entitled Consumption Surveys: Cast Studies, Zambia and Botswana. Copies of the papers are available on request.

4. There was much interest shown in the work that the IEN department was doing and a brief description of our department was left behind and published in the draft report. This is given in the annex together with the report of the working party on National Information on Woodfuel. It was recommended that FAO prepare a practical guide for designing and carrying out woodfuel surveys, but this Unit has much experience and should at least assist FAO in this task if not be the lead agency.

5. Discussions were held with representatives from various countries who expressed interest in helping them undertake various projects as follows:

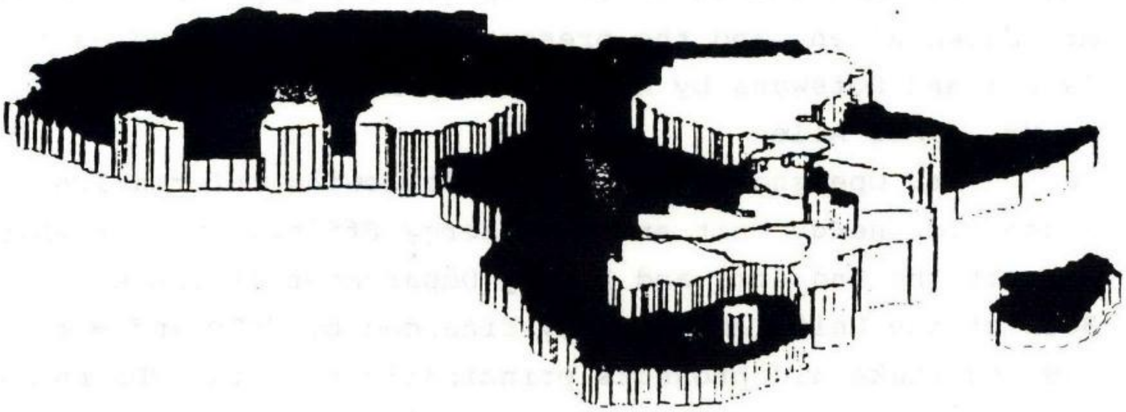
Malawi - Urban Household Energy Survey; Improved stove commercialization; Lilongwe fuelwood plantation;
Swaziland - Inventory of biomass survey;
Zimbabwe - Energy survey

Many countries also said they would like an invitation to the SADCC Household Energy Training Seminar that is to be held this autumn in Zimbabwe.

cc: Churchill, Saunders, Kalim, McKechnie, Becherer (IEN)
All IENHE Higher Level Staff

KOpenshaw:yg

FORESTRY STATISTICS IN AFRICA



Blantyre, Malawi
12-25 November, 1989

REPORT

STATISTICS ON FUELWOOD AND CHARCOAL

27. The discussion of statistics on fuelwood and charcoal was introduced by Mr. P. Wardle followed by a presentation on the design and execution of fuelwood consumption surveyed by Mr. James Allen, and the presentation of case studies from Zambia and Botswana by Mr. Keith Openshaw and from Swaziland by Mr. James Allen.

28. Mr. Openshaw provided the following information about the Household Energy Unit and the Energy Efficiency Unit which are part of the Industry and Energy Department of the World Bank. Both of the Units are jointly financed by UNDP and World Bank and undertake aid projects principally through UNDP but sometimes directly through World Bank. Both Units carry out research activities and run training courses in their particular fields. The Household Energy Unit has undertaken projects in the field of energy assessment, biomass supply, charcoal production, end use efficiency, particularly cooking devices, and work on various renewables. The Energy Efficiency Unit has looked at the production and distribution of electrical energy, refinery systems, boiler efficiency, power losses, etc. Both Units are open to requests of held from developing countries and can approach donor agencies for assistance. The address is: Industry and Energy dept. World Bank, 1818 H. Street, N.W., Washington D.C. 20433, Fax: 202 477, 0547.

29. A Working Party was established to review collection of National information on fuelwood. Their findings are attached at Annex 2.

REPORT OF THE WORKING PARTY ON NATIONAL INFORMATION ON WOODFUEL

INTRODUCTION

After reviewing both the presentations and the ensuing discussions on woodfuel surveys, the Working Party endorses the following statements:

1. Fuelwood and charcoal (woodfuel)make up a very large proportion of total wood and energy consumption in African countries, and their production and consumption have very significant social, economic and environmental importance.
2. Just as with other resources of national importance, it is critical that detailed information on woodfuel consumption be obtained on a regular basis. Such information is critical for forestry policy formulation and development planning.
3. The present state of information on woodfuel consumption leaves much to be desired. There is currently little support for collecting the necessary information, and therefore the capability for collecting this information is poorly developed in most countries.
4. Since most of the woodfuel consumed never passes through the formal (record-keeping) sector of the economy, sample surveys are necessary for data collection.
5. Woodfuel surveys should be accorded higher priority in national planning, and adequate funding allocations should be made to Forestry Departments to facilitate the executions of such surveys.

PLANNING

Both the presentations and ensuing discussions highlighted the fact that woodfuel surveys can be both complex and expensive, and therefore good planning is absolutely essential.

To ensure that woodfuel surveys are well-planned, the following strategy is suggested.

1. Begin by carefully considering the objectives and scope of the proposed survey.
2. Conduct a thorough review of existing sources of information pertinent to the survey objectives.
3. In recognition of the legitimate interest that other parties may have in woodfuel, call a pre-survey workshop/ coordination meeting. Examples of parties that might be invited to this meeting include representatives of the Central Statistical Office, the National Energy Authority, and relevant Regional and National Political Authorities.
4. The parties with the greatest interest in the results of the woodfuel survey should be regularly informed of survey progress, perhaps by forming a steering or coordination committee which meets on a regular basis.
5. Conduct appropriate reconnaisance surveys and field studies to sharpen understanding of the composition of fuelwood consumption

In addition to developing specific objectives and determining the scope of the survey, the following should be carefully considered in the planning phase.

1. Sample Design:

(a) Sample design considerations include determination of the sampling frame, sampling method(s), sample stratification, and sample size.

(b) It is essential that the sampling design be developed through consultation with a qualified statistician. Other technical experts that may be consulted include energy experts, economists, and sociologists.

(c) The sample design should strike an appropriate balance between statistical rigour (precision and accuracy) and cost. It should be simple and designed to fit both the objectives and any predetermined methods of analysis.

(d) The sampling design should stratify for essential features of the population that are relevant in planning and policy formulation (e.g. political, and ecological divisions)

(e) A greater intensity in sampling should be considered for major commercial and industrial users.

(f) Rule(s) of thumb about sample size?

2. Funding :

(a) In the planning phase, the total amount of funding required to complete the survey should be determined as accurately as possible, and it should be very clearly decided who will be responsible for providing the necessary funds.

3. Logistics :

(a) Plans should be drawn up regarding the manpower needs of the survey, which may include supervisors, enumerators, data processing specialists, and support staff. Training needs should be considered carefully and training programmes should be developed.

(b) Lists of all necessary equipment and supplies should be drawn up, and plans made for their timely acquisition and distribution. Protection (security) of the equipment and supplies, as well as possible maintenance needs, should be planned for.

(c) Transportation needs and accommodations for field staff should be fully planned.

QUESTIONNAIRE DESIGN AND MEASUREMENT CONSIDERATIONS

The questionnaire and any associated measurements are an extremely critical element of any woodfuel survey.

1. Questionnaire Design :

(a) One thing that should be determined very early is whether more than one questionnaire will be necessary, such as an urban household questionnaire, rural household questionnaire, a restaurant/small industry questionnaire, and a larger industry questionnaire.

(b) Questionnaire designers should strike a balance between the desire to obtain all relevant information and the need to keep the questionnaire simple and relatively short.

Each proposed question should be reviewed to ensure that it is both directly relevant to the survey objectives, and simple, precise, and unambiguous.

(c) In the case of household questionnaires, there should be some questions that will enable stratification by socioeconomic status. These questions should be carefully worded so as to obtain the desired information without appearing threatening to survey respondents.

(d) In most cases, it will be desirable to include questions on the use of other fuels, such as electricity, coal, gas, cattle dung, and crop residues.

(e) Questionnaire designers should consult with sociologists and others with expertise in general questionnaire design, other forms of energy, and the various cultures/ ethnic groups that will be included in the survey.

(f) The questionnaire will be written in the official language and should be supported by glossaries to ensure that translation into local languages is unambiguous.

(g) The questionnaire should be thoroughly pretested in the field.

2. Measurement Considerations:

(a) Measurement techniques have been one of the weakest elements of past woodfuel surveys, and every effort should be made to improve upon past techniques.

(b) Measurement techniques should be chosen to ensure the greatest accuracy possible given resource limitations, and should be applied in a consistent (standardized) manner.

RECRUITMENT, TRAINING, AND SUPERVISION OF ENUMERATORS

Without good enumerators, a survey cannot be fully successful. It is therefore essential that the best enumerators possible be recruited, and that they be given proper training and supervision.

1. Recruitment:

(a) Enumerators should be literate, numerate and intelligent

(b) Enumerators should be responsible, socially/culturally appropriate/ include both male and female and conversant in the local language.

(c) Enumerators should be committed to the survey and available at the right time(s).

(d) Ideally, enumerators should have a good knowledge of forestry/woodfuels, or should be capable and willing to lear n.

(e) Terms of payment for enumerators should be agreed upon at the time they are hired.

2. Training :

(a) Enumerators should be given thorough training in the use of the questionnaire and any associated measurement techniques.

(b) Training should include both lectures and practice in the field.

(c) As best as possible, enumerators should be thoroughly briefed on what field conditions will be like and what they should do when the unexpected happens (e.g. when a respondent gives an unplanned for response to a question).

3. Supervision :

(a) Enumerators should be closely supervised. Ideally, supervisors should meet with their enumerators every day.

(b) Supervisors should carefully review every completed questionnaire.

(c) Supervisors should verify that enumerators actually conducted the interviews they were supposed to, perhaps by revising a selected subject of the units sampled and asking if the enumerator had in fact been there and conducted the interview. Supervisors in turn must be adequately controlled by the project management

RECOMMENDATIONS FOR FOLLOWUP ACTIVITIES

1. Due to the complexity and many practical problems encountered in woodfuel surveys, the working party recommends that F.A.O. take the initiative to publish a very practical guide to designing and carrying out a woodfuel survey, with particular emphasis on sample design and measurement techniques.

2. In view of the major importance of fuelwood and charcoal in their economies, it is strongly recommended that Governments give adequate priority to the survey of fuelwood and charcoal essential to support their energy and forestry planning

3. The F.A.O. should take an active role in the promotion of the capabilities of each participating country to carry out its own woodfuel surveys. This should be done by promoting technical and financial support for establishing appropriate statistical units within Forestry Departments and in the context of surveys.

MALAWI CHARCOAL PROJECT

BACKGROUND, CURRENT ACTIVITIES, OUTLOOK FOR THE FUTURE

1. BACKGROUND

In a contract dated 16 October, 1986, IPC GmbH Frankfurt was commissioned by the Government of Malawi to provide Consultancy Services to the Forestry Department in the field of improved charcoal production and utilization. The Project is funded under World Bank Loan Agreement 2486 MAI "Wood Industries Restructuring Project: Part B". In order to reduce costs in the area of technical assistance the charcoal component of the Second Wood Energy is also executed within the framework of Malawi Charcoal Project.

The Project's overall objective is to contribute to a more efficient use of the country's natural resources with special emphasis given to charcoal, fuelwood and coal. The raw material used for charcoal production is waste material generated by forestry operations and silvicultural treatment in both the Viphya and the Chambe Forest Plantations.

2. THE MARKET FOR PLANTATION CHARCOAL

The Project has executed a market analysis for plantation charcoal. In total the market potential is approximately 95,000 tons per year and can be broken down as follows:

Substitution of imported coal (Portland Cement, Steam boilers)	32,000
Substitution of firewood in tobacco Industries Central Region	12,000
Substitution of diesel oil	1,000
Substitution of household charcoal	45,000
TOTAL	95,000 tons

3. PRODUCTION POTENTIAL

The Viphya Plantations generate approximately 500,000 m^3 per year of forest wastes over the next 10 years. A charcoal production of 40,000 tons per year could be realised from this raw material which would otherwise be wasted.

The Chambe Forest (Mulanje) could produce approximately 3,000 tons of charcoal per year for a period of 5 years. Other plantations such as Dedza and Zomba will also generate substantial quantities of timber and waste material for which no identified market exists and which could be used for charcoal production. In the framework of a national forest management and utilization plan a controlled annual charcoal production of approximately 60,000 tons could be performed which would conserve both indigenous forest and foreign exchange.

4. THE PILOT PRODUCTION OF MALAWI CHARCOAL PROJECT

Malawi Charcoal Project has established Pilot Production Schemes on the Viphya (currently 3600 tons/year capacity) and on the Chambe (600 tons per year capacity). The production is performed on a semi-industrial scale and employs fire brick kiln technology. The kilns are three times as efficient as traditional charcoal production methods. They require only a minor investment and can be constructed from local material. One unit producing 100 tons of charcoal per year costs 300 MK. 30 kilns builders and operators have already been trained and the technology could be transferred to the local staff of the Forest Plantations within a short period of time. Currently Malawi Charcoal Project employs 200 workers in the pilot schemes. So far 12,000 bags of charcoal have been produced. The charcoal is used to perform combustion trials in various industries (tobacco curing, cement, textile, brewery, match company). Moreover marketing trials have been started in the household sector.

5. PRICING OF PLANTATION CHARCOAL

The Project staff have developed a pricing scheme for charcoal produced from forest wastes. The recommended price of charcoal consists of the pure production costs including overheads and profits (MK 41.50 per ton) and a stumpage fee which was calculated on the basis of replacement costs (MK 9.15 per ton of charcoal). A detailed pricing study on this issue is available. To the ex-factory costs of charcoal (MK 51 per ton) transport costs must be added. Currently private road transporters haul the charcoal from Chikangawa to Lilongwe at MK 63 per ton; to Zomba and Blantyre at MK 100 per ton was to be paid. The landed costs are competitive with imported coal. In the household sector the project has still to compete with charcoal from indigenous forest which is produced illegally, i.e. with charcoal for which no stumpage fee was paid.

6. MANAGEMENT AND ADMINISTRATION OF THE PROJECT

The Project is executed under the leadership of the Forestry Department. The Deputy Chief Forestry Officer Mr. W.M. Ndovi was appointed as the Project Manager. The Project team consists of six professionals, two on a long term basis and four short term consultants:

Mr. G.H. Zieroth	IPC Co-ordinator
Mr. G.S. Motti	Energy Systems Engineer (Energy Studies Unit)
Mr. B. Chronowski	IPC Combustion Engineer
Dr. W. Emrich	IPC Charcoal Production Viphya
Mr. W. Friedel	IPC Charcoal Production Chambe
Dr. W. Teplitz	IPC Project Economist

Up till now the pilot production and marketing of the charcoal is administered under the Forestry Department. According to the terms of reference a gradual commercialization should take place during the lifetime of the Project. Currently the Project tries to attract private sector intiatives.

7. PERSPECTIVES OF THE PROJECT

The development of Malawi Charcoal Project to a full scale commercial charcoal production would have a substantial impact in the forestry sector. 60,000 tons of charcoal produced from waste plantation wood would conserve 2 million m^3 of wood from indigenous forests if the charcoal was sold in the household market. A revenue of 600,000 MK could be generated for Malawi Government and the operation would ease the financial burden of Viphya and other plantations. Other because charcoal production would pay for all silvicultural treatments. Significant savings per year could be achieved.

Charcoal production would create approximately 3,000 jobs for local workers and help to develop the economy of the Northern Region by producing additional income in the range of 1 million MK per year. Moreover charcoal production could be a flexible method to use forest wates until other solutions have been found. Due to the very low investments costs for the charcoal production centers, they could be established only for a short period of time without increasing production costs substantially. A gradual up-scaling is possible and therefore the charcoal production can respond quickly to the requirements of the market. Last not least charcoal from plantations can be regarded as stretegic fuel which helps Malawi Industries to keep producing in case of supply interuptions of imported coal.

MALAWI CHARCOAL PROJECT

BACKGROUND, CURRENT ACTIVITIES, OUTLOOK FOR THE FUTURE

1. BACKGROUND

In a contract dated 16 October, 1986, IPC GmbH Frankfurt was commissioned by the Government of Malawi to provide Consultancy Services to the Forestry Department in the field of improved charcoal production and utilization. The Project is funded under World Bank Loan Agreement 2486 MAI "Wood Industries Restructuring Project: Part B". In order to reduce costs in the area of technical assistance the charcoal component of the Second Wood Energy is also executed within the framework of Malawi Charcoal Project.

The Project's overall objective is to contribute to a more efficient use of the country's natural resources with special emphasis given to charcoal, fuelwood and coal. The raw material used for charcoal production is waste material generated by forestry operations and silvicultural treatment in both the Viphya and the Chambe Forest Plantations.

2. THE MARKET FOR PLANTATION CHARCOAL

The Project has executed a market analysis for plantation charcoal. In total the market potential is approximately 95,000 tons per year and can be broken down as follows:

Substitution of imported coal (Portland Cement, Steam boilers)	32,000
Substitution of firewood in tobacco Industries Central Region	12,000
Substitution of diesel oil	1,000
Substitution of household charcoal	45,000
TOTAL	95,000 tons

3. PRODUCTION POTENTIAL

The Viphya Plantations generate approximately 500,000 m^3 per year of forest wastes over the next 10 years. A charcoal production of 40,000 tons per year could be realised from this raw material which would otherwise be wasted.

The Chambe Forest (Mulanje) could produce approximately 3,000 tons of charcoal per year for a period of 5 years. Other plantations such as Dedza and Zomba will also generate substantial quantities of timber and waste material for which no identified market exists and which could be used for charcoal production. In the framework of a national forest management and utilization plan a controlled annual charcoal production of approximately 60,000 tons could be performed which would conserve both indigenous forest and foreign exchange.

4. THE PILOT PRODUCTION OF MALAWI CHARCOAL PROJECT

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CHARCOAL PROJECT

1. BACKGROUND AND HISTORY

Guyana Manufacturing and Industrial Development Agency (GUYMIDA) has expressed an interest, following a visit of Mr. C. Wlazlo from SCIENCE sprl, in February 1987, in Georgetown, in the carrying out of feasibility study in the field of renewable energy. The main goal of the study is to formulate a comprehensive document on the alternate energy possibilities in Guyana relating primarily to charcoal production, gasifiers and micro-hydro applications and to examine the possibilities of local manufacturing of the equipment on basis of joint venture agreement with European companies.

The European companies KAMENEV (gasifiers), CIRA (micro-hydro) and LAMBIOTTE (charcoal production) have confirmed their interest in a joint venture for this purpose and it was agreed that SCIENCE sprl will perform the feasibility study.

The terms of reference of the project were discussed with all interested parties during the visit in Brusseis of Mr. C.D.M. Duncan, Executive Director of Guyana Manufacturing & Industrial Development Agency (GUYMIDA).

The objectives of the study are:

- Gasifiers and micro-hydro equipment: Substantiate and quantify the local needs and examine the technical, commercial and economical viability for setting up a manufacturing plant in Guyana. Identification of potential demonstration projects.
- Charcoal: Examine the technical and economic viability of setting-up an industrial charcoal production plant (local manufacturing of the retort). Examination of the potential markets for produced charcoal in Europe and North America.

The present document deals with the charcoal project. The other projects are discussed in a separate document.

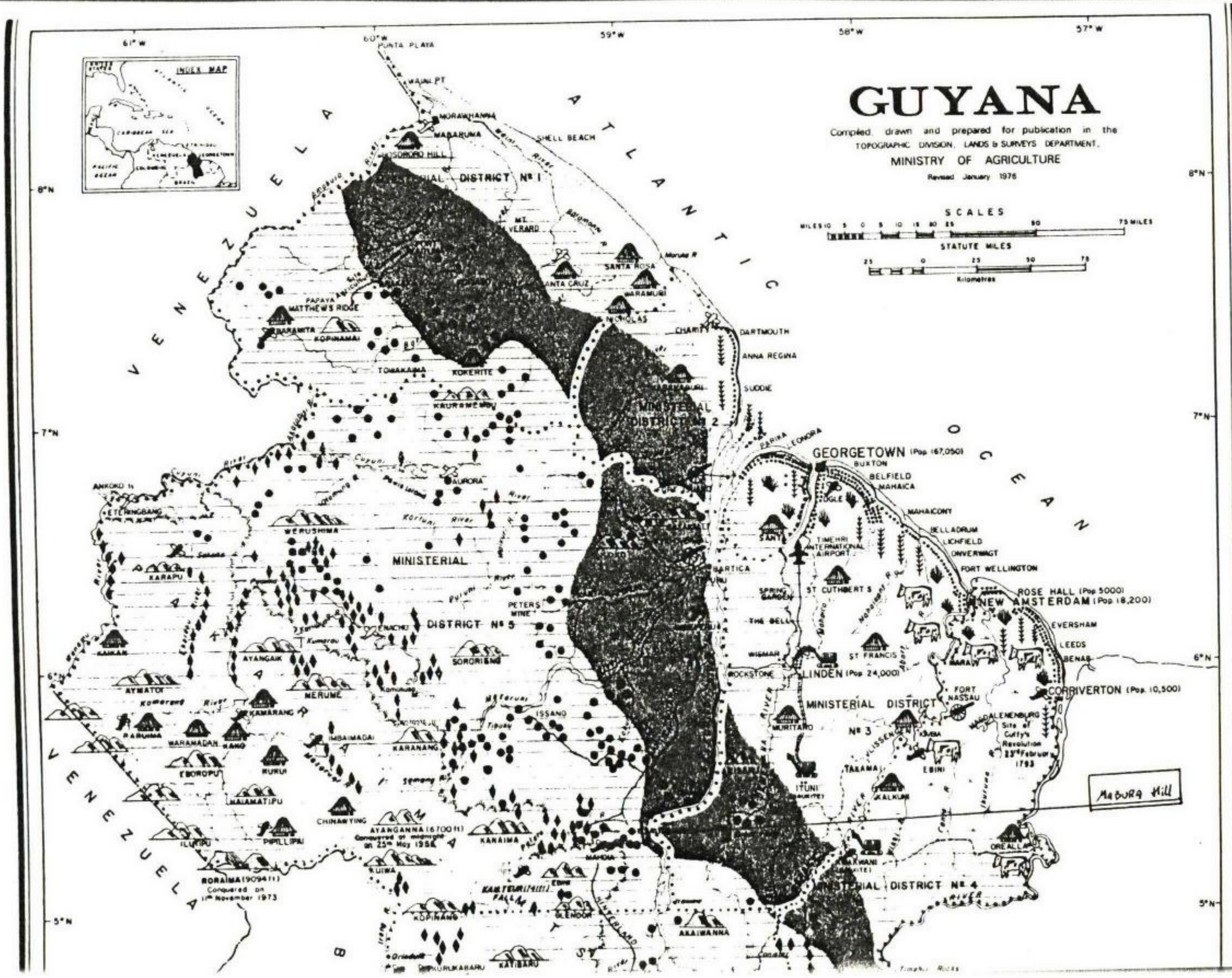
Following LAMBIOTTE and SCIENCE experts' visit to Guyana between January 25 and March 8, 1988, DEMERARA WOODS LTD. has been identified as a potential partner for the setting-up of a charcoal production unit (6000 tons per year) and the feasibility study takes as a potential site de MABURA HILL (see attached map).

2. PROJECT PRESENTATION

2.1. Location and characterists of Mabura Hill

Mabura Hill is located at 150 miles from Georgetown. A highway (64 miles) links Georgetown to Linden and a track (86 miles) links Linden to Mabura.

In Mabura is sited one of the most important sawmill of the country: Demerara Woods Limited, which uses more than 120 personnel staff.


GUYANA
Compiled, drawn and prepared for publication in the TOPOGRAPHIC DIVISION, LANDS & SURVEYS DEPARTMENT,
MINISTRY OF AGRICULTURE
Revised January 1976
SCALES
STATUTE MILES
Kilometres
INDEX MAP
61° W
60° W
59° W
58° W
57° W
8° N
7° N
6° N
5° N
ATLANTIC OCEAN
VENEZUELA
PUNTA PLAYA
WAINI PT
MORAWHANNA
MABARUMA
SHELL BEACH
HOSORORO HILL
DISTRICT Nº 1
MT. EVERARD
SANTA ROSA
SANTA CRUZ
MATTHEWS RIDGE
BARAMITA
KOPINAMAI
TOMAKAIMA
KOKERITE
KAURAMEMBU
CHARITY
DARTMOUTH
ANNA REGINA
SUDDIE
MINISTERIAL DISTRICT Nº 2
GEORGETOWN (Pop. 167,050)
LEONORA
PARIKA
BUXTON
BELFIELD
MAHAICA
MAHAICONY
BELLADRUM
LICHFIELD
ONVERWAGT
FORT WELLINGTON
ROSE HALL (Pop. 5000)
NEW AMSTERDAM (Pop. 18,200)
EVERSHAM
LEEDS
CORRIVERTON (Pop. 10,500)
TIMEHRI INTERNATIONAL AIRPORT
BARTICA
ST CUTHBERT'S
THE BELL
WISMAR
ROCKSTONE
LINDEN (Pop. 24,000)
ST FRANCIS
FORT NASSAU
MAGDALENENBURG
Site of Cuffy's Revolution 23rd February 1763
MINISTERIAL DISTRICT Nº 3
ITUNI
TAKAMA
EBINI
KALKUNI
OREALLA
KWAKWANI
MINISTERIAL DISTRICT Nº 4
MaBURA Hill
ANKOKO I.
ETERINGBANG
AURORA
WERUSHIMA
MINISTERIAL DISTRICT Nº 5
PETERS MINE
KARAPU
AYANGAIK
SORORIENG
KAIKAN
AYMATOI
MERUME
KAMARANG
WARAMADAN
KAMO
PARUIMA
IMBAIMADAI
KARANANG
ISSANO
KUKUI
EBOROPU
MAIAMATIPU
CHINAWYING
AYANGANNA (6700 ft) Conquered on 25th May 1956
KANAIMA
ILUPIRU
PIPILLIPAI
RORAIMA (9094 ft) Conquered on 11th November 1973
KUIWA
MAHDIA
KAIETEUR (741 ft) FALLS
KOPINANG
GLENDOR
AKAIWANNA
KURUKABARU
KATIBARU

The Demerara Woods concession covers 300 000 ha, with a maximum width of 75 miles.

The inventory of the wood stock has been performed, the results of which are given in Appendix 1.

The availability of Wallaba has not been done because it is hardly used in the sawmill. However, a new photo-interpretation, is under study.

The sawmill is presently mainly using the green hard.

2.2. Objectives and Interests of the Project

The main object of the project is to upgrade and use the sawmill waste in transforming them in high-quality charcoal which could be exported.

The project has four main advantages:

1) Upgrade the non-used waste.

2) Creation of employment.

3) Create an income of foreign currency which can compensate up to 2,3 % of the total country balance of payment.

4) 15% of the production (the charcoal with grain size between 1 and 20 mm) could be sold on the local market. At a later stage, the charcoal waste could be used to produce activated charcoal.

These various points are detailed hereunder.

The raw material which will be used in the plant has been assumed to come from two main origins: 18 000 tons from the sawmill waste itself and 18 000 tons from the wood left in the forest.

Presently the wood waste available in the sawmill could already cover three years of production of the LAMBIOTTE plant; the waste left in the forest after cutting the trees' tops and branches and base of the trunck would represent the same amount as the total wood which is processed in the sawmill.

The present capacity of the sawmill is estimated to be 18 000 tons/year. In the future, it is anticipated the production would reach 45 000 tons.

Besides the financial advantage of upgrading the wood waste from the sawmill, it should also be borne in mind that it is highly desirable for the sawmill to suppress the potential danger by fire hazard linked to the presence of large quantities of wood waste around the plant and presently special sites for storing these wood waste are required.

Moreoever, the operation of the charcoal units is creating jobs (at the factory itself and also in the forest). At the factory 42 persons would be employed and in the forest around 40.

Project would also be profitable to all the local industry because LAMBIOTTE has agreed to manufacture as much as possible of the equipment locally on the basis of secrecy agreements, of course. It is presently foreseen to manufacture locally the retort, the silos, the transport belts, etc... for a total value of 5.000.000 G$ (engineering not included).

Finally, the export of charcoal would represent a non-negligible source of foreign currency, while the non-exported part of the production (the fines) could also contribute to the supply of charcoal on the local market.

The Société LAMBIOTTE has moreover shown its interest to buy-back the whole production of the retort at least during the reimbursement period. This buy-back agreement would of course be reached on the basis of the market price of the charcoal. This buy-back agreement is also linked to the fact that the charcoal produced should reach the quality required by the European Standards (see European Standards, Appendix 2.).
Therefore, in the preliminary discussion, it has been agreed that a LAMBIOTTE engineer would be detached to the project and ensure the technical management of the factory during the buy-back period.

Finally, the société LAMBIOTTE has accepted the idea to participate with SBI (Société Belge d'Investissement) and with the Region Wallonne to a joint venture and takes 20% of the equity shares.

A proposal for the joint venture and agreement with LAMBIOTTE and the various partners is attached. (Appendix 6.).

N.B.:

In the study, the charcoal production unit has been considered totally independent of the Demerara sawmill for any of the operating aspects (staff, workers, water supply, electricity, wood etc.). In this respect, a computer run (case III) has been performed taking as an hypothesis that the plant is purchasing its wood totally from the forest; this assumes that there is no dependence on the sawmill plant operation.

This does not exclude the possibility of establishing close collaboration between the sawmill and the charcoal production unit, as for example for the electricity supply, for the wood waste supply etc.

3. FINANCIAL ANALYSIS

The exchange rate used in this study are:

10	G$	for 1	US$
36	BF	for 1	US$
5,83	G$	for 1	DM

For each computer run of the financial analysis model, it has been considered that the factory operates a 50% capacity the first year and would reach 100% capacity at the beginning of the second year.

The main results of the computer runs are given after description of each case; the complete results are detailed and presented in Appendix 3, 4 and 5.

CASE I

The Case I considers an annual inflation rate of 18% and a European participation of 20% to the equity shares.

18 000 tons of wood are coming from the forest and 18 000 tons are taken from the sawmill waste.

3.1 INVESTMENTS

3.1.1. Land : land lease: 0,05 G$/acre/year p.m.

3.1.2. Infrastructure

3.1.2.1. Developing the land

The necessary area for setting-up the charcoal production unit is 3 ha, including a zone for tractor and lorry movement, a zone for wood conditioning, a zone for the carbonization unit and a zone for storage and packaging of the final products.

The area required for storage and drying of wood (6 months) is also 3 ha.

Developing the land: 23 400 G$/ha x 6 ha = 140 400 G$

3.1.2.2. Water supply

The cooling of the retort required 0.5 m3 per hour (= 12 m3/d), and a water tank of 60 m3 is installed at a higher level than the top of oven for fire fighting purposes.

It is assumed that a 300 m deep bore hole will be drilled at a maximum distance of 1 000 meters from the water tank, this water tank would be at 40 meter high.

water supply: piping : 100 G$/m installed x 1 400 m =
140 000 G$

Bore hole drilling : 1 000 G$/m x 300 m =
300 000 G$

3.1.2.3. Electricity supply

Electricity would be supplied by a diesel generator set. One assumes 200 m of electrical line to be installed.

Electricity supply: line: 3 000 G$/m x 200 m =
600 000 G$

3.1.3. Factory buildings

3.1.3.1. Sheds

Two open sheds of very simple design will be built at Mabura Hill.

Shed for wood preparation : 310 G$/m2 x 600 m2 = 186.000 G$

Shed for charcoal packing and storage : 600 m2 x 310 G$/m2
= 186.000 G$

Similarly an open shed will be built in Linden (if no other shed is available) to store the packed charcoal before shipping. The charcoal will be bagged in big bags of 500 kg (2m3) as will be seen later.
It is assumed that one has to store around four months production or 2.200 big bags representing a total area of 2.200 m2 if the bags are stocked at two levels.

Shed in Linden: 2.200 m2 x 310 G$/m2 = 682.000 G$

3.1.3.2. Water tank

As indicated in 3.1.2.2., a water tank is also set up at a higher level than the retort top (in order to be able to fight the fire and for feeding the retort cooling circuit). This reservoir will be 60 m3 in capacity.

Water storage tank: 110 G$/m3 x 60 m3 = 7.000 G$

3.1.4. Office building

The office required will cover a maximum area of 50 m2, would be built in wood and concrete and supplied with electricity.

Office building: 2.420 G$/m2 x 50 m2 = 121.000 G$

3.1.5. Staff houses

Around 20 staff houses which could house two families each or three bachelors would be built. They are planned for lodging the management and the staff, as well as the workmen and drivers of the factory.

Staff houses: 150.000 G$/house for 2 families x 20
= 3.000.000 G$

3.1.6 Machinery (FOB) and engineering

The equipment for water supply, wood treatment, electrical equipment for the retort, hyraulic engine, ventilators,etc.) are described hereunder. Most of the equipment has to be imported.

- submersible pump: 120.000 G$
  (1 US$ = 36 FB, 432.000 FB)
- 3 guillotines : 2.167.000 G$
- 3 splitters : 833.000 G$
- electrical material: 4.590.000 G$

Other equipment which could be built locally includes the retort, the auxiliary (like belt conveyors, sieves, silos). These equipment will be locally built by Industrial Engineering Limited.

The price of the raw material has been taken into consideration.

- mild steel: 88 tons, 611.000 G$
- stainless steel: 16 tons, 556.000 G$
- refractory lining: 22 tons, 278.000 G$
- steel for aux. (44 t.) and silos 400 m3 (36 t.): 556.000 G$

IEL has indicated an average cost for this type of equipment of 18,055 G$/kg. It is therefore possible to estimate the local construction cost and after adding the detailed engineering studies which will be performed by Lambiotte.

Local construction: 184 tons x 18.055 G$/ton = 3.322.120 G$
(this does not include the refractory lining)

The engineering costs will include the salary of three Lambiotte engineers, present during ten weeks for the supervison of the erection and the commissionning of the retort (5.000 G$/ing./day).

Engineering: (a) 972.000 G$ for the drawing preparation and the erection supervision

(b) 972.000 G$ for assisting the erection and the setting up of the retort and the training.

3.1.7. <u>Freight and installation</u>

3.1.7.1. Freight

Based on his experience, Mr. DUNCAN, director of GUYMIDA, indicated that the cost for transport would cost around 15% of the total value of the equipment. Taking this high cost of transport compared to information obtained from transport companies, one is sure to be on the safe side for computation.

The total freight cost for steel, refractory lining, 2 gensets, pump, guillotins, splitters, electric material, vehicles is:

15% of FOB value (17.932.400 G$) = 2.690.000 G$

3.1.7.2. Installation

The installation includes the subsistence costs of the Lambiotte engineers, the salaries of the specialized workmen needed for the erection and the non-specialized workmen required for later operation of the plant and their presence is required during this early period so they have a good knowledge of the plant in detail.

Installation:

- 3 Lambiotte engineers (wages included in engineering)
- 3 flight tickets : 3 x 15.300 G$ = 45.900 G$
- Accommodations: 700 G$/day x 210 days (week-end included) = 147.000 G$
- 9 skilled workers x 8 weeks x 125 G$/day = 45.000 G$
- 5 unskilled workers x 8 weeks x 54 G$/day = 10.900 G$

In these costs one should also include the training of one foreman in the Marbehan plant (Belgium).

- Training in Marbehan for one skilled worker:

2 weeks:	accommodation:	840 G$/day x 14 days
	ticket	: 13.900 G$
	wage	: 100 G$ x 10 days
	total	: 26.700 G$

TOTAL installation: 275.000 G$

3.1.8. Other equipment

Under this heading we find mainly the electricity generator and telecommunication equipment. This other equipment is equipment which have a five-year amortization period as opposed to 15 years for the main plant equipment. In the computer print, this heading is also indicated under "Tools and Small Equipment".

- Radio communication equipment: 250.000 G$ CIF

Two gensets are foreseen (the main one and a stand-by); they will be installed in order to ensure a full autonomy of the production unit although electricity could be purchased from the sawmill. The generator sets are delivered in prefabricated containers and no infrastructure is required. The stand-by genset will operate only as a stand-by for the main genset or during the maintenance.

- Main genset "1" (283 kW) : 398.000 G$ FOB
  (1.432.500 FB with body, 24m3, 5,9 tons)

  fuel consumption: 0.242 l/kWh
  oil consumption : 1% of fuel consumption

- Stand-by genset "2" (177 kW) : 383.000 G$ FOB
  (1.379.000 FB with body, 22m3, 5,3 tons)

  fuel consumption: 0.260 l/kWh
  oil consumption : 1% of fuel consumption

All maintenance and operating costs are considered later.

3.1.9. Factory and office equipment

A lump sum of 60.000 G$ has been taken for the purchase of office furniture, chairs, ventilators, typewriters, etc...

3..1.10. Vehicles (FOB)

The costs related to the vehicle operation (fuel, oil, drivers, maintenance, insurance, taxes) are considered later on. The vehicles are used for four main purposes:

(a) Transport of charcoal to Linden:

1 truck 30 t (1.259.000 G$) with 2 axles platform semi-trailer (714.580 G$)

fuel consumption: 35 litres/100 km

This truck will travel once a day to Linden during 250 days. Mabura-Linden and return equals 69.250 km/year with a maximum charge of 24 tons or 48 big bags.

(b) Transport and moving wood between the sawmill and the wood storage parc and to the charcoal production unit:

2 tractors : 1.983.600 G$ (for the unit)

6 trailers rear tipping (6.4 tons) : 520.500 G$

1 clark bobcat 843 with excavator and fork : 416.660 G$

The tractors are of the agricultural type and are fitted with trailers loaded with wood between the sawmill and the wood storage parc and between the wood storage parc and the factory. Five trailers are necessary for covering the various operations of loading, unloading and transfer. A reserve trailer is foreseen.

The tractor dedicated to transport between the sawmill and the wood parc (18.000 tons/year) will perform 8 travels a day during a 4-hour period.

The tractor dedicated to transport between the wood parc and the factory (36.000 tons/year) will perform 16 travels a day during an 8-hour period.

The fuel consumption of the tractors loaded is assumed to be 10 liters of fuel/hour.

The clark ensuring the handling of the wood and of the charcoal in the factory area (loading the feeding skip of the retort, moving the big bags). It should be operating 8 hours a day with a consumption of 5 liters per hour.

(c) Transport of the wood from the forest to the wood storage parc:

2 tractors: 1.983.600 G$ (for the forest)

4 trailers with self-loading device: 2.111.200 G$

The tractors of the agriculture-type will be used for bringing the wood from the forest to the wood storage park (18.000 tons per year).

It is assumed that the transport will be performed on 30 km average distance return. The tractors will perform 3 transports per day during 250 days per year, the estimated time for return trip is 2h30. While the tractors will be on their way with the trailers, other trailers will be loaded in the forest.

The consumption is 10 liters/hour.

(d) Management cars

Two cars for the management have been foreseen. We have only taken into account the investment costs and we assume that the cost for the fuel will be paid by the users:

2 cars: 260.860 G$

3.1.11 Contingency rate : 10%

3.1.12. Preliminary expenditure

(a) EQUITY

The equity is assumed to be 30% of the total funds needed. It is estimated to be 16.600.000 G$

(b) LOAN

The rest of the required money is obtained through two types of loans:

1) The foreign exchange for the purchase of the gensets, pumps, imported machinery, raw material for local construction, payment of the engineering, air tickets, transport of material.

   This loan is estimated to be at 25.400.000 G$

2) The local currency for the rest of the investment is estimated to be 13.500.000 G$.

The preliminary expenses are the following:

registration : 0.5% of (a)

charges on loan : 1.5% of (b)

start of account: 2.500 G$

TOTAL : 669.000 G$

3.2 SALES 18% inflation per year

A rate of 18% inflation per year has been taken into account during the computer runs Case I and Case III. This inflation rate is applied to the production value expressed in G$, starting production value is given hereunder.

3.2.1. Charcoal

80% of the output of 7.500 tons consists of charcoal graded quality European norm A and could be exported.

Its price in Antwerp is 500 US$ per ton CIF. See buy-back agreement with Lambiotte.

Charcoal: 6.000 tons x 500 G$/t (CIF Antwerp) = 30.000.000 G$

3.2.2. Fines

15% of the output consists of fines; they are to be sold on the local market:

Fines: 1.125 tons x 2.100 G$/t (ex-factory) = 2.362.500 G$

3.3 VARIABLE EXPENDITURE

The similar inflation rate of 18% has been taken into consideration for the simulation program in Case I and Case III. It is applicable to the variable expenditures and the fixed expenditures on the basis of the starting value given hereunder.

3.3.1. Raw material

As explained under Chapter 2, 18.000 tons of wood are collected in the forest, 18.000 tons are collected in the sawmill waste.

A value has been estimated for these two types of wood. This value is based on the work needed to collect, cut and handle these raw material:

Wood from the forest: 18.000 tons x 74 G$/t = 1.332.000 G$

Waste from sawmill : 18.000 tons x 52 G$/t = 936.000 G$

The hypotheses taken into account for evaluating these costs are given hereunder:

The cost of a man's day non-specialized is 54 G$

(a) Wood from the forest:

tree felling (280 cuft/manxday)	: 0.2 G$/cuft
Stump the wood (140 cuft/mxd)	: 0.4 G$/cuft
Bring the wood, to the road, loading truck (140 cuft/mxd)	: 0.4 G$/cuft
Unloading in the storage park (280 cuft/mxd)	: 0.2 G$/cuft

Loading from the park to the factory (240 cuft/mxd) : 0.2 G$/cuft

Stumpage fees : 0.6 G$/cuft

Contingency (5%) : 0.1 G$/cuft

TOTAL........................ 2.1 G$/cuft or 74 G$/m3

(b) Wood from the sawmill:

Bring the wood to the road, loading truck : 0.4 G$/cuft

Loading at the sawmill : 0.2 G$/cuft

Unloading at the wood storage : 0.2 G$/cuft

Loading from park to factory : 0.2 G$/cuft

Stumpage fees : 0.2 G$/cuft

Contingency (5%) : 0.07 G$/cuft

TOTAL........................ 1.47 G$/cuft or 52 G$/m3

As this wood is considered as a waste, a low value for the stumpage fee has been taken into account (case b).

3.3..2. <u>Spare parts</u>

3.3.2.1. For charcoal unit

Every two years, a set of spare parts valued at 250.000 G$ for the retort and 250.000 G$ for the rest of the plant is needed.

3.3.2.2. For the vehicles

The spare parts and the maintenance of the vehicles and trailers is estimated to be 100 G$/hour for the tractors and 10 G$/km for lorries.

The number of operating hours and mileage per year has been described in point 3.1.10.

For the 2 tractors and 5 trailers (100 G$/h) = 396.000 G$ (near the charcoal unit)

For 1 truck and 1 trailer (10 G$/km) = 692.500 G$

For 1 bobcat (100 G$/h) = 264.000 G$

For 2 tractors and 4 trailers (100 G$/h) = 450.000 G$ (in the forest).

3.3.2.3. For the power plant

The main generator set is running 24 hours a day (and 330 days a year), e.g. 7 920 hours, around 8 000 hours/year.

The first year, there is no need for spare parts, nor for the sixth year, because a new genset is purchased after five years. This explains the ratio 8/10 used for determining the annual cost of the spare parts.

Main genset: on basis 381.625 G$/10 000 hours:
8 000/10 000 x 381.625 x 8/10 =
244 000 G$/year

The stand-by genset is only running a few hours per year and one set of spare parts could last 10 years.

Stand-by: on basis 265.000 G$/10 000 hours
one set of spare parts for 10 years = 26.500 G$/year

3.3.3. Fuel oil

The price of fuel oil indicated was 3.06 G$/lit. at Mabura Hill and 2.48 G$/lit. at Linden.

The running cost for the vehicles are calculated on the basis of information given under point 3.1.10.

Fuel from Linden (for the truck carrying charcoal): 60.000 G$

Fuel from Mabura for
- 2 tractors: 122.000 G$ (unit)
- 2 tractors: 137.700 G$ (forest)
- 1 bobcat : 40.400 G$
- power plant:
  a) main genset (150 kW x 24h x 330 days x 0.242 lit/kWh x 3.06 G$/lit) = 860.000 G$
  b) stand-by genset (100 kW x 200h x 0.260 lit/kWh x 3.06 G$/lit) = 16.000 G$

Oil: 10% of fuel consumption value = 125.610 G$

3.3.4. Electricity

The electricity is generated by the genset belonging to the factory and all the operating costs have been taken into account under the appropriate headings.

The mean consumption of electricity is 150 kW x 24 hours x 330 days per year, or a total of 1.188.000 kWh.

The stand-by genset is normally running 200 hours a year or a few hours in case of stoppage of the main genset, this means during the outtage period of the main genset for maintenance or repair.

3.3.5. Packaging

The most economical solution for the transport of the charcoal has been found to be the use of big bags of 500 kg each (or 2m3). There is a need for 12 000 of these big bags per year. The big bags can be used at least twice (but of course this will depend on the transport conditions and handling).

12 000 big bags at 78 G$ each = 936.000 G$ for 2 years

The cost of transport of the bags is:

freight (2 kg/bag, 2m3 for 200 bags):
90 US$/m3 i.e. 0.9 US$/bag x 2 (cfr supra)
= 216.000 G$ every two years

Finally, this item represents an annual expense of

(936.000 + 216.000)/ 2 = 576.000 G$

3.3.6. Freight and distribution

3.3.6.1. Transport of wood

All costs relating to the transport of wood have been taken into consideration when looking at the operating costs of the tractors.

3.3.6..2. Transport of charcoal to Linden

The charcoal is transported to Linden by lorry and in Linden there are facilities for shiploading sea going vessels.

The costs of this transport is included in the operating costs.

3.3.6.3. Transport of charcoal to Europe

The transport cost of charcoal to Europe is 100 US$/ton and, following quotation from a shipping company, it is not out of question that this price could still be decreased if it is confirmed that a large quantity of annual freight could be guaranteed.

- Transport from Linden to Antwerp
  1000 G$/ton x 6000 tons = 6.000.000 G$

3.3.7. Labour

On the basis of an operation 24 hour a day, 330 days per year (taking into account that the wood preparation and conditioning are only performed during the working days) the factory would require 17 workers during the day and one worker at the retort 24 hours a day (this represents five workers for the retort). The total labour requirement is:

22 unskilled workers x 330 days x 54 G$/day = 392.040 G$

The different vehicles would require a team of 10 lorry drivers.

10 drivers x 330 days x 75 G$/day = 247.500 G$

The wood collection at the sawmill and in the wood requires also a labour force but it is assumed that this is done on a contract basis and this working force is included in the price of the wood itself.

3.4. FIXED EXPENDITURE

An annual inflation rate of 18% has been taken into consideration for the computer runs Case I and III. It is applied to the fixed expenditure as well, the cost of which for the first year are indicated hereunder.

However, the computer program is not foreseen to have increasing expenditure fixed yearly. Therefore, the fixed expenditure have been inserted under the heading "Various Expenses in VARIABLE EXPENDITURE". For each of these expenditures, we indicate the heading of the variable expenditures under which it has been inserted. This is not at all affecting the final results.

3.4.1. Maintenance

3.4.1.1. Charcoal unit

The maintenance of the factory is depending on the output and it is calculated as indicated hereunder:

1/4 man-day / ton of charcoal
i.e. 0.25 x 54 G$ x 6.000 tons = 81.000 G$

3.4.1.2. Power Plant

The maintenance of the electricity power plant is given hereunder. It is performed by an electrician and a technician:

2 hours each 400 hours: 125 G$/day x 5 days = 625 G$
4 hours each month : 125 G$/day x 6 days = 750 G$

Moreoever, the plant is operated 24 hours a day by a technician and during the working days an electrician.

5 technicians and 1 electrician: 6 x 125 G$/day x 330 days = 247.500 G$

3.4.1.3. Vehicles

The costs of maintenance of vehicles have been included in the spare spart.

"Maintenance" has been classified under "Other" variable expenditure

3.4.2. Insurance

Vehicles : 1% of total value = 65.000 G$

Building : 17 G$/1.000 G$ of investment:
17 x 1.182 = 20.000 G$
(staff and workers houses not included)

3.4.3. Taxes

1000 G$/truck or tractor = 6.000 G$
300 G$/car = 600 G$

"Insurance and Taxes" have been classified in "Intermediary material" variable expenditure.

3.4.4. Personnel

```
One manager        = 180.000 G$/y
One accountant     =  72.000 G$/y
One foreman        =  48.000 G$/y
One electrician    = 125 G$/day x 330 days = 41.250 G$
One Lambiotte plant production manager:
                   = wage: 925 G$/day x 330 days = 305.250 G$
                     local expenses: 1.370 G$/day x 365
                     = 500.000 G$
```

"Personnel" has been classified in "Labour" variable expenditure.

3.5. REPAYMENT OF LOANS

3.5.1. Loan in foreign currency

This loan amounts to 25.400.000 G$ (see 3.1.12.)

Interest rate: 14%
10 years max. repayment
2 years grace
First year of reimbursement: year 3

3.5.2. Loan in local currency

This loan amounts to 13.500.000 G$ (see 3.1.12.)

Interest rate: 14%
10 years max. repayment
2 years grace
First year of reimbursement: year 3

3.5.3. Overdraft interest : 18%

3.6. DEPRECIATION

Infrastructure	: 20 years
Factory building	: 20 years
Office building	: 20 years
Staff house	: 20 years
Plant and machinery	: 15 years
Vehicles	: 5 years
Other equipment	: 5 years
Prelim. expenditure	: 5 years

3.7. CURRENT ASSETS

Cash	: 3 months
Raw material	: 6 months
Other/spare part	: 2 months
Work in progress	: 1 month
Packaging	: 4 months
Finished products	: 4 months
Receivables	: 2 months

3.8. LIABILITIES

Raw material	: 3 months
Other/spare parts	: 2 months
Packaging	: 1 month

3.9. FISCAL INCENTIVES

3.9.1. Corporate Taxes

There is a tax holiday obtainable for a period up to 10 years on income and dividends (refer to the general climate investment in Guyana).

It is also foreseen to obtain duty free importation on equipment.

3.9.2. Personal Income Taxes

The taxes on staff income has been calculated on the basis of the following information (extracted from "Investor's Guide to Guyana"):

under 1.000	exempt
from 501 to 1.500	25 + 5% on excess over 500
from 1.501 to 3.000	75 + 10% on excess over 1.500
from 3.001 to 4.800	225 + 15% on excess over 3.000
from 4.801 to 6.800	495 + 25% on excess over 4.800
from 6.801 to 8.800	995 + 35% on excess over 6.800
from 8.801 to 11.800	1.695 + 40% on excess over 8.800
from 11.801 to 15.800	2.895 + 50% on excess over 11.800
from 15.801 to 20.300	4.895 + 60% on excess over 15.800
over 20.300	7.959 + 70% on excess over 20.300

The total taxes for 22 unskilled labours, 10 drivers, 5 technicians, 2 electricians, 2 managers, 1 accountant and 1 foreman reach 846.096 G$.

3.10 FOREIGN EXCHANGE EARNINGS

3.10.1. Inflow

- The participation of the European investissor Lambiotte, SBI and the Region Wallonne is assumed to be 20% of the equity, e.g. 3.300.000 G$.
- Without considering inflation rate, the export earnings reach 24.000.000 G$ per year or the value of 6.000 tons per year sold (sales minus transport).

3.10.2. Outflow

The need in foreign currency is linked to the purchasing of the investment goods and this is estimated to be 25.400.000 G$.

APPENDIX 2

EUROPEAN STANDARDS FOR CHARCOAL
(France, Belgium, Germany)

CDU
UDC : 662.71

NORME BELGE - BELGISCHE NORM

PROJET - ONTWERP

CHARBON DE BOIS A USAGE DOMESTIQUE	HOUTSKOOL VOOR HUISHOUDELIJK GEBRUIK	NBN
DENOMINATION - SPECIFICATIONS - ESSAIS	BENAMING - SPECIFICATIES - PROEVEN	M 11-001
		1e éd., ... 1e uitg.,... ... ...

Holzkohle für den Hausgebrauch - Benennung - Spezifikationen - Versuche

Charcoal for domestic use - Designation - Specifications - Tests

Documents à consulter :

NBN 831-01 - Combustibles minéraux solides - Détermination du taux de matières volatiles - 1970

NBN 831-03 - Combustibles minéraux solides - Détermination du taux de cendres - 1970

NBN 831-04 - Combustibles minéraux solides - Détermination de l'humidité totale du charbon - 1970

Te raadplegen documenten :

NBN 831-01 - Vaste minerale brandstoffen - Bepaling van het gehalte aan vluchtige bestanddelen - 1970

NBN 831-03 - Vaste minerale brandstoffen-Bepaling van het asgehalte - 1970

NBN 831-04 - Vaste minerale brandstoffen - Bepaling van het totale watergehalte van steenkolen - 1970

1 OBJET

La présente norme a pour objet de fixer la dénomination, les spécifications et essais applicables au charbon de bois et au charbon de bois aggloméré (briquettes) à usage domestique.

1 ONDERWERP

Deze norm heeft als doel de benaming, de specificaties en de proeven vast te leggen die van toepassing zijn op houtskool en op geagglomereerd houtskool (briketten) voor huishoudelijk gebruik.

2 SPECIFICATIONS

2.1 Charbon de bois

2 SPECIFICATIES

2.1 Houtskool

Caractéristiques, sur le produit tel quel Karakteristieken, op het produkt als dusdanig	Catégorie Categorie		Tolérances Toleranties
	A	B	
Granulométrie comprise entre (sera complété ultérieurement) Granulometrie begrepen tussen (zal later ingevuld worden)			
Humidité maximale Maximaal watergehalte	7 %		
Teneur minimale en carbone fixe Minimum gehalte aan koolstof	82 %	75 %	- 2

Le charbon de bois à usage domestique ne doit pas contenir de corps étranger.

Houtskool voor huishoudelijk gebruik mag geen vreemde insluitsels bevatten.

Commission "Charbon de bois" de
l'INSTITUT BELGE DE NORMALISATION (IBN)
Enquête publique de 1983-07-15 à 1983-10-14
Adresser les observations éventuelles à l'IBN
Commissie "Houtskool" van
het BELGISCH INSTITUUT VOOR NORMALISATIE (BIN)
Publikatie ter kritiek van 1983-07-15 tot 1983-10-14
Eventuele aanmerkingen naar het BIN sturen

Prix : groupe
Prijsgroep : 5

2.2 Charbon de bois aggloméré (briquettes)

2.2 Geagglomereerd houtskool (briketten)

Caractéristiques, sur le produit tel quel Karakteristieken, op het produkt als dusdanig	Catégorie Categorie		Tolérances Toleranties
	A	B	
Teneur maximale, en masse, de liant Maximaal gehalte aan bindstof, in massapercenten	10 %		
Teneur minimale, en masse, de charbon de bois Minimaal gehalte aan houtskool, in massapercenten	90 %		
Teneur minimale en carbone fixe des agglomérés Minimaal gehalte aan koolstof van de briketten	67 %	60 %	- 3
Humidité maximale des agglomérés Maximaal watergehalte van de briketten	8 %		
Teneur minimale en carbone fixe du charbon de bois avant agglomération Minimaal koolstofgehalte van het houtskool vóór agglomeratie	76 %	69 %	- 3

L'aggloméré de charbon de bois ne doit pas contenir d'adjuvant de combustion ou de combustible autre que le charbon de bois. Le liant doit d'une part être conforme à la réglementation des produits destinés à être au contact des denrées alimentaires et ne doit pas d'autre part être de nature à altérer la qualité du produit consommable exposé au foyer.

Het houtskoolagglomeraat mag geen verbrandingshulpstof of brandstof bevatten behalve houtskool. Het bindmiddel moet enerzijds beantwoorden aan de reglementering inzake produkten die in contact worden gebracht met voedingswaren en mag anderzijds de kwaliteit van het aan het vuur blootgestelde consumptieprodukt niet wijzigen.

3 ESSAIS

3 PROEVEN

3.1 Détermination de la granulométrie

En préparation

3.1 Bepaling van de granulometrie

In voorbereiding

3.2 Détermination de l'humidité

Selon la méthode du chapitre 3 de la NBN 831-04.

3.2 Bepaling van het watergehalte

Volgens de methode van hoofdstuk 3 van NBN 831-04.

3.3 Détermination du carbone fixe

La teneur en carbone fixe de l'échantillon analysé est égale à :

3.3 Bepaling van de koolstof

Het gehalte aan koolstof van het geanalyseerde monster is gelijk aan :

$$100 - (W + A + V)$$

où

W est l'humidité, en pourcentage en masse, selon NBN 831-04, chapitre 3;

A est le taux en cendres, en pourcentage en masse, selon NBN 831-03;

V est la teneur en matières volatiles, en pourcentage en masse, selon NBN 831-01.

waarbij

W het watergehalte is, in massapercenten, volgens NBN 831-04, hoofdstuk 3;

A het asgehalte is, in massapercenten, volgens NBN 831-03;

V het gehalte is aan vluchtige bestanddelen, in massapercenten, volgens NBN 831-01.

3.4 Détermination de la teneur en liant

En préparation.

3.4 Bepaling van het gehalte aan bindmiddel

In voorbereiding.

3.5 Procès-verbal d'essai

Le procès-verbal d'essai doit indiquer la méthode utilisée et les résultats obtenus.

Il doit, en outre, mentionner tous les détails opératoires non prévus dans la norme ou facultatifs, ainsi que les incidents éventuels susceptibles d'avoir agi sur les résultats.

Le procès-verbal d'essai doit donner tous les renseignements nécessaires à l'identification complète de l'échantillon.

4 DESIGNATION

Le charbon de bois à usage domestique ou les briquettes de charbon de bois sont désignés dans l'ordre par :

- la dénomination "charbon de bois à usage domestique", "briquettes de charbon de bois à usage domestique".
- la catégorie et la teneur en carbone fixe :
  - A 82 % ou B 75 % (charbon de bois)
  - A 67 % ou B 60 % (briquettes),
- la référence à la présente norme.

5 MARQUAGE

Les étiquettes ou emballages, ainsi que les documents d'accompagnement, portent dans leur désignation de produit, les indications suivantes :

1 - la dénomination suivie de la référence de la présente norme "Charbon de bois" "Briquettes de charbon de bois" (1) et l'indication de la teneur en carbone fixe,

2 - le nom du responsable de la mise sur le marché,

3 - dans le cas de produits importés, le nom du pays d'origine sauf pour les marchandises qui sont originaires d'un Etat membre de la Communauté économique européenne,

4 - la mention "Produit fragile - Craint l'humidité",

5 - la masse et le volume, ou la masse et la masse volumique apparente, exprimée en kilogrammes par mètre cube (kg/m^3),

6 - la teneur en charbon de bois, pour le charbon de bois aggloméré (briquettes).

(1) La dénomination est simplifiée pour le marquage.

3.5 Proefverslag

Het proefverslag moet de gebruikte methode en de bekomen resultaten opgeven.

Het moet daarenboven alle niet in de norm voorziene of facultatieve werkwijzedetails vermelden, alsook de eventuele voorvallen die de resultaten zouden kunnen hebben beïnvloed.

Het proefverslag moet alle nodige inlichtingen bevatten die het monster volledig identificeren.

4 AANDUIDING

Houtskool voor huishoudelijk gebruik of houtskoolbriketten worden aangeduid door :

- de benaming "houtskool voor huishoudelijk gebruik", "houtskoolbriketten voor huishoudelijk gebruik",
- de categorie en het koolstofgehalte :
  - A 82 % of B 75 % (houtskool)
  - A 67 % of B 60 % (briketten),
- de verwijzing naar deze norm.

5 MERKEN

De etiketten of verpakkingen, alsook de begeleidende documenten, geven, in hun aanduiding van het produkt, volgende inlichtingen :

1 - de benaming gevolgd van de verwijzing naar deze norm "Houtskool" "Houtskoolbriketten" (1) en de aanduiding van het koolstofgehalte,

2 - de naam van de commerciële verantwoordelijke,

3 - in geval van ingevoerde produkten, de naam van het land van herkomst, behalve voor produkten afkomstig uit een Lidstaat van de Europese Ekonomische Gemeenschap,

4 - de vermelding "Breekbaar produkt - Vreest vocht",

5 - de massa en het volume, of de massa en de schijnbare volumemassa, uitgedrukt in kilogram per kubieke meter (kg/m^3),

6 - het gehalte aan houtskool, voor het geagglomereerde houtskool (briketten).

(1) De benaming wordt vereenvoudigd voor het merken.

tue épreuve
reçue le 13-08-84

NORME FRANÇAISE HOMOLOGUÉE	CHARBON DE BOIS ET BRIQUETTES DE CHARBON DE BOIS À USAGE DOMESTIQUE Dénomination — Spécifications — Essais	NF B 55-101 Septembre 1984

éditée par l'association française de normalisation (afnor) — tour europe cedex 7 92080 paris la défense — tél. (1) 778-13-26

AVANT-PROPOS

La présente norme a été publiée sur proposition du Syndicat des producteurs de charbon de bois et de combustibles forestiers.

À sa date d'homologation, il n'existe pas de document sur le même sujet en provenance de l'Organisation Internationale de Normalisation (ISO).

1 OBJET

La présente norme a pour objet de fixer la dénomination, les spécifications et essais applicables au charbon de bois et aux briquettes de charbon de bois (aggloméré) à usage domestique, lors de l'ensachage ou au poste de dédouanement.

2 RÉFÉRENCES

NF M 03-002	Combustibles minéraux solides — Détermination de l'humidité.
NF M 03-003	Combustibles solides — Détermination du taux de cendres des houilles.
NF M 03-004	Combustibles minéraux solides — Détermination de l'indice de matières volatiles du charbon.
NF X 11-501	Tamis et tamisage — Toiles métalliques et tôles perforées dans les tamis de contrôle — Dimensions nominales des ouvertures.
NF X 11-504	Tamis et tamisage — Toiles métalliques et tôles perforées dans les tamis de contrôle — Exigences techniques et vérifications.
NF X 11-507	Analyses granulométriques — Tamisage de contrôle.

Homologuée par décision du 1984-08-20 effet le 1984-09-20	La présente norme remplace la norme expérimentale de même indice de décembre 1982	© afnor 1984 Droits de reproduction et de traduction réservés pour tous pays

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Charcoal and charcoal briquets for domestic use — Designation — Specifications — Tests

SPÉCIFICATIONS

1 Charbon de bois

Caractéristiques, sur le produit tel quel	Catégories		Tolérances
	A	B	
Granulométrie : > 20 mm	75 %		− 5
> 10 mm ⩽ 20 mm	19 %		+ 4
⩽ 10 mm (poussier)	6 %		+ 1
Humidité maximale	7 %		—
Teneur minimale en carbone fixe	82 %	75 %	− 2

charbon de bois à usage domestique ne doit pas contenir de corps étranger.

2 Briquettes de charbon de bois (aggloméré)

Caractéristiques, sur le produit tel quel	Catégories		Tolérances
	A	B	
Teneur maximale, en masse de liant	10 %		—
Teneur minimale, en masse de charbon de bois	90 %		—
Teneur minimale en carbone fixe des ~~agglomérés~~	67 %	60 %	− 3
Humidité maximale des ~~agglomérés~~ briquettes	8 %		—
Teneur minimale en carbone fixe du charbon de bois avant agglomération	76 %	69 %	− 3

s briquettes de charbon de bois ne doivent pas contenir d'adjuvant de combustion ou de combustible autre que charbon de bois. Le liant doit d'une part être conforme à la réglementation des produits destinés à être au ntact des denrées alimentaires et ne doit pas d'autre part être de nature à altérer la qualité du produit nsommable exposé au foyer.

ÉCHANTILLONNAGE

r Annexe A

ESSAI

Détermination de la granulométrie

r Annexe E

Détermination de l'humidité

r Annexe B

5.3 Détermination du carbone fixe

La teneur en carbone fixe de l'échantillon analysé est égale à :

$$100 - (H + A + V)$$

où :

H est l'humidité, en pourcentage en masse, selon l'annexe B,

A est la teneur en cendres, en pourcentage en masse, selon l'annexe C,

V est l'indice de matières volatiles, en pourcentage en masse, selon l'annexe D.

5.4 Détermination de la teneur en liant

En préparation.

6 PROCÈS-VERBAL D'ESSAI

Le procès-verbal d'essai doit indiquer la méthode utilisée et les résultats obtenus.

Il doit, en outre, mentionner tous les détails opératoires non prévus dans la norme ou facultatifs, ainsi que les incidents éventuels susceptibles d'avoir agi sur les résultats.

Le procès-verbal d'essai doit donner tous les renseignements nécessaires à l'identification complète de l'échantillon.

7 DÉSIGNATION

Le charbon de bois à usage domestique ou les briquettes de charbon de bois sont désignés dans l'ordre par :

— la dénomination « charbon de bois à usage domestique », « briquettes de charbon de bois à usage domestique »,

— la catégorie et la teneur en carbone fixe :

— A 82 % ou B 75 % (charbon de bois),

— A 67 % ou B 60 % (briquettes),

— la référence à la présente norme.

8 MARQUAGE

Les étiquettes ou emballages, ainsi que les documents d'accompagnement, portent dans leur désignation du produit, les indications suivantes :

1 — la dénomination suivie de la référence de la présente norme « Charbon de bois » « Briquettes de charbon de bois » (1) NF B 55-101 et l'indication de la teneur en carbone fixe,

2 — l'indication du responsable de la mise sur le marché, son numéro codé et son numéro d'identification, et dans la mesure du possible, le GENCOD. Si le conditionneur français est différent du responsable de la mise sur le marché une marque ou inscription doit permettre de l'identifier. Le responsable de la mise sur le marché doit avoir son siège en France.

(1) La dénomination est simplifiée pour le marquage.

3 — dans le cas de produits importés, le nom du pays d'origine sauf pour les marchandises qui sont originaires d'un État membre de la Communauté économique européenne. Dans ce cas, et notamment si les emballages portent le sigle « e », une marque ou inscription doit permettre d'identifier le conditionneur ou l'importateur de ces emballages.

4 — la mention « Produit fragile — Craint l'humidité »,

5 — la masse ou le volume,

6 — la teneur minimale en charbon de bois, pour les briquettes de charbon de bois (aggloméré).

// ANNEXES (1)

ANNEXE A

MÉTHODE D'ÉCHANTILLONNAGE EN VUE DES ANALYSES

A.1 Objet

La présente annexe décrit une méthode de prélèvement des échantillons de charbon de bois pour les analyses suivantes : humidité — cendres — matières volatiles.

Pour la granulométrie, se reporter à l'Annexe E.

A.2 Principe

Prélever un échantillon représentatif, soit dans les lots commercialisés, soit au niveau de l'ensachage, soit au poste de dédouanement.

Les prélèvements pour les analyses sont obtenus par la méthode des quartiers, c'est-à-dire, partage et divisions successives à l'aide d'une plaque non métallique.

A.3 Matériel

A.3.1 Feuilles de papier glacé ou en polyéthylène de $1 m^2$ ($1 m \times 1 m$)

A.3.2 Plaque de carton ou de bois de dimensions convenables

A.4 Prélèvement de l'échantillon

La méthode décrite ci-dessous concerne le mode de prélèvement et non le nombre d'échantillons à prélever.

A.4.1 Au niveau de l'ensachage

Maintenir une feuille de papier glacé ou en polyéthylène (A.3.1) propre et sèche (2) juste à la sortie du dispositif d'ensachage, et délivrer environ 2 kg de charbon.

Placer l'ensemble sur une surface plane et diviser l'échantillon en quatre parts (en 2 opérations) en se servant d'une plaque de carton ou de bois.

La hauteur et la largeur de cette plaque doivent être supérieures à celles de la pyramide formée par l'échantillon sur la feuille.

A.4.2 Au niveau du stockage dans le circuit de commercialisation

Peser un préemballage prélevé au hasard

A.4.2.1 *Si le préemballage a un contenu* ≤ 2 kg

L'échantillon est le contenu de la totalité du préemballage.

Placer le sac horizontalement sur une feuille (A.3.1).

Couper le contour du sac à l'aide de ciseaux (les 2 longueurs et les 2 largeurs) 1 cm en-dessous de la ligne médiane. Retirer le sac coupé (partie supérieure) et diviser en 4 parts comme prévu en A.4.1.

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(1) Les annexes suivantes sont applicables au charbon de bois et aux briquettes de charbon de bois à usage domestique, néanmoins, le terme "charbon de bois" est seul utilisé dans la suite du texte.

(2) *La feuille de réception d'échantillon peut être placée dans dans une boite.*

DK 662.71 : 641.526.3 : 620.1 DEUTSCHE NORM Entwurf März 1984

Grill-Holzkohle und Grill-Holzkohlebriketts

Anforderungen, Prüfungen

DIN 51 749

Grill charcoal and briquets of grill charcoal; requirements; test methods

Charbon de bois à grillage et briquettes du charbon de bois à grillage; spécification, essais

Einsprüche bis 30. Jun 1984

Anwendungswarnvermerk auf der letzten Seite beachten!

In dieser Norm bedeutet % bei Angabe von Gehalten Massenanteile in Prozent (bisher Gewichtsprozent (Gew.-%)).

1 Zweck und Anwendungsbereich

Diese Norm legt Anforderungen sowie Prüfverfahren für Holzkohle und Holzkohlebriketts fest, die vorwiegend zur Verwendung in Grillgeräten dienen sollen.

2 Begriffe

2.1 Grill-Holzkohle

Im Sinne dieser Norm ist Grill-Holzkohle der feste Rückstand, der bei der Verschwelung von Holz bei Temperaturen oberhalb von 380 °C erhalten wird, wobei Kohlenstoff den Hauptbestandteil darstellt und nur ein geringer Anteil an mineralischen Bestandteilen vorliegt.

2.2 Grill-Holzkohlebriketts

Im Sinne dieser Norm bestehen Grill-Holzkohlebriketts aus Grill-Holzkohle nach Abschnitt 2.1. Sie werden unter Verwendung eines Bindemittels durch Verpressen hergestellt.

3 Bezeichnung

Bezeichnung von Grill-Holzkohle (H) nach DIN 51 749:

Holzkohle DIN 51 749-H

Bezeichnung von Grill-Holzkohlebriketts (B) nach DIN 51 749:

Holzkohlebriketts DIN 51 749-B

4 Anforderungen

4.1 Grill-Holzkohle

Grill-Holzkohle muß frei von artfremden Beimengungen sein.

4.1.1 Feuchtigkeit

Die Feuchtigkeit darf 8 % nicht übersteigen.

4.1.2 Körnung

Der beim Abfüllen gemessene Anteil < 20 mm soll möglichst gering sein. Er darf 10 % nicht überschreiten. Die Kornobergrenze soll 80 mm nicht überschreiten. Hierbei ist zu berücksichtigen, daß Einzelstücke länger sein können, wenn sie das Sieb aufgrund ihres Durchmessers passieren.

4.1.3 Asche

Der Aschegehalt darf 6 %, bezogen auf trockene Holzkohle, nicht überschreiten.

4.1.4 Flüchtige Bestandteile

Der Anteil an Flüchtigen Bestandteilen darf höchstens 16 %, bezogen auf trockene Holzkohle, betragen.

4.1.5 Fixer Kohlenstoff

Der Anteil an fixem Kohlenstoff soll, bezogen auf trockene Holzkohle, über 78 % liegen.

4.2 Grill-Holzkohlebriketts

4.2.1 Feuchtigkeit

Die Feuchtigkeit darf 8 % nicht übersteigen.

Fortsetzung Seite 2 und 3

Normenausschuß Materialprüfung (NMP) im DIN Deutsches Institut für Normung e.V.

4.2.2 Form und Größe

Form und Größe der Grill-Holzkohlenbriketts sollen für die Verwendung in Grillgeräten geeignet sein. Abrieb und Bruchstücke kleiner als 20 mm dürfen 10 % nicht überschreiten.

4.2.3 Asche

Der Aschegehalt darf, bezogen auf Trockensubstanz, 15 % nicht überschreiten.

4.2.4 Flüchtige Bestandteile

Der Anteil an Flüchtigen Bestandteilen darf, bezogen auf Trockensubstanz, höchstens 20 % betragen.

4.2.5 Fixer Kohlenstoff

Der Anteil an fixem Kohlenstoff soll, bezogen auf Trockensubstanz, über 65 % liegen.

4.2.6 Bindemittel

Das verwendete Bindemittel darf die Qualität des Lebensmittels, das dem Feuer ausgesetzt ist, nicht beeinträchtigen.

4.3 Kennzeichnung

4.3.1 Die Verpackung der zum Verkauf angebotenen Grill-Holzkohle bzw. Grill-Holzkohlebriketts muß folgende Angaben aufweisen:

a) Name oder Zeichen des Herstellers oder Lieferers

Benennung (Grill-Holzkohle oder Grill-Holzkohlebrikett)

c) Hinweise, die für den sicheren und korrekten Gebrauch der Grill-Holzkohle und -briketts notwendig sind

d) Warnvermerk: "Achtung! Keinen Spiritus, Benzin oder ähnliche Flüssigkeiten zum Anzünden oder Wiederanzünden verwenden!"

4.3.2 Die Übereinstimmung des Produktes mit dieser Norm darf vom Hersteller oder Lieferer eigenverantwortlich durch den zusätzlichen Hinweis DIN 51 749 zum Ausdruck gebracht werden.

5 Prüfung

5.1 Feuchtigkeit

Der Wassergehalt wird nach dem Trockenschrankverfahren nach DIN 51 718 ermittelt.

5.2 Körnung bzw. Unterkorn

Die zu untersuchende Probenmenge, die 3 kg nicht unterschreiten soll, wird über ein Drahtsiebgewebe von 20 mm lichter Maschenweite nach DIN 4187 Teil 2 abgesiebt und der Siebdurchgang durch Wägen ermittelt. Die Absiebung wird durch Schütteln des Siebes solange vorgenommen, bis kein merklicher Siebdurchgang beobachtet wird.

5.3 Asche

Die Bestimmung des Aschegehaltes erfolgt nach DIN 51 719. Abweichend von der Veraschungstemperatur von (815 ± 15) °C in DIN 51 719 ist für Holzkohle eine Veraschungstemperatur von (710 ± 15) °C anzuwenden, da bei höheren Temperaturen flüchtige Aschebestandteile entweichen können.

5.4 Flüchtige Bestandteile

Die Bestimmung des Gehaltes an Flüchtigen Bestandteilen erfolgt nach DIN 51 720 in einem mit Deckel verschlossenen Quarztiegel bei (900 ± 10) °C.

5.5 Fixer Kohlenstoff

Der Gehalt an fixem Kohlenstoff (C_{fix}) als Massenanteil in % wird als Differenzbetrag nach folgender Formel berechnet:

$$C_{fix} = 100 - (\text{Gehalt an Flüchtigen Bestandteilen} + \text{Aschegehalt})$$

6 Prüfbericht

Der Prüfbericht soll folgende Einzelheiten enthalten:

a) Alle erforderlichen Angaben zur vollständigen Kennzeichnung der Probe

b) die angewendeten Verfahren unter Hinweis auf diese Norm

c) die erhaltenen Ergebnisse, ggf. Mittel- und Einzelwerte

d) alle Einzelheiten während der Durchführung, die nicht in dieser Norm beschrieben sind oder als wahlweise angesehen werden, die das Ergebnis beeinflußt haben könnten.

Zitierte Normen

DIN 4187 Teil 2 Siebböden; Lochplatten für Prüfsiebe, Quadratlochung

DIN 51 718 Feste Brennstoffe; Bestimmung des Wassergehaltes

DIN 51 719 -; Bestimmung des Aschegehaltes

DIN 51 720 -; Bestimmung des Gehaltes an Flüchtigen Bestandteilen

Weitere Normen

DIN 66 077 Grillgeräte zur Verwendung im Freien; Sicherheitstechnische Anforderungen, Prüfung

Erläuterungen

Dieser-Norm-Entwurf wurde vom Arbeitskreis "Holzkohle" (Federführung: Dr. H.-G. Brocksiepe, Bodenfelde) im Arbeitsausschuß NMP 691 "Prüfung fester Brennstoffe" (Obmann: Dr.-Ing. A. Scholz, Essen) ausgearbeitet.

Anwendungswarnvermerk

Dieser Norm-Entwurf wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtige Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfes besonders zu vereinbaren.

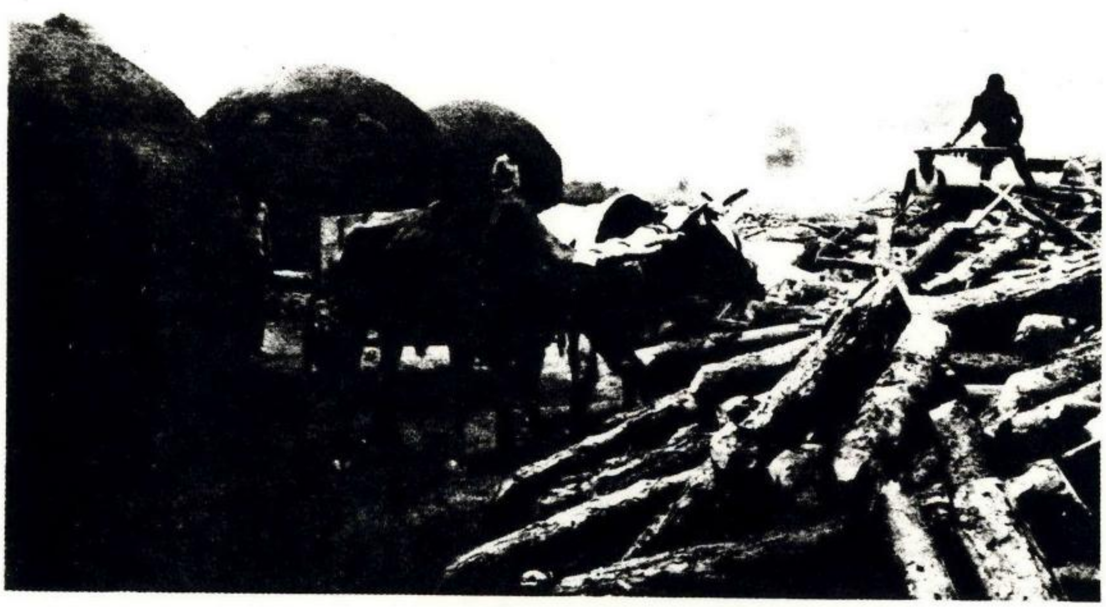
Stellungnahmen werden erbeten an den Normenausschuß Materialprüfung (NMP) im DIN, Burggrafenstr. 4-10, 1000 Berlin 30.

MALAWI CHARCOAL PROJECT

Charcoal Production from Plantation Wood

A Guide to the Development of Small-Scale Charcoal Industries

Dr. W. Emrich
G.H. Zieroth



Lilongwe, February 1987

Table of Contents

1. Introduction

1.1 The following guide deals with the establishment and operation of semi-industrial charcoal production schemes in Malawi. The methods and technologies described below have already been introduced on a pilot scale in the Viphya Forest, one of the largest forest plantations in Africa and the single most important wood resource in Malawi. The guide summarizes the results obtained so far in the framework of the Malawi Charcoal Project and incorporates the practical insights gained by the Project Team in the course of implementing the various charcoal production activities that have been undertaken to date. It is obviously beyond the scope of this brief guide to provide succinct practical advice on the solution of any and all problems that may arise in the development of small charcoal industries. However, the authors are confident that it will prove to be a valuable basic tool for project planners and managers, as it will help them to understand the fundamental issues involved in setting up such industries and deal with the problems most commonly encountered in the establishment and operation of semi-industrial charcoal production schemes.

1.2 The Malawi Charcoal Project is financed by the World Bank and is being executed by the Forestry Department. IPC Consultants, Frankfurt, were commissioned by the Government of Malawi to provide management and technical assistance in the field of improved charcoal production methods. IPC hopes that this guide will help to promote improved natural resource management in Malawi by contributing to more efficient biomass utilization.

G. Zieroth, Project Coordinator

2. The Choice of Kilns

2.1 The purpose of a charcoal industry is to produce an economically competitive fuel for industrial and household consumers. As a commercial operation, the production process must be organized and run in a cost-effective way in order to allow a charcoal company to make a reasonable profit. On the other hand, however, the technology employed should permit the production of the maximum possible amount of charcoal from a given biomass resource. The kiln technology influences:

- the investment costs,
- the labour costs, and
- the feedstock costs (royalites, stumpage fees and internal transport).

2.2 There are two different kiln technologies that may be considered basically suitable for use in a semi-industrial charcoal operation: **steel kilns and clay or fire brick kilns**. Although the utilization of traditional earth mound kilns does not involve investment costs, they must be ruled out at the semi-industrial level for the following reasons:

- process and quality control are very difficult,
- contamination of the product with soil cannot be avoided,
- under wet weather conditions such as those encountered in the Viphya Forest, they do not permit year-round operation of production facilities, and
- they are less efficient than the other two options and give rise to high specific feedstock costs.

Only the fact that most of the wood used in the traditional charcoal sector is obtained at either zero or near-zero cost makes the earth mound kiln as attractive as it is for the individual charcoal burner. At the other end of the technology range are the sophisticated industrial carbonization units such as converters and retorts. They require a high level of capital investment and are used in situations where labour costs are high and the feedstock for carbonization is expensive. With such systems, a gradual, step-by-step development of charcoal industries is not possible, and projects employing high-tech converters are risky if the market for the products is uncertain. They have to be ruled out as unsuitable options for semi-industrial charcoal operations such as the Viphya charcoal industries.

Steel Kilns

2.3 On the one hand, steel kilns produce an output that meets the quality standards required of industrial charcoal, and on the other, they can meet the need for a certain level of efficiency - important advantages at the semi-industrial level. However, their investment costs are high. In Malawi, a Mark V or Aldred-design steel kiln costs MK 2,500 (US$ 1,225), excluding surtax. The lifetime of these kilns is limited, and field experience in many charcoal production schemes has shown that their maximum service life is usually only about one year if they are operated on a full-time basis. Moreover, steel must be imported in countries such as Malawi and paid for with foreign exchange. The major advantage of steel kilns - their transportability - can only be regarded as an important criterion if internal transport costs are high due to dispersed availability of wood, i.e. if feedstock resources are scattered over a large catchment area. This is not the case in forest plantations such as the Viphya where ox-carts can be used as a cheap means of wood transport. In addition, wood preparation costs are higher if Mark V kilns or other steel kilns of similar design are used (feedstock must be cut into 0.3-metre-long pieces). Finally, in view of the fact that the average yields of steel kilns are lower than those that can be achieved with brick kilns, it is clear that they cannot be considered a cost-effective option for charcoal making (see table at end of next section).

Brick Kilns

2.4 Brick kilns are employed in huge numbers in South America. Hundreds of industrial charcoal operations rely on this technology, which has been in use for many years and whose cost-effectiveness has been clearly established for decades. Brick kilns can be constructed from locally available materials and they can be easily operated by local people. Their efficiency is high compared to other systems.

Of the various kinds of brick kilns, the "Half Orange Fire Brick Kiln" and the "Beehive Kiln" are the two most popular designs. Although kilns of this general type vary greatly in terms of both size and precise mode of operation, this guide will concentrate on one particular model - the Half Orange - which has proved to be an appropriate solution within the framework of the Malawi Charcoal Project. One unit of this type costs approximately MK 300, including bricks, clay soil, transport and labour input. Fire brick kilns can be repaired on site if they are damaged. If properly operated, they last for fifteen years. In case they have to be moved, they can be dismantled and rebuilt elsewhere. Wood preparation is less costly than, say, with steel kilns. The Half Orange kiln can accomodate logs up to 1.8 metres in length and 0.3 metres in diameter. The advantages of fire brick kilns are obvious. However, like all kiln-based charcoal making systems, they also have certain drawbacks:

- Due to their smoke exhausts, batteries of more than 12 kilns may be regarded as a nuisance by nearby residents.

- The recovery of charcoal by-products (tar, creosote) is feasible, but requires costly and sophisticated equipment.

The Characteristics of the "Mark V Steel Kiln" and the "Half Orange Fire Brick Kiln"

	Capacity m^3	Yield[1)] %	Cycle time hours	Cost per unit (MK)	Cost per m^3 (MK)	lifetime[2)] years
Mark V	8 - 10	18 - 22	24 - 36	3,000	300	2
Half Orange	10 - 20	28 - 32	36 - 60	300	20	15

1) for a given weight of properly seasoned wood

2) lifetime of steel kilns if properly operated

3. The Charcoal Making Process

3.1 Carbonization, charring or charcoal making takes place if organic matter - in general firewood - is heated up to temperatures of between 420° C and 550° C in the absence of air or if the air intake is restricted. Many different chemical reactions take place during the process of carbonization, but there are always two end products:

- charcoal (solid fuel), and
- carbonization gas (gaseous fuel).

The process can be controlled by regulating the heat which is applied to the kiln. The higher the temperature level of the carbonization process, the greater is the share of carbon in the resulting charcoal. For fire brick kilns, two different methods are used to control the temperature:

- internal heating (control of air inflow), and
- external heating (control of combustion in a separate fire box).

The Half Orange kiln described below is an internally heated model, i.e. a part of the kiln load has to be burnt to provide energy for the carbonization process.

3.2 The specific properties of the feedstock, i.e. the firewood used for charcoal making, have a great influence on the quality of the end product and the efficiency of the process. Hardwood is regarded as the best feedstock and yields a high-density charcoal with a high heating value per unit of volume. Softwood such as pine produces a lighter and more friable charcoal. By weight the heating value is comparable to that of hardwood charcoal. One kg of pinewood charcoal contains approximately the same amount of energy as one kg of hardwood charcoal.

For a given type of feedstock, the moisture content of the wood, i.e. the amount of water which it contains when loaded into a kiln, determines the efficiency of the charcoal making process and the quality of the end product. Firewood for charcoal making should always be **properly** seasoned: the moisture content of the wood must be 25% or less in order to achieve reasonable yields from the kiln. A high moisture content requires more heat to drive the water off and more wood has to be burnt for this purpose, thus reducing the amount which can be carbonized, i.e. turned into charcoal. The firewood loaded into the kiln should be dry, clean (not contaminated with soil), and of fairly uniform size.

4. Developing a Charcoal Industry

4.1 Many people have tried to introduce improved kilns and charcoal making methods in countries such as Malawi. Some have failed because they focused exclusively on the technology and ignored the business aspects of charcoal production. Before one begins to introduce charcoal technologies, one must have a clear picture of the market for which one will be producing. Prices for competing fuels such as kerosene, firewood, coal, diesel oil and, last but not least, charcoal made with traditional earth mound kilns, must be known. The cost of the raw materials, i.e. the effort involved in harvesting and transporting the feedstock to the kilns, is also important. Transport costs for the final product can kill any charcoal industry - even one with very efficient production methods - if the production site is too far away from the consumers. Thus, one must thoroughly investigate such factors before one begins spending money on any type of improved charcoal making facilities.

4.2 Charcoal making using improved methods is an organized manufacturing process requiring management, skilled labour and investment. A charcoal industry can never succeed if the company that produces and markets the fuel cannot make a profit. Even if resources that would otherwise simply be wasted are available for carbonization, e.g. wood from bush clearing and forestry operations such as thinning, the charcoal industry must still sell the end product at a price that is sufficient to cover the cost of making the charcoal. Moreover, even a small-scale charcoal industry has to invest money, pay back credits and cover operating costs. It is a business that requires planning! After he has set up his production facility and started operations, a charcoal maker has to manage and supervise his labour force, keep records, pay salaries and keep in touch with his customers. Warehousing might be required, and tools and internal transport equipment must be maintained, repaired and periodically replaced.

4.3 If the feedstock is taken from government forests or timber plantations, the charcoal industry must negotiate royalties or stumpage fees. An uninterrupted flow of raw material is essential in order to keep the business running and long-term supply arrangements might be necessary. A charcoal operation that is restricted to the charcoal maker's own land cannot go on forever. And even if the feedstock is being drawn from a relatively large area, at some point the supply of trees might be exhausted, thus making replanting a necessity. As soon as this stage has been reached, and assuming the objective is to continue production on a long-term, sustained basis, simple charcoal making gives way to a more complex process of biomass resource management. In any case, before a charcoal industry is established, a comprehensive feasibility analysis must be conducted which takes all of the relevant issues and problems into consideration.

5. Setting Up a Charcoal Industry on the Basis of Half Orange Brick Kilns

5.1 Once a decision has been made to produce charcoal on a semi-industrial scale, it is of crucial importance to select a suitable site for the production centre. In the case of the Viphya Forest operation, thinning wastes are the most important feedstock for charcoal production. An uninterrupted flow of raw material must be assured so as to permit year-round operation of the facility, and, logically enough, the size of the catchment area that will be required is determined by the size of the production centre that is to be established. Based on operational experience to date, a battery of 12 Half Orange kilns with an annual throughput of 1,000 stacked m^3 each may be considered an appropriately sized production centre. The total biomass input required for a centre of this type is 12,000 stacked m^3 per year, and the productivity of the Viphya

Forest permits the extraction of approximately 20 stacked m^3 of wood per ha and year. Consequently, a catchment area of between 600 and 1,000 ha is needed in order to supply this amount of raw material on an annual basis.

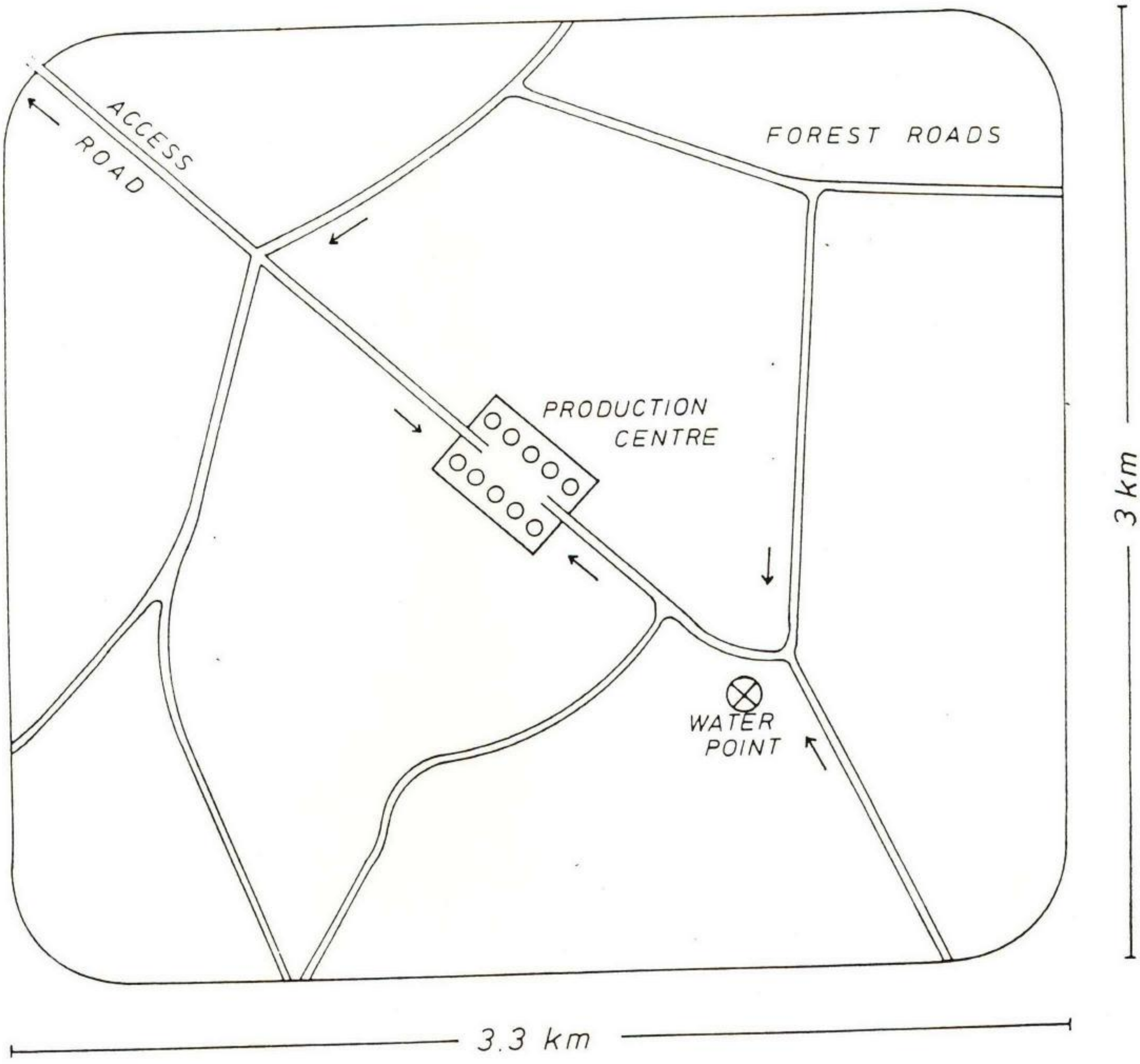
5.2 The site of the charcoal production facility should be close to the centre of the catchment area. The maximum transport distance for firewood should not exceed 2,000 metres if ox logging or ox-cart transport are used. The production centre should be provided with an all-weather access road capable of accomodating heavy trucks. Road improvement measures such as gravelling may be required to permit year-round access. The centre should also have good drainage conditions to prevent flooding during heavy rains. There should also be a water point within the catchment area (well, stream), and it should be located as close to the centre as possible. Water is required for the preparation of mortar (kiln construction and sealing of kiln shell) and for extinguishing burning charcoal (see sketch).

5.3 As a rule, six or more kilns will be installed in a battery, and the site must be large enough to accomodate the total number of kilns that is planned for the centre. There must also be sufficient space at the site for the storage of both firewood and charcoal. In addition, a store room for tools and bags is required as well as a shelter for watchmen and operating personnel, and there must be room for two or three water tanks in the vicinity of the kilns. The total area required for a 12-kiln production centre is approximately 0.8 ha (see sketch).

5.4 The site should be cleared of all vegetation. If necessary, the site should be levelled or filled in. A separate drainage ditch must be dug around each kiln. The drainage system should be installed before or during construction. If kilns are constructed during the wet season, plastic sheets or tarpaulins will be required to protect the unfinished kilns from damage by heavy rains. A partially completed kiln may be destroyed by a heavy rain!

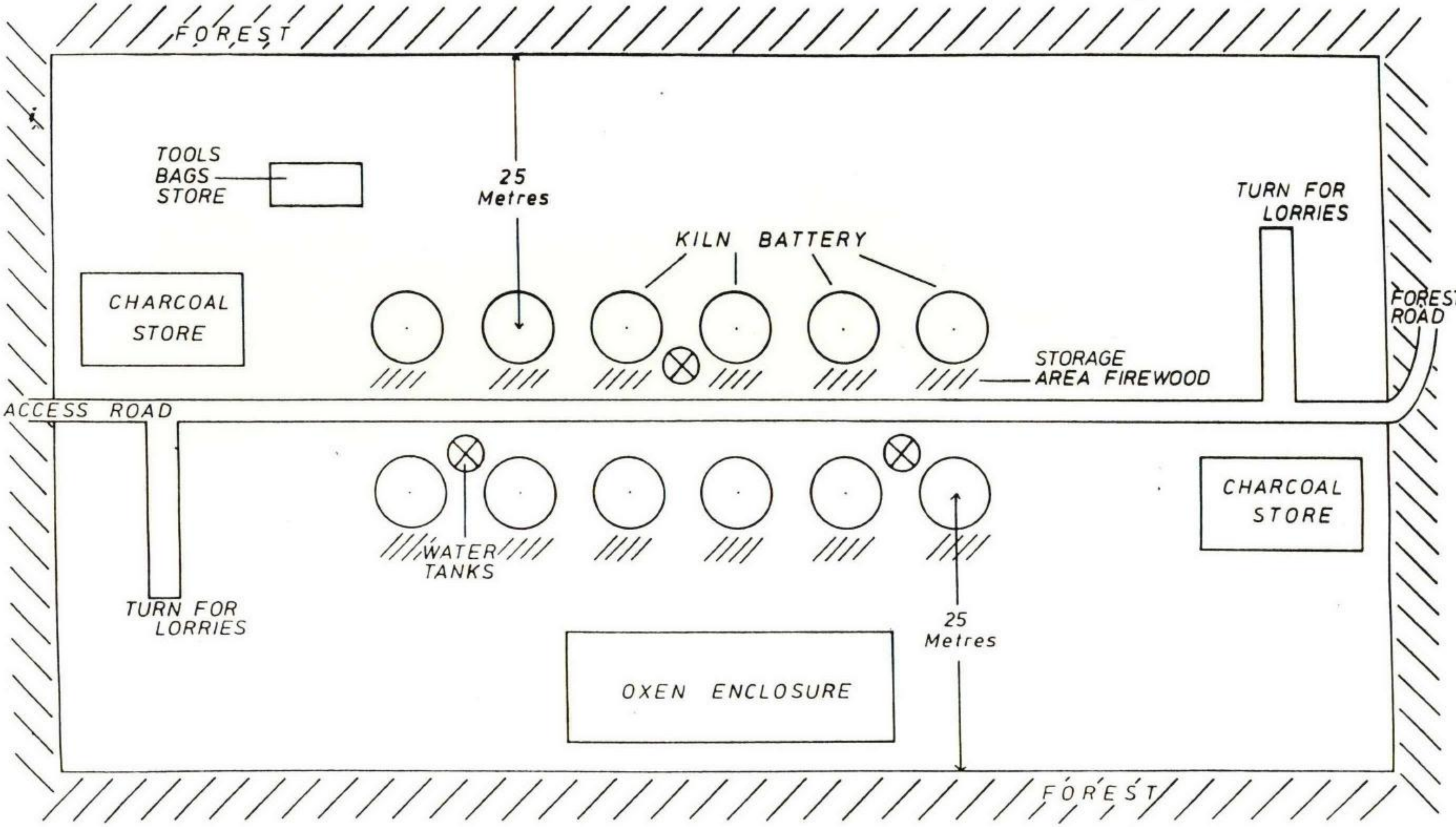
CHARCOAL PRODUCTION CENTRE

Catchment Area



CHARCOAL PRODUCTION CENTRE (General lay out)

Total area required: 0,8 hectare



Scale: 1: 500

Before starting construction, all necessary equipment should be brought to the site. This includes:

- axes, panga knives
- mason's tools (level, radius rod with leader)
- shovels, hoes, spades
- water buckets
- ropes
- plastic sheets, tarpaulins
- construction material (per kiln approximately 2,500 soft burned bricks, 0.5 m^3 of clay soil and 2 pieces of angle iron or flat bars).

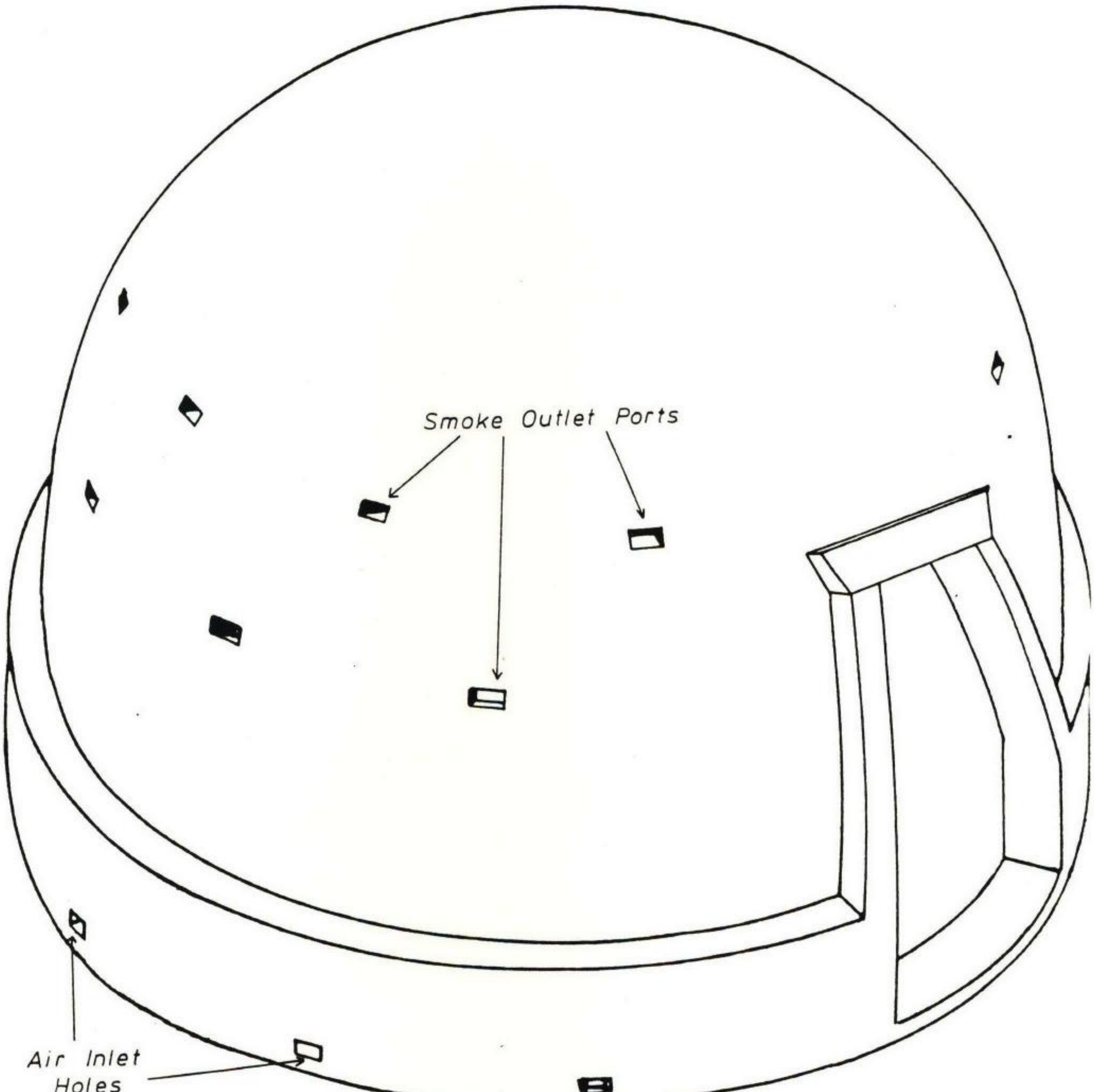
The steel bars may not be required, but they facilitate kiln construction.

6. Construction of Half Orange Kilns

6.1 The basic design and outward appearance of the "Half Orange" kiln are shown in Figure 1. The main dimensions are given in Figures 2a and 2b. After the site preparation works have been completed, the place for each kiln should be marked as shown in Figure 3. It is advisable to set wooden pegs at 80-cm intervals along the inner and outer circles of the foundation line. It is essential to ensure that the centre pole (see Figure 3) at each individual kiln site is firmly implanted in the ground to prevent it from being accidentally removed or broken off.

6.2 After the site has been properly marked, the foundation ditch is dug; the inner and outer circle lines should be closely followed (Figure 3). The recommended depth is 50 cm. When completed, the ditch is usually half filled with gravel. (Depending on the consistency of the soil, this 25-cm-thick layer of gravel may not be required; in most places in the Viphya Forest, for example, the foundation can be built without gravel.) It is advisable to check the foundation frequently with a level as the work progresses to ensure that the kiln base is in fact horizontal (Figure 4).

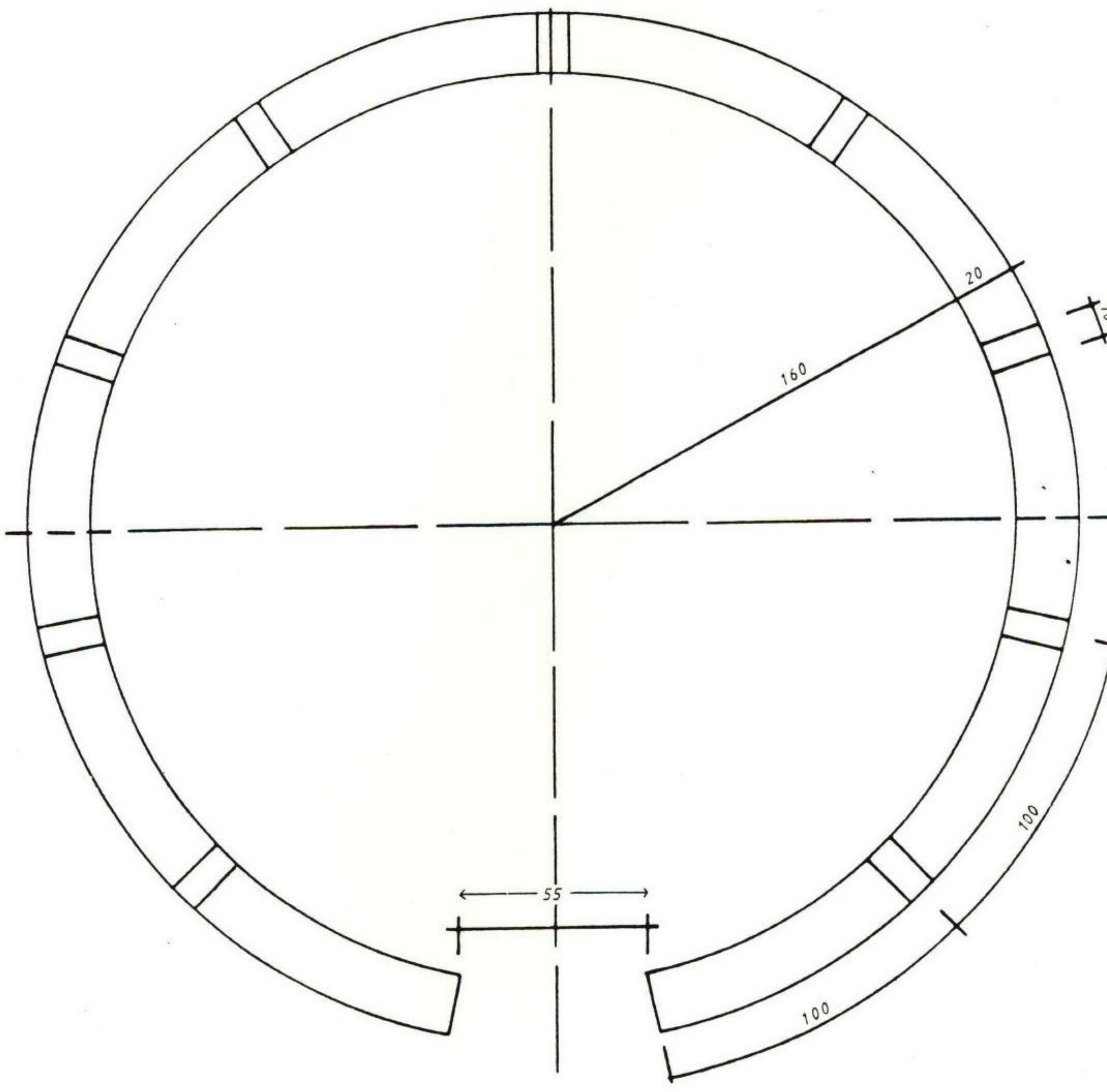
Figure 1: Half Orange Fire Brick Kiln



CONSTRUCTION MATERIAL:

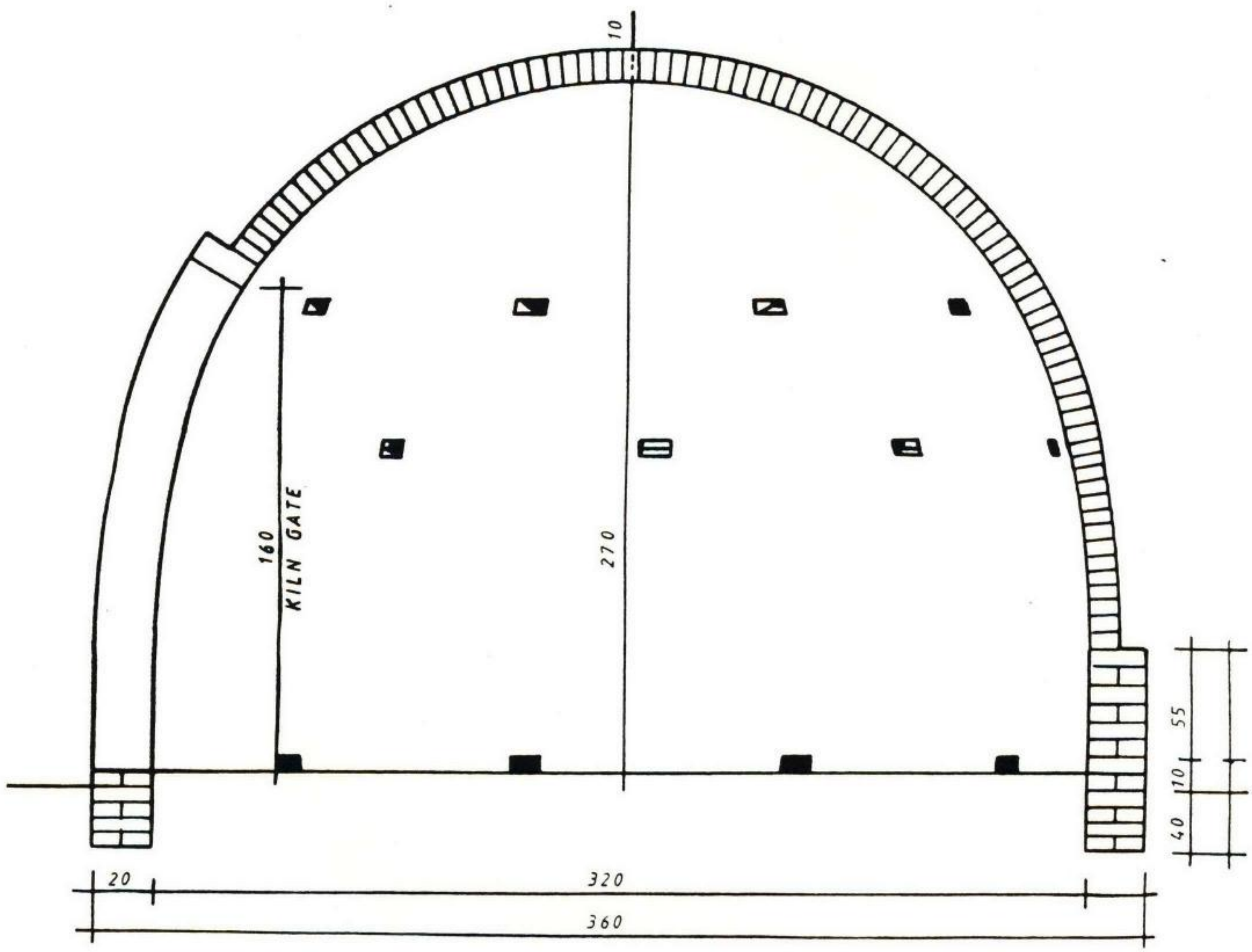
2,500 bricks: 22.5 x 18 x 8.5 cm
0.5 m^3 of clay soil
2 pieces of angle iron 60 cm (or flat bars)
water

Figure 2a: Ground Plan



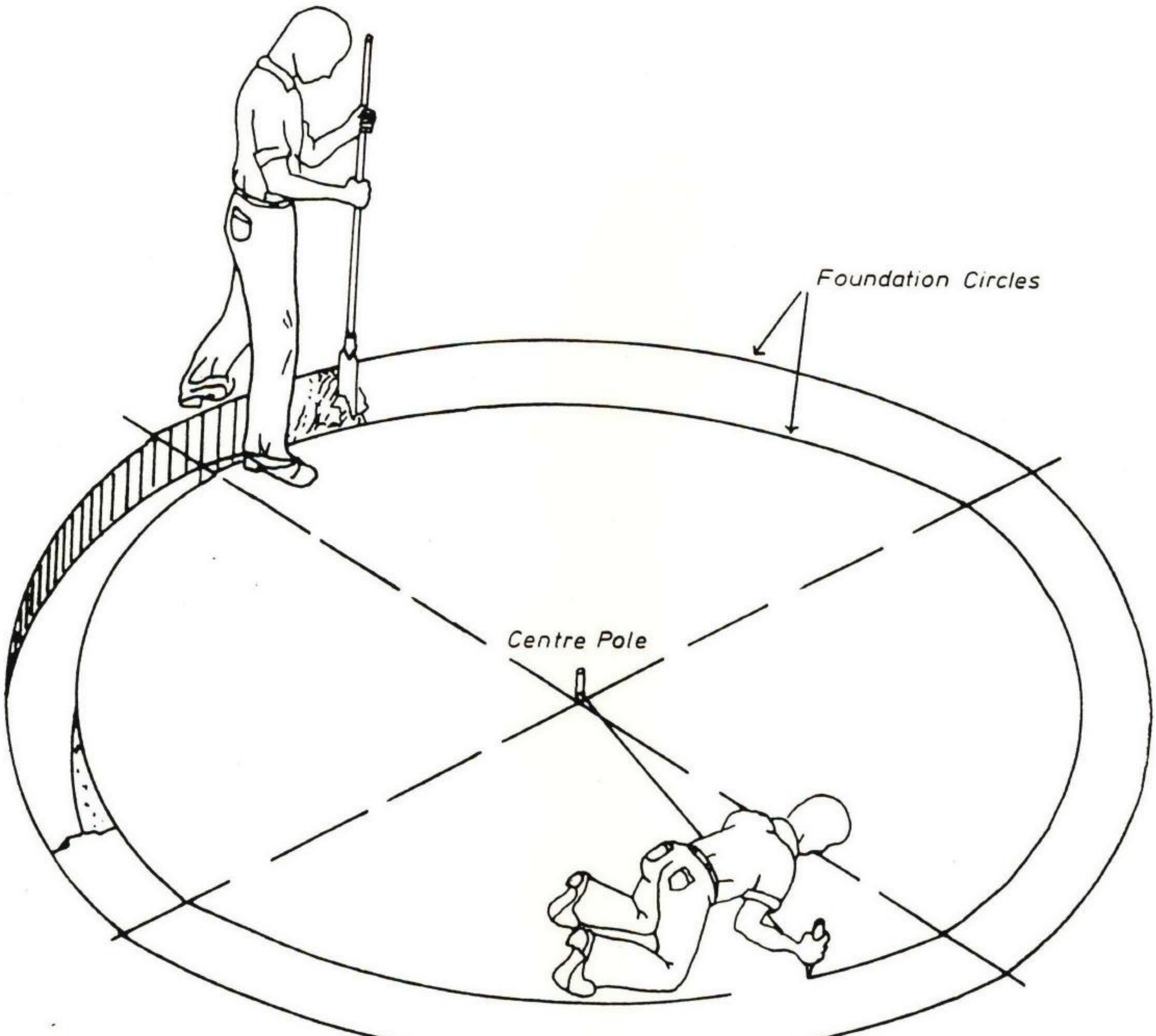
Dimensions in cm

Figure 2b: Cross Section



Dimensions in cm

Figure 3: Marking the Kiln Site



The off-ground construction work begins with the fifth row of bricks. Nine air inlet holes, as well as the 60-cm-wide base of the kiln entrance, must be positioned in the first row (Figure 2a). The air inlet holes measure 9.0 x 6.0 cm and are approximately 1.0 m apart (Figure 2a). The vertical part of the kiln is called the "straight jacket" and consists of seven layers of bricks. A tool called a radius rod (as shown in Figures 5, 6 and 7) can be a great help in maintaining a precise, uniform distance between the "straight jacket"/cupola wall and the centre of the kiln.

6.3 While the kiln foundation and the "straight jacket" are constructed as double walls, the kiln cupola is designed as a single-wall structure, except for the two reinforced sides of the kiln entrance (Figure 7). The space enclosed by the cupola of the kiln is not strictly spherical; rather, the cross-section of the structure resembles a semi-circle which has been "elongated" vertically to a height of 2.70 m. In order to construct the cupola, the unskilled builder needs a radius rod with a "leader" as shown in Figure 6. The use of this radius rod is illustrated in Figure 7. Using the "leader", the distance between the individual rows of bricks and the centre can be changed by extending the radius rod according to the following resetting table:

Number of brick row: cupola	Resetting of the leader
Rows 1 - 5	1.0 cm for each layer
Row 6	2.0 cm
Rows 7 - 10	2.5 cm for each layer
Rows 11 - 14	2.0 cm for each layer
Rows 15 - 18	1.5 cm for each layer
Rows 19 - 24	1.0 cm for each layer
Rows 25 - 32	0.5 cm for each layer
Rows 33 - 37	NO RESETTING

Figure 4: Building the Foundation

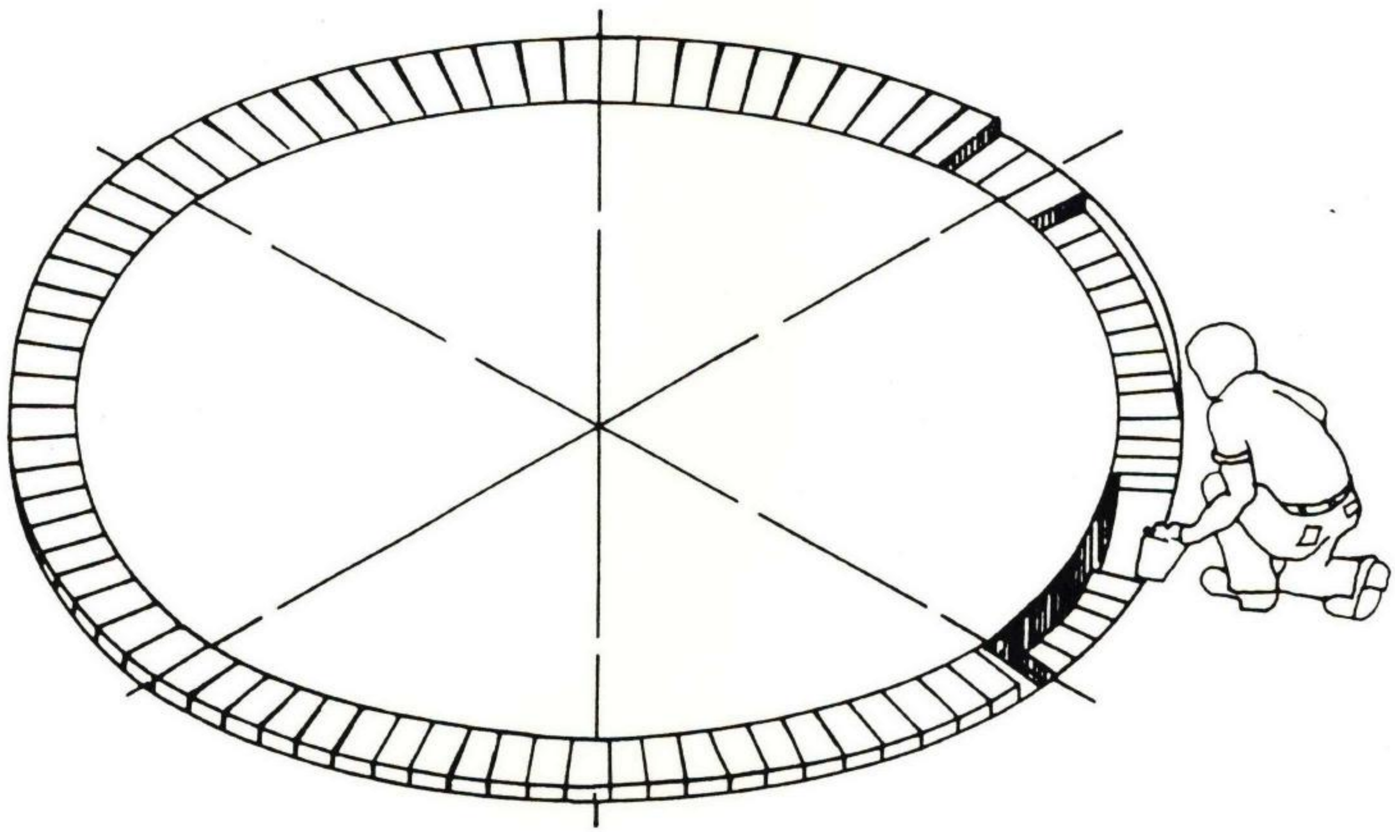


Figure 5: Putting in the Last Fire Brick Layer of the "Straight Jacket"

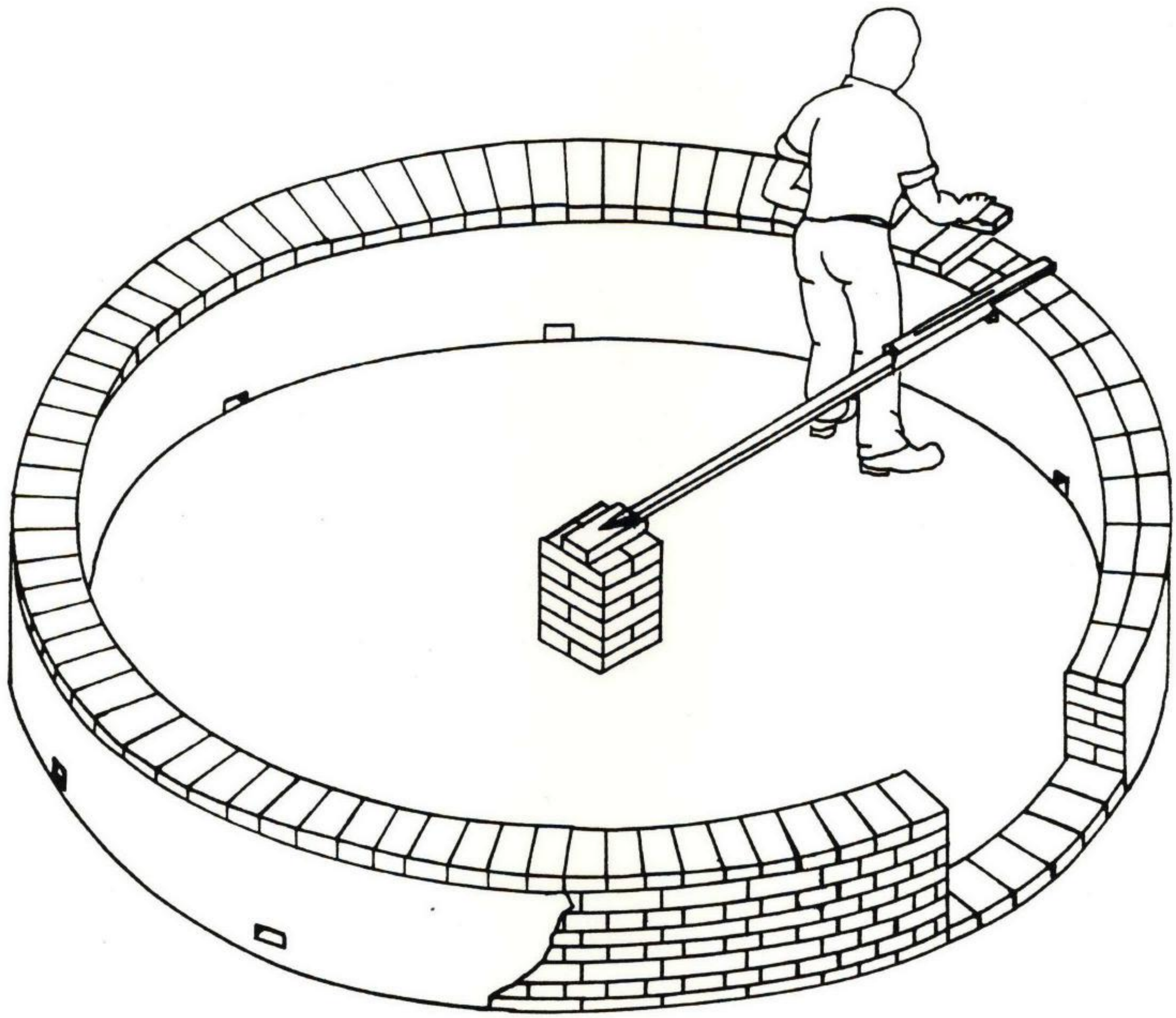


Figure 6: Radius Rod with "Leader"

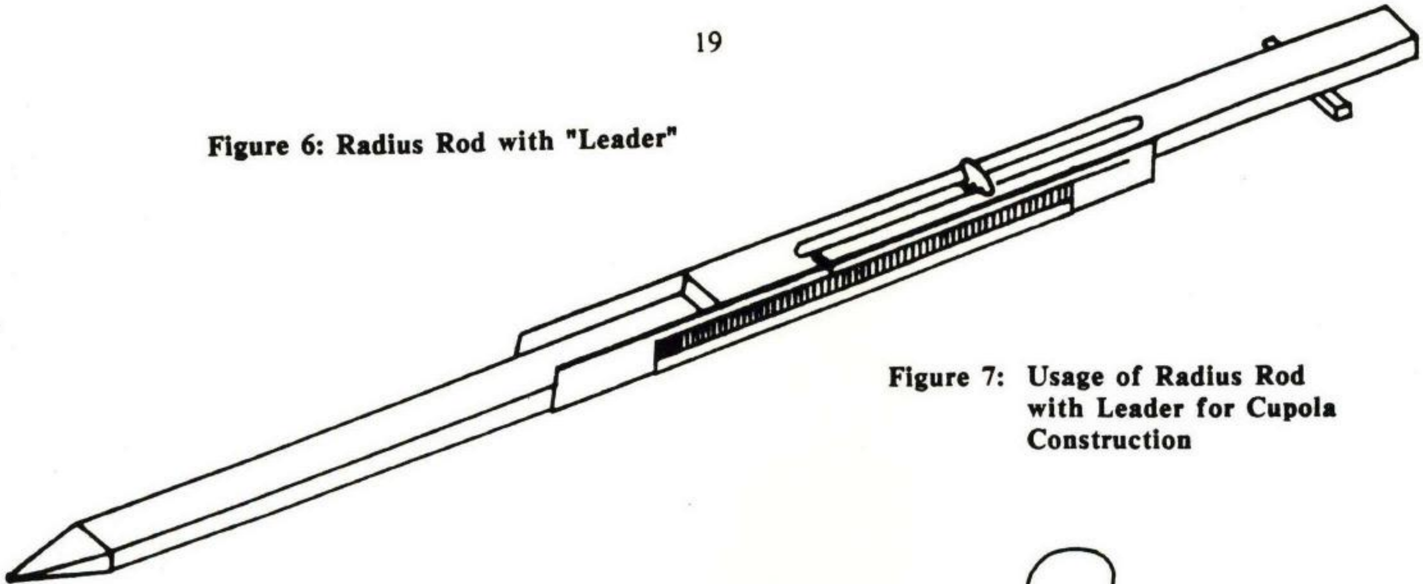
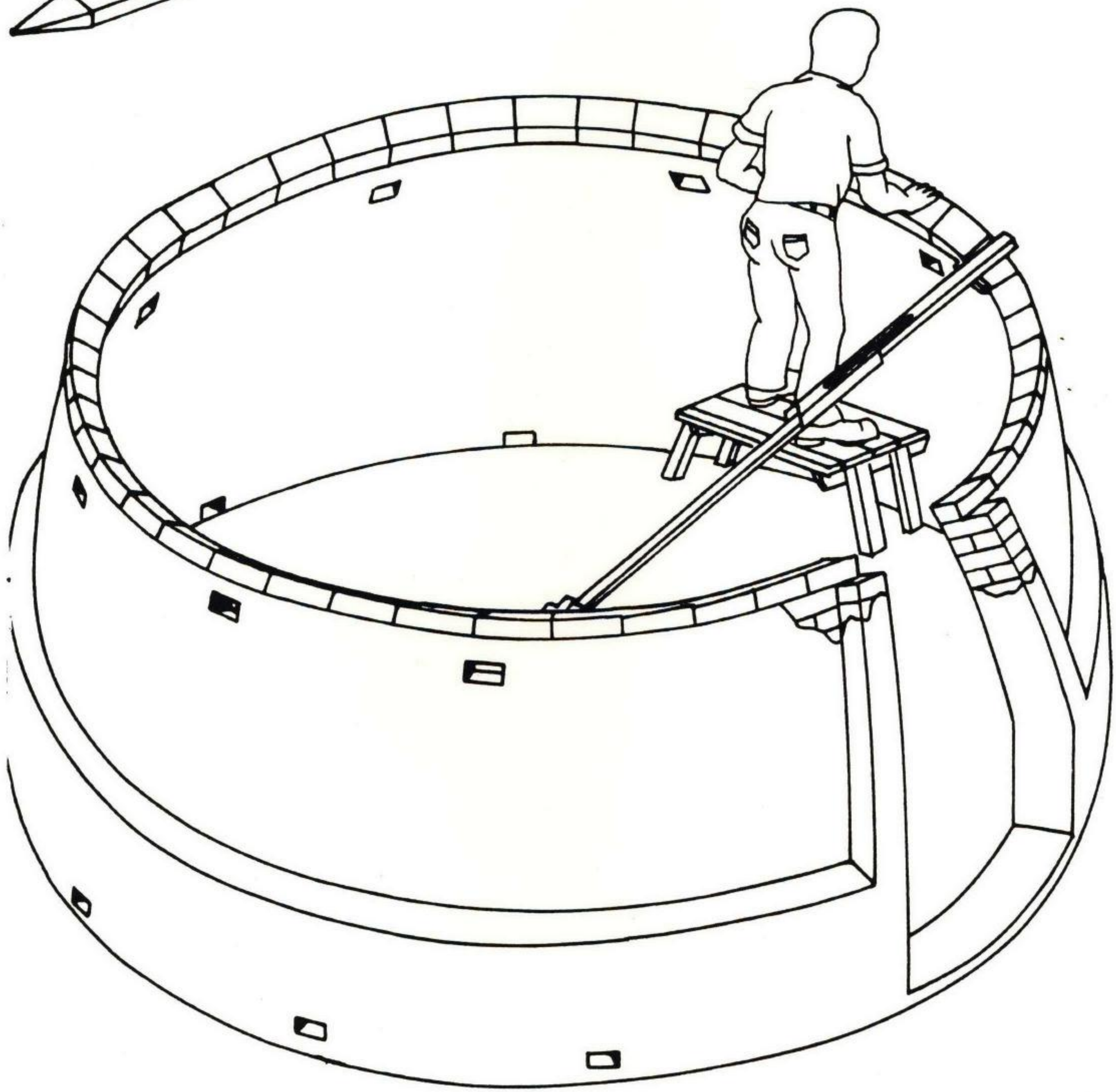


Figure 7: Usage of Radius Rod with Leader for Cupola Construction



This resetting table has been calculated for bricks measuring 22.5 x 18.0 x 8.5 cm. If other brick sizes are used, the resetting figures must be adjusted accordingly. The technical details of the radius rod with "leader" are illustrated in Figure 8.

The total height of the entrance should not exceed 170 cm. The ten lower smoke outlet ports, which measure 10 x 6 cm, are positioned approximately two brick rows above the top of the entrance (Figure 1). The seven upper smoke outlet ports (10 x 6 cm) are located eight brick rows above the lower outlet ports; they are spaced equidistantly and staggered with respect to both the lower smoke ports and the air inlet holes (Figure 9).

For optimal kiln construction it is important to apply as little mortar as possible within the "straight jacket" and cupola areas. All bricks within the cupola must be positioned so that their inner edges fit tightly together.

After the construction work has been finished, the entire kiln shell must be coated on the outside with mortar to seal cracks through which air could escape. The thickness of the mortar cover should not exceed 1.0 cm.

Before the first charcoal run, the wet kiln must be burnt out for several days. For this purpose, a fire is maintained continuously inside of the kiln. The flames should not be allowed to reach the ceiling of the cupola. Thus, an attendant must be on duty round the clock during the entire burning-out period. Even after the burning-out process is finished, a kiln is still considered to be "green". The structure does not achieve its full strength and durability until the completion of three to four charcoal runs.

Figure 8: Details of a Radius Rod with Leader for the Construction of Half Orange Kilns

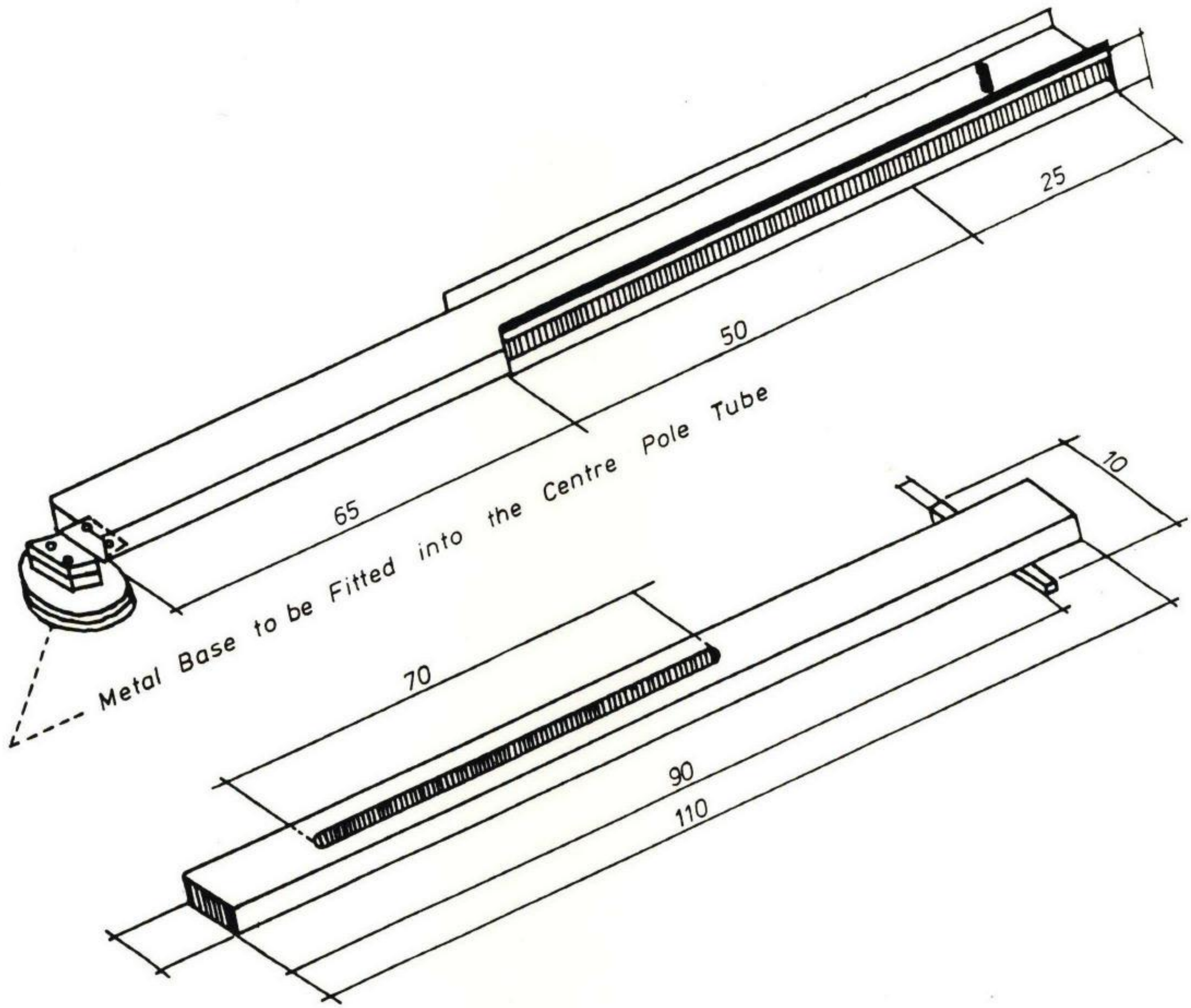
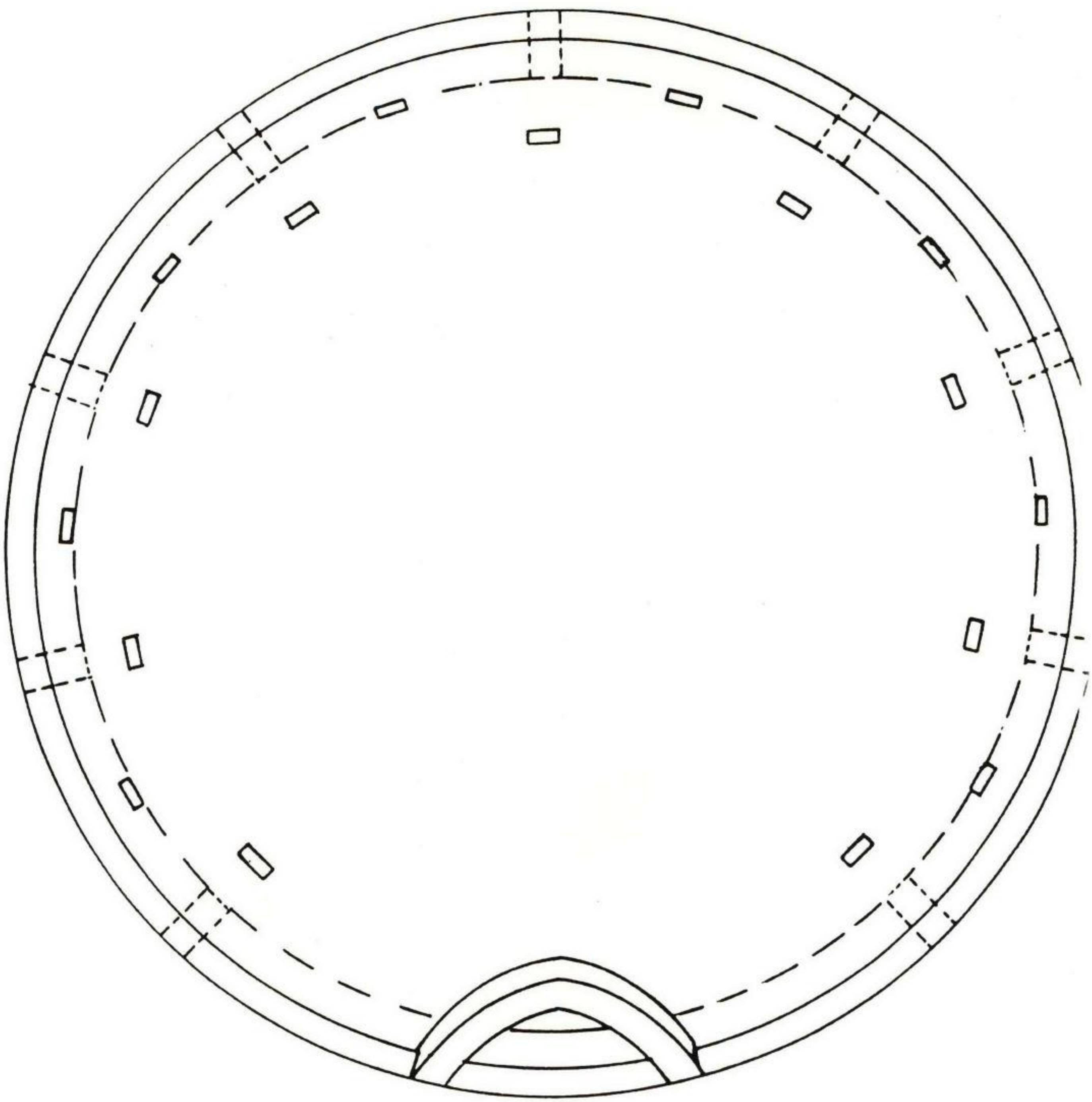


Figure 9: Distribution Plan of Air Inlet Holes and Smoke Outlet Ports



7. Operation of Half Orange Kilns

7.1 Fuelwood Preparation

Fuelwood which is to be utilized as feedstock is cut into pieces approx. 1.2 - 1.5 m in length having a minimum diameter of 3.0 cm and a maximum diameter of 30.0 cm.

The fuelwood which is transported to the kiln site should be stored as close as possible to the kiln in which it is to be carbonized. A minimum of three months air drying time is recommended. A moisture content of 25% (wet basis) is desirable for efficient charcoal production. Thicker logs, i.e. those having a diameter in excess of 30 cm, should be split once or twice to facilitate the reduction of the moisture content to an acceptable level, and, in turn, shorten the air drying time. Normally, the diameter of the thinnings in the Viphya Forest is such that they do not have to be split.

7.2 Charging the Kiln

First of all, stringers are placed on the kiln floor and arranged in such a way as to form a grid. This is to prevent direct contact between the fuelwood and the ground and to provide sufficient space to allow free circulation of the air from the inlet holes all the way through to the centre of the kiln. The logs are stacked vertically on top of the stringers and packed as tightly as possible. The bigger logs are positioned in the centre of the kiln so that they will be exposed for as long as possible to the higher, carbonization-level temperatures. The kiln charge is completed by the addition of a layer of logs which is stacked horizontally on top of the vertical logs. The kiln will accomodate a total load of approx. 12 stacked m^3 of wood. Special care must be taken to ensure that the air inlet holes at the kiln base remain open. Some dry wood or rubbish is placed in the upper part of the kiln door to serve as kindling. When the kiln has been fully charged, the door is sealed with bricks and mortar and covered with mud from the outside, except for an opening measuring approx. 20.0 x 20.0 cm in the upper part of the door. This hole is called the "ignition eye" and is closed after ignition of the charge.

7.4 Ignition of the Charge

All inlet holes and smoke ports must be open. One or two shovels full of glowing charcoal are thrown in through the ignition eye. Initially, the kiln will give off bluish smoke, which turns white after a short time. This indicates that the initial phase of distillation has begun and that the fuelwood is losing water content. At this time the ignition eye should also be filled in with bricks and mortar and then tightly sealed from the outside with mud. As a rule, the time between ignition and the closing of the eye - by which point the charge has caught fire - does not exceed twenty minutes.

7.5 The Carbonization Phase

The white smoke will continue to be given off through the upper smoke ports for several hours and then start to turn bluish. As soon as blue smoke is released from a particular smoke port, the operator closes this port with a brick fitted to the opening and seals it with mud mortar.

There is no set rule as to where the smoke colour change from white to blue will occur first - i.e. one cannot predict which port will be the first to emit bluish smoke - and this may also depend very much on the prevailing wind direction at each individual kiln location. Furthermore, once bluish smoke has begun to be emitted from one of the ports, the change in colour will not occur immediately in all of the other smoke ports as well; rather, one port after another will begin to discharge blue smoke. After the upper smoke ports of the kiln have been closed and properly sealed, the white smoke will be released through the lower row of smoke ports only. In closing the lower ports, the operator follows the same procedure as in the case of the upper ports, carefully monitoring the colour of the smoke.

As soon as the smoke from a particular port has clearly turned bluish, the operator uses a stick to probe inside to the centre of the kiln in order to ascertain whether or not there is an obstruction (uncarbonized wood). If there are no obstructions and charcoal can be felt, this smoke port may be closed. If uncarbonized or partly carbonized wood obstructs the path of the probe to the centre, the hole may be partially closed using a specially fitted brick. But under no circumstances should it be sealed completely. This procedure serves to delay the combustion of the charcoal in the vicinity of the smoke port and enhance carbonization. If the hole is re-checked within one hour's time and the second probe indicates that a significant amount of uncarbonized wood is still present, it is advisable to slow down the air influx by partially closing the two nearest air inlet holes at the base of the kiln using brick "stoppers". After all the lower smoke ports have been closed and properly sealed, smoke will also begin to exit through some of the air inlet holes. This is perfectly normal and all monitoring and operational procedures must be strictly followed as outlined above until the last air inlet hole has been closed and sealed, at which point the cooling phase begins. If the kiln has been properly charged and operated, the carbonization phase should be completed some ten to twelve hours after ignition.

7.6 The Kiln Cooling Process

It is important that the kiln shell be airtight, i.e. it must be free of leaks or cracks through which air could enter. If air is present, the charcoal charge will start burning and cooling will be delayed significantly. Therefore, after all kiln openings have been closed, the kiln shell is coated at least once with a mud slurry. This will help to reduce the cooling time. When the kiln has cooled down sufficiently, the door may be opened and the fire extinguished with water. After this has been done, unloading may begin, with additional water being applied as necessary. Note that the presence of uncarbonized wood in the kiln will cause a fire to break out, making unloading difficult and requiring the application of more water to extinguish the flames.

The kiln is unloaded by two or three men using special rakes. These tools have 12 - 14 teeth spaced 2.0 cm apart; most of the fines (pieces with a diameter of less than 20 mm) fall through the gaps between the teeth and remain in the kiln. The fines may be removed later after the interior of the kiln has cooled down further. Once it has been unloaded from the kiln, the charcoal is hauled to the nearby storage area. The most common method is simply to place the charcoal on a piece of canvas, which is then carried to the storage area by 3 - 4 men. Experience so far in the Viphya area indicates that a total average cycle time (carbonization and cooling) of 48 hours can be achieved with the Half Orange kiln.

7.7 The Final Step: Allowing the Charcoal to Cure

Any freshly made charcoal tends to absorb oxygen from the ambient air. This reaction results in the emission of heat, and charcoal stored in piles can self-ignite. Thus, charcoal should not be handled or transported in large quantities until it has been allowed to "cure" for a sufficient length of time following its removal from the kiln. A curing time of eight to ten days is usually considered adequate. During curing, neither the height nor the diameter of the charcoal piles should exceed 1.5 m; otherwise, exposure to the air will be insufficient.

7.8 Maintenance of the Kiln

The structure of the Half Orange kiln can be damaged in the course of charcoal production operations, for example by the impact of logs, and this should be avoided. Bricks which have fallen out of the walls or have become loose should be put back into place and rammed tight. Periodically, the excess clay which has accumulated on the exterior of the kiln as a residue of the successive coatings of clay slurry should be removed with a rasp. This will accelerate the charcoal cooling process.

The kiln floor should always be kept level. If necessary, depressions should be filled in with wet clayish soil, which should then be stamped down until it forms a relatively level surface. The water drainage ditches around the kilns must always be kept unobstructed and clear of all rubbish.

8. Operating a Kiln Battery as a Charcoal Production Centre

8.1 To make full use of the installed production capacity in a charcoal centre, the kiln battery should be operated round the clock on a shift basis, with an 8-hour day shift being followed by a 16-hour night shift. During the day shift, the kilns are loaded and unloaded, the charcoal is bagged and transported to the storage area, and necessary maintenance work is performed. During the night shift, one or two attendants are required to operate the kilns (monitoring of the carbonization process, sealing of kilns). The centre should be operated 7 days a week. If it is run on this basis, the centre will produce 35 to 40 kiln loads of charcoal per week, each weighing approx. 1,000 kg. The annual production capacity of the centre will thus be 1,400 tonnes (assuming it is operated for 40 weeks a year). In practice, capacities of around 1,200 tonnes per year or 100 tonnes per month will probably be the norm.

8.2 The flow of firewood must be managed by a separate group of workers. They cut down trees in the forest that have been marked for felling by the Forestry Department. After a sufficient drying period has elapsed - usually between 3 and 6 months - the trees are cut into 1.5-metre-long logs and loaded onto ox-carts or sledges and hauled to the production centre. The centre should always maintain a large enough "stockpile" of firewood to keep the kilns running for one week even if there is an interruption in feedstock supply. The water tanks at the centre should have a total capacity of 5-6 m^3. They must always be kept full. In case of a fire in the wood stocks or in the nearby forest, this water must be readily available. Empty bags must also be kept in store. Approx. 3,000 bags should be on hand at all times.

8.3 A standard production centre has to employ a labour force of between 50 and 60 people. Their tasks are as follows:

1 centre manager/supervisor
1 foreman: transport
3 kiln operators
12 workers: charcoal production
35 wood cutters/transporters
6 ox-cart attendants
2 watchmen

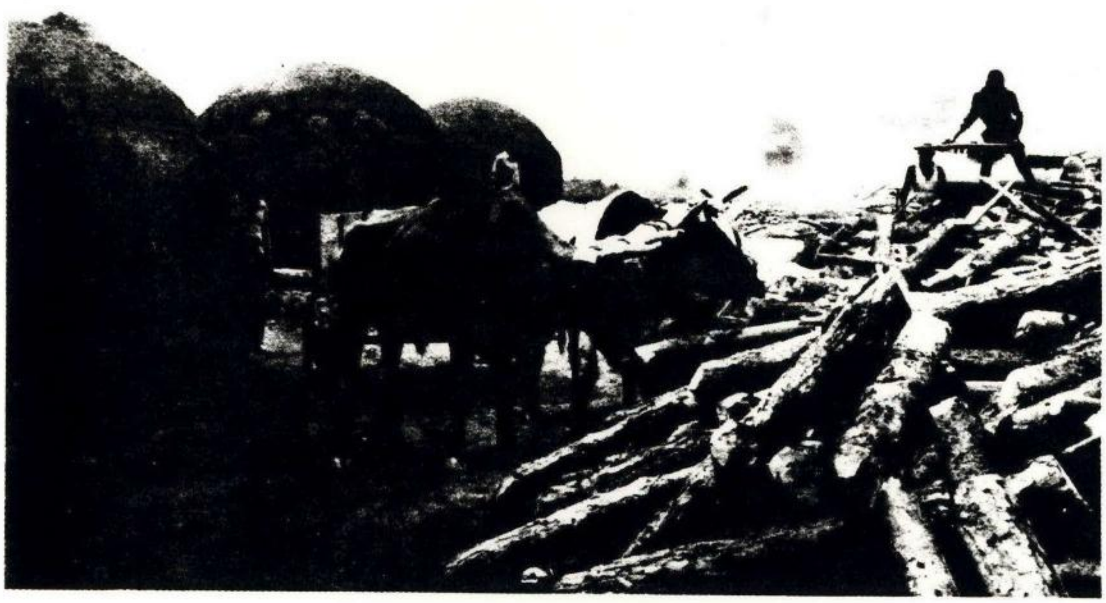
Utilization of the shift system means that 40 workers will be at the site during the day shift (assuming each works a 5-day week). The night shift can be performed by two people (1 watchman and 1 kiln operator).

MALAWI CHARCOAL PROJECT

Charcoal Production from Plantation Wood

A Guide to the Development of Small-Scale Charcoal Industries

Dr. W. Emrich
G.H. Zieroth



Lilongwe, February 1987

Table of Contents

1. Introduction

1.1 The following guide deals with the establishment and operation of semi-industrial charcoal production schemes in Malawi. The methods and technologies described below have already been introduced on a pilot scale in the Viphya Forest, one of the largest forest plantations in Africa and the single most important wood resource in Malawi. The guide summarizes the results obtained so far in the framework of the Malawi Charcoal Project and incorporates the practical insights gained by the Project Team in the course of implementing the various charcoal production activities that have been undertaken to date. It is obviously beyond the scope of this brief guide to provide succinct practical advice on the solution of any and all problems that may arise in the development of small charcoal industries. However, the authors are confident that it will prove to be a valuable basic tool for project planners and managers, as it will help them to understand the fundamental issues involved in setting up such industries and deal with the problems most commonly encountered in the establishment and operation of semi-industrial charcoal production schemes.

1.2 The Malawi Charcoal Project is financed by the World Bank and is being executed by the Forestry Department. IPC Consultants, Frankfurt, were commissioned by the Government of Malawi to provide management and technical assistance in the field of improved charcoal production methods. IPC hopes that this guide will help to promote improved natural resource management in Malawi by contributing to more efficient biomass utilization.

G. Zieroth, Project Coordinator

2. The Choice of Kilns

2.1 The purpose of a charcoal industry is to produce an economically competitive fuel for industrial and household consumers. As a commercial operation, the production process must be organized and run in a cost-effective way in order to allow a charcoal company to make a reasonable profit. On the other hand, however, the technology employed should permit the production of the maximum possible amount of charcoal from a given biomass resource. The kiln technology influences:

- the investment costs,
- the labour costs, and
- the feedstock costs (royalites, stumpage fees and internal transport).

2.2 There are two different kiln technologies that may be considered basically suitable for use in a semi-industrial charcoal operation: **steel kilns and clay or fire brick kilns**. Although the utilization of traditional earth mound kilns does not involve investment costs, they must be ruled out at the semi-industrial level for the following reasons:

- process and quality control are very difficult,
- contamination of the product with soil cannot be avoided,
- under wet weather conditions such as those encountered in the Viphya Forest, they do not permit year-round operation of production facilities, and
- they are less efficient than the other two options and give rise to high specific feedstock costs.

Only the fact that most of the wood used in the traditional charcoal sector is obtained at either zero or near-zero cost makes the earth mound kiln as attractive as it is for the individual charcoal burner. At the other end of the technology range are the sophisticated industrial carbonization units such as converters and retorts. They require a high level of capital investment and are used in situations where labour costs are high and the feedstock for carbonization is expensive. With such systems, a gradual, step-by-step development of charcoal industries is not possible, and projects employing high-tech converters are risky if the market for the products is uncertain. They have to be ruled out as unsuitable options for semi-industrial charcoal operations such as the Viphya charcoal industries.

Steel Kilns

2.3 On the one hand, steel kilns produce an output that meets the quality standards required of industrial charcoal, and on the other, they can meet the need for a certain level of efficiency - important advantages at the semi-industrial level. However, their investment costs are high. In Malawi, a Mark V or Aldred-design steel kiln costs MK 2,500 (US$ 1,225), excluding surtax. The lifetime of these kilns is limited, and field experience in many charcoal production schemes has shown that their maximum service life is usually only about one year if they are operated on a full-time basis. Moreover, steel must be imported in countries such as Malawi and paid for with foreign exchange. The major advantage of steel kilns - their transportability - can only be regarded as an important criterion if internal transport costs are high due to dispersed availability of wood, i.e. if feedstock resources are scattered over a large catchment area. This is not the case in forest plantations such as the Viphya where ox-carts can be used as a cheap means of wood transport. In addition, wood preparation costs are higher if Mark V kilns or other steel kilns of similar design are used (feedstock must be cut into 0.3-metre-long pieces). Finally, in view of the fact that the average yields of steel kilns are lower than those that can be achieved with brick kilns, it is clear that they cannot be considered a cost-effective option for charcoal making (see table at end of next section).

Brick Kilns

2.4 Brick kilns are employed in huge numbers in South America. Hundreds of industrial charcoal operations rely on this technology, which has been in use for many years and whose cost-effectiveness has been clearly established for decades. Brick kilns can be constructed from locally available materials and they can be easily operated by local people. Their efficiency is high compared to other systems.

Of the various kinds of brick kilns, the "Half Orange Fire Brick Kiln" and the "Beehive Kiln" are the two most popular designs. Although kilns of this general type vary greatly in terms of both size and precise mode of operation, this guide will concentrate on one particular model - the Half Orange - which has proved to be an appropriate solution within the framework of the Malawi Charcoal Project. One unit of this type costs approximately MK 300, including bricks, clay soil, transport and labour input. Fire brick kilns can be repaired on site if they are damaged. If properly operated, they last for fifteen years. In case they have to be moved, they can be dismantled and rebuilt elsewhere. Wood preparation is less costly than, say, with steel kilns. The Half Orange kiln can accomodate logs up to 1.8 metres in length and 0.3 metres in diameter. The advantages of fire brick kilns are obvious. However, like all kiln-based charcoal making systems, they also have certain drawbacks:

- Due to their smoke exhausts, batteries of more than 12 kilns may be regarded as a nuisance by nearby residents.

- The recovery of charcoal by-products (tar, creosote) is feasible, but requires costly and sophisticated equipment.

The Characteristics of the "Mark V Steel Kiln" and the "Half Orange Fire Brick Kiln"

	Capacity m^3	Yield[1] %	Cycle time hours	Cost per unit (MK)	Cost per m^3 (MK)	lifetime[2] years
Mark V	8 - 10	18 - 22	24 - 36	3,000	300	2
Half Orange	10 - 20	28 - 32	36 - 60	300	20	15

1) for a given weight of properly seasoned wood
2) lifetime of steel kilns if properly operated

3. The Charcoal Making Process

3.1 Carbonization, charring or charcoal making takes place if organic matter - in general firewood - is heated up to temperatures of between 420° C and 550° C in the absence of air or if the air intake is restricted. Many different chemical reactions take place during the process of carbonization, but there are always two end products:

- charcoal (solid fuel), and
- carbonization gas (gaseous fuel).

The process can be controlled by regulating the heat which is applied to the kiln. The higher the temperature level of the carbonization process, the greater is the share of carbon in the resulting charcoal. For fire brick kilns, two different methods are used to control the temperature:

- internal heating (control of air inflow), and
- external heating (control of combustion in a separate fire box).

The Half Orange kiln described below is an internally heated model, i.e. a part of the kiln load has to be burnt to provide energy for the carbonization process.

3.2 The specific properties of the feedstock, i.e. the firewood used for charcoal making, have a great influence on the quality of the end product and the efficiency of the process. Hardwood is regarded as the best feedstock and yields a high-density charcoal with a high heating value per unit of volume. Softwood such as pine produces a lighter and more friable charcoal. By weight the heating value is comparable to that of hardwood charcoal. One kg of pinewood charcoal contains approximately the same amount of energy as one kg of hardwood charcoal.

For a given type of feedstock, the moisture content of the wood, i.e. the amount of water which it contains when loaded into a kiln, determines the efficiency of the charcoal making process and the quality of the end product. Firewood for charcoal making should always be **properly** seasoned: the moisture content of the wood must be 25% or less in order to achieve reasonable yields from the kiln. A high moisture content requires more heat to drive the water off and more wood has to be burnt for this purpose, thus reducing the amount which can be carbonized, i.e. turned into charcoal. The firewood loaded into the kiln should be dry, clean (not contaminated with soil), and of fairly uniform size.

4. Developing a Charcoal Industry

4.1 Many people have tried to introduce improved kilns and charcoal making methods in countries such as Malawi. Some have failed because they focused exclusively on the technology and ignored the business aspects of charcoal production. Before one begins to introduce charcoal technologies, one must have a clear picture of the market for which one will be producing. Prices for competing fuels such as kerosene, firewood, coal, diesel oil and, last but not least, charcoal made with traditional earth mound kilns, must be known. The cost of the raw materials, i.e. the effort involved in harvesting and transporting the feedstock to the kilns, is also important. Transport costs for the final product can kill any charcoal industry - even one with very efficient production methods - if the production site is too far away from the consumers. Thus, one must thoroughly investigate such factors before one begins spending money on any type of improved charcoal making facilities.

4.2 Charcoal making using improved methods is an organized manufacturing process requiring management, skilled labour and investment. A charcoal industry can never succeed if the company that produces and markets the fuel cannot make a profit. Even if resources that would otherwise simply be wasted are available for carbonization, e.g. wood from bush clearing and forestry operations such as thinning, the charcoal industry must still sell the end product at a price that is sufficient to cover the cost of making the charcoal. Moreover, even a small-scale charcoal industry has to invest money, pay back credits and cover operating costs. It is a business that requires planning! After he has set up his production facility and started operations, a charcoal maker has to manage and supervise his labour force, keep records, pay salaries and keep in touch with his customers. Warehousing might be required, and tools and internal transport equipment must be maintained, repaired and periodically replaced.

4.3 If the feedstock is taken from government forests or timber plantations, the charcoal industry must negotiate royalties or stumpage fees. An uninterrupted flow of raw material is essential in order to keep the business running and long-term supply arrangements might be necessary. A charcoal operation that is restricted to the charcoal maker's own land cannot go on forever. And even if the feedstock is being drawn from a relatively large area, at some point the supply of trees might be exhausted, thus making replanting a necessity. As soon as this stage has been reached, and assuming the objective is to continue production on a long-term, sustained basis, simple charcoal making gives way to a more complex process of biomass resource management. In any case, before a charcoal industry is established, a comprehensive feasibility analysis must be conducted which takes all of the relevant issues and problems into consideration.

5. Setting Up a Charcoal Industry on the Basis of Half Orange Brick Kilns

5.1 Once a decision has been made to produce charcoal on a semi-industrial scale, it is of crucial importance to select a suitable site for the production centre. In the case of the Viphya Forest operation, thinning wastes are the most important feedstock for charcoal production. An uninterrupted flow of raw material must be assured so as to permit year-round operation of the facility, and, logically enough, the size of the catchment area that will be required is determined by the size of the production centre that is to be established. Based on operational experience to date, a battery of 12 Half Orange kilns with an annual throughput of 1,000 stacked m^3 each may be considered an appropriately sized production centre. The total biomass input required for a centre of this type is 12,000 stacked m^3 per year, and the productivity of the Viphya

Forest permits the extraction of approximately 20 stacked m^3 of wood per ha and year. Consequently, a catchment area of between 600 and 1,000 ha is needed in order to supply this amount of raw material on an annual basis.

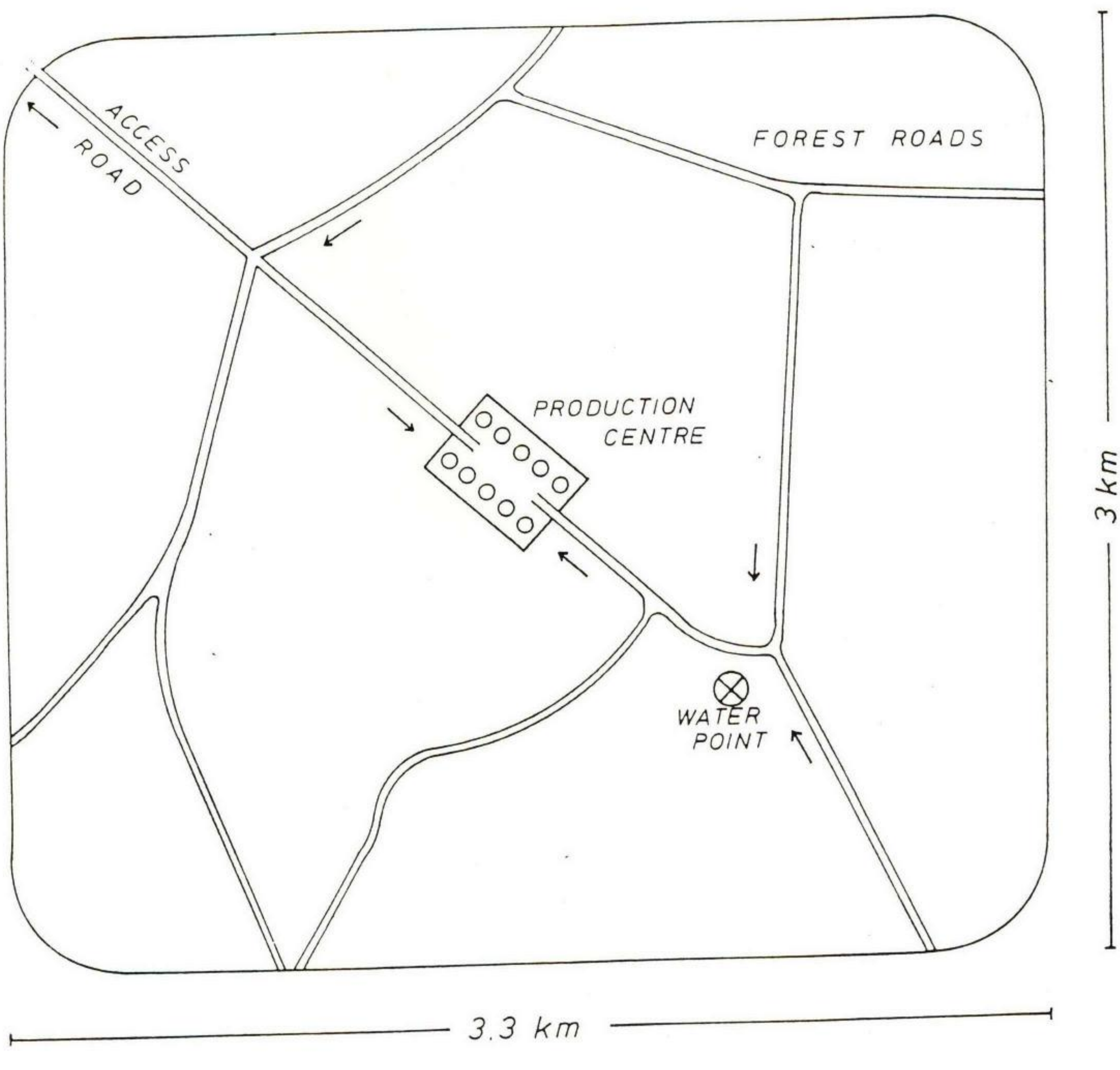
5.2 The site of the charcoal production facility should be close to the centre of the catchment area. The maximum transport distance for firewood should not exceed 2,000 metres if ox logging or ox-cart transport are used. The production centre should be provided with an all-weather access road capable of accomodating heavy trucks. Road improvement measures such as gravelling may be required to permit year-round access. The centre should also have good drainage conditions to prevent flooding during heavy rains. There should also be a water point within the catchment area (well, stream), and it should be located as close to the centre as possible. Water is required for the preparation of mortar (kiln construction and sealing of kiln shell) and for extinguishing burning charcoal (see sketch).

5.3 As a rule, six or more kilns will be installed in a battery, and the site must be large enough to accomodate the total number of kilns that is planned for the centre. There must also be sufficient space at the site for the storage of both firewood and charcoal. In addition, a store room for tools and bags is required as well as a shelter for watchmen and operating personnel, and there must be room for two or three water tanks in the vicinity of the kilns. The total area required for a 12-kiln production centre is approximately 0.8 ha (see sketch).

5.4 The site should be cleared of all vegetation. If necessary, the site should be levelled or filled in. A separate drainage ditch must be dug around each kiln. The drainage system should be installed before or during construction. If kilns are constructed during the wet season, plastic sheets or tarpaulins will be required to protect the unfinished kilns from damage by heavy rains. A partially completed kiln may be destroyed by a heavy rain!

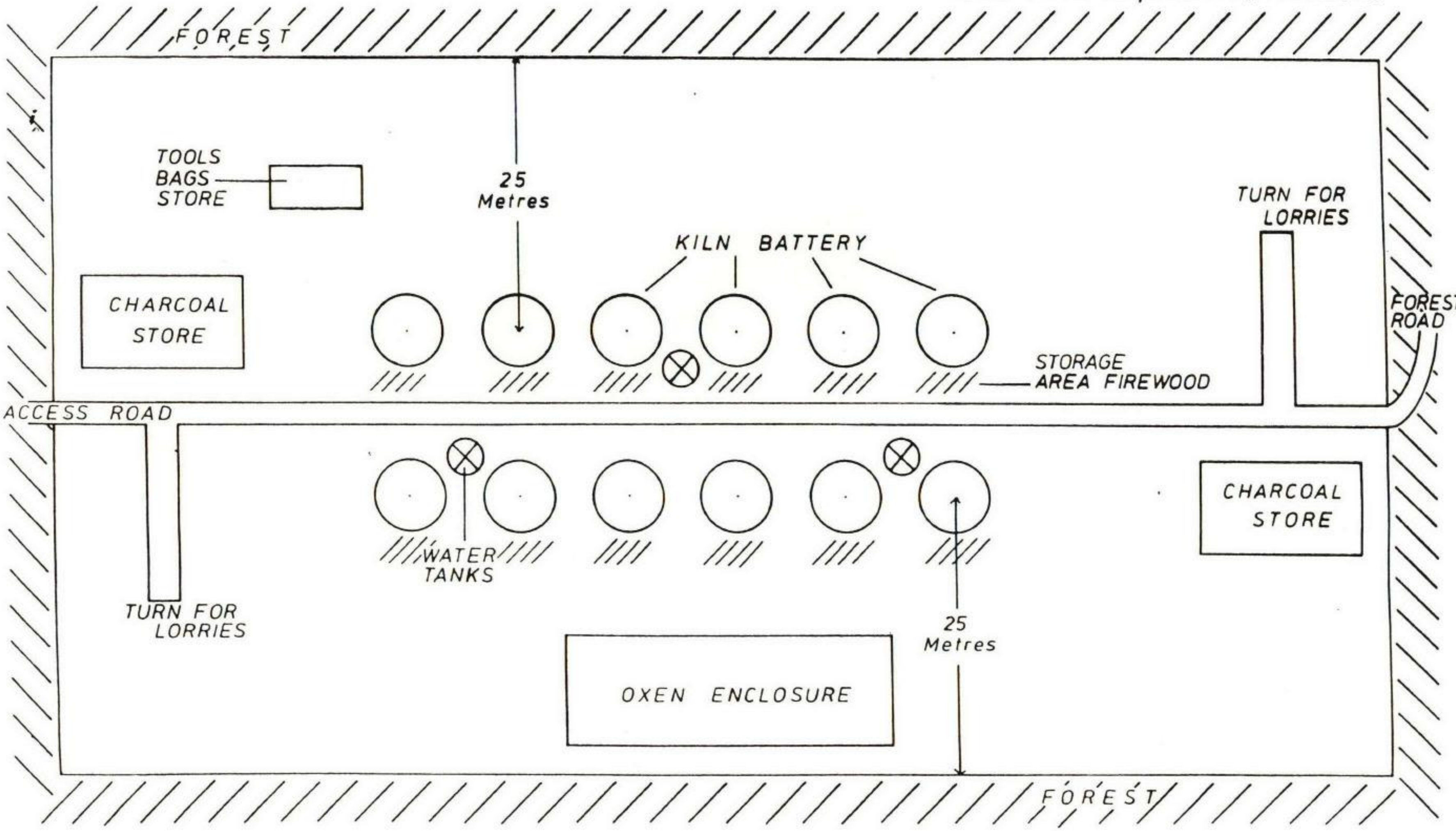
CHARCOAL PRODUCTION CENTRE

Catchment Area



CHARCOAL PRODUCTION CENTRE (General lay out)

Total area required: 0,8 hectare



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Before starting construction, all necessary equipment should be brought to the site. This includes:

- axes, panga knives
- mason's tools (level, radius rod with leader)
- shovels, hoes, spades
- water buckets
- ropes
- plastic sheets, tarpaulins
- construction material (per kiln approximately 2,500 soft burned bricks, 0.5 m^3 of clay soil and 2 pieces of angle iron or flat bars).

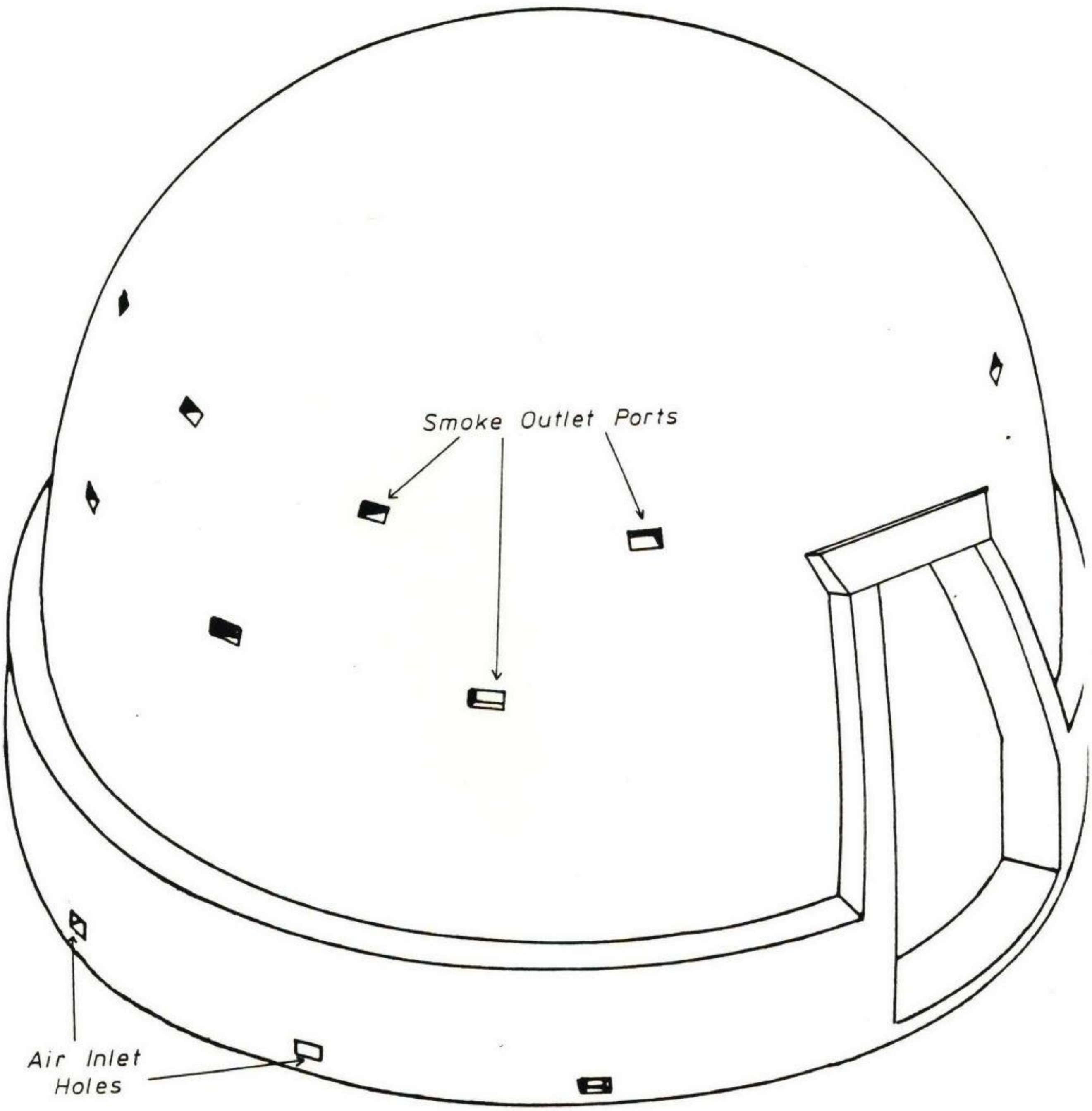
The steel bars may not be required, but they facilitate kiln construction.

6. Construction of Half Orange Kilns

6.1 The basic design and outward appearance of the "Half Orange" kiln are shown in Figure 1. The main dimensions are given in Figures 2a and 2b. After the site preparation works have been completed, the place for each kiln should be marked as shown in Figure 3. It is advisable to set wooden pegs at 80-cm intervals along the inner and outer circles of the foundation line. It is essential to ensure that the centre pole (see Figure 3) at each individual kiln site is firmly implanted in the ground to prevent it from being accidentally removed or broken off.

6.2 After the site has been properly marked, the foundation ditch is dug; the inner and outer circle lines should be closely followed (Figure 3). The recommended depth is 50 cm. When completed, the ditch is usually half filled with gravel. (Depending on the consistency of the soil, this 25-cm-thick layer of gravel may not be required; in most places in the Viphya Forest, for example, the foundation can be built without gravel.) It is advisable to check the foundation frequently with a level as the work progresses to ensure that the kiln base is in fact horizontal (Figure 4).

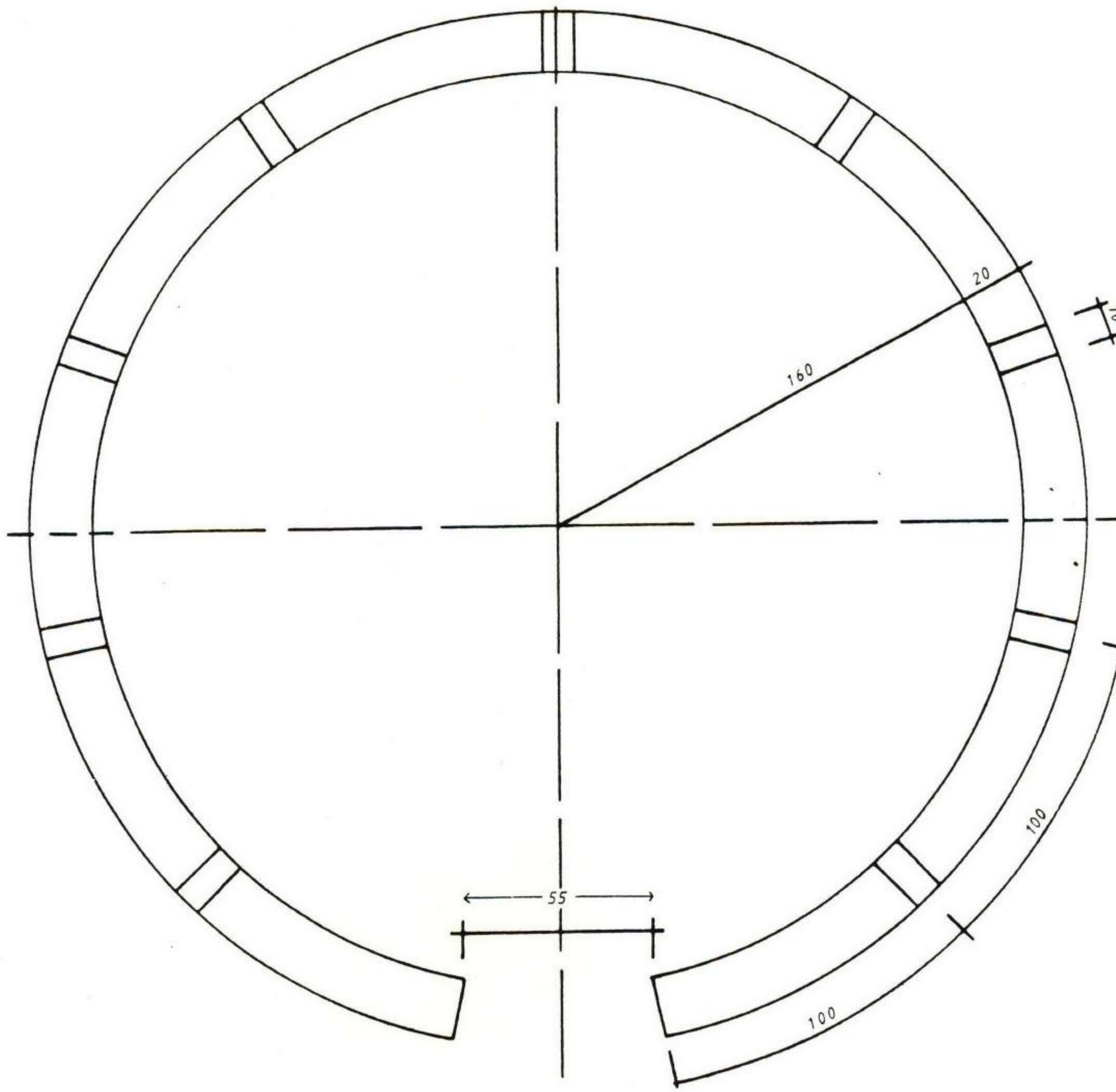
Figure 1: Half Orange Fire Brick Kiln



CONSTRUCTION MATERIAL:

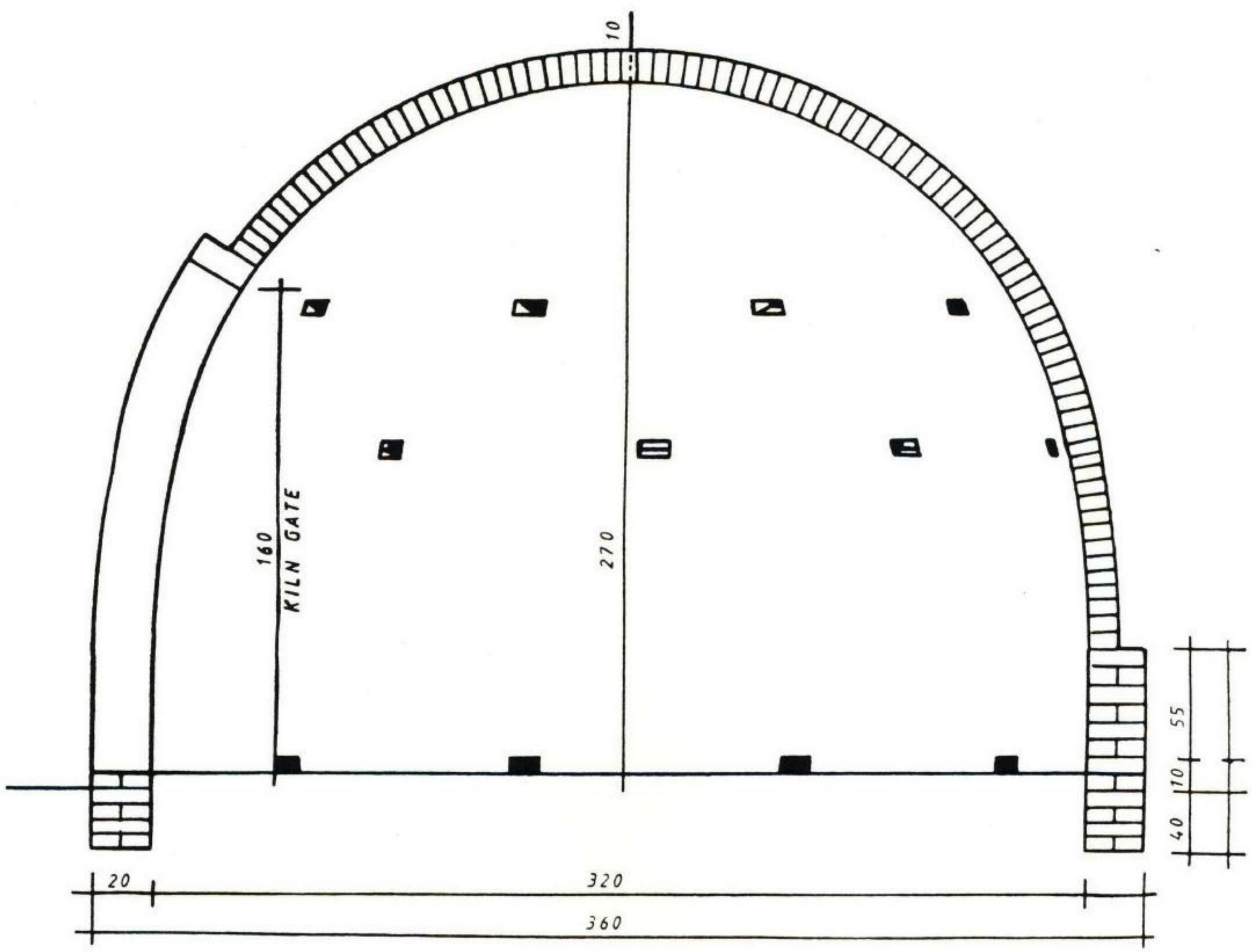
2,500 bricks: 22.5 x 18 x 8.5 cm
0.5 m^3 of clay soil
2 pieces of angle iron 60 cm (or flat bars)
water

Figure 2a: Ground Plan



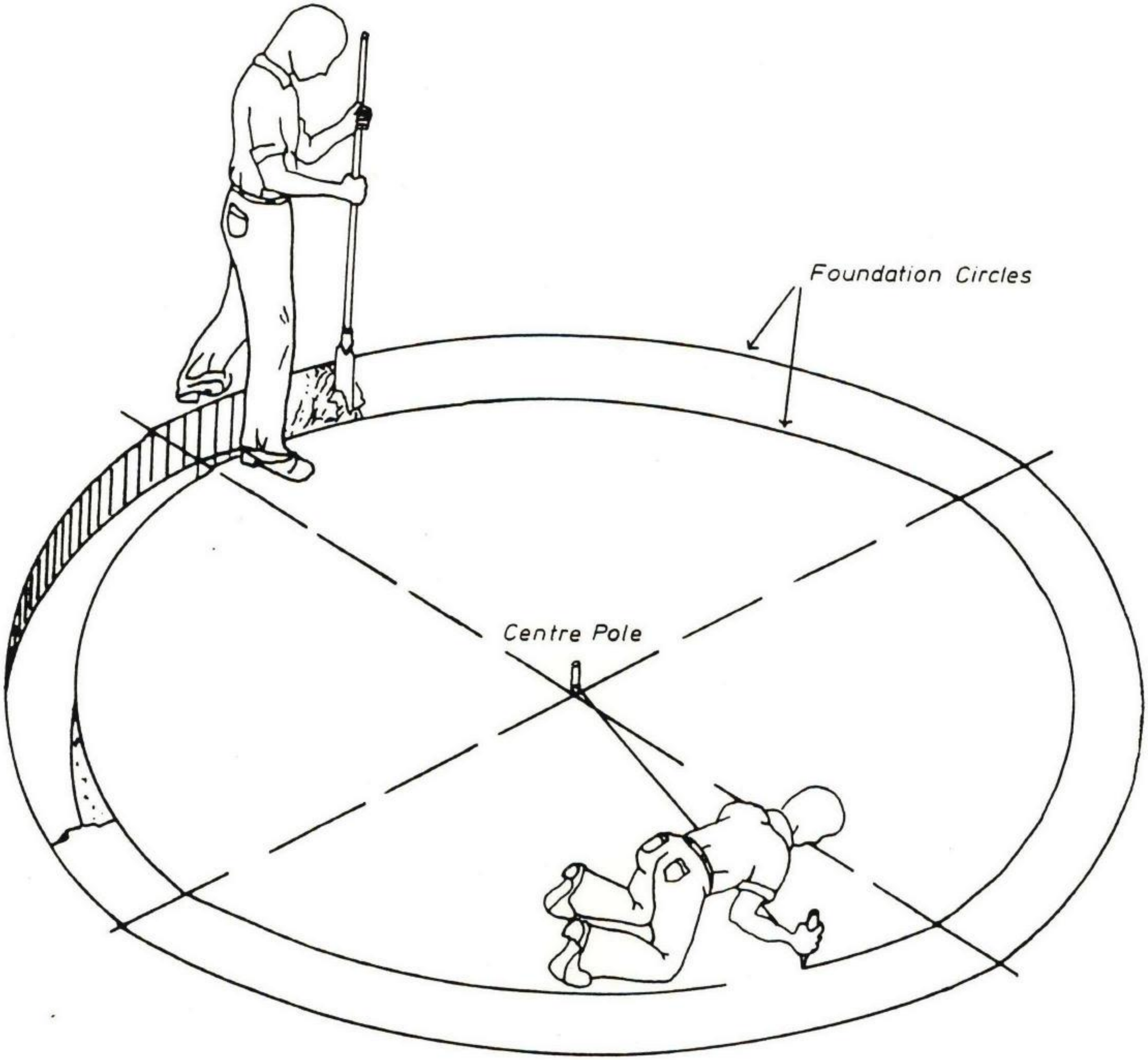
Dimensions in cm

Figure 2b: Cross Section



Dimensions in cm

Figure 3: Marking the Kiln Site



The off-ground construction work begins with the fifth row of bricks. Nine air inlet holes, as well as the 60-cm-wide base of the kiln entrance, must be positioned in the first row (Figure 2a). The air inlet holes measure 9.0 x 6.0 cm and are approximately 1.0 m apart (Figure 2a). The vertical part of the kiln is called the "straight jacket" and consists of seven layers of bricks. A tool called a radius rod (as shown in Figures 5, 6 and 7) can be a great help in maintaining a precise, uniform distance between the "straight jacket"/cupola wall and the centre of the kiln.

6.3 While the kiln foundation and the "straight jacket" are constructed as double walls, the kiln cupola is designed as a single-wall structure, except for the two reinforced sides of the kiln entrance (Figure 7). The space enclosed by the cupola of the kiln is not strictly spherical; rather, the cross-section of the structure resembles a semi-circle which has been "elongated" vertically to a height of 2.70 m. In order to construct the cupola, the unskilled builder needs a radius rod with a "leader" as shown in Figure 6. The use of this radius rod is illustrated in Figure 7. Using the "leader", the distance between the individual rows of bricks and the centre can be changed by extending the radius rod according to the following resetting table:

Number of brick row: cupola	**Resetting of the leader**
Rows 1 - 5	1.0 cm for each layer
Row 6	2.0 cm
Rows 7 - 10	2.5 cm for each layer
Rows 11 - 14	2.0 cm for each layer
Rows 15 - 18	1.5 cm for each layer
Rows 19 - 24	1.0 cm for each layer
Rows 25 - 32	0.5 cm for each layer
Rows 33 - 37	NO RESETTING

Figure 4: Building the Foundation

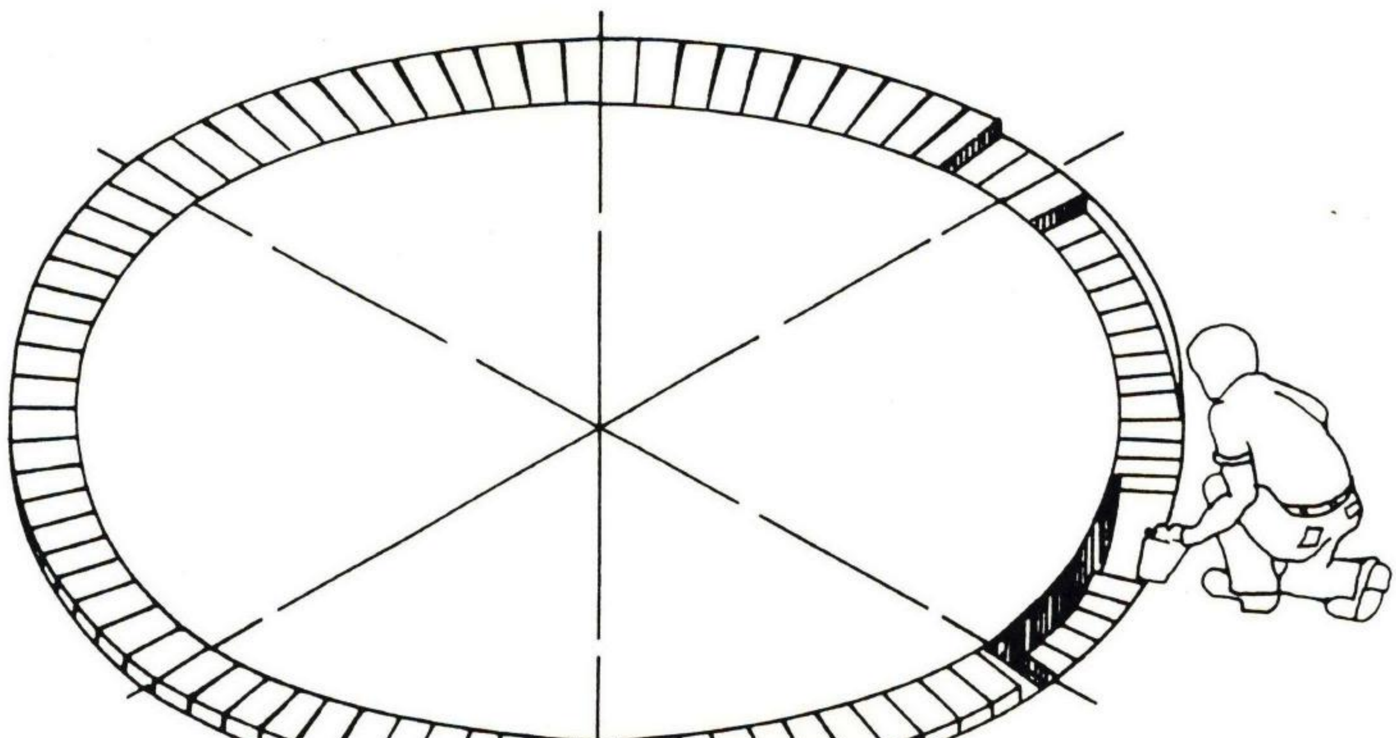


Figure 5: Putting in the Last Fire Brick Layer of the "Straight Jacket"

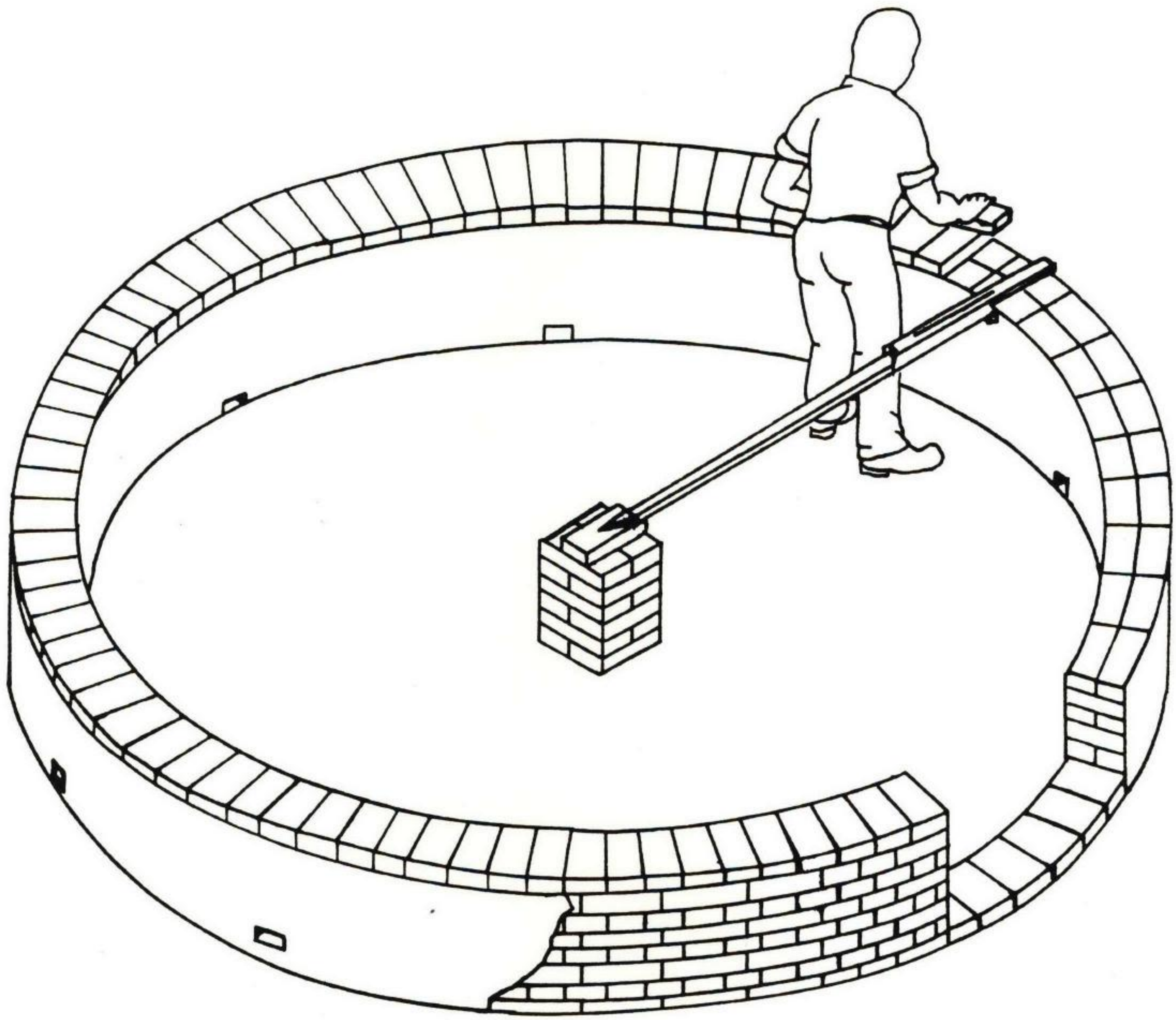


Figure 6: Radius Rod with "Leader"

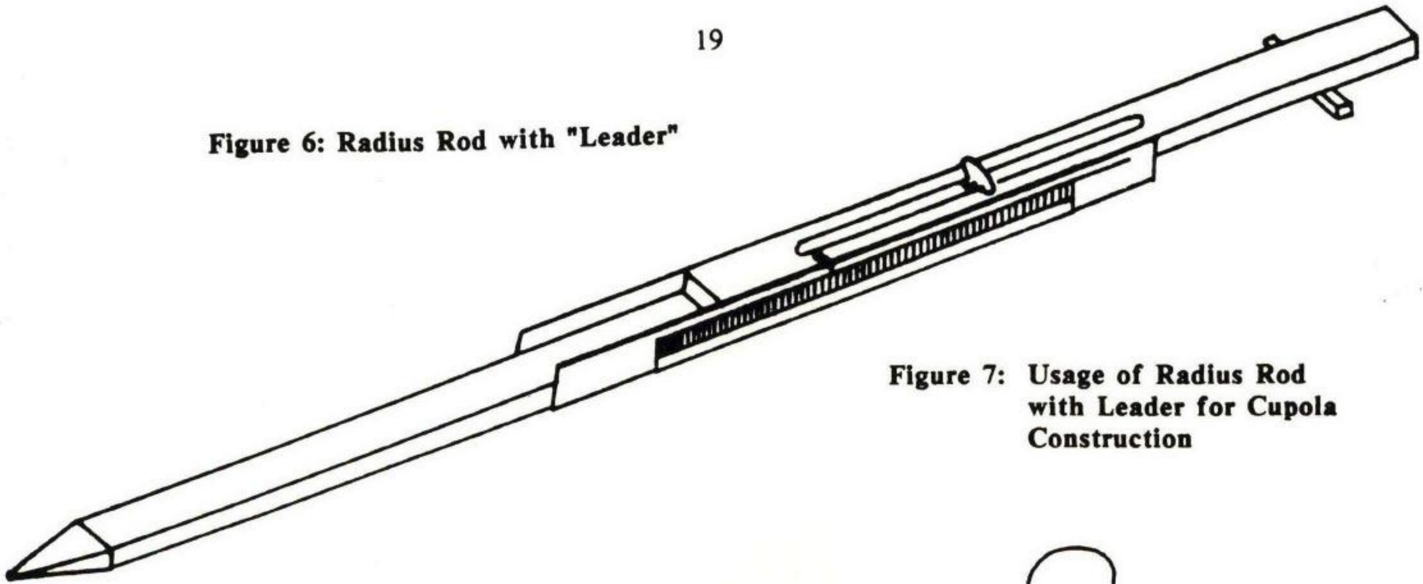
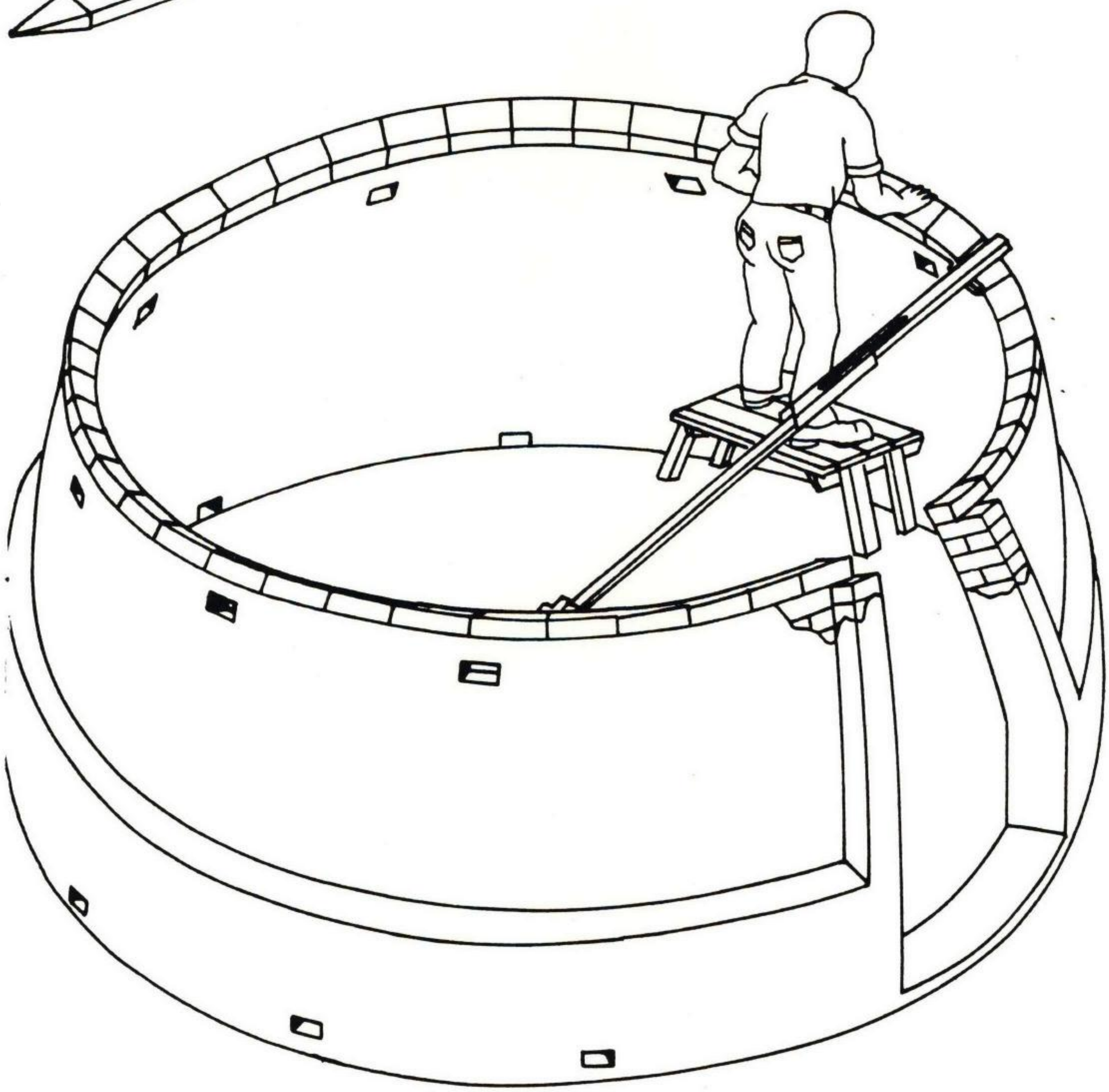


Figure 7: Usage of Radius Rod with Leader for Cupola Construction



This resetting table has been calculated for bricks measuring 22.5 x 18.0 x 8.5 cm. If other brick sizes are used, the resetting figures must be adjusted accordingly. The technical details of the radius rod with "leader" are illustrated in Figure 8.

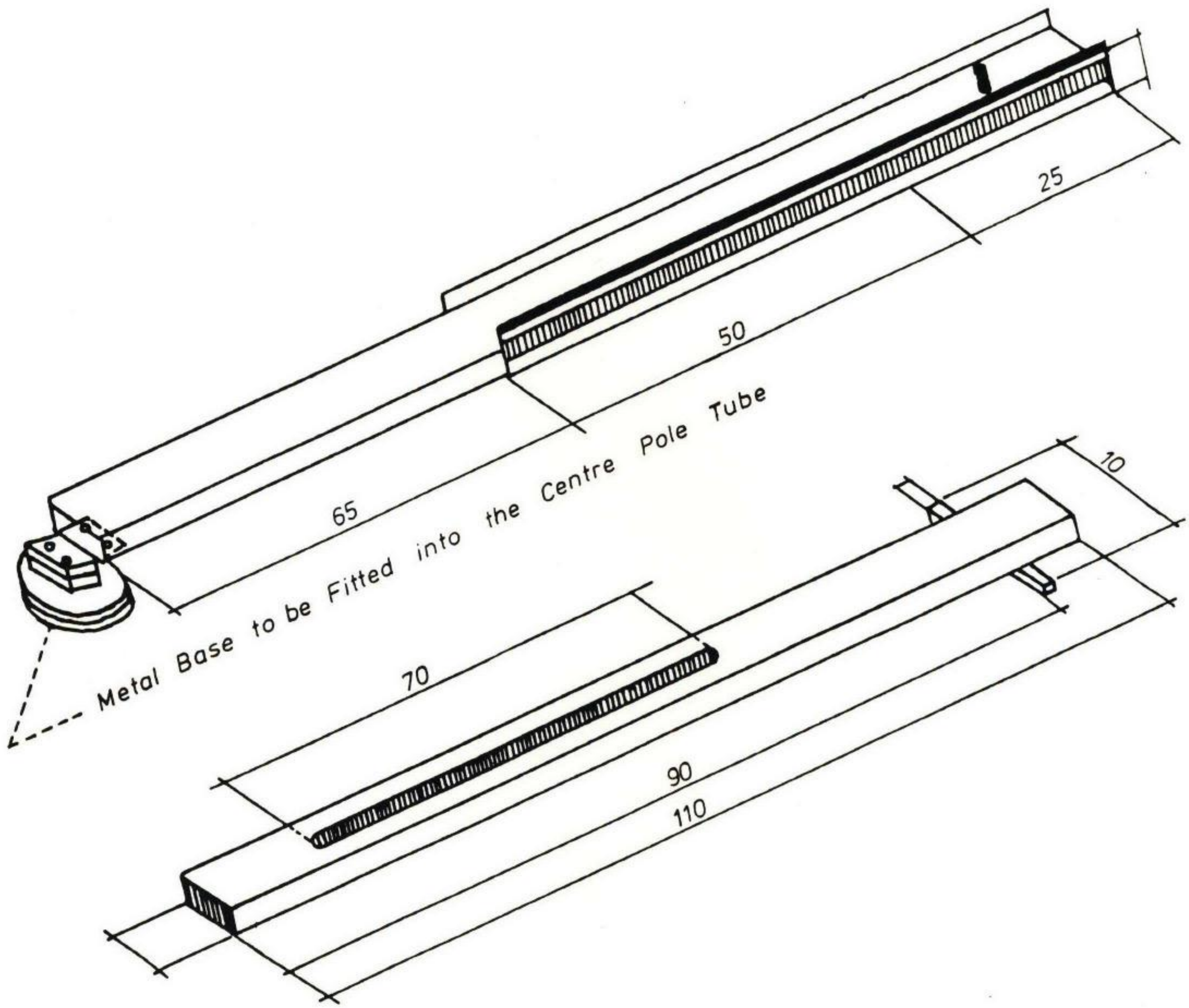
The total height of the entrance should not exceed 170 cm. The ten lower smoke outlet ports, which measure 10 x 6 cm, are positioned approximately two brick rows above the top of the entrance (Figure 1). The seven upper smoke outlet ports (10 x 6 cm) are located eight brick rows above the lower outlet ports; they are spaced equidistantly and staggered with respect to both the lower smoke ports and the air inlet holes (Figure 9).

For optimal kiln construction it is important to apply as little mortar as possible within the "straight jacket" and cupola areas. All bricks within the cupola must be positioned so that their inner edges fit tightly together.

After the construction work has been finished, the entire kiln shell must be coated on the outside with mortar to seal cracks through which air could escape. The thickness of the mortar cover should not exceed 1.0 cm.

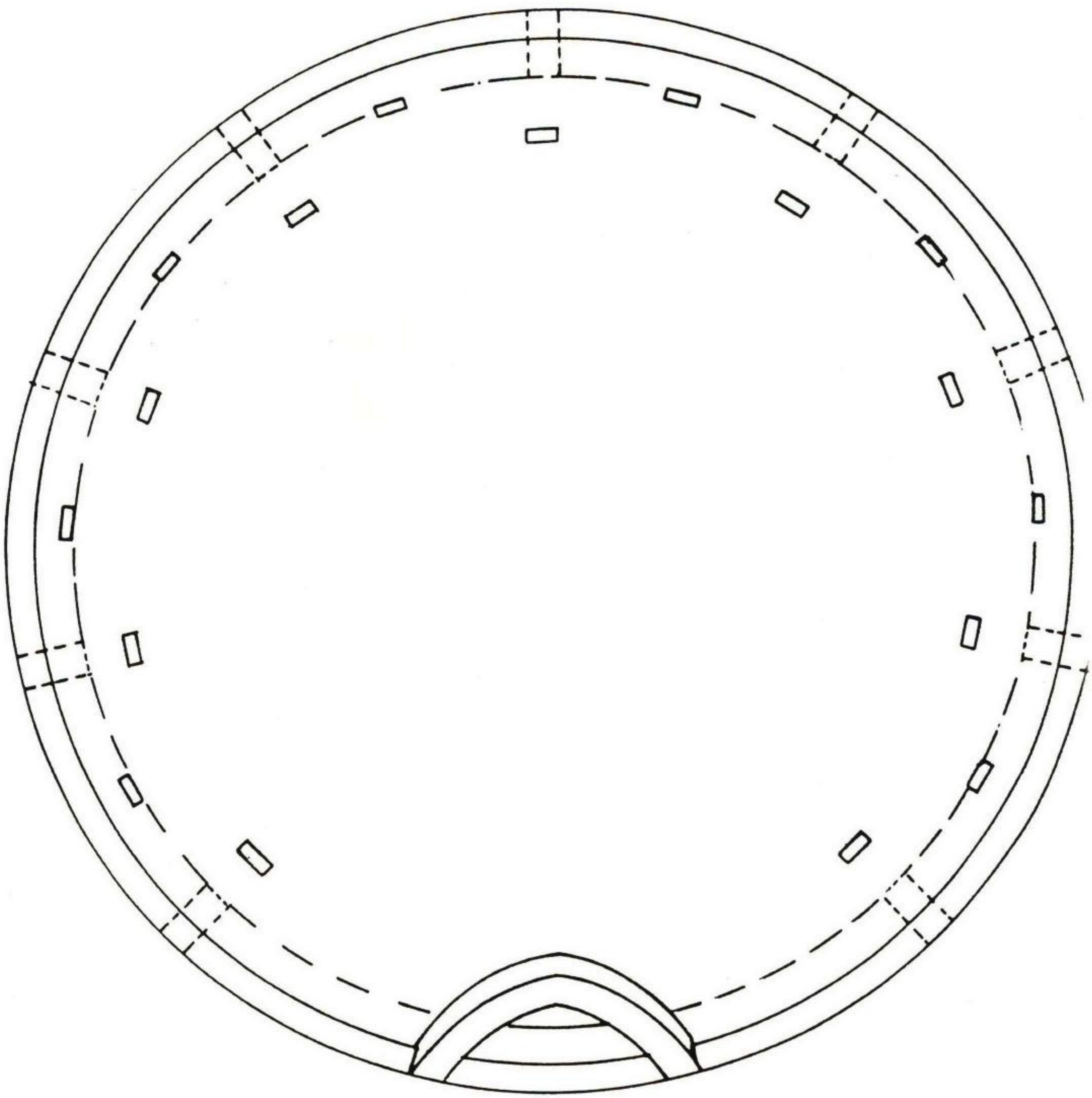
Before the first charcoal run, the wet kiln must be burnt out for several days. For this purpose, a fire is maintained continuously inside of the kiln. The flames should not be allowed to reach the ceiling of the cupola. Thus, an attendant must be on duty round the clock during the entire burning-out period. Even after the burning-out process is finished, a kiln is still considered to be "green". The structure does not achieve its full strength and durability until the completion of three to four charcoal runs.

Figure 8: Details of a Radius Rod with Leader for the Construction of Half Orange Kilns



Dimensions in cm

Figure 9: Distribution Plan of Air Inlet Holes and Smoke Outlet Ports



7. Operation of Half Orange Kilns

7.1 Fuelwood Preparation

Fuelwood which is to be utilized as feedstock is cut into pieces approx. 1.2 - 1.5 m in length having a minimum diameter of 3.0 cm and a maximum diameter of 30.0 cm.

The fuelwood which is transported to the kiln site should be stored as close as possible to the kiln in which it is to be carbonized. A minimum of three months air drying time is recommended. A moisture content of 25% (wet basis) is desirable for efficient charcoal production. Thicker logs, i.e. those having a diameter in excess of 30 cm, should be split once or twice to facilitate the reduction of the moisture content to an acceptable level, and, in turn, shorten the air drying time. Normally, the diameter of the thinnings in the Viphya Forest is such that they do not have to be split.

7.2 Charging the Kiln

First of all, stringers are placed on the kiln floor and arranged in such a way as to form a grid. This is to prevent direct contact between the fuelwood and the ground and to provide sufficient space to allow free circulation of the air from the inlet holes all the way through to the centre of the kiln. The logs are stacked vertically on top of the stringers and packed as tightly as possible. The bigger logs are positioned in the centre of the kiln so that they will be exposed for as long as possible to the higher, carbonization-level temperatures. The kiln charge is completed by the addition of a layer of logs which is stacked horizontally on top of the vertical logs. The kiln will accomodate a total load of approx. 12 stacked m^3 of wood. Special care must be taken to ensure that the air inlet holes at the kiln base remain open. Some dry wood or rubbish is placed in the upper part of the kiln door to serve as kindling. When the kiln has been fully charged, the door is sealed with bricks and mortar and covered with mud from the outside, except for an opening measuring approx. 20.0 x 20.0 cm in the upper part of the door. This hole is called the "ignition eye" and is closed after ignition of the charge.

7.4 Ignition of the Charge

All inlet holes and smoke ports must be open. One or two shovels full of glowing charcoal are thrown in through the ignition eye. Initially, the kiln will give off bluish smoke, which turns white after a short time. This indicates that the initial phase of distillation has begun and that the fuelwood is losing water content. At this time the ignition eye should also be filled in with bricks and mortar and then tightly sealed from the outside with mud. As a rule, the time between ignition and the closing of the eye - by which point the charge has caught fire - does not exceed twenty minutes.

7.5 The Carbonization Phase

The white smoke will continue to be given off through the upper smoke ports for several hours and then start to turn bluish. As soon as blue smoke is released from a particular smoke port, the operator closes this port with a brick fitted to the opening and seals it with mud mortar.

There is no set rule as to where the smoke colour change from white to blue will occur first - i.e. one cannot predict which port will be the first to emit bluish smoke - and this may also depend very much on the prevailing wind direction at each individual kiln location. Furthermore, once bluish smoke has begun to be emitted from one of the ports, the change in colour will not occur immediately in all of the other smoke ports as well; rather, one port after another will begin to discharge blue smoke. After the upper smoke ports of the kiln have been closed and properly sealed, the white smoke will be released through the lower row of smoke ports only. In closing the lower ports, the operator follows the same procedure as in the case of the upper ports, carefully monitoring the colour of the smoke.

As soon as the smoke from a particular port has clearly turned bluish, the operator uses a stick to probe inside to the centre of the kiln in order to ascertain whether or not there is an obstruction (uncarbonized wood). If there are no obstructions and charcoal can be felt, this smoke port may be closed. If uncarbonized or partly carbonized wood obstructs the path of the probe to the centre, the hole may be partially closed using a specially fitted brick. But under no circumstances should it be sealed completely. This procedure serves to delay the combustion of the charcoal in the vicinity of the smoke port and enhance carbonization. If the hole is re-checked within one hour's time and the second probe indicates that a significant amount of uncarbonized wood is still present, it is advisable to slow down the air influx by partially closing the two nearest air inlet holes at the base of the kiln using brick "stoppers". After all the lower smoke ports have been closed and properly sealed, smoke will also begin to exit through some of the air inlet holes. This is perfectly normal and all monitoring and operational procedures must be strictly followed as outlined above until the last air inlet hole has been closed and sealed, at which point the cooling phase begins. If the kiln has been properly charged and operated, the carbonization phase should be completed some ten to twelve hours after ignition.

7.6 The Kiln Cooling Process

It is important that the kiln shell be airtight, i.e. it must be free of leaks or cracks through which air could enter. If air is present, the charcoal charge will start burning and cooling will be delayed significantly. Therefore, after all kiln openings have been closed, the kiln shell is coated at least once with a mud slurry. This will help to reduce the cooling time. When the kiln has cooled down sufficiently, the door may be opened and the fire extinguished with water. After this has been done, unloading may begin, with additional water being applied as necessary. Note that the presence of uncarbonized wood in the kiln will cause a fire to break out, making unloading difficult and requiring the application of more water to extinguish the flames.

The kiln is unloaded by two or three men using special rakes. These tools have 12 - 14 teeth spaced 2.0 cm apart; most of the fines (pieces with a diameter of less than 20 mm) fall through the gaps between the teeth and remain in the kiln. The fines may be removed later after the interior of the kiln has cooled down further. Once it has been unloaded from the kiln, the charcoal is hauled to the nearby storage area. The most common method is simply to place the charcoal on a piece of canvas, which is then carried to the storage area by 3 - 4 men. Experience so far in the Viphya area indicates that a total average cycle time (carbonization and cooling) of 48 hours can be achieved with the Half Orange kiln.

7.7 The Final Step: Allowing the Charcoal to Cure

Any freshly made charcoal tends to absorb oxygen from the ambient air. This reaction results in the emission of heat, and charcoal stored in piles can self-ignite. Thus, charcoal should not be handled or transported in large quantities until it has been allowed to "cure" for a sufficient length of time following its removal from the kiln. A curing time of eight to ten days is usually considered adequate. During curing, neither the height nor the diameter of the charcoal piles should exceed 1.5 m; otherwise, exposure to the air will be insufficient.

7.8 Maintenance of the Kiln

The structure of the Half Orange kiln can be damaged in the course of charcoal production operations, for example by the impact of logs, and this should be avoided. Bricks which have fallen out of the walls or have become loose should be put back into place and rammed tight. Periodically, the excess clay which has accumulated on the exterior of the kiln as a residue of the successive coatings of clay slurry should be removed with a rasp. This will accelerate the charcoal cooling process.

The kiln floor should always be kept level. If necessary, depressions should be filled in with wet clayish soil, which should then be stamped down until it forms a relatively level surface. The water drainage ditches around the kilns must always be kept unobstructed and clear of all rubbish.

8. Operating a Kiln Battery as a Charcoal Production Centre

8.1 To make full use of the installed production capacity in a charcoal centre, the kiln battery should be operated round the clock on a shift basis, with an 8-hour day shift being followed by a 16-hour night shift. During the day shift, the kilns are loaded and unloaded, the charcoal is bagged and transported to the storage area, and necessary maintenance work is performed. During the night shift, one or two attendants are required to operate the kilns (monitoring of the carbonization process, sealing of kilns). The centre should be operated 7 days a week. If it is run on this basis, the centre will produce 35 to 40 kiln loads of charcoal per week, each weighing approx. 1,000 kg. The annual production capacity of the centre will thus be 1,400 tonnes (assuming it is operated for 40 weeks a year). In practice, capacities of around 1,200 tonnes per year or 100 tonnes per month will probably be the norm.

8.2 The flow of firewood must be managed by a separate group of workers. They cut down trees in the forest that have been marked for felling by the Forestry Department. After a sufficient drying period has elapsed - usually between 3 and 6 months - the trees are cut into 1.5-metre-long logs and loaded onto ox-carts or sledges and hauled to the production centre. The centre should always maintain a large enough "stockpile" of firewood to keep the kilns running for one week even if there is an interruption in feedstock supply. The water tanks at the centre should have a total capacity of 5-6 m^3. They must always be kept full. In case of a fire in the wood stocks or in the nearby forest, this water must be readily available. Empty bags must also be kept in store. Approx. 3,000 bags should be on hand at all times.

8.3 A standard production centre has to employ a labour force of between 50 and 60 people. Their tasks are as follows:

1 centre manager/supervisor
1 foreman: transport
3 kiln operators
12 workers: charcoal production
35 wood cutters/transporters
6 ox-cart attendants
2 watchmen

Utilization of the shift system means that 40 workers will be at the site during the day shift (assuming each works a 5-day week). The night shift can be performed by two people (1 watchman and 1 kiln operator).