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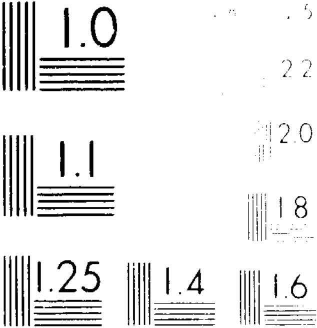
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DP/ID/SER.A/232
21 February 1980
English

CONSULTANCY IN NITROGEN AND PHOSPHATE FERTILIZERS

SI/MLW/79/801

MALAWI

Technical Report: Part I - The fertilizer market, Part II - Ammonium nitrate manufacture, Part III - The financial and economic evaluation */

Prepared for the Government of Malawi
by the United Nations Industrial Development Organization
executing Agency for the United Nations Development Programme

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		Page
PART I:	THE FERTILIZER MARKET	1
PART II:	AMMONIUM NITRATE MANUFACTURE	50
PART III:	THE FINANCIAL AND ECONOMIC EVALUATION	115

K = US$ conversion figure to be mentioned: US$1.00 = MK 0.82

PART I: The Fertilizer Market

TABLE OF CONTENTS

1. General Background

2. The Agriculture Sector

3. The Fertilizer Market

3.1 Trends in Fertilizer Consumption

3.2 Trends in Fertilizer Use By Types and Grades

3.3 Fertilizer Use by Crops

3.4 Fertilizer Use by Region

3.5 The Seasonal Pattern of Fertilizer Use

4. Fertilizer Marketing and Distribution

4.1 Import Procurements and Forwarding

4.2 Distribution

4.3 Pricing and Economics of Fertilizer Use

4.4 Credit Availability and Supply

5. Fertilizer Demand Forecast

5.1 Requirements by crops

5.2 Trend Method

1. GENERAL BACKGROUND

Malawi is a landlocked country extending to some 900 km from North to South and 200 km from East to West.

It is bordered by Zambia to the West, Mozambique to the East and South and Tanzania to the North-East.

The Country has access to the Indian Ocean through the ports of Beira and Nacala in Mozambique.

Topographically the country can be divided in three Distinct Regions:

1. The Littorals including the Shire Valley and the Lake Malawi, ranging in altitude from 40 to 760 metres.
2. The Plateau's comprising the Shire Highlands, The Central Region and parts of the North of which the elevation is between 760 and 1400 metres.
3. The Highlands in the Central, Northern and Southern parts of the country with altitudes between 1400 and 2750 metres. Mount Mulanje (3,000 metres) is the highest peak.

The climate has two well-defined seasons. The rainy season, which extends from November to March with an annual mean rainfall of 1140 mm varying from 635 to over 3,000 mm.

The period from May to August is cool (15-22°C) and dry, while the months of September and October can be characterized as hot (24-27°C) and dry.

The total land area of about 94,000 km^2 (excluding Lake Malawi) is inhabited by some 5.57 million people (1977 census) and divided into three political regions i.e.

The Northern Region (28.6% of the totalland area)
The Central Region (37.7%) and
The Southern Region (33.7%).

About 37% (3.5 million HA) of the land is considered to be arable but, according to aerial survey's conducted in 1966/67 an additional 3.2 million Hectares could be classified as potentially arable land and suitable for cultivation. The remaining area has to be discarded and classed as uncultivable due to constraints imposed by topography, water surfaces, drainage, erosion, climate and infrastructure (villages, roads, etc.)

1/ N.R.D.P. Policies, Strategy and General Features. Sept, 1978

2. THE AGRICULTURAL SECTOR

Agriculture is the main industry in MalaŴi and the largest single contributor to the National Income. It accounts at present for about 46% of the gross domestic product (G.D.P.) and for 94% of export earnings (1977).

Including Animal Husbandry , Forestry and Fisheries it directly and indirectly provides work for some 80% of the entire population. Crop production is divided into two distinct sectors, i.e. estates and Small Holders. The area of socalled Customary Land is cultivated by small-scale Farmers, growing mainly maize for own subsistence in addition to cassava and pulses. Tobacco (Dark-fire cured, Sun/Air cured and Oriental), cotton groundnuts, rice, coffee and wheat are grown as cash crops. It is estimated that in 1977 some 3 million hectares of land were cultivated by over 1 million farm families. As may be expected holdings are generally small in size. The average size of an agricultural holding ranges from 1.3 ha in the South, to 1.4 ha in the North and to 1.9 ha in the Central Region. The per capita potential arable land is about 1.[illegible] hectares, of which some 0.54 hectares per capita were cultivated in 1977.

Taking into account the present relatively high density of the rural population which increases at an average of 2.92% per annum, it is anticipated that by the early nineties the overall cultivated area will exceed the suitable arable land available. There are now already localized areas in the South where unsuitable land is under cultivation due to the pressure on land.

The Commercial or Estate Sector of farming is occupied mainly by plantation crops like Tea, Tobacco (Flue-Cured, Burley), Sugar Cane, and miscellaneous crops like Maize, Oilseeds etc., and covers a total of about 0,1 million hectares of land. The country is largely sufficient in food production and exports in addition, substantial quantities of valuable commodities. Tobacco with a 51% share of total exports earnings in 1977 is the leading crop+. It is followed in importance by Tea (23%), Sugar (9%), Groundnuts (6%), Cotton (2%), Coffee and other crops (5%). Small holders production accounted for about 34% share in domestic export earnings and Estates 66%.

The performance of Agricultural production is the most important determinant of the country's balance of payment position.

+ As a matter of fact, MalaŴi is the World's second largest exporter of specialized Fire-Cured Tobacco.

Since 1973 the estates sector has been spearheading in growth, while the Smallholder sector has been lagging behind. They are on the fringes of the market economy. Their staple food is Maize and the principal cash crops are Tobacco and Groundnuts. The pressure on land is increasing while the returns from production are marginal. The main objective of the Government policy is to increase Agricultural productivity from existing land. Its main strategy is to give priority to investments with an immediate impact on Agriculture. This strategy is among others, embodied in the National Rural Development Programme to be implemented over a 20 years period through about 40 Development Projects of which 4 major ones are in operation with an additional 8 in the pipeline.

The major projects in operation are:

(1) The Lilongwe Land Development Programme (LLDP) covering an area of about 445,000 hectares in the Central Region, containing 104,000 farm families (445,000 people). The major crops are maize, groundnuts and tobacco. It started in 1968/69 and is supported with credits provided by the IDA.

(2) The Shire Valley Agricultural Development Project (SVADP) initiated in 1969/70 and also supported by IDA credits. The project covers an area of about 688,000 hectares in the Southern Shire Valley (including two Game Reserves), with 70,000 farm families (300,000 people). Cotton, maize, (rice) are the main crops.

(3) The Lakeshore Rural Development Project (LRDP) launched in 1968 with funds provided by the West German Government but is now receiving financial support from the European Development Fund. It is located along the Central part of Lake Malaŵi and it now covers an area of about 357,000 hectares, containing some 67,000 families (300,000 people) cultivating mainly cotton, maize, groundnuts and rice.

(4) The Karonga-Chitipa Rural Development Project (K-CRDP) It started in 1972 and is located in the North of the country. It is also supported with IDA credits. The total area extends to about 769,000 hectares, containing about 38,000 farm families (168,000 people) engaged in the cultivation of rice, maize, groundnuts and cotton.

In the context of this strategy, particular emphasis is being placed on fertilizer and seed as the major force behind increased crop production. To ensure supplies at stable prices and at the time they are needed, the Malaŵi Government has been considering since 1975 the possibility of establishing an own fertilizer manufacturing facility.

(1) As a hedge against serious problems which may arise from total reliance on imports.

(2) To alleviate serious constraints in regard of transport as inherent to a land-locked country.

(3) To save foreign currency and reduce costs.

(4) To develop and/or utilize local raw materials and available utilities.

The objective of this study is to establish a viable concept for such a fertilizer plant and to evaluate the impact it will have on the country's economy and the agricultural sector in particular

3. The Fertilizer Market

3.1 Trends in Fertilizer Consumption

Commercial quantities of chemical fertilizer were first used in Malawi in the early fifties by the Tea Estates. As Estates used to import their own requirements, no official records are available until 1970. Encouraged by subsidies fertilizers started being used by small holders in the customary sector of farming effectively in 1960. Initially, consumption by small holders grew slowly but it reached already some 23,000 tons in the 1970/71 crop season. The main indicators of fertilizer consumption since 1970 are the imports and the salesrecorded by the two major fertilizer distributors in the country i.e. The Agricultural Development and Marketing Corporation (ADMARC) and A Commercial Company Optichem Ltd. Official statistics on actual use per crop and acreage of land are not available, as no field monitoring system exist. The annual sales figures of the aforementioned distributors in the period 1972/73-1978/79 are therefore first consolidated according to quantities of fertilizer types sold (Table 1) and subsequently relat- to crop use, Regional and seasonal patterns of offtake and supposed consumption.

The figures of Table 1 are at the first instance used to calculate consump- for all types of fertilizer on a nutrient basis, the result of which is presented in Table 2. Since 1972 consumption of all fertilizer has increased albeit at wide variances at an average annual rate of 5.8% per cent on a product basis and 6.8 per cent on a nutrient basis, to reach 93,800 tons of products in the current cropping season 1978/79; the equivalent of about 26907 tons of NPK of which the greater part, namely around 17,200 tons, is Nitrogen.

It provides an indication for a trend towards using higher concentrated types of fertilizer. This is further evidenced by the share of compounds in total consumption, particularly those of a higher grading, which has increased from 35 per cent in 1972/73 to almost 44 per cent in the current cropping season. Yet, the average nutrient content of all fertilizer used in Malawi in 1978/79 is still only 28.7kgs of NPK per ton of product sold, which is rather low and unfavourable in view of long lines of supply (freight costs) and constraints in the domestic distribution system (transport). Subjecting the overall consumption figures to a further scrutiny then it appears that the use of N-fertilizer only increased by 5 per cent on a compound annual average over the past 6 years from some 13,000 tons in 1972 to 17,200 tons in 1978/79, against a 10 and 12 per cent increase for phosphate (P_2O_5) and Potassium (K_2O) fertilizer respectively.

This can be explained by the relatively high rate of growth of the so called "Tobacco Mixtures" (11.4% per annum) which carry on a tonnage basis proportionally higher quantities of both P_2O_5 and K_2O nutrient elements than Nitrogen.

Simultaneously, and for the same reason, the ratio in which Nitrogen was applied in relation to P_2O_5 and K_2O changed on an overall basis from 7:1.8:1 in 1972/75 to 4.7:1.6:1 in 1978/79. This, apart from tobacco grown by estates, does not imply however a trend to a more balanced use of NPK in general. Maize and tobacco, grown by small holders are still receiving fertilizer dressings which may be qualified as unbalanced in regard to Nutrient application.

Trends of Fertilizer Consumption
(1,000 Nutrient Tons)

Year	N	P_2O_5	K_2O	Ratio : N : P_2O_5 : K_2O
1972/73	12958	3405	1846	7 : 1.8 : 1
1975/76	10903	3336	2246	
1978/79	17196	6083	3628	4.7 : 1.6 : 1

Consumption of all fertilizer, though N-fertilizer in particular, declined sharply during the period 1974-76, in the aftermath of the oil crisis as the above figures (and table 1 and 2) illustrate. The scarcity of fertilizer in the world market in that period, coupled with un precedented price increases (over 150 per cent) in the local market, inversely affected the use of fertilizer in the Customary Sector of farming, but to a much lesser extent estate farming as the above figures of consumption for both P_2O_5 and K_2O demonstrate. They remained stable and even increased (K_2O). The decline could have been even more severe, was it not for the 'Buffering" effect of the four rural development projects in operation at that time.

Credit facilities available to small-holders, farming in the project areas, and which are coupled to the inputs of fertilizer and seeds, in addition to better marketing facilities for the disposal of surplus food crop production and cash crops, ensured consumption in those areas to continue at a distinct higher level as compared to the rest of the country. This will be illustrated more clearly in the section on credit (4.4), as it provides evidence of the stabilizing effect of the projects on the pattern of national fertilizer consumption. Lower fertilizer costs and higher crop prices in subsequent years, restored the economies of fertilizer use on a national level, while impoved conditions on the World market for major export crops anf for maize on the local market provoked a sharp upturn in consumption in recent years.

In the period from 1975/76 till 1978/79 fertilizer offtake jumped from 16,000 tons of NPK to almost 27,200 tons. Nitrogen-Fertilizer alone spurred from a bare 10,900 tons of N, at an average of 16.4% per annum to 17,200 tons. The upsurge could have been more pronounced if no contraints in the supplies and distribution of fertilizer, Sulphate of Ammonia in particular, had occurred lately effecting once more the growers of tobacco and maize in the Customary Sector of farming heavier than Estate farming. Thus demand seemed to have exceeded supplies in the current cropping year. It would justify the assumption that there would apparently have been still scope for larger increases in consumption if those constraints had not developed.

Taking the present per-hectare-consumption into consideration, which is still as low as about 9.3 kgs of NPK (per hectare of cultivated land, as well as the approximation that less than 10 per cent of all cultivated land had received fertilizer in 1978/79, then the potential of a further expansion in the use of fertilizers, is quite evident. It may therefore be anticipated that the rate of consumption increase as expected in recent years will continue albeit at a distinct slower pace, provided crop marketing conditions and the economic returns for fertilizer use in the Customary Sector of farming remain adequate.

3.2 Trends in Fertilizer Use By Types and Grades

Fertilizer use in the current cropping season (1978/79) reached about 93,800 tons. The greater part of it was in the form of various NPK and NP formulations (43.7%), the balance in the form of straight fertilizer; Nitrogenous mainly. Phosphate and Potassium are mainly applied in the form of compounds or mixtures. The principal types of fertilizer used in 1978/79 are consolidated and listed by sales percentages and nutrient content below.

Type	M Tons	% Of Total	N	P_2O_5	K_2O
Sulphate of Ammonia (21N)	40201	42.9	8442	-	-
Tobacco Mixtures (Av. 6:18:15)	18000	19.2	989	3243	2654
25:5:5	10520	11.2	2630	526	526
CAN (26^N)	9896	10.6	2567	-	-
20-20-0	8971	9.6	1624	1624	-
3-2-1 (12.5: 19:5.1)	2581	2.8	323	490	132
Nitrate of Soda (16^N)	1274	1.4	191	-	-
Urea (46^N)	356	0.4	166	-	-
Single and Triple Super Phosphate	563	0.6	-	200	-
Sulphate and Chloride of Potash	550	0.5	-	-	316
Mixtures Non Specified	874	0.8	-	-	-
	93803	100.0			

Sulphate of Ammonia (SA) is still the leading fertilizer with almost 43% in overall consumption. However, its importance is gradually declining in favour of Non-Sulfur based compounds and Calcium Ammonium Nitrate. The acidifying and depleting effect on soils brought about by the continued use of sulphate of ammonia and sulphate containing mixtures and compounds is increasingly being recognized by research and practical experience, in particular by Estate farming. Sulphate of Ammonia is at present almost exclusively used by Small growers of maize and Tobbaco, simply because it is more cheaper priced on a Ton-Nutrient basis than for instance CAN and Urea. The Customary Sector of farming used to apply CAN on a much larger scale prior to 1973 when it was readily available from neighbouring countries and competitive in price with SA.

The so-called Tobacco Mixtures are mainly used by Estates as a basal dressing for Flue-Cured and Burley Tobacco and are complemented by a top dressing of CAN. On the other hand, Nitro-phosphates (20-20-0) are preferred by small-holders growing Western types of Fired, Sun and Air Cured tobacco's for the same reason they use SA as a top dressing, namely, it is much cheaper priced than the tobacco mixtures. Yet also here it is increasingly being recognized that the continued use of Non-Potassium containing formulations on tobacco leads to a significant decline of quality. In the longer term a shift to more balanced formulations for tobacco in the Customary Sector of farming, may therefore be anticipated. Nitro-phosphates though to a much lesser extent, are also used by the Customary Sector of farming on maize, lately as a substitute for SA which was in short supply.

Whereas response to phosphate has not clearly been established by research on a nation-wide scale, it may be foreseen that more balanced applications of NP for maize are desirable in the long run, in particular in connection with the growing of improved and high-yielding varieties of this crop. This is recognized by the Estate Sector of farming which prefers the 3-2-1 (12N, 19 P_2O_5,5K_2O) formulation as a basal dressing for maize followed by a top dressing of CAN. Likewise, the Tea Industry increasingly prefers the use of the 25-5-5 Compound rather than SA. This practice provides ample evidence that in Tea cultivation, the trend towards more balanced nutrient applications and the use of Non-Acid-Forming types of fertilizers, nowadays prevails. CAN as mentioned before, is at present almost exclusively used by Estates as a top dressing for tobacco and maize. Nitrate of Soda is still popular as a fertilizer for tobacco because of its quick effects. UREA however does not find much application in Malawi Agriculture and is variably used in tobacco, maize and Paddy cultivation. Straight phosphate and potassium fertilizers are to a limited extent, in use by the Sugar Cane Industry and Tobacco Estates.

The trends in growth for the various types of fertilizer is given in Table 2. Tobacco mixtures and the 3-2-1 formulation (estate maize) have shown the fastest and most consistent growth over the last 6 years (11 and 47% respectively), followed by CAN and the 25-5-5 formulation (Tea) (6.7 and 5% respectively). The use of Nitro Phosphates and Sulphate of Ammonia which are mainly used in the Customary Sector of farming (for Tobacco and Maize) has been growing at a much slower pace except in recent years. The reason is that the recovery of fertilizer use in the Customary Sector of farming after the depressed years 1974-76 has lagged behind Estate farming, yet it sharply accelerated during the last 3 years. Whereas one would expect SA growth to be equal to that of 20-20-0, this was not the case as SA was in short supply and 20-20-0 seems to have been used as a substitute for SA in maize growing.

Nonetheless, not too much importance can be attached in general to those trends as the type of fertilizer used by the Small grower is mainly determined by price and availability of supplies and less by agronomic considerations, whatever the recommendations may be. Yet, it is worthwhile to draw attention to the pronounced rate of increase in the use of CAN, which is distinctly higher than that for tobacco-mixtures. The record of sales provides an interesting illustration of how tobacco growing estates in general have pushed production by proportinally increasing the quantities of top dressing per acre in relation to basal dressings (of mixtures) to capitalize on the favourable conditions offered by the world tobacco market in recent years.

Another feature of imminent importance is the steady increase of Nitric-Acid based Nitrogen-fertilizer as compared to Sulphuric-Acid based products. As the figures of Table 3 reveal, Nitric-Acid based compounds mixtures and straight fertilizer (CAN) have grown in importance at an average annual rate of 30.5% in the last 4 years as against only 9.2% for Sulphuric Acid based N-Fertilizer. Outstanding was the rate of growth for Nitric-Acid based compounds (36.8%). This trend is indicative of the preference given by Estate farming to Nitric-Acid based products, which can be regarded as the result of their own field experiences. Whereas Sulphur has been found to be useful in bringing virgin lands into cultication, research has still to provide a valid justification to continue to favour the inclusion of Sulphur in all fertilizer formulations for Dry-Land farming on a nation-wide scale and in a consistent manner. The acidifying and soil depleting effects of such formulations seem to have become noticeable in recent years. It may therefore be anticipated that a gradual switch back to CAN in the Customary Sector of farming will take place if current price differentials prevailing between the various types of N-Fertilizer would be phased out.

3.3 Fertilizer use by crops

The distribution of sales according to crops has been worked out for the 1977/78 and the 1978/79 crop season and are shown in table 4 as well as in a synopsis below (1978/79). Several approximations and assumptions had to be made as outside the estate sector of farming, little information is available on crop acreages, actual application of fertilizer per acre, etc.

Moreover, it seems that substantial quantities of CAN and to a lesser extent 20-20-0 and SA sold by ADMARC to small holders have found their way indirectly to the estate sector of farming in recent years due to differences in price which currently prevail for the same type of fertilizer sold by the 2 distributing organizations as well as the difference in costs between the various N-fertilizer if calculated on a per ton nutrient basis. Nevertheless, the figures presented in table 4 and below, are accurately enough to present the situation and to make the following observations and appraisal.

Fertilizer use by crops (1978/79)

Crop	Fertilizer type	M Tons	% Total	NPK	% Total	N	% Total
a. Tobacco:	Tob. Mixtures	18018		6886		989	
Flue-Cured	CAN[1]	4704)		2261		2261	
Burley		(3992))					
	Nitrate of Soda	1274		204		204	
	Sulphate of Potash	49		25		-	
	Sulphate of Ammonia	1551		326		326	
		29588	31.5	9702	36.8	3780	22.0
b. Western	20-20-0	6200		2480		1240	
Fire/Sun/Air Cured	SA	12400		2600		2600	
Oriental	Others	870		340		50	
		19470	20.8	5420	20.6	3890	22.6
Maize	3.2.1	2531		945		323	
Estates	CAN	1200		312		312	
Small holders	20-20-0	2771		1108		554	
	SA	19439		4082		4082	
		25991	27.7	5447	20.7	5271	30.6
Tea	25.5.5	10520		3682		2630	
	SA	1311		275		275	
		11831	12.6	3957	15.0	2905	16.9

1 Between brackets CAN supplies supposed to originate from ADMARC

Sugar cane	SA	5500		1155		1155	
	SSP	206		37		-	
	TSP	357		164		-	
	KCL	403		242		-	
		6466	6.9	1598	6.0	1155	6.7
Paddy	SA/UREA	554	0.7	209	0.8	209	1.2
	TOTAL	93803	100	26907	100	17196	100

1. Estate Tobacco

The quantities of fertilizer used by tobacco estates leave little ground for inaccuracies.

Estates apply at an average 250 to 300 kgs per acre (600-700 kgs/ha) of the C-tobacco mixture (6.18.15) as a basal dressing and 150 to 200 kgs of CAN (400-500 kgs/ha) as a top dressing onto both fire-cured and burley tobacco.

As mentioned earlier, top dressing with CAN have significantly increased in recent years.

Crop acreages multiplied by rates of application fairly well correspond with the quantities of tobacco mixtures sold by Optichem and the joint sales of Optichem and ADMARC for CAN.

It appears therefore that the estate tobacco's share an overall consumption in 1978/79 was 31.5% but that it took part with only 22% in overall Nitrogen use.

2. Small holder tobacco

To assess the quantities of fertilizer used by the small scale grower of fire, sun and air cured types of western tobacco is more cumbersome.

In the absence of accurate date on crop acreages, actual rates of application as well as precise figures on fertilizer off take, several approximations had to be made.

Yet it may be assumed that in recent years, all growers of tobacco used chemical fertilizer on their crop at an average rate of 50 Kgs of 20:20:0 per acre as a basal dressing and 100 Kgs of SA per acre as a top dressing.

Assuming average saleable yields of 300 to 400 lbs of dried and cured leaves per acre and relating them to the annual purchases of tobacco by ADMARC, then one arrives at an approximate figure for acreages, which in turn allow to assess the quantities of 20:20:0 and SA actually consumed.

In the cropping year 1978/79 some 6,200 tons of 20:20:0 and 12,400 tons of SA are estimated to have been used by small holders for their tobacco crop.

Thus, small holder tobacco ranks with 20.6% of overall sales and 22.6% in N-fertilizer use as the third largest fertilizer outlet in the country.

Maize

The acreage of maize cultivated by estates is fairly well known. The standard application is 200 Kgs of 3-2-1 (12N. 19 P_2O_5, $5K_2O$) per acre (400-500 Kgs/ha) as a basal dressing followed by 100 Kgs of CAN (200 - 250 Kgs/ha) as a top dressing.

Though some but negligible quantities of 3-2-1 may have been used for estate tobacco, it may be assumed that practically all sales of 3-2-1 in 1978/79 were taken off by estates growing maize. This works out to about 4% in overall fertilizer consumption.

The uptake of fertilizer by small holders growing maize can only be assessed by deducting from ADMARC sales of 20:20:0 and SA, the quantities which are supposed to be used for tobacco.

Those farmers who do fertilize their maize crop (both hybrids and local varieties) almost exclusively apply SA at a rate of 100 to 150 Kgs per acre (250 - 370 Kgs/ha) on hybrids, whatever the recommendations for a basal dressing with 20:20:0 and a top dressing with SA are. For local varieties of maize it is customary to apply 180 Kgs of SA per hectare only.

In 1977/78 some 22,500 tons of SA are estimated to have been used onto maize in general. Total sales of seeds amounted to 625 tons of hybrid maize and 436 tons of UCA (composite and synthetic). As the recommended seed rate is 10 Kgs per acre (25 Kgs/ha), the land cultivated with hybrid and UCA maize in 1977/78 would have been around 25,300 hectares and 17,650 hectare respectively onto which 9,375 tons and 6,540 tons of fertilizer (SA) are estimated to have been used. Thus a total of 15,915 tons for improved varieties of maize, leaving a balance of about 6,585 tons of fertilizer (SA) for local varieties of maize grown on approximately 36,600 hectares of land.

By and all some 80,000 hectares of land cultivated with maize in 1977/78 may have received fertilizers (about 8-10% of the total maize acreage).

Because of supply problems encountered in 1978/79 which effected in particular the Central Region, only some 19,400 tons of SA were available for maize. As 20:20:0 was in ample supply, farmers were encouraged to take up this fertilizer for maize. As a result the sales of 20:20:0 in 1978/79 increased by not less than 41% as compared to the preceding year. This increase could in no way be related to offtake by tobacco farmers alone.

It is therefore most likely that the balance of demand of SA for maize has been met by the purchase of additional quantities of about 2,770 tons of 20:20:0.

As a matter of fact the 20:20:0 compound is calculated on a ton nutrient basis, cheaper than SA and should therefore be more attractive to farmers.

Total uptake of fertilizers by small holders growing maize in 1978/79 is estimated to have been about 22,200 tons, an increase of about 8,000 tons over and above the level of SA consumption in 1972/73 (14,100 tons), an indication that the average rate of increase over the past 6 years has been in the order of 8% per annum.

In 1978/79 some 724 tons of hybrid seed and 543 tons of UCA maize seed were issued to farmers, which works out to a maize acreage of approximately 29,300 ha and 22,000 ha respectively.

A breakdown of the total quantity of fertilizer (SA + 20:20:0) used onto maize in 1978/79 indicates that some 10,860 tons may have been used on hybrid maize, 8,150 tons on UCA and 5,200 on local varieties of maize, and that a total of some 70,000 hectares cultivated with maize had received fertilizer in 1978/79.

4. Tea

With a total of 11,831 tons of fertilizer (SA and 25-5-5) in 1978/79, tea ranks fourth in the nation-wide pattern of fertilizer consumption (12.6% in overall and 16.9% in total N-Fertilizer use).

5. Sugarcane, paddy rice

The sugarcane estates shared with 6.9% in overall fertilizer use in 1978/79 while the balance of about 1% can be credited to paddy rice and other crops.

Average Rate of Nutrient application per hectare

Customary Farming	Fertilizer Grade	Rate Kgs./ha	N	P_2O_5	K_2O
Western Tobaccos	20:20:0	125	25	25	-
	SA	250	52	-	-
		Total	77	25	-
Maize (local varieties)	SA	180	36	-	-
Hybrid	SA	370	75	-	-
Estate Farming					
Tobacco					
(Fuel-Cured; Burley)	6.18.15	600 - 700	44	133	111
	CAN	350 - 450	104	-	-
		Total	148	133	111
Maize					
	3-2-1	400 - 500	60	95	25
	CAN	200 - 250	65	-	-
		Total	125	95	25

3.4 Fertilizer use by Region

Customary sector of farming

ADMARC's sales to small holders have been compiled according to Region and fertilizer grades and are presented in the tables 7 and 8.

The data show that ADMARC's sales nation-wide have been growing from 14,847 M tons in 1974/75 at the impressive rate of 32.6% per annum to reach 45,788 M tons in 1978/79. The figures also indicate that the Central Region at present predominates as ADMARC's major outlet with over 51% of overall sales. In the Central Region sales increased at an average rate of 32.3% from 7,624 M tons in 1974/75 to 23,364 M tons in 1978/79 and 25,388 1/ tons if Lakeshore Division is included.

The Southern Region is ADMARC's second largest market area (average 28.5% of nation-wide sales in 1977-79). The average rate of growth during the last 4 years has been 26% per annum and the volume of sales in 1978/79 amounted to 13,255 tons 2/ Whereas the most pronounced growth over the last 4 years occurred in the Northern Region (38%), sales in this Region amounted to 7,145 tons 3/ or only 15.6% of ADMARC's total fertilizer turn-over in 1978/79.

1/ Of which 11,940 tons of 47% of the total, sold through ADMARC's retail points located in the LLDP and the LRDP areas.

2/ Of which less than 2% has been sold within the SVADP area

3/ Of which some 911 tons or 12.7% were taken up within the KCRDP area.

Estate sector of farming

Similar records of Optichem's sales in the various Regions are not available. Yet, in relating the various fertilizer grades to crop and areas of cultivation; ./ it appears that of Optichem's total sales in 1978/79 i.e. 48,000 M tons some 56% should have been used in the Southern Region and about 39% in the Central Region (Table 8).

National level

Compound the sales of the two distributing organizations (Table 8) than it appears that of total supplies in 1978/79 i.e. 93,800 M tons, some 43% moved to the Southern Region (40,000 M tons), 47% to the Central Region (44,000 M tons) while the balance (10,000 M tons) was sold in the Northern Region. Although in the medium term, the share of the North in overall fertilizer movements will increase, it is evident that the bulk of all future supplies will continue to move mainly to the Central and Southern parts of the country.

./ Tea and sugarcane are mainly grown in the South, maize is almost exclusively grown by estates in the Central Region while for tobacco it is assumed that 10% of all flue-cured and burley is grown in the North, 59% in the Central and 31% in the Southern Region.

3.5 The seasonal pattern of offtake

Customary sector of farming

Climatic conditions in Malawi impose on agriculture a single cropping season which depending on rains starts end November/beginning December and ends in April/May.

The movement of fertilizer at the retail level and the distribution of monthly sales by ADMARC is depicted in table 5 and illustrated by chart A. Fertilizer offtake starts to accelerate in October, peaks in December, subsequently declines sharply and whithers to almost zero in the period April - October. The slight upward movement in the curve during June may be due to purchases for irrigated rice in the rural development projects areas and vegetables. Over 90% of the annual fertilizer sales occur in the period November - February and from 65 to 70% in the month of December and January alone. As this pattern appears to be consistent from year to year, it needs no wonder to experience serious constraints in the logistics of supply and in proportion to the annually increasing volume of sales. Shortages of fertilizer at the retail level seem to be at present a frequent recurring problem as evidenced by the dip in the offtake curve for 1977 and 78 and the records of fertilizer movements and stock positions of ADMARC. This happens regardless of the large quantities of strategic reserve stocks which ADMARC carries over from year to year and which are stored in the various depots at a Regional level. In the past, these stocks even exceeded the tonnages of average annual sales.

The same pattern of offtake also reflects the buying habit of the average farmer, who usually short of cash, buys his fertilizer shortly before application and and mostly at the time he receives a bonus payment for his tobacco (November, December); an amount that varies from year to year and naturally influences the quantities he is able to purchase. His means to buy fertilizers could be greatly enlarged and simultaneously, the logistical contraints of supply substantially be relieved, by having ADMARC stock retail outlets at its permanent markets with fertilizer in the period from June to September when the farmer sells at regular intervals to ADMARC his cured tobacco, surplus maize, and other produce. Storage of fertilizer at the farmer's level should not pose too serious problems because of the dry season and the small quantities of fertilizer involved per average farmer.

Estate sector of farming

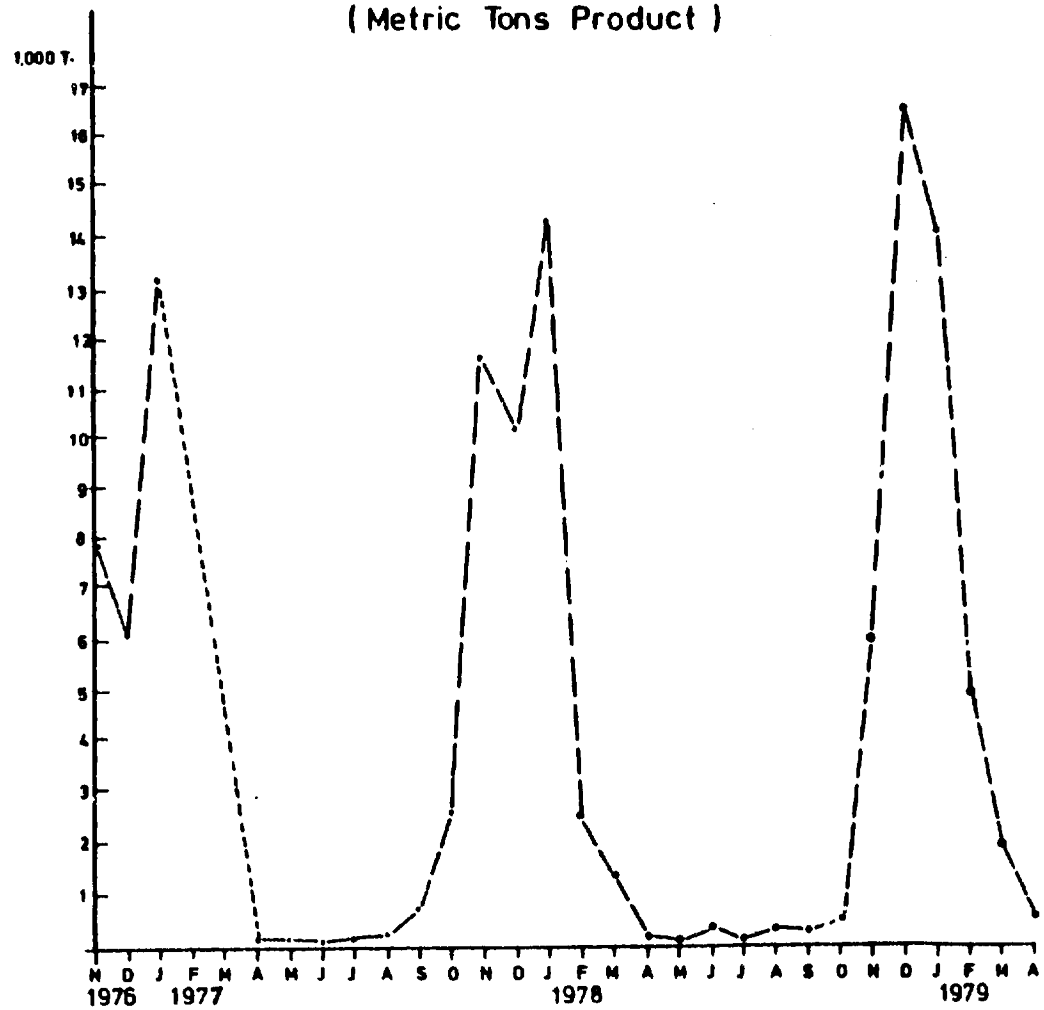
Fertilizer offtake by estates is much more evenly spread over the year. This holds in particular for the tea estates, as well as for sugarcane. Even tobacco estates procure and haul their next season requirements in the period from May till September when the tobacco product is carried to and sold at the Auction market of Blantyre which is also the place of supply for estate fertilizer (Optichem)..

CHART A

SEASONAL PATTERN OF FERTILIZER OFF-TAKE 1978/79 BY CUSTOMARY FARMING

(Metric Tons Product)

MONTH	YEAR	MET. TONS	TOTAL % OFF TAKE
APRIL	1978	277·47	
MAY	1978	104·89	
JUNE	1978	329·36	
JULY	"	146·59	
AUGUST	"	271·06	
SEPTEMBER	"	526·56	
OCTOBER	"	568·10	
NOVEMBER	"	5,948·71	13·1
DECEMBER	"	16.107·65	35·1
JANUARY	1979	14099·60	30·7
FEBRUARY	"	5121·16	11·0
MARCH	"	1966·53	
TOTAL	1978/79	45,938·00	



4. FERTILIZER MARKETING AND DISTRIBUTION

4.1 IMPORT PROCUREMENTS AND FORWARING

In the absence of own manufacturing facilities, Malaŵi had to procure all its fertilizers from abroad at annually increasing quantities.

The tonnages of different fertilizer materials which were imported since 1970 are shown in Table 9. In comparing the quantities of imports with the sales volume in corresponding years, it appears that in the period 1975-77 substantially larger tonnages were imported, particularly Sulphate of Ammonia, than sold domestically, to replenish stocks depleted in preceding years, albeit not always at a favourable price level, as the import value indices show.

Stock positions as recorded by ADMARC for the period 1976-79 and shown in Table 5 illustrate the large quantities of fertilizer which were carried over from year to year and which exceeded annual sales.

Major suppliers of fertilizer to Malaŵi are Europe, Japan, the USA, South Africa and previously also Rhodesia. Prior to the closure of the Rhodesian border a significant part of the imports used to be hauled in by rail and in bulk to be bagged locally. At present all imports are in bags and imported through the ports of Nacala (40% and Beira (60%) in Mozambique.

From those ports shipments are hauled by rail to the major centres of distribution in the country over distances of 500 and 355 miles respectively. Initial storage is usually at Luchenza and Liwonde from where fertilizers are distributed to the various depots and retail points throughout the country by a combination of road and rail transport.

As the main period of sales to estates starts in March and last until August/September and to small holders from October till February, orders are usually placed in the last quarter of each year. Shipments are scheduled to arrive in the first half of the year. Late arrivals due to constraints in ports and inland forwarding have been occurring frequently in recent years. It nowadays takes at least 3 months for arrivals to reach inland destinations, often too late for the season as ADMARC's records show (Table 5, receipts November, 1977, January and December 1978, January, February 1979). The annual requirements are procured by Optichem on the international market by tenders, but a no objection permit may be granted to other organisations wishing to import fertilizer on their own.

4.2 DISTRIBUTION

OPTICHEM Acts as the wholesale distributor for estates, i.e. tea, and sugarcane plantations and the estates, growing tobacco and maize.

It sells fertilizers ex ware-house, Limbe (Blantyre) from where the customer collects and transport his procurements to his own stores.

The company's major market outlet (56%) is located in the South. However, to meet the increasing volume of sales in the Central Region the company is constructing a ware-house with a capacity of 3000 tons at Lilongwe, in addition to its existing facilities at Chichiri (Blantyre), having an overall capacity (bulk and bag storage) of 11,000 tons

ADMARC - A statutory body is charged with the responsibility of supplying fertilizers to the customary sector of farming as well as with the marketing of all agricultural produce grown on customary land by small holders (tobacco, maize, groundnuts, pulses, cassava, cotton, coffee, rice etc.) and from those lands affected by the NRDP (National Rural Development Programme).

Sales of farm inputs and collection of farm outputs are effected at retail level in the districts.

From a total of 93,800 tons of fertilizer sold in the current cropping season (1978/79) ADMARC handled some 45,800 tons or 49% against Optichem 48,000 tons. ADMARC's share of the local market has steadily grown since 1972/73 from about 25,000 tons (or 38% of the total) to the present level, at an average rate of 10.5% per annum.

The tonnages sold by Optichem on the other hand remained fairly stable since 1972, varying between 38,000 and 42,000 tons, but recently increased significantly to reach 48,000 tons in 1978/79 (Table 6 and 8).

To execute its task, ADMARC operates a marketing and distribution system structured around 12 main regional depots (2 in the north 3 in the central region and 7 in the south) and 79 permanent markets at district level (24 in the north, 32 in the central region and 23 in the south).

The permanent markets are supplemented by over 800 seasonal produce buying centres (bush -markets) clustered around each permanent market at an average of 10 per markets.

The function of the warehouse facilities is multipurpose. They store both fertilizer and farm produce (in separate sheds).

ADMARC's nation wide storage capacity exceeds 0.7 million M^3 with a loading capacity of over 450 000 tons.

The 12 main depots (Table 13) stock the corporation's strategic reserves to cope with fluctuations in demand and shortages due to late arrivals of fertilizer supplies from overseas.

The overall loading capacity of those depots is over 260 000 tons and up to 100 000 tons of fertilizers could be stored, if needed. In the past few years ADMARC's stock positions in the off season ranged between 20 000 and 60 000 tons (Table 5).

Depots at the district level (permanent markets) merely serve in a transit-retail capacity. They are supplied with fertilizers from the regional depots (in principal) shortly before the cropping season starts, usually not earlier than October and continue to be re-plenished until February/March, where after the facilities are being used for produce intake. Tobacco for instance is sold and delivered by the farmer to the permanent market, while maize is collected by ADMARC at the seasonal (bush) markets from May till September. Only a relatively small number of seasonal markets (10-15%) remain open till February to retail fertilizer.

The bulk of ADMARC's annual sales (84%) are handled through its network of retail outlets at the district level as illustrated in the table below:

ADMARC's Total Sales in 1978/79 (tons)	Off take: Regional Depots	Off take: Permanent District Markets	Off take: Seasonal Markets (Estimate)	Average Sales per District Depot (tons)
45,788	7,499	38,289	10-15%	736

Taking into consideration that ADMARC operates its distribution system through 12 major and 79 minor sales points then there should be at an average one outlet per 1470 KM^2 or one for every 45,000 hectares of cultivated land. Each sales point handles at an average 736 tons of fertilizer per annum and operates within a radius of 22 Km to serve about 15,600 farm holdings. Thus the average farmer has to travel a distance of about 11 Km to get his supplies which he hauls by ox-cart, bike or as a head weight. These figures illustrate the extent of ADMARC's network of retail distribution which is in fact very thinly spread and a reflection of the small tonnages of sales per capita and per unit of cultivated land. In reality the situation is somewhat better as the above figures do not take into account the geographical distribution of cultivated land, the location of sales points within those areas and the fact that part of the seasonal markets remain, open for fertilizer sales in the period October till February. But even if these aspects are taken into account, as for instance has been done for the Central Region, then the mean distance over which fertilizers have to be hauled by farmers remains 8 to 9 Km. For the Lilongwe Land Development Programme which has a much better infrastructure it is estimated that fertilizers' sales points are within a 5 to 6 Km reach of the average farmer.

ADMARC's permanent markets are equipped in general with the so-called house-type of stores with a capacity ranging between 50 to 150 tons per unit. Mean annual sales per unit amount to 736 tons. In practice they vary between 70 and 1,200 tons. This works out to an average throughout of 7 to 8, a figure which is indicative of a satisfactory rate of capacity utilization. Nevertheless, those transit retail stores have to be replenished some 70 to 80 times within a short period of 3 to 4 months by trucks hauling 10 tons per time on an average, over relatively long distances.

It needs no wonder that with the increasing volume of sales constraints in the logistics of supply have been developing in recent years. As evidenced by shortages at retail level which occurred in localised areas (Central Region) in the crucial period of demand. This in spite of the fact that ample reserves were available at the Regional level elsewhere. ADMARC's sales and stock positions for SA, 20:20:0 and CAN in 1978/79 have been presented in table 10. From the records it becomes clear why serious shortages in SA supplies could develop in the previous cropping season. For the Central Region, being ADMARC's largest consumer area, stock positions of SA at the retail and the Regional level never exceeded 20% overall annual sales in 1978/79. Stocks were fully depleted at the end of the season (less than 2% of annual turn over) regardless the fact that elsewhere over 5,000 tons were available which had to be carried over to the forth coming season. On the other hand overall stock positions of both CAN and 20:20:0 appeared to have been excessive in relation to actual demand. In addition the facilities for fertilizer storage seem to be poorly distributed over the country. Whereas the Central Region consumes at present about 51% of its annual turn-over, ADMARC only maintains facilities to keep buffer stock reserves at 3 locations, against 7 in the South. Against sales of almost 42,000 tons in 1978/79 the facilities for fertilizer storage in the Central Region have a capacity of about 23,000 tons only, while those in the south (ADMARC + OPTICHEM) exceed 70,000 tons capacity

In summary it may be concluded that the basic weaknesses in ADMARC's distribution system concerns at the retail level (1) sparcely spreaded sales outlets (2) the remoteness of those sales outlets from the average farmer and (3) the availability of stocks in too short a period. And at the Regional level (4) the location and quantities of buffer stocks which appear to be unevenly balanced vis-a-vis the volumes of sales in the different areas.

4.3 Pricing and Economic of Fertilizer Use

Fertilizer Prices

There exist a dual price system for fertilizer in MalaՁi. The Commercial sector of farming pays the full landed cost for all types and grades of fertilizer, while small holders in the customary sector of farming are provided with fertilizers at a subsided rate through ADMARC.

COMPUTATION OF FERTILIZER PRICES
(Kwacha's/Metric Ton)

	Sulphate of Ammonia		CAN		20:20:0		C-Mixture	
	1977	1978	1977	1978	1977	1978	1977	1978
F.O.B. Europe/USA	66.12	79.73	97.85	113.63	143.40	140.59		
Ocean Freight + Insurance	23.10	33.33	23.10	24.95	23.10	33.30		
Cost C.I.F. Beira	89.22	113.06	120.95	138.58	166.50	173.89		
Port/Clearing/Rail charges	24.20	26.14	30.70	33.16	30.70	33.16		
Sundries	5.10	5.50	4.49	4.85	8.00	8.64		
COSTS - LIMBE	118.52	144.70	156.14	176.59	205.20	215.69		
F.O.R. Price Limbe (Optichem)		150		174.60				223
ADMARC's Retail Price to Small-holders	110.28	110.28	155.39	155.39	170.43	170.43		203
Kwachas/ton Nutrient	524		596		425			
ADMARC'S ACTUAL COSTS K/ton		156		189		228		

As the above table shows ADMARC in agreement with the Government, follows a single-price policy for each type and grade of fertilizer at retail level. The retail prices to small holders remained unchanged during the last 3 years regardless the increase in landed costs.

Sulphate of Ammonia is at present the cheapest straight nitrogen fertilizer available and also carries the heaviest rate of subsidy. This subsidy includes a part of the landed costs plus all local costs of handling, storage and transport. The latter costs are reported to be about K13.50. Thus, the total subsidy on SA in 1978/79 amounted to about K46 per ton or 30% of actual costs.

The subsidy on sales of the 20-20-0 compound is approximately K58 per ton or 25% of actual costs. As a matter of fact this fertilizer is on-a-ton-nutrient basis the cheapest product available to farmers. The subsidy on actual costs of CAN is estimated at K34 per ton or 18%.

The cost of the subsidies are borne by ADMARC and recovered from the revenues of its trade in agricultural commodities.

In view of the large differences in prices for certain types of fertilizer such as SA, and CAN, which are commonly used in both sectors of farming, it is natural for the market to become porous. The distinction in market share between the commercial and the customary sector of farming has become distorted because substantial quantities of CAN and to a lesser extent also SA and 20:20:0 (in the Central and Lake Shore Region) have been transferred indirectly from ADMARC to the holders of small tobacco and other estates who are officially not entitled to buy from ADMARC. In case of shortages in supply such trends will only strengthen, as there does not seem to exist a swap agreement between the two distributing organizations.

It may seem odd but it happens that one of the organizations may have ample stocks of certain grades lying unsold in the store while clients of the other distributor had no way of procuring them in an official manner.

Crop Prices in the customary sector of farming

ADMARC, in its capacity of a statutory body with full financial and administrative independence, guarantees in consultation with the government, the minimum guaranteed farm-gate prices each season before the planting begins. Likewise are the prices of fertilizer fixed. At the time of marketing those crop prices may either be confirmed or increased depending upon prevailing auction parity values.

For tobacco for instance a two-tiers producer price structure has been in operation since 1969 whereby first payments are accompanied by bonus payments, varying between 15% and 60% or the value of the tobacco sold, generally in the period November/December. This improves the liquidity position of the small holder and enables him to purchase the fertilizer he requires for the next cropping season.

AVERAGE FARMGATE PRICES PAID BY ADMARC

	1975/76		1976/77		1977/78		1978/79 (Estimate)	
	t/lb	K/Ton	t/lb	K/Ton	t/lb	K/Ton	t/lb	K/Ton
TOBACCO:								
Fire-Cured	13.36	294	15.22	335	21.4	471.00	19.0	418
Sun/Air Cured	13.74	302	15.19	334	21.2	466.00	19.0	418
Oriental	21.59	475	21.22	467	21.3	469.00	22.2	490
MAIZE	2.25	49.50	2.25	49.50	2.25	49.50	2.25	49.50
GROUNDNUTS	7.77	171	8.31	183	9.70	213	12.80	280
COTTON	7.67	169	8.57	189	10.50	231	10.50	231
RICE	4.48	99	4.46	98	4.46	98	4.46	98

ECONOMIC OF FERTILIZER USE IN THE CUSTOMARY SECTOR OF FARMING

Though most farmers in Malaŵi may nowadays be aware of the effects fertilizer have on crop yields, fertilizer use is far from being a generalized practice.

This is the result not only of a lack of means to buy fertilizer but also of limited scope of commercialization of staple food crops, unattractive returns on investments as well as inadequacies in the distribution system particularly at the retail level.

Fertilizer application in the customary sector of farming is at present almost exclusively confined to maize (both local and hybrid varieties), tobacco and irrigated rice.

Other cash crops like groundnuts, cotton, etc. are not fertilized, regardless existing marketing facilities and the quantities of products annually purchased by ADMARC. No results of simple trials and demonstrations carried out on a large scale in farmers' field are available to identify economically increases in yields that would be obtained from fertilizer dressings of tobacco, maize, groundnuts, cotton and rice. Yet it is evident that at present the use of fertilizer on tobacco gives beneficial returns.

Spurred by a 60% increase in farmgate prices since 1975/76 production of western tobacco has been growing at a corresponding rate in recent years. The uptake of tobacco fertilizer (20:20:0) rose by not less than 120% between 1975/76 and 1977/78. It is indicative of the price responsiveness of a crop like tobacco but also the sensitiveness to changes in the margin of profits.

Taking into consideration that the base yield of tobacco is about 300 Kgs. per hectare and the incremental yield from the standard fertilizer application is about 2, the average yield of fertilized western tobacco amounts to an average of 600 to 700 Kgs per hectare. Only 400 to 500 Kgs is reportedly saleable because of quality. Sales of dried and cured leaves to ADMARC vary between 300 to 400 Kgs per hectare on an annual basis while for 70 to 100 Kgs the farmer reportedly finds an outlet on the local market.

The average farmer invests about K50 per hectare in applying the standard fertilizer dressing and the value of his saleable incremental yield averages K75 (to an estimated maximum of K100). Thus the cost/benefit ratio is about 1.5 (with an optimum of 2).

It is obvious that the slightest narrowing of margins between farmgate price and fertilizer costs may result in a sharp decline in the use of chemical fertilizer and consequently in production as the yield records over the past 10 years distinctly show.

More Differentiated is the Picture for Maize

The scanty information available from the project areas indicate that the application of 1 Kg of SA in amounts up to 200 Kgs per hectare usually guarantee an average of 2.5 Kgs of additional grain in the case of local varieties and at least 4 Kgs in the case of hybrid maize, for quantities of SA up to 370 Kgs/ha. As both grains are equally priced, the cost/benefit ratio obtained from the use of SA on local maize is as low as 1.13 against not less than 1.8 for hybrid maize. Yet in spite of the marginal gains from applying fertilizer onto local varieties of maize, the number of farmers following such practice must have significantly increased in recent years. Some 724 tons of hybrid maize seed have been sold during the current cropping season which is, based on an average sowing rate of 25 Kgs per hectare, equivalent to a cultivated area of about 29,300 hectares.

As the greater part of the seed package is issued with some 370 Kgs of fertilizer (SA per hectare) and practically all hybrid maize is fertilized the quantity of fertilizers used on hybrid maize in 1978/79 must have amounted to 10,860 tons, leaving a balance of 12,340 tons for local plus synthetic and composite varieties of maize.

Outstanding is therefore the fact, that small holders in MalaŵI are prepared to accept margins of profit, that are substantially lower than elsewhere. It may indicate a pressure on land in case for instance, through a favourable marketing environment, a greater part of the small holding is being planted with a cash crop, increasing yields of staple food (local maize) on the remaining land may become a stringent need to avoid buying maize on the open market in the off season at a substantial higher price. It is also obvious that the current marginal reports to be derived from fertilizing local maize leave little room for elasticity in prices. The slightest increase in the price of SA will immediately invoke an averse effect on fertilizer consumption.

Much different is the case for hybrid maize. Fertilizer use gives returns attractive enough to expect a steady increase corresponding to the expansion in hybrid maize production, even if the subsidy on SA would be abolished, as long as ADMARC continues to function as a residual buyer.

For other cash crops like groundnuts (75,000 ha) and cotton (25,000 ha) farmgate prices are maintained at such a low level, that cost/benefit ratios offer farmers hardly an incentive to use fertilizer at all at present.

The same holds for rice (rainfed 11,000 ha, irrigated: 2,600 ha)

Not withstanding the low rate of return, the practice of applying fertilizers onto irrigated rice has been introduced in the project areas, but less than 40% of the farmers growing rice are reportedly using fertilizer (SA) onto their crop.

4.4 CREDIT AVAILABILITY

The major source of agricultural credit in Malawi is of an institutional nature.

In the absence of a Central Credit Bank, Small holders have access to seasonal and medium term credit, through the following public sources:

(1) The four major agricultural development projects (LLDP, KRDP, SVADP, LRDP)

(2) The Department of Agricultural Development (Settlement Schemes)

(3) Crop Development Authorities

(4) Government Loans Board

(5) ADMARC

Seasonal Credit Accounts for about 85% of total lending. It is given out for seeds, fertilizers and insecticides on a package basis by the Institutions mentioned above.

The extent of seasonal credit in 1976/77 and 1977/78 amounted to K2.1 million and K2.73 million respectively and was issued to about 100,000 small holders, taking up an average loan of K20 per season. (Table 11)

The standard interest to individual borrowers is 15% and the recovery rate seem in general to be very satisfactory (94.7%).

To reduce the high cost of administering individual loans, the current, policy is to issue seasonal credit exclusively on a group basis to self-accounting farmers. The interest charge to genuine groups is 10%.

Funds issued by the four major projects alone amounted to K1.74 million (93% of total issues) in 1976/77 and to K2.32 million in 1977/78.

The fertilizer component of the seasonal credit issued in 1977/78 by the four major projects amounted to K1.3 million or 55% of total credit issues.

Fertilizers taken up under the credit facilities available in the project areas accounted for 75% of all sales as against a national average of about 10%.

Projects	Total Amount Seasonal Credit 1977/78 (K)	Value all Fertilizer Sales (K)	Value Fertilizer Sold on Credit (K)	CREDIT FERTILIZER % of Total Credit Issued	CREDIT FERTILIZER % of all Fertilizer Sales
LLDP	1,292,000	1,240,000	928,175	72	75
LRDP	591,712	235,240	231,400	39	98
KRDP	252,632	202,600	98,000	54	54
SVADP	181,094	22,220	22,220	9	100
Total:	2,317,438	1,700,000	1,279,795	55	75

It is evident that the sales of fertilizer on credit plays an important role in the project areas.

Fertilizers are offered in a package deal with improved seed (Maize and rice) and the greater part of the seed package bought with project credit was issued with 3 bags (of 50 Kgs) of fertilizer (per acre).

The availability of credit coupled with the security of crop sales and the existing marketing facilities seems to have had a stabilizing effect on fertilizer consumption in the LLDP area. This is illustrated in the table below.

The figures reveal that in the period 1972-75, when farm gate prices were low and fertilizer costs sharply increased (1974/75), the decline in fertilizer uptake was much lower in the LLDP than in the Non-Project areas of the Central Region.

Furthermore, the rebound which followed in subsequent years as a result of improved farm gate prices, showed a proportionally higher rate of recovery in the non-project areas.

Another feature of interest is the trend in fertilizer cash sales in the LLDP area, which showed a distinct movement upward from 1975 onwards. Farmers' liquidity positions apparently improved to such extent, as a result of higher tobacco prices and not at least by recurring bonus payments (between 40% and 60%) that they preforred cash purchases rather than expensive credit uptake.

The lowering of the bonus payment to 15% last December (1978) had an immediate effect on the trend in cash sales. It declined from almost 30% in 1975/78 to 15% in the current cropping season (1978/79).

No bonus payment is expected to be paid on the tobacco sold to ADMARC this year.

FERTILIZER SALES IN CENTRAL REGION AND LLDP

	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79
Total Sales Central Region				14,446	7,624	10,854	16,450	25,151	25,387
Total Sales LLDP	877	3,936	3,942	7,055	4,286	5,365	6,460	9,485	10,223
% LLDP Sales of Total Central Region Sales				48.8	56.2	49.2	39.3	37.7	40
Cash Sales as % of total Uptake in LLDP	9.5	1.5	1.3	17.7	13.0	28.7	20.3	28.2	15.7
Tobacco Bonus payments(% of guaranteed minimum price)		15	-	-	40	40	60	15	-
Month of payment									

The bonus which is usually paid in November/December on last season's crop has apparently, a direct bearing on the farmer's cash position and determines to a large extent his ability to purchase fertilizer for the following cropping season. Within the project area's the farmer can fall back on credit in case he is short of cash, not so ingeneral in the non-project areas.

It shows the substitutive effect of credit as against cash in a fertilizer market characterized by small returns (except for Hybrid maize) to small holders with limited and varying cash positions but who have security of selling their produce.

Credit as such is however not the major factor in promoting fertilizer use, whatever its apparent importance in the project areas. Low and variable rates of return, coupled with a limited scope for expanding saleable surpluses and shortages in input supply, are the major impedements to an increase in fertilizer use at present.

A policy of providing farmers with larger margins of economic return on a regular basis coupled with a system of encouraging saving deposits or to purchase inputs with cash in advance of the season would provide a more effective means to promote fertilizer use than reliance on credit supply alone.

5. FERTILIZER DEMAND FORECAST

The low consumption per capita (1977: 16.9 kgs of fertilizers) and per hectare of cultivated land (9 kgs of NPK) seems to offer ample scope for substantive increases in the use of fertilizers in Malawi.

However, the projections for the growth in demand have to be modest as long as the economics of the effect of fertilizer use on crop production remain invariable low and at times even marginal, and problems of supply continue to have their impact on consumption.

As the records show, consumption of fertilizers in the customary sector of farming has been erratic in the past and the practice of using chemical fertilizers is confined to a few crops only.

The classical techniques of estimating fertilizer requirements have therefore to be used with caution, because the prerequisites to a steady and effective development of demand are not present.

A further handicap is the lack of accurate statistics on total acreage of crops brought under cultivation each year, as well as the absence of any information on the percentage of customary land and crops annually fertilized.

In assessing future fertilizer requirements and in forecasting demand in the coming 10 years, a distinction has to be made between crops grown by estates and those cultivated by small holders. Different methods, appropriate to each market segment have to be used.

5.1. REQUIREMENTS BY CROPS

Estate Tobacco

There exist a distinct correlation between the expansion in acreage of flue-cured and burley tobacco and the uptake of the so-called tobacco mixtures, which are invariably used on both types of tobacco as a basal dressing and at a standard rate of application per unit of land.

In the period 1970/71 - 1978/79, estate tobacco acreage has been expanding from year to year at a compound rate of about 12% (Table 12).

Likewise, consumption of tobacco mixtures has been growing at a rate of 12% for P_2O_5 and 10.5% for Nitrogen (Table 2).

A simple extension of trend lines of past consumption is however not applicable as growth in both flue-cured and burley tobacco production is expected to slow down significantly as compared to preceding years. After the upsurge in world demand over the past 4 years, a period of consolidation seems to have set in and only the better grades of tobacco are still in strong demand.

It is therefore expected that production in the period 1980/85 will increase at an annual average of about 5% only. A somewhat higher growth rate of 6% is reportedly feasible for the period 1985-90.

As yields in estate farming are expected to increase only marginally, growth in production has to be attained largely by an expansion in acreage from about 33 000 ha at present to 41 500 ha by 1985 and 55 600 ha by 1990. This, in itself, would involve fertilizer requirements up to 5560 tons of N by 1985 and 7450 tons of N by 1990 as shown below:

	Base Year 1977-79	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Basal Dressing												
Tobacco mixtures (Metric tons)	17300	18165	19073	20027	21028	22080	23184	24575	26050	27613	29270	31025
nutrient equivalent (metric tons)												
P_2O_5	3114	3270	3433	3605	3785	3974	4173	4423	4689	4970	5268	5585
K_2O	2595	2725	2861	3004	3154	3312	3478	3651	3834	4026	4227	4438
N	1038	1090	1144	1202	1262	1325	1391	1475	1563	1657	1756	1862
Top Dressing												
(Metric tons N)	3114	3270	3432	3606	3786	3975	4173	4425	4689	4971	5268	5586
Total N	4152	4360	4576	4808	5048	5300	5564	5900	6252	6628	7024	7448

Customary farming tobacco

The production of western types of tobacco over the past 7 years (1970-78) has not only been far less expansive than both flue-cured and burley tobacco, but also more erratic.

Inadequacies in the quota system, constraints on the world market, as well as fluctuations in the habit of using chemical fertilizers are in debt for the absence of consistency in growth and the variations in output from year to year (Table 12).

Acreages for all types of western tobacco increased from about 37 000 ha in 1970/71 to 45 600 ha in 1977/78 corresponding to a compound rate of growth of 3% per annum. The use of the standard basal dressing, namely 20-20-0 has been increasing in the same period at a somewhat higher rate i.e. 4% per annum, because not all farmers had applied fertilizers in years when economic returns of fertilizer use were only marginal.

Though the top quality of the country's fire-cured tobacco is renowned, a substantial part of the annual output is of an inferior grade for which there is at present little demand on the world market.

Large stocks of unsold fire-and sun-cured tobacco have been accumulating in recent years and it is expected that output will remain static if not decline until 1981.

From then onwards it is anticipated that production will resume its upward trend again at a rate which is reportedly assumed to be around 5% per annum.

Because the availability of land suitable for tobacco cultivation is limited, a significant part of the anticipated growth in production of western tobacco 's will have to come from increments in yields of quality tobacco on existing lands. This has to be attained by more balanced nutrient and higher rates of fertilizer application. For the sake of simplicity it is assumed that the rate of fertilizer consumption increase will be similar to the one forecast for production i.e. 5% per annum from 1981 onwards. In this was it is expected that fertilizer requirements for the customary sector of tobacco cultivation will amount to about 4600 tons of N by 1985 and 5860 tons of N by 1990.

	Base Year 1977-79	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Basal Dressing												
20-20-0 (metric tons)	6000	6000	6300	6615	6946	7293	7658	8040	8443	8865	9308	9773
Nutrient equivalent (metric tons)												
P_2O_5	1200	1200	1260	1323	1389	1459	1532	1608	1689	1773	1862	1955
N	1200	1200	1260	1323	1389	1459	1532	1608	1689	1773	1862	1955
Top dressing (metric tons N)	2400	2400	2520	2646	2778	2917	3063	3216	3377	3546	3723	3909
Total N	3600	3600	3780	3969	4169	4376	4595	4824	5066	5319	5585	5864

Maize

The basic staple food in MalaΩi is maize which covers annually an estimated average of 65 per cent of the total cropped area. According to the Government projections, future maize requirements, and production, are to increase at the same rate as the NET population growth i.e. 2.9% per annum.

National maize requirements for the period 1980-90 would therefore be as follows:-

Year	Population	Maize consumption	Increase	Equivalent in area planted with improved varieties	Corresponding fertilizer requirements, expressed in mtons of sulphate of ammonia	Nitrogen equivalent
	(1000)	(1000 mt)	(1000 mt)	(1000 ha)		(1000 mt)
1977 (Base Year)	5570	1550				
1980	6060	1700	150	75	26.3	5.13
1985	7000	2000	450	225	79.0	15.80
1990	8060	2170	620	310	108.0	21.60

Since the projected increase in production has to come mainly from substituting improved varieties of maize (hybrids, composite and synthetics) for local types, giving a yield increment of about 2 tons of grain per hectare, an additional area of some 225 000 ha should be planted with improved maize by 1985 and some 310 000 ha by 1990.

This in itself would require the use of not less than 79 000 tons of sulphate or ammonia by 1985 and 108 000 tons by 1990. It is unlikely that the above pattern of maize production will materialize and consequently the figures for corresponding fertilizer requirements would appear to be on high side.

As a matter of fact, basing fertilizer demand estimates entirely on food crop requirements is not very reliable and other methods have to be adopted in **forecasting** a more realistic demand.

As no improved maize is growth without fertilizer, there exist a natural correlation between the acreages under improved varieties of maize and fertilizer use.

Unfortunately no precise data on crop acreage are available and the only key to assessing actual and future demand are the quantities of seed annually issued to farmers by ADMARC .

Some 724 tons of SR 52 and 543 tons of UCA seed have been distributed in 1978/79 against 625 tons and 346 tons respectively in 1977/78.

The supply of the above quantities of seed correspond to approximately 29 300 ha of land planted with SR 52 and 22 000 ha of land planted with UCA in 1978/79 against 25 300 ha and 17 650 ha respectively in 1977/78.

This implies that about 19 [illegible]0 tons of fertilizers (mainly SA) had been applied onto improved maize in 1978/79 against 15 900 tons in 1977/78, an increase of about 21%.

Future targets of growth in seed production and distribution are reportedly estimated to be between 5 and 10% on an annual basis. Taking an compound annual growth of 7% as an average for the period 1980-90, then the area under improved varieties of maize and the corresponding fertilizer requirements would be as follows:-

Base Year	Area under improved maize (ha)	Fertilizer Requirements as expressed in M tons of SA	Nitrogen equivalent (metric tons)
1977-79	47 125	17 500	3 675
1980	54 459	20 233	4 249
1981	58 543	21 740	4 565
1982	62 934	23 371	4 908
1983	67 654	25 124	5 276
1984	72 728	27 008	5 672
1985	78 183	29 033	6 097
1986	84 046	31 211	6 554
1987	90 390	33 552	7 046
1988	97 126	36 068	7 574
1989	104 410	38 773	8 142
1990	112 241	41 681	8 753

No estimates for the requirements of phosphatic fertilizer can be given, as the practice or applying P_2O_5 in conjunction with Nitrogen has not yet been firmly established.

From the agronomic point of view, it would however be justified to assess the required tonnages of P_2O_5 at half of those estimated for Nitrogen.

Tea

The formulation 25-5-5 has by now almost entirely replaced sulphate ammonia as a fertilizer in the tea cultivation.

The standard recommendation for mature tea is 730 kgs per hectare per year, applied in two equal dressings in the months of November and December.

The above recommendation works out to an annual application of 182 kgs of N and 36.5 kgs of both P_2O_5 and K_2O.

For young tea the recommended rate is 320 kgs of 25-5-5 per hectare per year.

Tea production and acreages have expanded consistently over the past 10 years at an average of 2% per year, to reach 17 400 ha in 1977 and 17 820 ha in 1978. (Table 12).

Nitrogenous fertilizer uptake in the corresponding years amounted to 2450 tons and 2900 tons of N respectively, which is equivalent to about 140 kgs of N per hectare.

It is anticipated that in the period 1980-90 tea production in the estate and small holder sector of farming will increase by 3% a year, as a result of an expansion in acreage (2%) and an increase in productivity to be obtained from new techniques, substituting old plant material by higher yielding clones, increase in rates of fertilizer application, etc.

It seems therefore justified to forecast for the period 1980-90 a similar rate of growth in fertilizer use, which would result in 3100 tons of N being required by 1985, and some 3600 tons by 1990.

	Base Year 1977-79	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
N	2600	2672	2757	2840	2925	3013	3104	3197	3293	3391	3493	3598
P_2O_5	520	534	551	568	585	603	621	639	659	678	699	720
K_2O	520	534	551	568	585	603	621	639	659	678	699	720

Because of labour shortages and costs there has recently been a noticeable shift from manual to aerial application of fertilizers. Some 20 to 25% of the land under tea is now being fertilized by plane, and with urea instead of the 25-5-5 formula, because of costs considerations. It is anticipated that the new technique will expand but not fully replace application by hand.

Sugar cane

Mainly Nitrogenous fertilizers have been applied in the past onto sugar cane, and one single application of sulphate of ammonia per year has been the common practice. A shift to urea is however anticipated. The cost per unit of Nitrogen in urea is at present aubstantial lower than the N-unit costs of both sulphate of ammonia and calcium ammonium nitrate. Urea and SA will therefore be applied alternatively, where sulphur deficiencies are suspected or single super phosphate and sulphate of potash will be applied as alternative sulphur carriers.

As the soils of the sugar estates appear to be rich in micaceous fractions convincing responses to potash applications could not been detected so far. Future consumption of both potash and phosphate is therefore difficult to forecast.

On the other hand, increase in Nitrogenous fertilizer use will closely follow the expansion in area under cultivation and production at a rate of about 1.36 kgs of Nitrogen per ton of cane.

In the context of the sugar cane expansion programme consumption of Nitrogenous fertilizer will reach some 2400 tons of N by 1985, and will further increase to some 2650 tons of N by 1990.

ESTIMATES OF SUGAR CANE PRODUCTION AND NITROGENOUS FERTILIZER REQUIREMENTS

Cane production	1976	1977	1978	1979	1980	1985	1990
(1000 M tons)	875	884	967	1220	1550	1775	1950
N - Requirements (M tons)	1190	1202	1315	1659	2110	2414	2652

Overall requirements

By determining for the major fertilizer consuming crops the future nutrient requirements and by consolidating the resulting figures in an overall demand estimate, it appears that the market would reach a total of about 21 800 tons of Nitrogen, 6400 tons of P_2O_5 and 4100 tons of K_2O by 1985.

Corresponding figures for 1990 would amount to 28 300 tons of N, 8300 tons of P_2O_5 and 5200 tons of K_2O respectively.

ESTIMATE OF FERTILIZER REQUIREMENTS IN THE PERIOD 1980-90 (metric tons of nutrients)

Crops	1980			1985			1990		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Estate tobacco	4360	3270	2725	5564	4173	3478	7448	5585	4438
Western tobacco	3600	1200	?	4595	1532	?	5864	1955	?
Maize	4249	?	?	6097	?	?	8753	?	?
Sugar cane	2110	?	?	2414	?	?	2652	?	?
Tea	2672	534	534	3104	621	621	3598	720	720
Total	16991	5004	3259	21774	6326	4099	28315	8260	5158

5.2 TREND METHOD

5.2.1. Overall Nitrogen demand

Trend lines show that overall consumption of Nitrogen has been increasing over the past 6 years at a compound average rate of 5% per annum. (Table 2). Whereas a simple extension of this line is in itself not a very reliable method, in the context of the market structure and conditions as prevailing in Malaŵi, it may well provide a fair indication of the quantities of Nitrogen that will most likely be consumed in the medium term.

Thus, a simple extrapolation of the trend line shows that by 1985, the market would be capable of taking up some 24000 tons of N, equivalent to 29 300 tons of ammonia (NH_3) per annum, and some 31 000 tons of N (37 800 tons of NH_3) by 1990.

NITROGEN DEMAND FORECAST BY TREND ANALYSIS
(weighed annual increase: 5%)

Base year 1972-74 weighed average consumption (M tons N)	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91
13545	19059	20012	21013	22063	23167	24325	25541	26818	28159	29567	31046
NH_3 equivalent	23240	24400	25620	26900	28130	29660	31145	32700	34340	36050	37860

Compared to the Nitrogen requirements, as consolidated for all crops in a preceding section, it appears that the trend method would indicate somewhat higher levels of demand for the period 1980-90. This is not surprising after all as the estimates of individual crop requirements were deliberately conservative and confined to crops which figured prominently in the pattern of past consumption.

5.2.2. Nitrogen fertilizer types and grades

To determine the future product-mix of the market, it is not feasible to simply extrapolate the trend lines of past consumption for the different types and grades (Table 2).

Future growth in demand will vary from product to product, due to changes in agronomic recommendations, unit cost price and availability of supplies. Nevertheless, it will be possible to give a fair estimate of future demand for compounds and straight nitrogenous fertilizer because the pattern of consumption is rather static, while tea and tobacco mixtures, which are currently in use will continue to prevail in the market.

The rationale for segmentation of the market by types and grades at this stage is to establish (1) the flow of products to be compounded or mixed locally and (2) to determine the quantities of nitrogen they will contain

Tea fertilizers

Regardless the tendency of substituting aerial for manual application of fertilizers in tea, the need for a balanced NPK ratio will remain. Those estates which for economic reasons started to apply urea by plane instead of the 25-5-5- formula, have it followed by a second aerial application of a potash-phosphate mixture.

It is not unlikely to see the practice of applying mixtures to be resumed as soon as currently differentials in prices between simple and compound fertilizers will disappear and to assume that the major part of future nitrogen requirements will be applied in the form of an NPK compound or mixture.

Tobacco fertilizers

It is anticipated that the socalled tobacco mixtures (average NPK ratio: 6-18-15) will gradually become the standard basal dressing for tobacco in both the estate and customary sector of farming.

An overriding consideration is substituting the 6-18-15 formula for nitrophosphate (20-20-0), presently used by the small holders, is the need to improve the quality of western types of tobacco.

Thus, it is estimated that approximately one third of the future overall nitrogen requirements for tobacco will be taken up in a mixed or a compound form while the balance will be applied as a straight nitrogenous fertilizer.

Maize fertilizers

The standard practice in estate farming is a basal dressing with the 12-19-5 formula, to be followed by a top dressing with CAN. The customary sector of farming uses almost exclusively sulphate or ammonia with occasionally a basal dressing of 20-20-0.

It is difficult to predict what success extension efforts in introducing a more balance nutrient ratio will have in the future but it seems most likely that demand will continue to be mainly for straight introgenous fertilizers.

By and large it is expected that about one third of future nitrogen demand will have to be supplied in a compound or mixed form. This works out to about 7200 tons of N in 1985 and 9300 tons of N in 1990.

NITROGEN PRODUCT - MIX
(metric tons)

	ACTUAL				ESTIMATES					
	1975/76	%	1978/79	%	1980/81	%	1985/86	%	1990/91	%
Compound N	2600	24	5616	33	5900	31	7200	30	9300	30
Simple (or straight) N	8303	76	11580	67	13100	69	16800	70	22500	70
Total N	10903	100	17196	100	19000	100	24000	100	31800	100
Average N content of compounds (%)	12		14		14		15		15	
Tonnages of compound/ mixtures	21411		39237		42000		48000		62000	

As the average N content in the mixtures and compound fertilizers in 1975-79 varied between 12% and 14% and no drastic changes are envisaged in regard of grades and NPK ratios, it seems justified to assume that the quantities of compound fertilizers and mixtures to be supplied by 1985 will amount to approximately 48000 tons in 1985 and to 62 000 tons in 1990.

Simple nitrogenous fertilizers

With regard to simple or straight nitrogenous fertilizers it has been already remarked earlier that consumers preference is clearly for ammonium nitrates,

and that this product would have been used on a much larger scale if the price would have been more competitive with both urea and SA.

As the nutrient content of ammonium-nitrate fertilizers (26-31% N) favourably compares to that of SA 21% N, it offers savings in the costs of transport, handling and storage. Future demand for simple nitrogenous fertilizer, estimated to be around 70% of total N. requirements could therefore be almost entirely met by ammonium nitrates. However for paddy-rice either SA or urea would remain the proper N-carrier.

TABLE I : TRENDS OF SALES BY FERTILIZER TYPES
(METRIC TONS PRODUCT)

Type of Fertilizer	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79
Compounds:							
NPK : 25-5-5	7,967	7,321	3,686	4,808	6,990	8,614	10,520
3-2-1	-	-	552	440	1,700	1,389	2,581
A : 2-18-15	251	683	457	470	480	988	1,025
B : 4-18-15	2,796	2,937	3,399	3,584	2,500	2,376	2,550
C : 5-18-15	4,691	5,274	7,627	8,288	11,800	12,805	13,902
D : 8-15-10	224	195	30	33	-	-	-
L : 8-10 15	664	394	457	495	-	-	-
M : 10-12-12	249	97	70	242	-	-	-
S : 6-16-6	172	297	296	308	400	370	541
X : 20-10-5	169	63	78	96	-	-	-
NP : 20-20-0	6,462	6,227	1,712	2,567	4,148	6,374	8,971
STRAIGHTS							
Am. Sulphate (21N)	34,304	30,149	34,558	31,067	31,926	41,894	40,201
CAN (26N)	6,681	8,398	4,271	5,680	5,251	8,903	9,896
UREA (46N)	295	4,143	990	540	303	343	356
Nitrate of Soda (16N)	340	266	418	358	650	1,022	1,274
SSP (18-20 P_2O_5)	151	173	194	193	350	257	206
TSP (44-46 P_2O_5)	93	141	60	57	180	173	35[illegible]
KCL (60 K_2O)	127	79	189	242	400	136	403
K_2SO_4 (50 K_2O)	4	10	15	16	20	49	147
Others (UN Specified) (MIXTURES)	1,353	307	401	804	1,293	999	874
TOTAL CONSUMPTION	66,993	67,151	59,655	60,368	68,391	86,692	93,803
OF WHICH COMPOUNDS	23,645	23,488	18,564	21,411	28,018	32,916	39,237
PERCENTAGE OF TOTAL	35.3	35.0	31.1	35.5	41.0	38.0	43.7

Source:

Ministry of Agriculture and Natural Resources

Fertilizer Manufacture Project, May 1978.

TABLE 2: TRENDS OF CONSUMPTION BY FERTILIZER TYPES
(METRIC TONS NUTRIENT)

	COMPOUNDS											STRAIGHTS										
	25-5-5			3-2-1			20-20-0		TOBACCO MIXTURES			UREA	CAN 26	AM. SUL. 21	NITRATE OF SODA	TSP/SSP	POTASH	T O T A L			
YEAR	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	N	P_2O_5	K_2O	N	N	N	N	P_2O_5	K_2O	N	P_2O_5	K_2O	NPK
1972/73	1992	398	398	-	-	-	1292	1292	540	1644	1570	136	1737	7204	51	71	78	12958	3405	1846	18207
1973/74	1830	371	371	-	-	-	1245	1245	596	1789	1491	1906	2183	6331	40	86	62	14131	3501	1914	19546
1974/75	922	184	184	69	105	28	342	342	757	2271	1892	455	1110	7266	63	64	121	10974	2966	2225	16165
1975/76	1222	244	244	55	84	22	513	513	810	2432	2027	248	1477	6524	54	65	166	10903	3336	2246	16485
1976/77	1748	350	350	213	323	87	830	830	911	2732	2277	189	1865	6704	98	148	260	12008	4383	2984	19365
1977/78	2154	431	431	174	264	71	1257	1257	995	2978	2447	167	2815	8797	153	127	107	15990	5075	3056	24121
1978/79	2630	526	526	323	490	132	1624	1624	989	3243	2654	166	2567	8658	191	200	316	17196	6083	3628	26907
COMPOUND									10.5	12	11.6							6.0%	10.1%	11.9%	
ANNUAL RATE OF INCREASE 1972/73		5%			47%		4%			11.4		-	6.7%	3%	-	-	-				6.8%
N/P/K RATIO																					
1972																		7	1.8	1	
1978																		4.7	1.6	1	

TABLE 3 : TYPE OF N-FERTILIZER USAGE

(METRIC TONS NITROGEN)

YEAR	NITRIC ACID BASED 1/				SULPHURIC ACID BASED 2/				GRAND TOTAL	PER CENT
	TOTAL	% TOTAL	COMPOUNDS	STRAIGHT	TOTAL	% TOTAL	COMPOUNDS	STRAIGHT		
1975/76	3322	33.6	1793	1531	7582	66.4	810	6772	10903	100
1976/77	4254	37.0	2791	1463	7754	63.0	910	6844	12008	100
1977/78	6071	39.3	3603	2468	9919	61.0	965+	8954	15990	100
1978/79	7335	44.2	4577	2758	9861	55.8	1039+	8822	17196	100
COMPOUND ANNUAL RATE OF INCREASE 1975-79	30.0%		36.8%	21.7%	9.2%		8.7%	9.0%	16.4%	

1/ Nitric Acid based compounds: 25-5-5; 3-2-1; 20-20-0
straights; CAN; Nitrate of Soda

2/ Sulphuric Acid based compounds; Tobacco Mixtures
straights; Ammonium Sulphate (UREA)

+Includes Tobacco Mixtures sold by ADMARC.

TABLE 4 : FERTILIZER CONSUMPTION BY PRODUCT, TYPE OR FARMING AND CROP (METRIC TONS)

CROPS	CULTIVATED AREA (1000 ha) 1977/1978	1978/79	FERTILIZER RECOMMENDATION FORMULAE	RATE (Kgs./Ha)	TOTAL CONSUMPTION 1977/78	1978/79	% TOTAL 1978/79	AREA FERTILIZER % TOTAL
ESTATE FARMING					42,127	48,018		
1. Maize	6.5	6.5	3-2-1(12-19-5)	400-500	1,389	2,581	4.0	100
			CAN	200-250	723	1,200		
2. Paddy	0.25	0.25	20:20:0	200-250		60		
			S/A	200-250		50		100
3. Tea	17.5		25-5-5		8,614	10,580		
			S/A		1,452	1,311	12.6	100
4. Sugar Cane	9.4		S/A		5,000	5,500		
			SSP/TSP		430	563	6.9	100
			KCL		135	483		
5. Tobacco			A: 2-18-15		988	1,025		
Flue-cured	17.8	19.8	B: 4-18-15		2,376	2,550		
Burley	8.7	12.6	C: 6-18-15	600-700	12,805	13,902		
			S: 6-18-6		378	541	31.5	100
			Nitrate of Soda		1,822	1,274		
			CAN	400-500	5,000	4,704		
			S/A	400-500	1,607	1,551		
			Sulphate of Potash		49	147		
CUSTOMARY FARMING					44,565	45,788		
1. Tobacco			20:20:0	125	5,700	6,290		
Fire-cured	36.2	N.A.	S/A	250	11,460	12,408		
Sun/Air Cured	8.4	N.A.	CAN	-	(3,131)	(3,392)	20.9	90-100
Oriental	0.8	N.A.	Tobacco Mixtures		899	870		
2. Maize								
Hybrid	...	...	20:20:0/SA	370	671	2,771		
Local	N.A.	N.A.	S.A.	180-250	22,480	19,439	23.7	
3. Rice Rainfed	4.3(11.3)	4.0	S/A	180	-	-		
Irrigated	2.0	2.7	S/A	370	211	564	0.7	43(80)

FERTILIZER MOVEMENTS ADMARC 1976 - 79 (METRIC TONS)

TABLE : 5

MONTH	YEAR	STOCKS ON HAND	ISSUES	ACCUMULATED SALES	RECEIPTS	TOTAL RECEIPTS
APRIL	1976	41543	189	189		
MAY		41884	111	300	529	
JUNE		44911	264	564	3292	
JULY		52090	342	606	7521	
AUGUST		55249	876	1482	4030	
SEPTEMBER		54597	1319	(2800)	571	
OCTOBER		44801	1303	4103	(-8494) 1/	
NOVEMBER		42280	7689	11792	5168	
DECEMBER		48216	6083	17875	12020 3/	
JANUARY	1977		13034	30909		
FEBRUARY					2717 3/	
MARCH		37899				
APRIL		36153	234	234	(1512) 1/	
MAY		35120	103	337	(930) 1/	
JUNE		37829	114	451	2824	
JULY		38508	200	651	879	
AUGUST		41566	334	985	3091	
SEPTEMBER		44758	865	1856	4057	
OCTOBER		44134	2989	4839	2366	
NOVEMBER		40997	11497	16336	8361	
DECEMBER		31495	10001	26338	499	
JANUARY	1978	25859	14276	40615	8641 3/	
FEBRUARY		23318	2678	43293	136	
MARCH		22707	1272	44565	662	31516
APRIL		22966	278	278	536	
MAY		21693	105	382	(1168) 1/	
JUNE		17344	296	678	(4350) 1/	
JULY		24174	143	822	6975	
AUGUST		26659	262	1084	2747	
SEPTEMBER		25425	525	1608	(-709) 1/	
OCTOBER		36495	1124	2733	12194	
NOVEMBER		34384	5949	8682	3838	
DECEMBER		27525	16108	24789	9248 3/	
JANUARY	1979	15891	14100	38889	2466 3/	
FEBRUARY		12258	5100	43989	1466 3/	
MARCH		18092	1950	45939	7784 3/	47253
APRIL'		20636	218	218	2761	

NOTES :

1/ Figures between brackets indicate differences between reported and factual stocks The "Negative" receipts are most likely due to stock corrections due to losses which are discounted.

2/ Book year is from April to April

3/ Shipments which arrived too late for the cropping season.

TABLE 6 : FERTILIZER SALES AND MARKET SHARE

MAJOR DISTRIBUTORS (1972/73 - 1978/79)

(METRIC TONS)

DISTRIBUTOR	PRODUCTS	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	Compound Annual Growth
ADMARC	Ammonium Sulphate	18,752	23,017	11,412	17,456	23,611	33,835	31,839	9.0
	20-20-0	2,328	4,265	1,636	2,567	4,148	6,374	8,971	26.2
	CAN	2,668	3,277	666	1,312	1,351	3,181	3,992	
	UREA	84	873	732	219	133	177	118	
	Others	1,353	307	40	804	1,293	999	873	
	TOTAL	25,185	31,736	14,847	22,349	30,536	44,566	45,788	10.6
OPTICHEM	Tobacco Mixtures	9,216	9,949	12,614	13,516	15,189	16,539	18,018	
	UREA	211	3,270	258	330	178	166	243	
	CAN	4,013	5,121	3,605	4,368	3,980	5,723	5,904	
	Ammonium Sulphate	10,443	648	17,746	392	750	1,607	1,551	
	Nitrate of Soda	340	266	418	358	650	1,022	1,274	
	20:10:0	4,134	1,962	76	-	-	-	-	
	3-2-1	-	-	552	440	1,700	1,399	2,881	
	25-5-5	7,967	7,321	3,686	4,888	6,990	8,614	10,520	
	Tea Am. Sulphate	2,112	2,354	156	5,819	3,765	1,452	1,311	
	Sugar Cane Am. Sulphate	3,800	4,130	5,239	7,490	3,800	5,000	5,000	
	SSP	151	173	194	193	[illegible]	257	206	
	TSP	93	141	60	57	180	173	357	
	KCL	127	79	189	242	400	135	403	
	K_2SO_4	4	10	15	15	20	49	147	
	TOTAL	41,808	35,415	44,808	38,019	37,855	42,127	48,015	2.3
GRAND TOTAL		66,993	,151	59,655	60,368	68,391	86,693	93,833	5.8
MARKET SHARE		38/62	47/53	25/75	37/63	45/55	51/49	49/51	

TABLE 7 : FERTILIZER USE IN CUSTOMARY FARMING BY REGION

(METRIC TONS OF PRODUCT)

REGION	AM. SULPHATE		UREA		CAN		20:20:0		OTHERS		TOTAL		% OF TOTAL	
	1977/78	1978/79	1977/78	1978/79	1977/78	1978/79	1977/78	1978/79	1977/78	1978/79	1977/78	1978/79	1977/78	1978/79
Lower Shire	23.77	86.03	-	0.50	-	0.50	-	9.50	-	-				
Namulenga Division	2255.78	2364.56	41.74	14.65	7.10	9.75	136.95	149.46	0.86	-				
Southern Division	6228.54	5367.98	42.45	21.34	242.75	77.98	263.06	1172.98	-	-				
Central Division	2433.55	3575.38	0.6	-	210.90	82.75	543.20	321.78	-	-				
TOTAL SOUTHERN REGION	10941.64	11393.95	84.79	36.49	460.75	170.98	943.21	1653.72	0.86	-	12431.25	13255.14	27.9	28.9
CENTRAL REGION	16915.17	15003.07	69.99	71.73	2037.69	2823.16	3589 05	5163.91	541.44	303.15	23153.34	23364	51.9	51.1
LAKESHORE DIVISION	1170.56	1131.65	0.1	0.5	0.8	5.40	823.05	885.98	3.45	-	1997.96	2023.5	4.5	4.4
NORTHERN REGION	4897.58	4310.66	21.75	3.95	681.97	992.72	1018.25	1267.30	a/ 453.17	570.14	6982.64	7144.8	15.7	15.6
TOTAL	33834.87	31839.33	175.63	112.67	3181.21	3992.26	6374.06	8970.91	998.92	873.29	44565.	45788	100.0	100.0
Lilongwe Depot Seasonal	779	544.60	28	22.1	368	580.00	412	621.03	192	127.28	1773	1894		
Salima Depot Seasonal	60	7.96	0.2	-	56	8.8	10	12.95	51	-	177	30		
Nkhotakota Seasonal	278	568.35	-	-	0.5	-	74	43.35	-	-	352	611		

TABLE 8 : FERTILIZER SALES BY ADMARC

ON A NATIONAL AND REGIONAL LEVEL (METRIC TONS)

REGION	1974/75	1975/76	1976/77	1977/78	1978/79	Compound Annual Growth %
Southern Region	5,254	8,005	8,835	12,431	13,255	26.1
Central Region	7,624	10,854	16,450	23,153	23,364	32.3
Lakeshore Division	-	-	-	1,998	2,023	
Northern Region	1,969	3,492	5,252	6,982	7,144	38.0
TOTAL	14,847	22,349	30,535	44,565	45,788	32.6

FERTILIZER SALES BY OPTICHEM (METRIC TONS)

REGION	1974/75	1975/76	1976/77	1977/78	1978/79	
Southern Region				23,448	26,811	
Central Region				16,173	18,505	
Lakeshore Division						
Northern Region				2,506	2,699	
TOTAL	44,908	38,019	37,055	42,127	48,015	1.8

FERTILIZER CONSUMPTION BY REGION

REGION	1974/75	1975/76	1976/77	1977/78	1978/79	
Southern Region				35,879	40,066	
Central Region				39,326	41,869	
Lakeshore Division				1,998	2,023	
Northern Region				9,488	9,843	
TOTAL	59,655	60,368	68,390	86,692	93,883	12.0

TABLE 9 : FERTILIZER IMPORTS BY TYPES IN SHORT TONS AND VALUE (K)

	1970		1971		1972		1973		1974		1975		1976		1977		1978*	
TYPE OF FERTILIZER	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value
Sodium Nitrate	210	15136	401	26763	352	29788	332	32125	717	192389	202	35119	882	147559	-	-	450	105978
Ammonium Nitrate	586	28350	246	12023	9	4062	12	2167	3002	503592	1	53	-	-	2863	354145	3183	401217
Calcium Nitrate	-	-	-	-	-	-	-	-	-	-	1	118	-	-	551	96885	-	-
Ammonium Sulphate	24322	933054	38658	1140092	35310	1313700	17771	809418	26307	3146066	43166	7536538	33145	2916743	40843	4233627	50563	5660172
Calcium Ammon. Nitrate	2003	84512	10011	469764	5190	263168	6226	424403	418	58798	12901	2177277	8580	939995	2915	358996	6180	674770
Urea	45	3422	410	17191	331	19021	3766	314995	65	15417	224	70198	2592	501944	-	-	919	197244
Liquid Fertilizer	-	-	-	104	22	5611	-	-	-	319	-	-	-	-	-	-	-	-
Calcium Cyanamide	-	-	100	7487	-	-	-	-	-	-	2	65	-	-	-	-	-	-
Nitrogenous Fertil. NES	5063	318866	43470	937308	16759	1186670	[illegible]	357772	1248	165702	7825	1748835	30212	4544631	39072	6110431	22165	3669250
Superphosphate, Single	40	874	241	11542	43	1989	248	11285	251	17285	14001	32392	-	-	-	-	2887	202458
Superphosphate, Double and Tripple	40	2202	230	27259	-	-	166	14255	-	-	357	142624	-	-	-	-	2206	272498
Phosphatic Fertilizers	2070	126600	480	29051	87	2918	462	40026	-	-	-	-	-	-	75	3481	1431	197948
Potassium Chloride (Muriate)	26	1756	163	11132	150	8504	-	424	-	-	386	51493	-	-	-	-	606	54274
Potassium Sulphate	-	-	20	1676	51	3636	-	-	-	-	-	-	-	-	-	-	331	44141
Potassic Fert., N.E.S.	65	4218	305	14531	-	-	30	1408	-	-	480	15445	154	25579	-	145	571	78600
Fertilizer, NES (D)	5207	325046	5857	652300	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fertilizer NES in Packings NE 22 lb.(E)	-	-	-	-	1	495	1	1708	-	-	.1	206	.06	252	92	430	-	34
Fertilizers NES 18(E)	-	-	-	-	4563	283212	14749	1240389	17441	1874501	21575	3458422	4236	677967	-	59	662	179016
TOTAL	40277	1844066	100592	3358257	62868	3022754	47913	3250435	47949	5905070	88520	15264780	79801	9754670	85768	11158731	92611	11737606
VALUE IMPORTS PER TON(K)								67.80		123.20		172.40		122.20		130.10		126.70

Note: *January-November 1978 only.

TABLE 10 : SULPHATE OF AMMONIA STOCK AND SALES POSITIONS
OCTOBER 1978 – MARCH 1979
(METRIC TONS)

PERMANENT MARKET		OCTOBER 1978		DECEMBER 1978		MARCH 1979		MARCH 1979			
		Accumulated		Accumulated		Accumulated		[illegible]-0		CAN	
		Sales	Stock	Sales	Stock	Sales	Stock	Sales	Stock	Sales	Stock
Southern Region		363	1330	3106	1682	7492	477	520	536	118	55
Central Region		603	2530	6108	3032	12902	250	3634	2029	2211	619
Lakeshore		19	232	335	493	1132	75	886	459	5	6
Northern Region		339	1598	1791	3355	4054	238	1245	969	913	1399
TOTAL		[illegible]	5696	1134[illegible]	8552	25580	1040	6291	3993	3247	2079
CENTRAL DEPOTS											
Bangula	Shire Valley	3	21	3	48	5	36	7	52	-	-
Chikwawa	" "	-	-	32	102	41	93	-	-	-	-
Luchenza	South	277	7530	1322	5963	2250	-	40	7	7	23
Limbe	"	142	1604	1299	2	219	145	311	103	-	-
Liwonde	"	2	3170	548	165	774	3987	745	2847	1	126
Lambulira	"	1	560	59	386	102	-	8	50	1	144
Balaka	"	23	91	379	17	425	-	17	10	44	11
Lilongwe	Central	28	826	218	443	545	77	521	1475	[illegible]	80
Salima	Central	2	34	7	58	8	-	13	63	9	1
Nkhotakota	Central	16	42	73	-	568	1	4[illegible]	1	-	-
Mzuzu	North	14	132	90	156	251	-	22	8	79	146
Chilumba	North	-	55	-	2	5	-	-	-	-	-
		513	14318	4029	7367	52[illegible]	4308	1828	4643	722	531
GRAND TOTAL		1638	20014	15450	15919	30860	5348	6118	8636	3969	2610

TABLE 11 : SEASONAL CREDIT ISSUES (K) BY SOURCE

SOURCE	1976/77 Total Issued	1976/77 Number Recipients	1976/77 Average Loan	1976/77 % Repayment 2/	1977/78 Total Issues	1977/78 No. Recipients	1977/78 Average Loan	1977/78 % Recovery	1978/79 Total Issues	1978/79 Number Recipients	1978/79 Average Loan	1978/79 % Repayment	No. Recipients as % Total Land Holders
L.L.D.P.	1,012,393	36,735	28	99.9	1,292,000	40,492	30.41	100	1,460,000	56,257	25.67	84.73	52.3
L.R.D.P.	306,990	23,006	16	88.4	591,712			92	369,421	17,684	20.90		
S.V.A.D.P.	270,840	24,127	11	98.4 3/	252,632	23,833	16.5	84	188,960	9,623			
K-CRDP	102,229	7,253	14	67.0	181,094	8,929	20.3	86					
Settlement Scheme	169,298	4,424	38.3	84.0	223,360	5,338	11.8	70					
Government Loans Board	86,266	40 4/	2157	96.4	100,440	2,068	48.6		164,455	3,022	54.5		
NRDP	46,035	13 4/	3541	99.0	92,692 1/	1,348	46.5		113,112	1,311	86.3		
TOTAL	2,108,511	98,072	20	94.7	2,733,930	82,609	33.1						

SOURCE: National Rural Development Programme, September, 1978.

1/ Not including K77,449 credit issues by the Namwera Rural Development Project.

2/ Repayment is generally only to September.

3/ Includes repayment of outstanding debts from earlier years.

4/ Number of farmer's groups to which credit was issued.

TABLE 12 : TRENDS IN CROP ACREAGES, YIELDS (LBS/ACRE) AND PRODUCTION (SHORT TONS)

TOBACCO	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	Estimate 1978/79	Annual Rate of Increase 1970/71 - 19[illegible]
Flue-Cured											
Acreage		14,338	17,592	15,494	23,481	26,381	32,010	37,551	43,982	47,[illegible]23	16
Yield		965	1,084	1,1[illegible]	989	1,245	1,114	1,140	1,12[illegible]		
Production		7,065	9,533	11,012	11,597	16 423	17,824	21,589	24,637		12.2
Burley											
Acreage		18,105	16,135	16,239	16,8[illegible]	17,660	21,558	21,403	31,065	34,920	8
Yield		69[illegible]	74[illegible]	770	659	908	674	1,048	1,042		
Production		6,245	6,[illegible]11	6,257	5,082	8 [illegible]15	7,265	11,211	10,189		
Western Fire Cured											1970/71 - 1977/78
Acreage		73,926	82,[illegible]12	71,427	[illegible],720	67,297	77,495	85,458	91,327		
Yield 1/		355	358	37[illegible]	[illegible]	332	346	48[illegible]	479		3.1
Production		13,125	14,834	13,494	10,177	11,168	13,293	2[illegible],409	21,907		
Sun/Air Cured											3.[illegible]
Acreage		17,150	19,750	16,13[illegible]	16,140	11,986	19,[illegible]2[illegible]	18,028	20,7[illegible]3		3.0
Yield 1/		299	325	322	233	31[illegible]	2[illegible]8	357	358		
Production		2,562	3,214	2,596	1,884	1,[illegible]62	1,978	3,221	3,690		
Oriental											
Acreage		545	628	744	1,277	[illegible]47	1,[illegible]37	1,853			
Yield		532	640	645	852	486	571	573			
Production		145	2[illegible]1	240	544	23[illegible]	295	625	565		
Tea Acreage		38	39	[illegible]	-	4[illegible].8	4[illegible]	43			
Sugar Cane											
Acreage		6,410	7,800	10,800	15,000	21,000	23,200	23,379			
Yield											
Production		35,740	37,945	55,118	51,764	75,543	98,961	105,036			
Rice											
Acreage											
Yield											
Production		19,142	21,856	19,399	23,475	15,353	27,357	26,558			
Maize Acreage									....	....	
Hybrid/UCA Acreage									156,[illegible]	126,70[illegible]	

1/ Yield Sold to ADMARC.

TABLE 13

ADMARC'S MAIN DEPO[redacted]TS, LOCATION AND STORAGE CAPACITY

Location	Number of sheds	Cubic capacity (M^3)	Overall load capacity at 80% (tons)	Approximate fertilizer load capacity (tons)
Southern Region [1]				
Balaka	5	36600	24700	13000
Lambulila	2	1400	900	300
Liwonde	1	48400	48000	13000
Limbe	6	106900	68000	14000
Luchenza	4	54000	34000	14000
Bangula	11	35500	22000	9000
Chikwawa	2	1300	850	300
		284100	182450	63600
Central Region [1]				
Lilongwe	5	34300	22500	10000
Salima	7	49200	31000	13000
Nkhotakota	N.A.	1400	900	300
		84900	54400	23300
Northern Region				
Mzuzu	N.A.	36000	24000	10000
Chilumba	N.A.	1400	900	300
		37400	24900	10300
Total		406400	261750	97200

1. Excluding the new facilities at Lilongwe's Industrial Area (55 000 tons) and Charter land Road Depot in the Southern Region (50 000 tons)

PART II. Ammonium Nitrate Manufacture

TABLE OF CONTENTS

II AMMONIUM NITRATE MANUFACTURE

1. THE PRODUCT GRADE
2. PRODUCTION PROGRAMME
3. LOCATION AND SITE DEVELOPMENT
4. PROJECT DESIGN
   - 4.1 The Plant Complex
   - 4.2 Main Installations and Capacities
   - 4.3 Process Technologies
   - 4.4 Materials and Utility Balance
   - 4.5 Off-site and Storage Facilities
   - 4.6 Buildings and Structures
5. PLANT ORGANIZATION AND MANPOWER REQUIREMENTS
6. IMPLEMENTATION SCHEDULE
7. PROJECT COST ESTIMATES
8. PRODUCTION COST ESTIMATES

ANNEXES:

1. Basis of Design
2. Assumptions for Operating Cost Estimates
3. Working Capital Calculation at 1979 Prices
4. Dolomite-Limestone Resources
5. By-products

II AMMONIUM NITRATE MANUFACTURE

1. THE PRODUCT GRADE

The main fertilizer types currently consumed are single nitrogenous fertilizers, i.e. sulphate of ammonia (21% N), calcium ammonium nitrate (26% N) and various NPK formulations, i.e. 25-5-5, 20-20-0, 12-19-5 and tobacco mixtures (ave. composition 6-18-15). All these formulations, with the exception of 20-20-0, are at present locally blended and granulated from imported intermediary products such as Urea, CAN, SA, SSP, TSP, potassium chloride and sulphate, which are all classified as straight fertilizers.

Because financing requirements would be onerous, it is impracticable to consider the manufacturing of the full range of straight fertilizers in Malawi, at least not in the near future.

The market for phosphate fertilizers, for instance, is far too small to justify any investment in processing installations to convert locally available rock phosphate into phosphatic fertilizers. Even for nitrogen the development of the demand, as anticipated over the coming ten years, is still too small to support economically more than one downstream product line because production costs would surpass the limits of viability. A choice has therefore to be made between ammonium nitrate and sulphate of ammonia as the main N-carrier for both straight fertilizer and ingredient in formulations.

The principal straight nitrogen fertilizer used is still sulphate of ammonia because agronomic considerations in the past required fertilizers to contain at least 5% sulphur, and also because it is the cheapest nitrogen product available to smallholders. The marked lowering of the pH-status of the soil due, as it has been observed over the years, to the continuous application of sulphur-bearing fertilizers, has resulted in a distinct change to the use of non-acidifying products such as CAN and nitric acid based NPK formulations. The latter already represent by now 45% of all compounds used.

All these aspects have been reviewed in detail in Part I of this study entitled: The Fertilizer Market. It suffices to add in this context that the manufacture of SA would also require the importation of substantial quantities of sulphur as long as the indigenous sources of pyrites are not being exploited. Furthermore, the cost of installations to manufacture SA are estimated to be 12-15% higher than those required to convert ammonia into ammonium nitrate fertilizer.

Thus, the product choice is clearly in favour of **ammonium nitrate.** As the concentrated form of ammonium nitrate (i.e. A.N. : 33.5 - 34.5% N) has, for blending purposes, distinct advantages over less concentrated grades, it is assumed that OPTICHEM will prefer the concentrated grade as an ingredient for its blending/granulation operations, and most likely, wishes to receive it in bulk rather than in bags.

However, the concentrated form of AN is not recommended for distribution to small farmers, as it is also an explosive, which may ignite if not stored properly, even in bags. 1/

Although concentrated AN is being used on a large scale in neighbouring countries, it may be expedient to use in Malawi calcium ammonium nitrate (CAN: 26% N) instead, by mixing AN with ground limestone or dolomite prior to granulation or prilling of the final product. By using a local dolomite, the final product will contain, in addition to nitrogen (26% N) some 7% CaO and 5% MgO which has significant plant nutritive importance.

1. Concentrated ammonium nitrate decomposes at 200°C by giving off toxic fumes which may ignite; it also may detonate if subjected to physical shocks, especially in the presence of organic material.

2. PRODUCTION PROGRAMME

The substitution of AN for SA in the NPK formulations presently manufactured in Malawi, will pose no technical difficulties to the existing blending and granulation facilities of OPTICHEM at Blantyre. Besides, it will affect neither the grade nor the agronomic quality of the products in use.

All tobacco mixtures for instance, already contain the nitrogen nutrient partly in ammoniacal (66%) and partly in nitrate form (33%). In addition, they contain some 9% of sulphur. If AN would be used exclusively as nitrogen ingredient then the ammoniacal/nitrate ratio would change to 50/50% while sulphur content would be lowered to about 5%.

Tea mixtures, which are currently formulated from Urea and SA, would equally contain half of the nitrogen in ammoniacal and the balance in nitrate form, if AN would be used as blending ingredient, but they would not bear sulphur any longer.

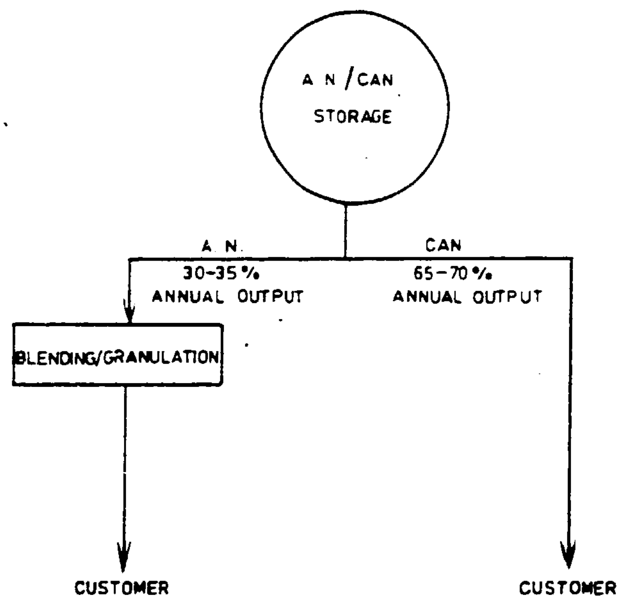
The maize mixture currently in use, i.e. 3-2-1 (or 12-19-5) already consists exclusively of AN, apart from TSP and KCl.

The remaining compound 20-20-0 which so far has been imported could be formulated locally from AN and TSP at the expense of a slight change in grading, i.e. 18-20-0. If mono-ammonium phosphate (11-54-0) or DAP (16-48-0) would be used instead of TSP, it would be possible to match the 20-20-0 grade. Yet, it is not recommended, as it would imply the import of nitrogen, albeit in compound form.

Following the analysis in Part I of the study (The Fertilizer Market, page 40), it is anticipated that about one third of the future nitrogen demand will have to be supplied in a compound or in mixed form. As a result some 30% to 35% of the plant's annual output will have to move to the blending facilities in Blantyre first, prior to being dispatched to estates and farmers. These blending facilities have sufficient inbuilt capacity (60,000 tons) to meet and handle domestic demand for compound fertilizers until 1986-88. A schedule of supplies is shown in the table below and in diagram form in figure 12.

Year	Demand (ton/year) N	Supply (ton/year) AN (32-34% N)	CAN (26% N)	Total Product
1980/81	19,059	19,250	48,870	68,120
1981/82	20,012	20,215	51,315	71,530
1982/83	21,013	21,224	53,877	75,101
1983/84	22,063	22,285	56,570	78,855
1984/85	23,167	23,400	59,400	82,800
1985/86	24,325	24,570	62,370	86,940
1986/87	25,541	25,800	65,492	91,292
1987/88	26,818	27,088	68,754	95,842
1988/89	28,159	28,442	72,200	100,642
1989/90	29,567	29867	75,815	105,682
1990/91	31,046	31,364	79,623	110,986

FIGURE 12 PRODUCT FLOW



3. LOCATION AND SITE DEVELOPMENT

In determining the best location for a fertilizer complex, as the proposed one, the following factors have to be considered first and foremost: (1) The proximity of supplies of electricity and water and of market outlets, because transport costs are of major significance; (2) The existence of basic infrastructure facilities such as road and rail connections with the market areas and/or intermediary storage facilities.

A fertilizer plant geographically located in the middle of the country would undoubtedly be ideal from a logistic point of view and for reasons of product transport cost.

As shown in Part I of this study, the bulk of all future fertilizer supplies will continue to move mainly to the central and southern parts of the country. From every 100 tons of output about 40% will be consumed in the south, 40% in the central region and the balance in the north.

Approximately 10,000 ton-miles will be involved in moving this 100 tons from a plant located in the central region, for instance at Lilongwe, to a central point of distribution in the two outer regions (40 x 150 + 20 x 200) [1] against 13,000 ton-miles, if the plant is located in the south (40 x 150 + 20 x 350). At the current road haulage rate of 15t per ton-mile, overall transport cost would work out to K25 and K325 per ton of product respectively.

Yet power has to be made available at any location beyond the Nkula Falls. As the existing grid has not sufficient in-built capacity, new transmission lines have to be constructed (including auxiliary facilities) to serve the fertilizer plant's requirements (54 MW per hour). The costs involved to install new (and double) H.T. power lines (133 KV) from Nkula to Lilongwe will amount to some K8 to K9 million and transmission costs to 0.44t/KWH or K16/ton of CAN product. This amount has to be added to each ton of product if manufactured at Lilongwe. Economically, it blots out any logistic advantage which a centrally located plant may have.

The contrasts would become even sharper in case rail haulage (ave. 6.7t/ton-mile) had been taken for comparison.

It is evident that for this particular technological process the selection of the plant location should follow resource rather than

1. This calculation does not take into account the quantities of output which have to move south for blending and subsequently north again for distribution in the Central and Northern Regions.

market centres.

Thus, fertilizer manufacture should be undertaken adjacent to the source of power and water supply and within a radius of 10 or maximum 20 km, depending on the existing facilities for product movement from the plant to the main centres of consumption and/or intermediary storage.

Another aspect to be considered in this context, is the need for a careful planning of daily and periodical load programmes. Any constraints in the supply of power will have an immediate impact on and consequential losses and implications for the fertilizer plant. Smooth operations will necessitate daily consultations between staff of power station and fertilizer plant regardless of the sophistication of modern control instruments and automatic load regulators.

Locations which qualify as a potential site for the fertilizer plant are: (1) Walkers Ferry, and (2) Lirangwe. Matope could be considered as a third alternative in case a hydro-power station operating exclusively for the purpose of the fertiliser plant were to be erected. (See Map).

Walkers Ferry

The place is located on the Shire River, some 2-3 kilometres upstream of ESCOM's Nkula hydro-power station where a major expansion project is nearing completion.

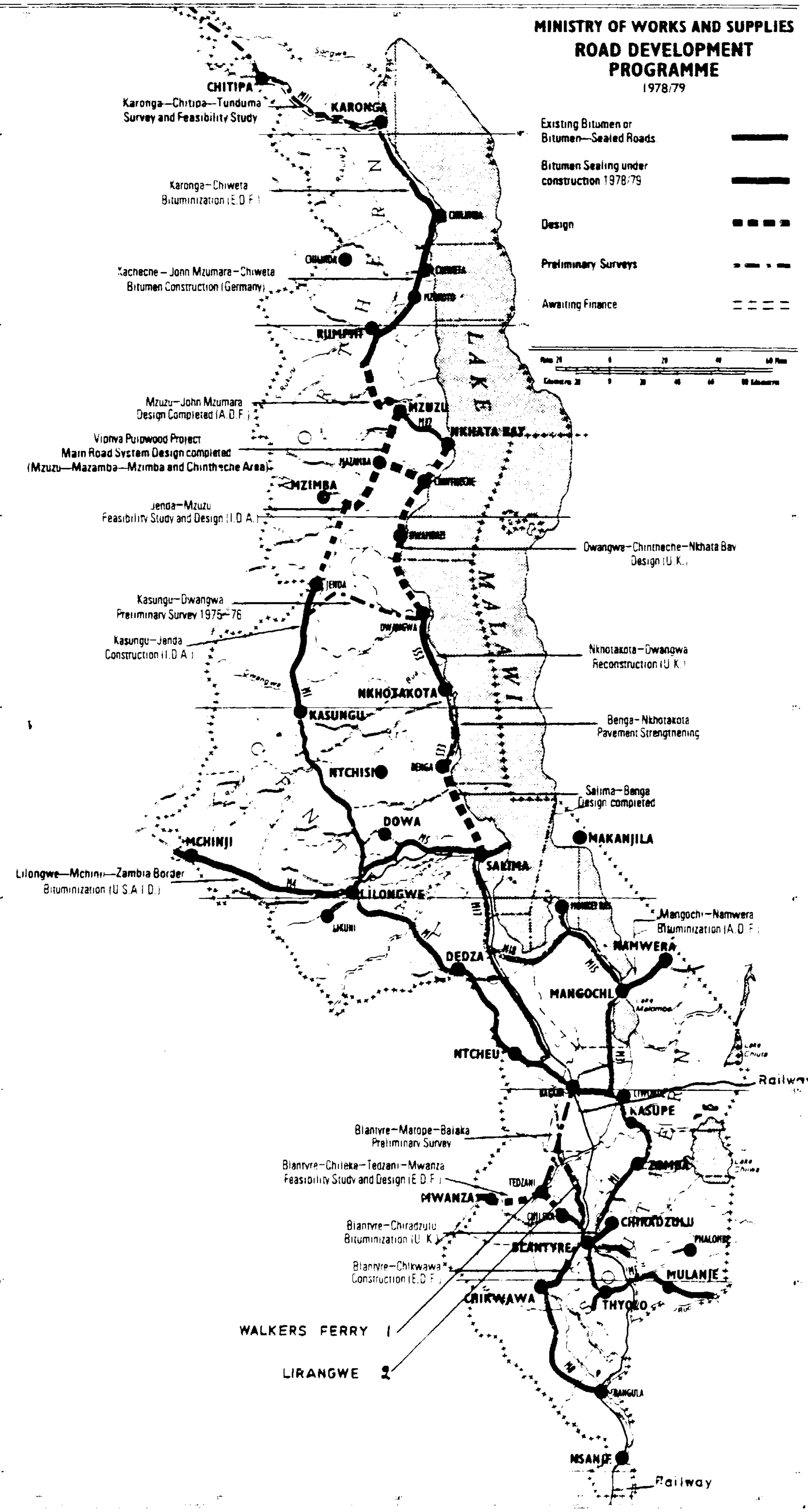
The place is some 50 km away from Blantyre, going in a south easterly direction. It is at present only accessible by road which is 7 m wide, for 30 km bitumized, while the remaining part is all-weather gravel type road.

This stretch of road will be upgraded to serve as the major link between Blantyre and Mwanza. (See Map). It will make use of the dam crossing the Shire River which is at present under construction for ESCOM. This road project is scheduled for completion by 1983. Preliminary surveys for upgrading the dirt road connection between Nkula/Tedzani and Balaka are currently conducted by the Department of Works & Roads. When implemented the site will have excellent connections by road via Blantyre with the large storage facilities of ADMARC and OPTICHEM in the south (Limbe, Luchenza, Bangula) and via Balaka with those in the other parts of the country, i.e. Balaka, Liwonde, Lilongwe and Salima; all having railway sidings.

The terrain around the site is rugged and thinly populated and it has no agriculture of importance.

REPUBLIC OF MALAWI

Map 27



The industrial area, serving ESCOM and the Blantyre Water Board Station, has a good social infrastructure consisting of housing (Malawi Housing Corporation) for labour, a primary school, a clinic and a Post Office. In addition, it has recreation facilities for swimming, tennis and for indoor sports and entertainment. Another factor which should be considered in regard to this site is the vast engineering skills and experience which have been acquired over the years relevant to site conditions and development in the context of ESCOM's expansion project at Nkula which undoubtedly will affect project costs in a favourable sense.

The major drawback of the site is its remoteness from the nearest railway siding, i.e. Blantyre (50 km) and Lirangwe (25 km). Also, in the absence of any direct road connection, Lirangwe can only be reached from Walkers Ferry via Blantyre (80 km).

The so-called Western Rail link connecting Utale station at the main north/south route (via Matope) with Nkula, down the Shire Valley, with the Beira/Tete rail line is now dormant as the project for moving coal from Tete (in Mocambique) to the Indian Ocean port of Nacala will not be implemented for the time being. In this way there seems little prospect that the site will have direct access to railage facilities in the near future.

<u>Lirangwe</u>

The small township of Lirangwe is some 33 km to the north of Blantyre and some 25 km to the east of Walkers Ferry.

The site would be ideal from the logistic point of view as it is situated on the main rail and road system connecting the south with the northern parts of the country.

The road between Blantyre and Lirangwe is tarred, the onward connection with Balaka is a gravel road. Preliminary surveys for upgrading this part to a first class road are being conducted by the Ministry of Works & Roads.

Lirangwe is also a station on the Blantyre-Salima-Lilongwe rail line which runs almost parallel to the road. An ideal site for the plant would be a location some 2-4 km south of Lirangwe station in between road and railway.

The terrain is undulating and easy to level and grade. The soil is lateritic and may have adequate bearing capacity. Provision for an additional rail siding and access to the main trunk road would involve a relatively small amount of expenditure (K35,000 to K40,000).

The area round the site is predominantly agrarian and of great agricultural importance.

However the major drawback of this site is that all electricity has to be supplied from Nkula power station over a distance of 25 km and at a cost of K800,000 (two power lines of 66 KV). Also water supply facilities are virtually absent.

The Lirangwe River, a tributary of the main Shire River, is a perennial stream, incapable of supplying the large quantities of water required. Consequently, a close-circuit water-cooling system has to be erected within the plant complex. This will require the construction of 3 large water-cooling towers, each having a capacity throughput of 1,500 M^3/hour and provisions for process boiler-feed and make-up water supply, at a cost of approximately K1.6 million.

Furthermore, in the absence of a social-infrastructure, housing for factory employees and staff has to be erected, in addition to other necessary facilities, involving costs estimated at K1.5 million. Besides, and due to the flatness of the terrain, there is little possibility for disposal of effluents if for ecological reasons, the natural drainage provided by the (mostly dry) Lirangwe River bed could not be used.

Assessment

By and large the additional costs of developing a site near Lirangwe estimated at K4 million outweigh the logistic advantage of good rail and road connections.

Walkers Ferry should therefore be considered as the site of preference provided the projects for road improvement and expansion are being implemented as scheduled and, in particular, if a feeder road could be constructed providing for a straight connection between Walkers Ferry and the railway line near Lirangwe (25 km).

Site Development

The waste materials produced by the proposed fertiliser manufacturing processes mainly concern co-product oxygen which has to be vented into the air and effluent cooling water which has to be discharged back into the Shire River at some point downstream of the water intake station of the Blantyre Water Board, and into the spillway of ESCOM's power station.

The emission of noxious NO_x tail gases can in any modern nitric acid plant be reduced by sophisticated abatement systems to less than 200 ppmv. They do not constitute any nuisance to the environment, in particular if the final site elected for the plant is not windward of the Water Board and ESCOM's facilities.

Dust emission resulting from limestone grinding and product granulation will be contained by dust collectors and recycled to the plant's process system.

The terrain around Walkers Ferry is rugged but the east bank of the Shire River, some 2-3 km upstream from the Nkula power station and the Blantyre Water Board, seem to offer good prospects of development at the least cost in regard to earth movement and levelling.

There do not exist structures, pipes, cables, etc., which will require removal or demolition and there are no streams to be diverted.

The soil is bed-rock covered with weathered material up to an average depth of 6 metres, in veins and joints occasionally up to 20 metres. Outcrops of rock occur which may necessitate incidental blasting.

The levelling, grading and filling of an area of about 5 hectares has been estimated by local civil engineering firms at K350,000. [1]

The type of soil formation seems to possess good intrinsic mechanical properties which would not require piling or other mechanical improvements to support the weight of the equipment and buildings to be installed (soil bearing capacity required: 2 kg/cm^2). Special foundations will therefore be limited to a minimum.

The natural drainage as provided by the elevation of the site (approximately 40-50 metres above the river bank) will pose no problems to disposal of effluents and sewer systems construction. Foundations, pavement (700 m) and construction of drains and sewers within the plant area and putting fences around it, are estimated at K125,000.

Connecting the site to the point of tie-in to ESCOM's power station will require a double 2-3 km transmission line (66 KV) of which the total costs are estimated at K60,000.

All in all, preparing and developing a flat 5 hectares of land at the indicated site near Walkers Ferry will most likely not exceed a total of K535,000 against approximately K4.5 million at Lirangwe.

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1. Earth to be removed: 80,000-100,000 m^3 at a rate of K3-4 per m^3.

4. PROJECT DESIGN

4.1. The Plant Complex

The total plant complex for the manufacture of ammonium-nitrate from electrolytic-hydrogen based ammonia will comprise the following main process units:

(a) Water electrolysis
(b) Air separation
(c) Synthesis gas compression
(d) Ammonia synthesis
(e) Nitric acid plant
(f) Ammonium nitrate plant
(g) AN/CAN granulation plant

In addition it will have relevant off-site facilities including:

(h) Hydrogen-gas storage
(i) Nitrogen-gas storage
(j) Ammonia storage
(k) Product storage, handling and bagging
(l) A river water pumping station
(m) A water treatment unit
(n) Limestone grinding
(o) Electrical distribution system
(p) Buildings for process units and administration.

The overall concept of the plant complex including mass balances is shown in diagram form in figures 13a and 13b.

FIG. 13A PROCESS FLOW AND PLANT CAPACITIES

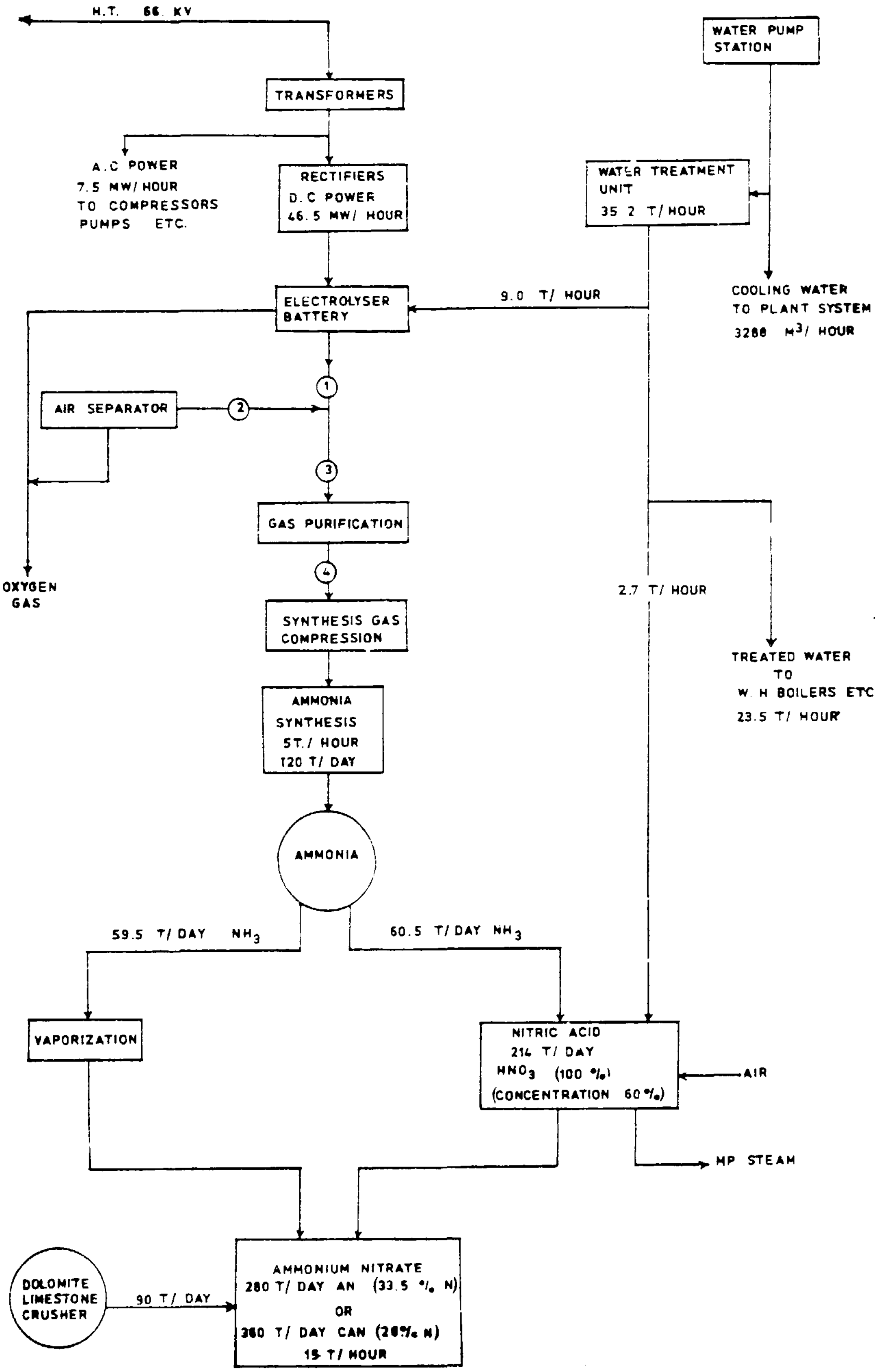


FIGURE 13 B

PLANT CAPACITIES: MASS BALANCE

	① OUTLET ELECTROLYSIS		② OUTLET AIR SEPARATION		③ INLET GAS PURIFICATION		④ OUTLET GAS PURIFICATION	
	NM^3/HR	VOL. %	NM^3/HR	VOL. %	NM^3/HR	VOL. %	NM^3/HR	VOL. %
H_2	9890·1	99·9	—	—	9890·1	74.95	9880·7	74·999
N_2	—	—	3293·8	99.99	3293·8	24·95	3293·8	25·000
O_2	9·9	0·1	0·016	—	9·916	0·079	—	—
ARGON	—	—	0·16	0·01	0·16	0·001	0·16	0·001
NH_3	—	—	—	—	—	—		
	9900·0	100·0	3293·98	100·0	13193·98	100·0	13174·66	100·0

4.2. Main Installations and Capacities

The forecast for nitrogenous fertilizers in the period 1980-90 as elaborated in Part I of this study and reproduced below, clearly indicates that the size of the production facilities needed to match market demand are by world standards very small, even in the case of a single down-stream product line. The common difficulty of small sized units is that small-scale operations impose the need for mechanical equipment whose performance in terms of flow rate is far lower than can be accommodated by large scale units. Secondly, heat losses from small equipment may become critical in that they may constitute a significant fraction of the heat flux necessary to maintain reactions. Thirdly, the smaller the plant design, the more limited is the availability of commercial equipment that can be selected. Though most reactor vessels and columns are custom design and are rarely available as commercial catalogue items, many other items and equipment are, such as valves, compressors, pumps, blowers, turbines and expanders, etc. But because of the low flow rates required, they also may need custom design or, in particular cases, even development. In addition, the amount of work involved in designing a small plant is in principal not much different from the work required for a large plant. Naturally, investments required per daily ton of design capacity for a small unit are proportionally much higher than for a large unit. For instance, for an ammonia reactor plus syngas compressors of 200 tons per day, the investment costs per daily ton of installed capacity are about K43,000 to K46,000 against only K22,000 to K24,000 for a unit with a design capacity of 1,000 metric tons per day. Consequently the capital charges per ton per day of fertilizer produced in a 200 MTPD unit will be almost twice as high as compared with those of a 1,000 MTPD unit. Thus, the economy of scale virtually impedes fertiliser manufacturing below a 100 MTPD of ammonia, a level which will not be reached in Malawi until 1987/88.

Year	Demand ton/year N	Demand ton/year NH_3	Rate of production[1] ton/day NH_3	Rate of production[1] ton/hour NH_3	Number of electrolysers required at constant max. load[2]	Ammonia Plant Rate of capacity utilisation[3] (a)	Ammonia Plant Rate of capacity utilisation[3] (b)
1980/81	19,059	23,240	70	-	-		
1981/82	20,012	24,400	74	-	-		
1982/83	21,013	25,620	78	-	-		
1983/84	22,063	26,900	82	3.4	19		
1984/85	23,167	28,130	85	3.54	19	71	65
1985/86	24,325	29,660	90	3.75	20	75	69
1986/87	25,541	31,145	94	3.90	21	78	72
1987/88	26,818	32,700	99	4.1	22	83	76
1988/89	28,159	34,340	104	4.3	23	87	80
1989/90	29,567	36,050	109	4.5	24	91	84
1990/91	31,046	37,860	115	4.8	26	96	88
1991/92	32,636	39,800	120	5.0	27	100	92
1992/93	34,235	41,750	126	5.3	29	-	97
1993/94	35,916	4[illegible],800	132	5.5	30	-	100

1. Based on 330 operating days per year.
2. Maximum capacity per electrolyser : 370 NM^3 of H_2 per hour (= 0.19 ton NH_3) or 5.4 electrolysers are required to produce one ton of NH_3 per hour.
3. (a) Based on an installed capacity of 120 MTPD NH_3.
   (b) " " " " " " 130 " "

AMMONIA UNIT

As no factory will perform at optimal capacity during the first years of operation it would nonetheless be possible to start production in a small-scale unit from 1983/84 onwards.

The lead time for bringing a small-scale fertiliser complex on stream will anyhow be between 24 and 30 months. Thus, it will not be before late 1983 or early 1984 that any production could be expected even if a decision for the realisation of the project were taken during 1980.

If 70% is taken as the minimum rate of capacity utilisation it would be acceptable to design the ammonia installations for a daily output of 120 tons.

Assuming that demand would follow the anticipated trend for nitrogen, then daily design capacity could be increased by about 5 tons for each year a decision is taken beyond 1980.

FIGURE 14 ESCOM INTERCONNECTED SYSTEM DAILY LOAD CURVE

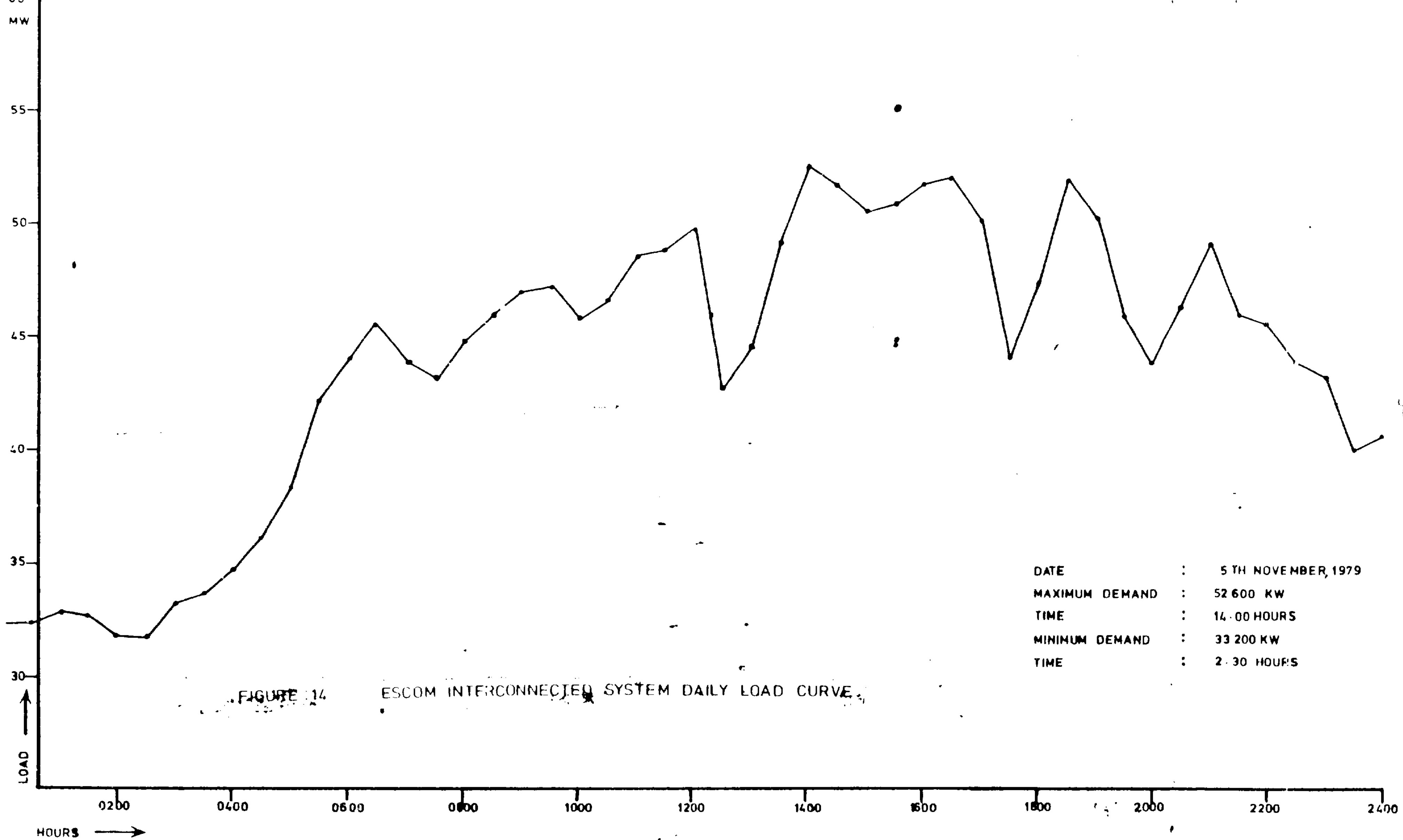
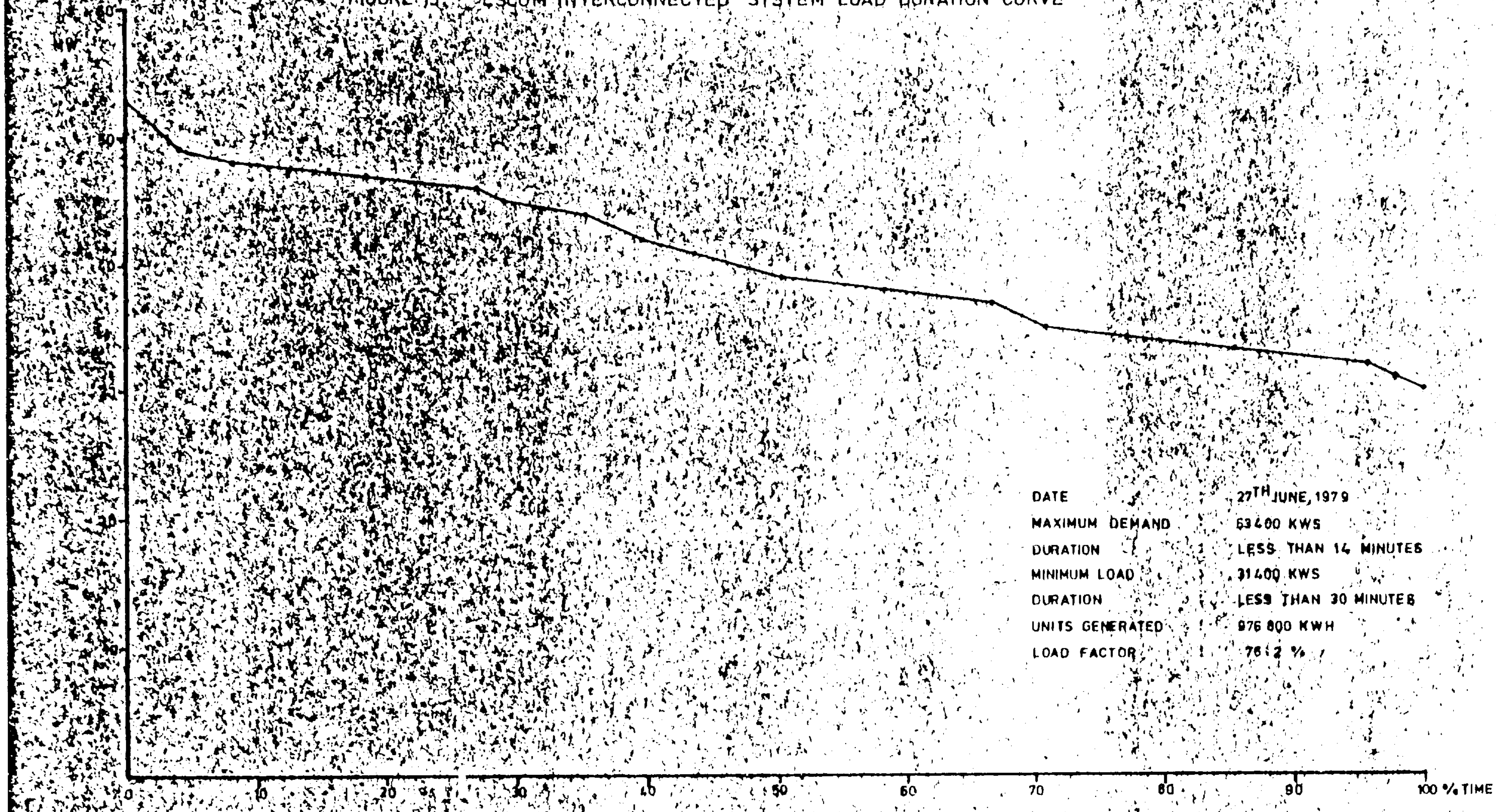


FIGURE 14 ESCOM INTERCONNECTED SYSTEM DAILY LOAD CURVE

FIGURE 15 ESCOM INTERCONNECTED SYSTEM LOAD DURATION CURVE



NITRIC ACID AND AMMONIUM NITRATE PLANT

On the basis of a daily capacity of 120 tons of ammonia, the size of the nitric acid plant should normally be 214 tons per day. (100% HNO_3, acid concentration 60%).

As the nitric acid has to be partly converted with ammonia into AN (33.5% N) and partly into CAN (26% N), the capacity of the final product plant has to be designed for a minimum of 280 and a maximum of 360 tons per day.

Nitrogen efficiency is assumed to be in the order of 95%-96%.

The daily material flow for a plant operating at design capacity is schematically illustrated in figure 13.

ELECTROLYSER BATTERY

As the ammonia and other down-stream units will operate below design capacity during the first six years of operation, the capacity of the electrolyser battery can be increased over the years in direct proportion to the development of demand, from 20 units in the initial stages to 27, once the fertilizer complex attains full capacity utilisation (see Page 62).

By dividing hourly ammonia demand, as expressed in corresponding hydrogen-gas volumes, by the design output of an electrolyser unit (370 NM^3 of H_2 per hour), one arrives at the number of units required. This calculation assumes optimum operational conditions at constant loads up to battery capacity during 24 hours per day.

This, however, will not be feasible if off-peak power has to be used exclusively.

Off-peak power availability follows, in a reverse sense, electricity demand. It reaches, as mentioned before, maximum levels at night time and in the early morning hours and diminishes to zero during mid-day (figure 14).

To utilise all available off-peak power, the capacity of the electrolyser battery should theoretically be equal to the difference between annual peak and minimum demand.

In the absence of data on ESCOM's minimum demand levels, the period 27 June to 4 July, 1979, is taken as an example. In this period daily electricity off-take varied at an average between 56% and 100% of peak demand. This is illustrated in the load duration curve for 26 June (figure 15). During that day electricity demand remained for almost 12 hours above and for the rest of the time below average demand which should be considered as an exceptional ideal case.

In reality load duration curves will show much sharper fluctuations from hour to hour as well as larger differences between peak and minimum demand. It is therefore assumed that at an average daily load varies between 50% and 100% of peak demand. This implies that the capacity of the electrolyser battery has to be designed about one third larger than off-peak power would indicate so as to cope with the hourly variations in load and to use off-peak power availability to the fullest extent.

This is demonstrated in the table below, which shows ESCOM's annual peak demand forecasts and off-peak power availability for the period 1984-1992 and corresponding electrolyser battery capacities, when all off-peak power is to be converted into hydrogen.

		1984	1985	1086	1987	1988	1989	1990	1991	1992
1.Peak demand	Mw	101	107	114	120	127	135	143	152	161
2.Est.minimum demand	MW	50.5	53.5	57	60	63.5	67.5	71.5	76	80.5
3.Off-peak power	Mw	38	40	43	45	47	50	53	57	60
4.Capacity electrolyser battery at constant load	Mw	38	40	43	45	47	50	53	57	60
5.Capacity electrolyser battery at variable load	MW	50.5	53.5	57	60	63.5	67.5	71.5	76	80.5
6.Difference in capacity	MW	12.5	13.5	14	15	16.5	17.5	18.5	19	20.5
7.Increase	%	133	134	133	133	135	135	135	133	134

It is evident that the exclusive use of off-peak power for meeting the fertilizer complex requirements would involve a significant increase in numbers of electrolyser units to be installed and consequently in investment.

This ought not to be the case when the surplus capacity of ESCOM's interconnected system is consumed first and off-peak power is used to supplement the balance of requirements as is shown in the table below.

By using a combination of surplus capacity and off-peak power during the period 1980-95, substantially less electrolyser battery capacity and investment will be required as compared with using off-peak power only.

It will be understood that at this stage the above figures concerning electrolyser battery capacity can only be regarded as approximations. They have to be refined from year to year in the context of fertilizer plant requirements and ESCOM's own demand and load programme development.

		1984	1985	1986	1987	1988	1989	1990	1991	1992
1.Plant requirements	MW	35.5	37.2	39.2	41.1	43.2	45.3	47.6	50	52.4
2.Surplus capacity (at 90%)	MW	29.0	41.0	34.0	28	21	31	41	32	41
3.Off peak power supplement	MW	6.5	-	5.2	13.1	22.2	14.3	6.6	18	11.4
4.Corresponding capacity requirement (133%)	MW	8.5	-	6.9	17.4	29.5	19.0	8.8	24	15
5.Capacity electrolyser battery at constant load (1)	MW	35.5	37.2	39.2	41.1	43.2	45.3	47.6	50	52.4
Electrolyser units	NR	17.4	18.2	19.3	20.2	21.2	22.3	23.4	24.6	25.7
6.Capacity electrolyser battery at variable load(2+4)	MW	37.5	37.2	40.9	45.4	50.5	50	49.8	56	56
Electrolyser units	NR	18.4	18.3	20.1	22.3	24.8	24.6	24.5	27.5	27

AIR SEPARATOR

The air separator should be designed for a minimum capacity of 3,300 NM^3 of nitrogen-gas per hour and for operating pressures between 5 and 6 bar. It can either be an air-screw or a turbo-compressor type of separator. If pressure electrolysers should be chose for water-electolysis, then a 2-stage piston compressor has to be added to this unit to bring the nitrogen gas up to the level (30 bar) of the hydrogen gas released by the electrolyser battery.

4.3 Process Technologies

NITRIC ACID

Commercial nitric acid (HNO_3) is produced by catalytic oxidation of ammonia to nitrogen dioxide and thence nitric acid by absorption in water. The overall process can be written in a single equation:
$NH_3(g) + 2O_2(g) \rightarrow HNO_3(l) + H_2O(l) + 98,700$ Kcal.

In reality there are three successive stages, namely:

(1) combustion of ammonia with air to nitric oxide:
$(NH_3(g) + 1.25\ O_2(g) \rightarrow NO\ (g) + 1.5\ H_2O(g) + 54,000$ Kcal)
(2) catalytic oxidation of nitric oxide to nitrogen dioxide
$(NO(g) + 0.5\ O_2(g) \rightarrow NO_2(g) + 13,600$ Kcal)
(3) absorption of nitrogen dioxide in water to produce a 60% nitric acid solution by weight
$(1.5\ NO_2(g) + 0.5\ H_2O(l) \rightarrow HNO_3(l) + 0.5\ NO(g) + 8,300$ Kcal)

Because nitrogen dioxide is not the genuine anhydride of nitric acid and because nitric oxide does not by itself dissolve in or react with water, the absorption tower must have many stages and the nitrogen dioxide-containing gas stream must contain enough molecular oxygen to ensure that the nitric oxide formed at each successive stage of absorption is reconverted into nitrogen dioxide, according to the reaction below, for reabsorption at the next stage:

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g)$$

In the actual process of production, liquid ammonia is taken from the store, vaporized, superheated and mixed with pre-heated air prior to oxidation.

The stoichiometric requirement is 14.2% NH_3, but to avoid the risk of explosion, the ammonia-air mixture in process operations is kept below 11.5% of NH_3 by volume, which is closely regulated by a flow controller.

The ammonia-air mixture enters the reactor to be burnt first to nitrogen monoxide (nitric oxide: NO) which is subsequently oxidized to nitrogen dioxide (NO_2) over a platinum-rhodium catalyst at pressures between 1 and 10 atmosphere according to the type of process chosen, and at temperatures between 800°C and 950°C.

The formation of nitric acid takes place in a multiple stage absorption tower in counter-current of nitrous gases with process water which is fed to the top of the tower. The acid drips and is collected at the bottom of the column.

Nitric oxide (NO) yields are improved by temperature increase, but it lowers the yield of NO oxidation to NO_2, the optimal level being dependent on the rate of gas flow. Increased flow rates promote the NH_3 oxidation process and avoid undesirable down-stream reactions between unconverted ammonia and nitrogen oxides, as well as the dissociation of nitric oxide into nitrogen and oxygen.

Increase in pressure may adversely effect the degree of ammonia oxidation but it increases the ratio of absorption of nitrogen oxides in water and in dilute nitric acid.

Numerous proprietary processes for nitric acid manufacture are nowadays available. They differ in design details and in operating conditions but not in fundamentals.

They can be classified into two main groups:

(1) The mono-pressure processes in which ammonia oxidation and absorption takes place at equal pressures, usually between 1 and 9 atmosphere.
(2) The dual-pressure processes, whereby ammonia oxidation occurs at a lower pressure (4-6 ata) than absorption (10-12 ata).

The availability of low, medium and high pressure techniques for oxidation and absorption offers a variety of alternative combinations by which nitric acid can be manufactured.

Pressure as compared to atmospheric operations, permit smaller units (one single oxidation reactor) to be used for a given output. It reduces capital as well as operating costs and it brings down the NO_x content in the tail gases, which leave the absorption tower at the top. Apart from NO_x, tail gas contains nitrogen, oxygen, moisture and inert gas. Overall nitrogen efficiency based upon the nitrogen content of ammonia and of the nitric acid produced, is nowadays in any modern dual-pressure and well operated plant between 95% and 97% while the NO_x content in the tail gas is below 500 ppmv. which corresponds to about 3.0 kg NO_x per ton of product. If the NO_x content in the tailgas has to be reduced to 200 ppmv or less, an abatement process has to be installed which is based on catalytic ammonia reduction, whereby ammonia and NO_x was converted into N_2 and water over a vanadium or titanium-based catalyst.

On the other hand operating pressures above the atmospheric induce greater catalyst losses and increase power requirements, unless equipment is installed for power recovery.

In making a choice between the processes available, consideration has to be given to the rate of energy recovery and nitrogen efficiency.

In any pressure operation, tail gas is heated up and expanded. The resulting power is used to meet a part of the power demand of the air compressor. The balance of the power required to drive the compressor systems, usually built in the form of a single, in-line unit comprising steam turbine and tail-gas expander, is supplied by steam produced in a W.H. Boiler, where the heat of reaction of the oxidation steps is recovered. Energy efficient processes even produce surplus steam for use in other plant sections.

Requirements per metric ton of 100% HNO_3 for a typical mono-pressure (4-6 bar) plant

Ammonia	kg	283-285
Process water	kg	250-300
Boiler feed water	kg	1,570
Cooling water (23°C)	M^3	150-160
Platinum consumption	g.	0.15-0.16
Electricity (cooling water pumps)	KWR	40-50
Instrument air (0°C 1 bar abs)	M^3	1.85
M.P. export steam	kg	575

Nitric Acid Process Technologies

Process owner	Type of processes	Pressure (bar)
Friedrich Uhde	mono/dual	1-5 5-5 3-10/12
Grande Paroisse	dual	3/4-7/8
Bamag Verfahrens Technik	mono/dual	1-3 3-5 7-11
Stamicarbon	mono	4-7 7-10
Weatherly Company	mono	9
Chemical Construction Corporation	mono	8
Societé Belge de l'Azote et des produits chimiques du Marley(SBA)	dual	3-9
Ugine Kuhlmann SA	dual	1-5
Fauser, Montedison	mono	5
C & I Girdler Inc.	mono	7

AMMONIUM NITRATE

Ammonium nitrate (NH_4NO_3) is produced commercially by neutralizing nitric acid with gaseous ammonia according to the following equation: $NH_3(g) + HNO_3(l) \rightarrow NH_4NO_3(l)$; depending on the strength of the feed acid, a 65-80% by weight solution is formed which is subsequently concentrated and processed to a solid product.

In the process, metered quantities of vaporized anhydrous ammonia from the store (figure 13) and 60% nitric acid are fed into a neutralizer, operating at atmospheric or elevated pressure (4-5 bar) and at temperatures between 140 and 180°C.

One mole of NH_3 reacts with one mole of nitric acid; a pH-controller is used to maintain the stoichiometry. The heat of the exothermic reaction is sufficient to concentrate the solution in the neutralizer to over 80% and to produce, in addition, steam which is usually employed to further concentrate the AN solution in subsequent steps up to 99.5%.

About 1 ton of steam is produced for each ton of NH_3 neutralised if 60% acid is used. Evaporators of the vacuum or falling-film type are generally employed to complete the final concentration whereby, as mentioned, exothermic heat and steam are used as a heating medium.

The concentrated AN solution is fed through a metering station into a granulator or prilling tower where recycled material is added from the screening (fines) and crushing equipment (oversized) and from the dust collecting facilities.

There are various proprietary processes for the manufacture of ammonium nitrate. They differ in combinations of neutralisation/evaporation systems and/or in drying and product finishing methods but not in fundamentals. In atmospheric neutralization, steam consumption for AN solution concentration is usually higher than in a pressure operation.

Pan-granulation is proposed for product finishing because it allows the manufacture alternatively of both AN (33.5% N) and CAN (26% N) of high grade quality in the same granulator, and because the cost of process equipment is lower as compared with prilling. Besides, the hardness and resistance to temperature variations of granulated AN/CAN is better than those of prilled products, consequently they exhibit better storage properties.

The granulation of AN, containing 33.5% N, is improved by the addition of small quantities of inert material. For granulating calcium ammonium nitrate (CAN-26% N), the components fed into the granulator are supplemented by powdered dolomitic limestone.

Metering facilities permit adjustment of the specified nitrogen content of the granulated product.

From the granulator, the hot and plastic granules are sent to the drying drum where they are dried by hot combustion gases.

The dried granules are screened and subsequently cooled in a fluidized bed cooled with air. The cooled final product is eventually sent to a coating drum for conditioning prior to being moved to the bulk storage facilities.

However the use of a high temperature pan-granulator makes the drying and conditioning step superfluous.

Specific consumption figures per metric ton of final product for a pressure type of neutralization

		AN(33.5%N)	CAN(26%N)
Ammonia (as 100% NH_3)	kg	205	159
Nitric acid (as 60% by weight but calculated as 100% HNO_3)	kg	768	597
Dolomitic limestone 1/	kg	26	244
Cooling water (Δ(23°C)	M^3	30	23
Electric power	KWH	40	31
Steam (8-16 bar, 200°C)	kg	248	193
Instrument air	NM^3/HR	90	90
(Heat for drying)	(Kcal (Mcal	45000 45	30000) 30)
Product qualities:			
N content	%	33.5	26.0
H_2O	%	0.25-3.0	0.25-4.0
CaO content 1/	%	-	7.3
MgO content 1/	%	-	5.1
Screen analysis	95%	1.3mm	2-4mm
Bulk density	kg/dM^3	0.85-0.9	0.98-1.0
Hardness	Kp	2.5-3.5	2.5-3.5

Note: 1. In case of use of a local dolomite, containing 45.72% $MgCO_3$ (21.86% MgO) and 54.27 $CaCO_3$ (30.41% CaO)

Ammonium Nitrate Processes

Process owner	Neutralization	Concentration
Kaltenbach	pressure (4-5) bar one step	2 steps evaporation (falling-film evaporator)
Stamicarbon	Pressure (4 bar) one step	2 step evaporation (vacuum), external heat needed
SBA	Pressure (5 bar) one step	2 steps evaporation, no external heat needed
ICI (Nitram)	Atmospheric, two steps	One step evaporation (falling film), external heat needed
C & I Girdler	Atmospheric, one step	One step evaporation (falling film), external heat needed
UHDE	Atmospheric, two steps	One step evaporation (falling film), external heat needed

Process owner	Neutralization	Concentration
Fisons	Atmospheric, one step	One step evaporation (falling film), external heat needed
Stengel	Pressure (5 bar) one step	Concentration in neutralization stage, external heat needed
Montedison	Atmospheric, one step	One step evaporation, external heat needed

4.4 Materials and Utility Balance

The materials and utilities required for the manufacture of AN/CAN from electrolytic-hydrogen based ammonia are enumerated and specified below. The overall balance is given in a composite table at the end (Page 77).

In this table it is shown that the main input requirements of the plant complex when operating at design capacity will be confined to <u>water</u> (3300 M^3/hour), <u>electricity</u> (54,000 Kw per hour) and dolomitic limestone (3,750 kg/hour).

In turn the output of the plant will be <u>AN/CAN</u> fertilizer (15 tons per hour) and <u>oxygen</u> (5,835 NM^3/hour).

ELECTRICITY REQUIREMENTS

A.C. current is required for driving compressors, pumps, power fans in air-heat exchangers, control and instruments, resistance heaters and lights. The foremost demand is for D.C. current in the water-electrolyser unit.

The A.C. and D.C. electricity requirements at the different process stages are enumerated in detail below. When operating at design capacity up to 360 tons of CAN per day, the plant will require an estimated 54 MW per hour or 3,600 KWH per ton of CAN (10,800 KWH on a ton NH_3 basis).

Power requirements

Main Process stages	Type of current	Volt-age	KwH/ton NH_3	KwH/ton HNO_3	KwH/ton product	Total Kw per hour
Electrolysis	D.C.		9,300 1/			46,500 1/
Air separation	A.C.		150			750
Syngas compression	A.C.		700			3,500
Ammonia synthesis	A.C.		3			15
Nitric acid plant (mainly pumps)	A.C.			48 2/		425 3/
AN/CAN plant	A.C.				40	467
Dolomite crushing/ grinding	A.C.					124
Utilities						
Water-pump station	A.C.					627
Water treatment	A.C.					14
Ammonia storage	A.C.		4.8			24
Product storage/ bagging	A.C.					200-30[illegible]

Lighting	A.C.	200-300
Total process		51,784
Total utilities		1,166
Total complex		52,950
With provision for losses in transformers (2%)		54,000

1. On basis of 98% current efficiency.
2. Power required to drive the air compressor (i.e. 500 KWH per ton HNO_3) is not shown, as this power is generated internally by the tail-gas expander (350 KWH) and by a steam turbine (150 KWH) provided for in any modern nitric acid process system.

WATER SUPPLY

Cooling water is required in several of the process heat exchangers and condensers and as indicated below, in substantial quantities in the nitric acid and the electrolyser plant. In addition, process water is needed for making nitric acid and to feed the electrolysis system. Also, waste-heat boilers will need specially treated water for steam raising. On the basis of a mean annual temperature of 23°C for Shire River water, it is estimated that the plant complex will require approximately 3,300 M^3 of water per hour or 219 M^3 per ton of CAN, when operating at design capacity (360 tons of CAN per day).

Process Stages	Hourly requirements			
	Cooling water ton	Process water ton	W.H. boiler feed water :	ton
Electrolysis	1,150 (230) 1/	9 (1.8) 1/	-	
Air separation	110 (22) 1/	-	-	
Syngas compression	165 (33) 1/	-	-	
Ammonia synthesis	215 (43) 1/	-	((4.5)) 4/	((0.9)) 4/
Nitric acid plant	1,426 (160) 2/	2.7 (0.3) 2/	14	(1.57) 2/
AN/CAN plant	222 (19) 3/	-	-	
Total	3,288	11.7	14	

1/ per ton of NH_3
2/ per ton of HNO_3
3/ per ton of AN
4/ if steam is recouped from the exo-thermic NH_3 reaction.

Due to the vicinity of the Shire River, the flow and the quality of its water, the cooling system can be simply designed as an open-circuit or so called once-through system, whereby river water pumped through a plate-type of heat exchanger will cool the pure water of the closed-circuit that is used for cooling the different process installations.

Thus, neither water-cooling towers nor purification of river water will be required. A pump station of 3,500 M^3/hour capacity will suffice, even to cover provisions for fire-fighting (on the basis of 20 M^3 per hydrant, and 8 to 10 hydrants installed).

On the other hand, a water purification unit has to be installed to meet process and boiler feed water requirements, as well as the small quantities of water to make up for the losses (2.5 m^3/hour) in the closed-circuit system [1] and for potable water (2.5 M^3/hour). Consequently the water treatment unit must have a capacity of about 35 to 40 tons an hour. It will be partly fed by condensates recovered within the plant complex and partly by fresh river water.

The power consumption to lift river water to a 40 meter head is estimated at 192 KWH/1,000 M^3 and for the water treatment system at 0.24 KWH/ton of water purified.

STEAM

The heat recovery system should be designed to make full use of the exothermic heat of the ammonia synthesis, the nitric acid formation and the ammonium nitrate neutralization, so as to make the entire plant complex self-supporting in steam and heat requirements.

Depending on the choice of processes and the ultimate design, the approximate steam balance of the complex (120 tons of NH_3/day or 5 tons/hour) may be as follows:

M.P. Steam	Production		Consumption		
Nitric acid plant (W.H.Boiler)	t/ton HNO_3 t/hour	0.3-0.5 2.7-4.5	AN/CAN plant	t/ton AN t/hour	0.25 2.90
Ammonia plant (W.H. Boiler)	t/ton NH_3 t/hour	0.7-0.9 3.5-4.5	Dolomite/ Drying	t/ton t/hour	0.03 0.11
Total	tons/hour	6.2-9.0		tons/hour	3.01
L.P. Steam					
Nitric acid plant	t/ton HNO_3	0.1	Nitric acid	t/ton HNO_3	0.1
	t/hour	0.9		t/hour	0.9
Total	tons/hour	0.9		tons/hour	0.9

It is evident that the complex has the potential to be self-supporting in steam and even to generate significant surpluses for use in

1. Assuming a quantity of 50 M^3 water in circulation per ton of ammonia and losses less than 1%, make-up water requirements of the closed-circuit will be maximum 0.5 M^3 per ton of NH_3 or 2.5 M^3 per hour.

power drives.

The steam generation capacity of the nitric acid plant alone amounts, depending on the choice of process, to a total of 0.9 to 1.0 tons M.P. steam per ton of HNO_3, of which 0.6 ton is used to drive the compressor system of the unit, leaving about 0.3 tons of M.P. steam for use in the other process sections, for instance in the AN/CAN plant.

It is a matter of economics whether the exploitation of the full steam potential of the plant complex, and the relevant investments in steam turbines will justify placing power drives on steam rather than on electricity.

DOLOMITE-LIMESTONE

Requirements of finely-ground dolomitic limestone are estimated at a maximum of 90 tons per day, once the plant is operated at design capacity and all AN would be converted into CAN. This works out to a rate of 0.25 ton of limestone per ton of CAN (26% N) or 3.75 tons per hour. When only two thirds of the AN has to be converted into CAN, then requirements would amount to 60 tons per day or 2.5 tons per hour.

Captive sources of dolomite of excellent quality are situated in the vicinity of the selected plant site, namely at Matope and at Lirangwe at a distance of some 25-30 km from Nkula. (Annex 3).

The costs of mining are estimated at K3-4 /ton of R.O.M. material, to which the cost of loading and transport (15t/ton-mile) must be added to arrive at a price of K7-8 per ton delivered at the factory.

POTASSIUM HYDROXIDE

The electrolyte used in water-electrolysis is a solution of potassium hydroxide of about 25% by weight in pure water (lye). Each electrolyser contains about 10 M^3 of lye (approximately 2.5 tons of KOH). The losses are less than 1% per year or about 0.0075 - 0.008 gram per NM^3 of H_2 liberated for atmospheric electrolysis (losses in pressure units are even lower and not more than 1 Mg KOH per NM^3 of H_2).

When working at full design capacity, some 9,890 NM^3 of H_2 per hour will be produced in the electrolyser plant, involving losses of KOH below 80 gram per hour (5.3 gram per ton of CAN manufactured).

Cost of 100% potassium hydroxide pellets is about K4,400/ton.

CATALYSTS

At three stages within the battery limits of the plant, catalysts are involved in process reactions, namely at (1) the H_2- gas purification step; (2) the ammonia synthesis, and (3) in the process of nitric acid formation, i.e. the oxidation of the nitric oxide to nitrogen dioxide.

The catalyst used for electrolytic-hydrogen purification is palladium, which promotes the conversion of traces of O_2 in the H_2 gas stream to water. Catalyst charge gas purification unit : 3.7 M^3. Catalyst consumption is negligible.

The catalyst used in the ammonia converter is composed of iron-oxides (Fe_2O_3) containing promotors of potassium oxide, calcium oxide and aluminium oxide. The catalyst is not active unless reduced. Depending on process technology the quantity of catalyst charged amounts to 30 to 50 kg per daily ton of installed ammonia capacity. It has a useful service life of up to 5 years provided the plant is well operated. Catalyst cost approximately K4.5 per kg; consumption is taken at 40 g per ton of NH_3 produced.

The catalyst used in the production of nitric acid is a wire-gauze, made of a noble-metal, i.e. a platinum-Rhodium alloy (9:1 composition), minimum cost K500 per troy ounce. Depending on process operating pressure and temperatures, the losses vary between 50 and 200 mg per ton of 100% HNO_3 manufactured, or 450 to 1,800 mg per hour based on a daily output of 214 tons of HNO_3 equal to 30 to 120 mg per ton of CAN (ave. 80 mg).

CONSUMPTION (PRODUCTION) BALANCE OF MATERIALS AND UTILITIES

Plant production		Processes								Off-sites											
NH_3 : 120TD	5TH																				
AN/CAN : 360TD	15TH																				
Items	Units	Electrolysis	Air separation	Syngas compression	Ammonia synthesis	Nitric acid production	AN neutralization	CAN product/ AN product	Total processes	Steam system	Water treatment	Pumping station	Cooling system	Instrument air	Storage hydrogen	Storage ammonia	Storage/bagging products	Lime crusher	Buildings lighting	Total utilities	Grand total
Hydrogen	NM^3/hr	(9880)	-	9880	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen	NM^3/hr	(4945)	(890)	-	-	-	-	-	(5835)	-	-	-	-	-	-	-	-	-	-	-	(5835)
Nitrogen	NM^3/hr	-	(3294)	3294	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngas	NM^3/hr	-	-	(13174)	13174	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia	kg/hr	-	-	-	(5000)	2520	2480	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric acid	kg/hr	-	-	-	-	(8917)	8917	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AN neutralization	kg/hr	-	-	-	-	-	(11397)	11397	-	-	-	-	-	-	-	-	-	-	-	-	-
AN/CAN product	kg/hr	-	-	-	-	-	-	(15000)	(15000)	-	-	-	-	-	-	-	-	-	-	-	(15000)
Cooling water	M^3/hr	1150	110	165	215	1426	222	-	3288	-	-	-	-	-	-	-	-	-	-	-	3288
Demineralized water	kg/hr	9000	-	-	-	2700	-	-	11700	-	(11700)	-	-	-	-	-	-	-	-	-	-
Potable water	kg/hr	-	-	-	-	-	-	-	-	-	(2500)	-	-	-	-	-	-	-	2500	-	-
Make-up water	kg/hr	-	-	-	-	-	-	-	-	-	(2500)	-	2500	-	-	-	-	-	-	-	-
Condensed water	kg/hr	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	-	-	-
Boiler feed		-	-	-	4500	14000	-	-	18500	-	(18500)	-	-	-	-	-	-	-	-	-	-
Steam H.P.	kg/hr	-	-	-	(3500)	(2700)	2900	110	(3200)	-	-	-	-	-	-	..	-	-	-	-	-
L.P.	kg/hr	-	..	-	-	(900)	900	-	-	-	n.a.	-	-	-	-	-	-	-	-	-	-
Electricity	KW/hr	46500	750	3500	15	428	467	-	51784	-	14	627	-	-	-	24	250	124	250	1166	52950 (54000)
Catalysts	gr/hr	negl.	-	-	200	1.4	-	-	200/1.4	-	-	-	-	-	-	-	-	-	-	-	200/1.4
Chemicals (KOH)	gr/hr	80	-	-	-	-	-	-	80	-	-	-	-	-	-	-	-	-	-	-	80
Dolomite-limestone	kg/hr	-	-	-	-	-	-	3750	3750	-	-	-	-	-	-	-	-	(3750)	-	-	3750
Instrument air/ Process air	NM^3/hr	-	- 4184	100	50	16.5	-	100	266.5 4184	-	-	-	-	-	30	-	- 108	n.a.	n.a.	296.5 4292	4588.5

4.5 Off-site and Storage Facilities

For the proper operation of the plant, the main process units within the battery limits have to be supported by relevant off-site and auxiliary facilities which are listed and specified below.

WATER PUMPING STATION

The Shire River will serve as the main source of water supply for the plant's cooling and water treatment system. The pumping capacity of the station has to be initially designed for 3,500 m^3 per hour and a pressure of 40 m water-head. A stand-by capacity of 1,000 m^3 per hour should be added at a later stage.

Seven pumps each of a capacity of 500 m^3/hour (134 H.P. or 103 KW) or alternatively 3 pumps of 1,200 m^3/hour capacity (320 H.P. or 240 KW) have to be installed along the river bank at a spot adjacent to the plant site to provide the required quantities of water.

Estimated costs K30,000.

WATER TREATMENT UNIT

This unit has to produce the specific water requirements of the electrolyser plant, the nitric acid plant, the W.H. Boiler feed, drinking water and the close-circuit cooling system's make-up water. Water purification has to consist of a coagulation-filtration step followed by a demineralization section.

Coagulation will take place in open tanks, filtration through gravel and/or activated coal. For demineralization there are commercial systems in use such as ion-exchange resins, reverse osmosis and electro-dyalisis. They operate fully automatic and circulation requires less than 0.24 KWH per ton of purified water. Ion-exchangers consist of two trains; while one train is in operation, the other stands by or is being regenerated.

Electrolysis feed water should be free of chlorides ($<$ 0.001% Cl), contain less than 10 mg/litre of solids and should have a conductance of less than 6 micromhos.

The capacity of the water treatment unit has to be between 35 and 40 tons per hour depending on whether one or two W.H. Boilers will be installed within the battery limits. Treated water has to be stored in a deionat or ebonite tank of about 300 m^3 holding capacity.

The approximate weight of the demineralisation unit will be 70 tons and cost K0.7 million. The space covered by the water coagulation/

filtration basin will be about 180 m^2.

AIR SYSTEM

The necessary air for pneumatic instrumentation installed to control process and off-site plant operations will require an instrument air compressor annex drying unit with a capacity of 300 m^3 per hour to be delivered at 4 atm.

Apart from process air for the air-separator, other plant units may require air for cooling purposes as for instance the ammonia, the nitric acid and the product finishing plant. No estimate can be given at this stage apart from the fact that the bulk product storage will require some 108 m^3 of air per hour for ventilation purposes.

ELECTRICAL DISTRIBUTION SYSTEM

Power is supposed to be supplied by ESCOM's interconnected system at Nkhula and to be transmitted by a 66 KV, 3-phase 3-wire (double) line terminating at the battery limits.

The maximum load as demanded by the plant complex operating at design capacity will be approximately 54 Mw. The scope of the design for the system has therefore to include all materials and equipment to distribute the above quantities of electricity efficiently to the various plant units within the complex, i.e. the rectifiers of the electrolysis plant (46.5 Mw) and A.C. power (7.5 Mw) to the H.T. and L.T. motors of compressors, process and water pumps, to the control/alarm system, the communication system instruments and lighting.

Power to the electrolyser battery has to be distributed as D.C. at 800 to 1,000 volt depending on choice of technology and electrical arrangement of the units within the battery.

The transformer/rectifier assembly to be installed for reducing supply voltage to the level needed by the electrolysis battery has to be equipped with appropriate control and measuring devices (induction regulators, tap changers) to allow voltage regulation for partial load operations (60-100%).

Power for H.T. electric-driven compressors (air, synthesis gas, ammonia) will have to be distributed as 6 to 10 kv, 3-phase and 50 cycles.

All power for process items consuming 160 Kw and less, is most likely to be distributed at 380 volts, 3-phase and 50 cycles.

For instrumentation, control/alarm and communication systems, as well as for lighting, a distribution at 110-220 V. will suffice.

The necessary H.T. and L.T. switch gear (30 fields), transformers (3) rectifiers (1), circuit-brakers, as well as bus-bars, cables, earth-fault monitors, etc. should be included in the scope of supplies and be designed according to the above-mentioned requirements.

PRODUCT HANDLING SYSTEM

The requirements for the transfer of finished products from the battery limits to the product store, and subsequently to the bagging and loading station is covered in this section.

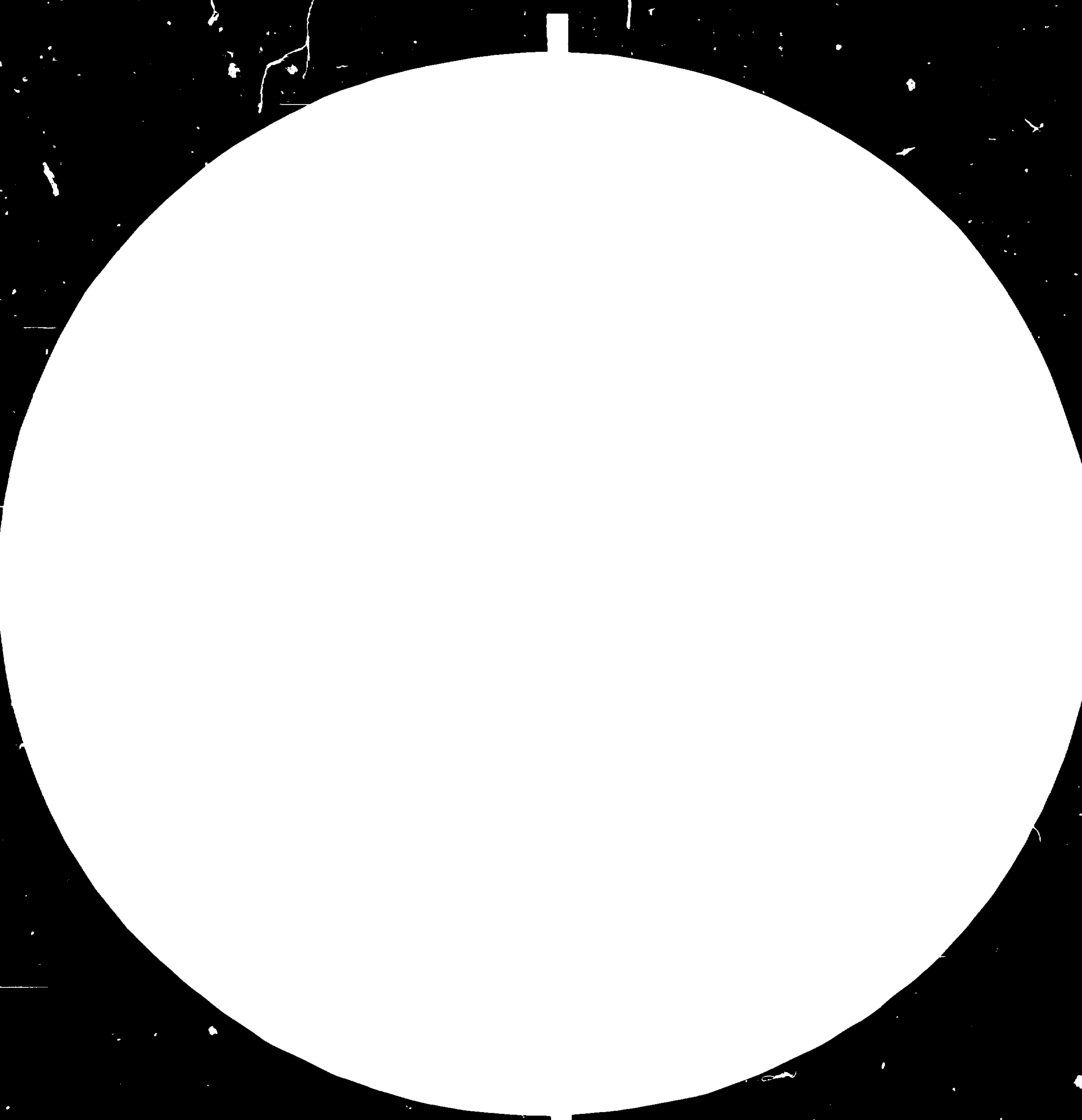
The system will consist of a bulk and bag store and a bagging/loading unit. The design of this system should allow for an average material flow of 40 tons per hour, with an in-built potential to reach 60 tons for short durations (1 to 2 hours). This is 2.5 times the daily output of the plant operating at design capacity, which should suffice.

The bulk store should have an overhead shuttle conveyor, equipped with a distribution chute, which can travel over the total length of the building.

From the bulk store the materials are moved by front-end loaders (2 units of 2 m^3 loading capacity each) to a bucket-elevator, which lifts and discharges the products to the conveyor-hopper system of the bagging plant. The bagging plant should be designed for two semi-automatic bagging lines each with a capacity of 20 tons per hour to be equipped with a device for closing plastic bags by heat-sealing. Via conveyors the filled bags are transported to a truck-loading station consisting of 4 lines (two per bagging line).

A facility to store 11,000 tons of products which equals one month's production of CAN when operating at full capacity should suffice. It is assumed that the marketing of the products will be undertaken by the two existing distribution organizations, which both have adequate storage facilities of their own to buffer the seasonal fluctuations in off-take. (Part I, The Fertilizer Market, page 17 and table 13).

Based on a bulk density of about 1, the height of the pile formed under free flowing conditions will not exceed a maximum of 10.5 meter. As the angle of repose is about 35-37 degrees, the width of the building should consequently be 30 m and the length 80 m. The roof structure should follow the angle of repose with a maximum height of 15 m. Effective floor space requirements will be 2,400 m^2 and the



1.0 2.5
2.2
1.1 2.0
1.8
1.25 1.4 1.6

volumetric requirements 18,000 m^3. Floor space distribution should allow for separate storing of AN (33.5% N) and CAN(26% N) and provide a reclaim aisle.

The floor of the bulk storage building and the walls (maximum height 2 m) have to be constructed of concrete and bricks respectively. While the roof structure can consist of aluminium, corrugated steel or concrete, the last is preferred.

LIMESTONE GRINDING

The granulation operations will require powdered limestone to be mixed with the concentrated AN solution at a rate of 2.5 to 3.75 tons per hour depending on the product-mix.

For this purpose a mill has to be installed at the plant site which crushes and grinds locally quarried dolomitic limestone to a mesh size of 100 (Tyler).

To allow for day-shift operation, the capacity of the mill should be approximately 10 tons per hour or 2.5 times the maximum hourly requirements of the process. After grinding, the product should be stored and air-dried prior to being used in granulating operations.

Electricity requirements will be about 34 KWH and heat requirements for drying 30-45 Mcal per ton of limestone.

Space requirements: 14 x 30 m.

STORAGE FACILITIES

Ammonia - Ammonia transferred from the manufacturing plant will be stored in a pressure-sphere at 20 bar and at $50^{\circ}C$. The sphere should be sufficiently large to store some 10 days of production of ammonia, i.e. 1,200 tons. Space requirements : 150 m^2; weight sphere: 270 tons.

Nitric acid - A nitric acid storage tank with transfer pumps should be located near the nitric acid plant to buffer supplies to the ammonia nitrate neutralization unit and the AN/CAN granulation plant. It should contain some 4 to 5 days of design output, i.e. 1,000 tons of nitric acid (60% HNO_3 solution).

Hydrogen-gas - As explained in a foregoing section (4.2, page 63) the use of surplus power in combination with off-peak power would enable the electrolyser battery to operate at near constant load levels. Thus the need for gas storage to buffer fluctuations in H_2-output, resulting from variations in load, and to ensure a steady supply of gas to the ammonia synthesis gas compressors, will be small. Theoretically less than an average of 5% of daily ammonia production will be needed as a buffer stock. Yet, for reasons of safety, it is recommended that a somewhat larger gas-storage facility be provided to hold 20,000 NM^3 of hydrogen gas, the equivalent of 10 tons of ammonia or 2 hours operation at design capacity.

Nitrogen-gas - While the air-separator can be designed to match fluctuations in hydrogen output, it is recommended that storage facilities for nitrogen gas also be installed, in order to provide for sufficient purge gas for electrolyser-operations in case of emergencies, and for reduction gas to ammonia and other plant units. A gas-holder with a capacity of 3,000 NM^3 will suffice, which is the equivalent of one hour supplies when operating at design capacity.

4.6 Buildings and structures

Apart from the steel structures needed for certain process units, most buildings inside battery limit and for off-sites can be built out of indigenous material, i.e. bricks, concrete, etc.

The main buildings together with relevant space requirements and local unit cost of construction, are listed below.

As no more than 50 staff personnel have to be employed in administrative and technical functions, the offices can, like all other structures, be designed as a one-storey building.

HOUSING

It is assumed that the Malawi Housing Corporation will provide housing for medium and lower level staff.

Executive staff will have to be lodged near the plant.

The provision of 25 pre-fabricated units will suffice and will involve expenditure of about K0.5 million.

	Measurements	Surface	Cost of construction	
	w x l x h(m)	m^2	Unit price K/M²	Costs K
Administration area				
Administration building	15 x 40 x 4	600	160	96,000
Technical operations building	10 x 30	300	160	48,000
Plant safety building		80	120	9,600
Laboratory		100	180	18,000
Factory gate/guards house		30	120	3,600
Ablutions (change house)	7 x 14	100	200	20,000
Contingencies		190	200	38,000
Total administrative area		1,400		233,200
Industrial area				
Electrolyser building	40 x 80	3,200	110	352,000
Air separator building	10 x 80	800	110	88,000
Compressor building	16 x 75	1,200	150	180,000
Ammonia, electric building	5 x 8	40	110	4,400
" synthesis (steel structure)		260	lump sum	50,000
Nitric acid plant building + steel structure	20 x 40	800	150	120,000
AN neutralization unit) AN/CAN granulation building)	15 x 30	450	200	90,000
Process control building	10 x 20	200	120	24,000
Shop warehouse/maintenance building	20 x 35	700	200	140,000
AN/CAN bulk store building	30 x 80	2,400	200	480,000
CAN bag store building		250	110	27,500
Bagging/loading station		500	110	55,000
Storage:				
hydrogen steel structure nitrogen " " ammonia " "		300) 100) 150)	lump sum	150,000
Water filtration basin + purification station		180	110	19,800
Electrical sub-station	20 x 10	200	lump sum	20,000
Contingencies		570	110	62,700
Total industrial area		12,000		1,863,400
Total industrial + administration area		13,400		2,096,600

Area within plant boundaries reserved for piping, drainage, roads, safety margins, etc.	36,600
Total surface site	50,000

5. PLANT ORGANIZATION AND MANPOWER REQUIREMENTS

The organization of a plant of the size and nature of the proposed fertilizer complex can be confined to 3 departments, i.e. production, maintenance and administration. No provision for a separate engineering department is being made, neither for a sales division, as marketing and distribution functions will, most likely, be undertaken by the two organizations operating in this field, i.e. ADMARC and OPTICHEM.

Procurement will be limited to materials and equipment for plant operations as no raw materials are required. The production and technical departments will undertake these functions as well as the responsibility for plant surveillance, fire protection, technical training, etc.

The plant will employ a total of less than 200 persons in technical and administrative functions of which some 16 professional staff, like chemical, electrical and mechanical engineers, accountants and chemists will be on the payroll. Most of them have to be recruited from abroad during the initial years of operation and consequently at a salary level substantially higher[b] than in the case of local employees.[a] Wages for labour and salaries for professional staff are estimated at K604,000 (£355,940) per year, which works out to K5.08 (£3.00) per ton of CAN, when the plant is operating at design capacity during 330 days of the year.

Training of shift supervisors and operators should, in the first instance, be organized at the plant on an in-plant basis and continuously, by the managerial staff, or by specially recruited expatriates. Locally recruited process engineers and a limited number of shift supervisors should undergo practical training in similar factories abroad in the pre-production period. At this stage, no cost estimate for training abroad can be given in the absence of information on the availability of local expertise in various fields.

PERSONNEL REQUIREMENTS

	Salary/wage base (K/annum)
A = Plant manager	20,000
B = Head of Department, assistant plant managers	15,000
C = Superintendents, process/mechanical/electrical engineers, accountants	5,000
D = Shift supervisors, office supervisors	1,200
E = Staff/operators	800
F = Secretarial assistants, typists	800

	A	B	C	D	E	F	Total
I Production Department		1				1	2
Ammonia production:							
Electrolysis			1	3	9	1	14
High pressure units			1	3	9		13
Nitric acid and fertilizers:							
Acids			1	3	9	1	14
Fertilizer/limestone grinding			1	3	12		16
Storage, bagging, dispatch:							
Storage					9		9
Bagging, dispatch				3	42		45
Off-sites, utilities:							
Power supply				1	3		4
Water supply/treatment					3		3
Laboratory			1		4		5
	-	1	5	16	100	3	125
II Maintenance Department		1				1	2
Workshop			1		10	1	12
Field repairs			1	3	15		19
Electrical and process control			1	1	6		8
	-	1	3	4	31	2	41
III Administrative Department		1				1	2
Personnel administration			1		3	1	5
General administration			1		4	1	6
Finance/accounts			2		8	2	12
	-	1	4		15	5	25
Plant total	1	3	12	20	146	10	192

Annual Manpower Costs	K273,000
(a) With provision for annual benefits and social security (30%)	K355,940
(b) With provision for expatriate staff (16) during first 6 years of operation	K604,000

6. IMPLEMENTATION SCHEDULE

As shown in the timetable chart (figure 16) the proposed fertilizer project can be brought on stream in 2½ years from initiation, if contracted on a turn-key basis.

The basic functions to get the plant completed require about 2 years. They are: (1) basic and detailed design; (2) civil engineering; (3) procurement of equipment and materials; (4) their shipment; and (5) erection.

Process design following process choice and detailed plant layout, will be mainly concerned with establishing final heat and material balances, process flow sheets, equipment data sheets for the 4 major and all sub-processes and with the preparation of operating manuals. It will also define intermediate and final product storage, as well as handling requirements.

Engineering design will develop a detailed plant layout, prepare general and detailed specifications, codes and standards to be used for the procurement of materials and equipment. It will also develop detailed process and instrumentation drawings for plant battery units, off-site facilities and utilities, and prepare detailed specifications, data sheets and drawings necessary for the following engineering disciplines, i.e. civil, structural, mechanical, piping, electrical, instrumentation and architectural.

It will further inspect and check purchased materials for compliance with specifications and monitor progress for compliance on delivery and shipment dates.

Construction and erection will deal with manpower, equipment and logistics required to erect the plant complex in each phase of the work from start to finish. It will provide overall supervision, direction and inspection of construction work and perform all mechanical checking and testing functions to certify mechanical completion of the plant complex.

Commissioning will involve starting-up operations. It will perform test runs on plant capacity and product quality for each section of the plant, check and test all utility systems, mechanical equipment and instrumentation and eliminate bottlenecks, mechanical failures, etc. as and when they occur.

COST ESTIMATES FOR IMPLEMENTATION

Overall costs of engineering services and erection as described above for a plant to produce CAN from electrolytic-hydrogen based ammonia with a design capacity of 360 tons per day, are estimated at K13.671 million and are based on present day cost of salaries and services prevalent in Europe. Details are presented in the table below. They do not include allocations for the build-up of administration, recruitment and training of staff.

Engineering Services and Erection Costs

(in million Kwachas)

	Engineering	Erection	Total
Electrolysis	2.87		2.87
Air separation	0.146		0.146
Ammonia synthesis	0.984		0.984
Nitric acid	1,936	3.03	4.966
Ammonia nitrate	0.475	0.24	0.715
AN/CAN granulation	1.232	0.78	2.012
Limestone grinding	0.132	0.37	0.502
Product storage	0.044	0.36	0.404
Product bagging/handling	0.176	0.72	0.896
Storage : Ammonia	0.044		0.044
Nitric acid	0.044		0.044
Hydrogen gas	0.044		0.044
Oxygen gas	0.044		0.044
Total cost of services	8,171	5.5	13.671

FIGURE 16

TIME SCHEDULE FOR A CAN FERTILIZER COMPLEX WITH A DAILY OUTPUT OF 360 MT. INCLUDING AN ELECTROLYSIS BATTERY, AMMONIA NITRIC ACID, AND AN/CAN PLANT

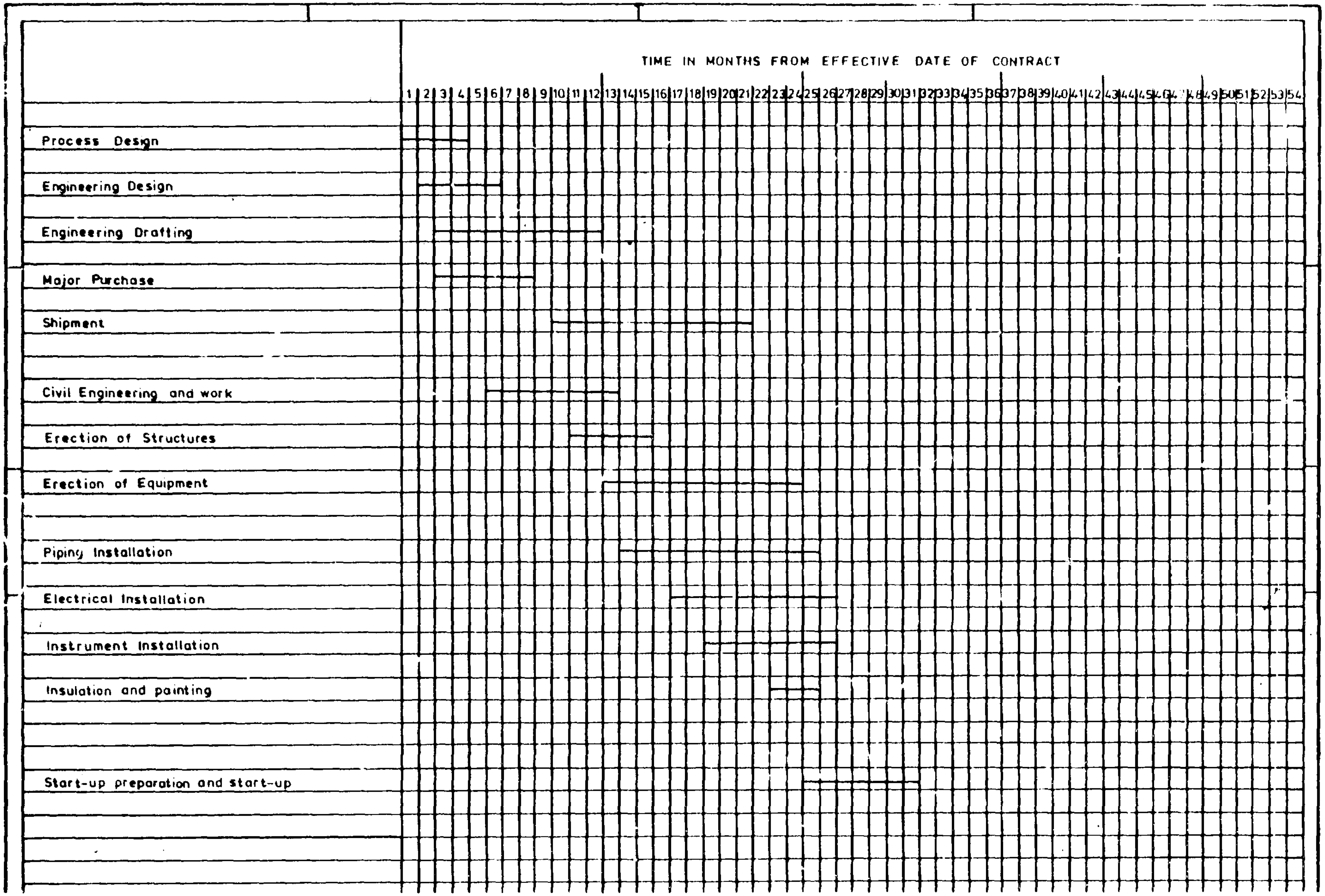
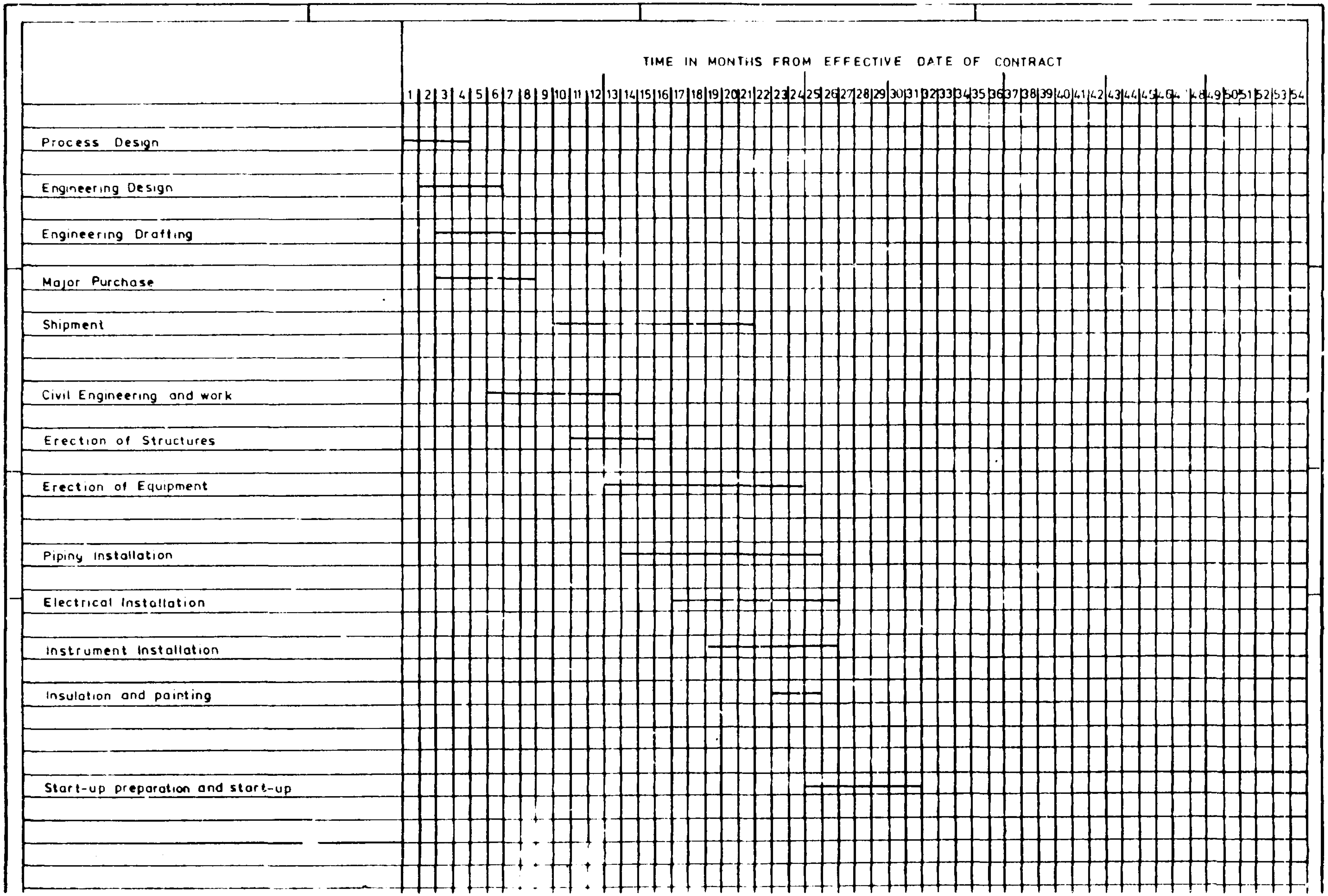


FIGURE 16

TIME SCHEDULE FOR A CAN FERTILIZER COMPLEX WITH A DAILY OUTPUT OF 360 MT. INCLUDING AN ELECTROLYSIS BATTERY, AMMONIA NITRIC ACID, AND AN/CAN PLANT



7. PROJECT COST ESTIMATES

The cost of the installed project is estimated at K54 million, including some K50 million or 92% in foreign exchange, and total financing requirements at K56 million equivalent.

Details of the various cost items have been dealt with elaborately in preceding chapters and are summarized in full below.

The list of main plant installations and their cost (1979-basis) includes all movable and immovable machines and equipment for production, processing and control as well as related off-site facilities which form an integral part of a plant complex having a design capacity of 360 metric tons of calcium ammonium nitrate (CAN: 26% N) per day and which is based on hydrogen feedgas generated by electrolysis of water with electricity supply from ESCOM's interconnected system.

Cost of equipment packed and delivered F.O.B. European ports will amount to K35.9 million of which not less than 46% has to be allocated to the electrolyser battery alone. As explained earlier, the layout of this battery in the initial phases of project project implementation can be limited to 75% of design capacity and capital costs can correspondingly be adjusted.

In the event that an independent source of power would be preferred, capital costs have to be increased by an amount of K40 million to construct a hydro-power station with an installed capacity of 60 MW.

The overall size of the packed equipment and materials will remain below 4,000 tons by weight and 7,000 m^3 by volume.

Ocean freight plus inland forwarding are, on the basis of current liner-term and unloading rates, railway tariffs and road transport, estimated to be K1 million. Thus, cost of machinery and equipment delivered at the plant site of Nkula will amount to about K37 million. It is assumed that a fertilizer plant will be exempted from customs duties on imported materials and component parts. No provision is made, either, for forwarding agency fees, bank charges or transit dues (1.37% ad valorem).

The cost of engineering services (including licence fees), construction and commissioning of the plant complex will amount to a total of some K13.6 million.

Expenses for site preparation and development, the erection of administrative and industrial structures will add a further K2.632

million to base costs. In addition an allocation of K0.5 million has been made for the provision of housing for executive staff and K0.275 pre-operational expenses.

Cost of land (5 ha) does not appear in the computations as no land can be acquired in Malawi and must be secured on lease against payment of annuities.

Thus, the overall cost of installment of the plant complex is estimated to be around K54 million or K150,000 per daily ton of installed CAN capacity.
To arrive at overall financing requirements an amount of K2,160 has to be added to cover working capital, in addition to interest charges during construction (n.a.) as soon as the financing plan has been established.

No significant price escalation in regard to cost of machinery, equipment and engineering services are anticipated in the short term, due to slack trade in the engineering and construction market for fertilizer plant at present. Besides the majority of capital cost elements has been expressed in a stable currency, i.e. German Marks (DM). Physical contingencies do not appear as a single item on budget capital costs, as adequate provision has been made separately under each cost element.

CAPITAL COST ESTIMATES

Installations 1/	Capacity per unit	No. of units	Costs (million) DM	US$	K	%
1. Electrolysis battery (including auxiliaries, electrical equipment, control instrumentation)	375 NM^3 H_2/hour	27	36.2	-	15.93	46.6
2. Air separator (including mechanical & electrical parts & piping	3500 NM^3 O_2/ hour	1	2.3	-	1.01	2.9
3. Ammonia plant: Syngas compressors (reciprocating)	13200 NM^3 Syngas/hour	1	-	2.10	1.72	5.0
Reactor (including separator condensers, circulators, ammonia recovery & electrical parts)	5T/hour	1	-	4.21	3.45	10.1
4. Nitric acid plant	214 T/day	1	11.50	-	5.06	14.8
5. Ammonia neutralization plant	280 T/day	1	1.30	-	0.572	1.7
6. AN/CAN granulation plant	360 T/day	1	4.10	-	1.804	5.3
Off sites						
7. Storage facilities:						
Hydrogen-gas holder	10,000 NM^3	2	3.6		1.5	4.4
Nitrogen-gas holder	3,000 NM^3	1	0.7		0.3	0.9
Ammonia-sphere	1,200 tons	1	-	0.4	0.33	0.9
Nitric acid storage	1,000 tons	1	0.36		0.16	0.5
8. Water-pump station	1,200M^3/hr	3	0.068		0.03	0.1
9. Water treatment plant	35-40 T/hr	1	1.62		0.713	2.1
10. Limestone crusher/grinder	10T/hour	1	1.25		0.55	1.6
11. Product storage, bagging & handling equipment	20T/hour	2	2.40		1.056	3.1
					34.185	100.0
12. Spare parts	5% value of equipment				1,709	5.0
13. Equipment and materials packed and delivered f.o.b. European ports					35.894	
14. Ocean freight: 7,000 freight tons liner terms at K94 ($115)					0.660	
15. Unloading 2/: 7,000 port tons at K7/ton					0.049	
16. Inland forwarding: Beira-Limbe-Nkula:						
Railage - 4,000 weight tons at K38					0.152	
Road - 4,000 weight tons at K50					0.200	
17. Total of equipment and materials delivered c.i.f. at plant site					36.955	
18. Engineering services (basic and detailed engineering, procurement, supervision of works)					8,171	
19. Erection and commissioning cost					5,500	
20. Pre-operating costs 3/					0.275	
21. Site preparation and development					0.535	

22. Civil works	2.097
23. Housing	0.500
24. Base cost estimate/installed cost [4]	54.033
25. Working capital [5]	2.160
26. Interest during construction	p.m.
27. Total financing required	56.193

1. Cost of equipment for power distribution and air system is being proportionally distributed over relevant main process and off-sites units.

2. Agency fees, bank charges and transit dues (1.37 % c.i.f. value) not included. It is further assumed that supplies are exempt from customs duty.

3. Includes training, corporate overheads, general, etc. estimated at 5% erection and commissioning costs.

4. No provision is made for price escalations and equipment costs are vali for 1979.

5. See Annex 9.3.

6. Exchange rates: DM = MK 0.44
   US$ = MK 0.82

8. PRODUCTION COST ESTIMATES

8.1 Calcium ammonium nitrate (26% N, bagged)

Most cost elements entering into production costs have been described in detail in preceding chapters.

For the sake of convenience they are briefly summarized and commented on in Annex 2: Assumption for operating cost estimates.

Relevant cost figures assembled in the table below, show that production costs, calculated at 1979 constant prices, will amount to a total of K12.96 million per year when the plant is operating at a design capacity, which is expected to be in the 7th year after start-up, (half-way the economic life of the plant).

The ex-factory cost per ton of bagged CAN, at 100% capacity utilization, will amount to about K109.00.

The principal cost element is electricity which accounts for almost 50% of total production cost. Electricity and depreciation charges together represent almost 80% of production costs. It is difficult to assess at this stage the foreign exchange component of production costs in the absence of details on the same for electricity unit costs.

In the second year of operation, at 70% capacity utilization or 83.160 tons of output, annual production costs are estimated at K10,684,328 (i.e. 70% of variable plus 100% of fixed costs) and the ex-factory cost at K128.5 per ton of bagged CAN. In reality the ex-factory cost at 70% plant utilization will turn out to be lower, if the number of electrolyser units is adjusted to actual demand and fixed costs are correspondingly lowered.

In the financial analysis (Part III) it will be demonstrated how sensitive the project will be to electricity charges and capacity utilization.

8.2 Ammonium/nitrate (33.5% bulk)

Because of market demand, a substantial part of the plant output may have to be produced in the concentrated form of ammonium nitrate (33.5% N) and to be delivered in bulk.

Most of the variable cost elements enumerated for CAN will also enter the cost structure for AN and unchanged with the exception of dolomite-limestone and bags, for which there is no need.

In addition, electricity consumption can be reduced by about 400 Kw per hour and fixed cost such as manpower and overheads by one quarter, because there will be no need for bagging and handling of bags.

Other fixed costs will remain unchanged. As a result, the annual cost of production of AN (33.5% N) will amount to approximately K11.75 million, when the plant is operating at full capacity, i.e. at a rate of 280 tons per day.

The ex-factory cost per ton of AN delivered in bulk will be about K127 which, on a per-ton-nitrogen basis, equals K379 against K419 for CAN.

The production of AN (33.5% N) offers distinct economic advantages as compared with CAN (26% N).

Calcium Ammonium Nitrate (26% N) Production Costs at Full Capacity

Operating days : 330 per year

Plant capacity : 118,800 MTPY; 360 MTPD: 15 MTPH

Process sequence : Water-electrolysis, air-separation, ammonia synthesis, nitric acid, ammonium nitrate neutralization, granulation, storage and bagging

Operating data	Item	Hourly requirements	Unit prices (K)
	Electricity	54 MW	0.015/KWH
	Process water	11.7 ton	p.m.
	Cooling water	3,288 m^3	p.m.
	Boiler feed water	14-18.5 ton	p.m.
	Chemicals KOH (100%)	10-80 gr	4.4/kg
	Dolomite-limestone	3.75 ton	8.0/ton
	Catalysts : ammonia	200 gr	4.5/kg
	: nitric acid	1.4 gr	500/troy oz.
	: H_2-gas purification	-	-
	Bags (plastic. 50 kg)	300	0.32/bag
	Direct manpower (labour and staff) including benefits & social security contributions (30%)	0.025	44.9/hour
	Overheads (administrative & factory) (50% manpr.)		22.5/hour
	Maintenance repairs: (2% CIF plant costs + civil works)		2367/day
	Depreciation: (7% project costs minus non-depreciables)		
	Insurance: (0.5% plant costs + civil works)		
	Interest		p.m.

		Kwacha	%
Variable costs per year	Electricity	6,415,200	49.62
	Water	p.m.	-
	Catalysts	160,418	1.24
	Chemicals	2,788	0.02
	Dolomite-limestone	237,600	1.83
	Bags	760,320	5.87
		7,576,326	
Fixed costs per year	Manpower	355,940	2.74
	Overheads	177,970	1.37
	Maintenance	781,040	6.03
	Depreciation	3,800,000	29.33
	Insurance	265,950	2.05
	Interest	-	-
		5,300,900	
Total manufacturing cost		12,957,226	100.00
Production costs per ton CAN bagged		109.06	

ANNEX : 1

BASIS OF DESIGN

1. **Elevation site above sea level**		m	200-300
2. **Climatic data**			
Air temperature :	Maximum	°C	45
	Daily average during hottest period (Sept.-Nov.)	°C	30
	Minimum	°C	8
	Daily average during coldest period (June-July)	°C	16
Relative humidity :	06.00 hours	%	65/83/92
	Average	%	50/68/84
	14.00 hours	%	35/54/68
Rainfall :	November-March	mm	60-70
	April-October		negligible
Barometric pressure		mb	974/979/983
Thunder storms :		days	70/100
		period	Nov-March
Wind velocity :		m/sec	-/8/30
	prevailing direction:		
	dry season		N. East
	wet season		S. East
3. **Shire River water analysis**			
pH			7.7
Temperature		°C	20-27
Conductivity		micromhos/cm	178-250
Total solids		ppm	130-200
Free chlorine		"	6
Free CO_2		"	2-4
Total alkalinity:	as $CaCO_3$	"	105-135
Total hardness :	as $CaCO_3$	"	76-86
Permanent hardness:	as $CaCO_3$	"	n.a.
Metals :	Iron	"	0.10-0.4
	Manganese	"	4-10
	Calcium	"	40-75
	Magnesium	"	20-37
Average annual flow rate		m^3/sec.	235
4. **Electricity**			
H.T. supply		KV	66
		phases	3
		cycles	50
Off-peak and surplus power availability in the period 1980-1990		MW	30-90
5. **Soil conditions**			
Gneissic rock-bed covered by weathered materials, thickness		m	6.-
Soil bearing capacity			n.a.
Required		kg/cm^2	2.-
6. **Cost data**			
Construction:			
Roads:	1st class (7 m width bitumen) axel load 8 tons	K/mile	150,000
	Secondary (7 m width, gravel)	K/mile	100,000
	District (dirt)	K/mile	50,000-70,000
Rail track:	(80 lb. rail on pre-cast concrete sleepers, with track fully stone-balasted)	K/mile	270,000-320,000
Power transmission:	66/130 KV first 20 km	K/mile	25,600
	longer distances	K/mile	33,600

ANNEX : 2 ASSUMPTIONS FOR OPERATING COST ESTIMATES

1. Electricity

Power is assumed to be supplied by ESCOM. The economic cost of offpeak power is taken at 1.5 t per kwh (ref. Chapter I, Section 3.8: Electricity charges, page 37).

2. Water

Water will not appear in cost calculations as raw water will be directly obtained from the Shire River at no cost.

The consumption of electricity for water pumping, purification, etc. as well as depreciation are covered under major cost items on an overall basis.

3. Catalysts and chemicals

These items have been dealt with under the relevant sections of Chapter II, Section 4.4, Materials and utility balance.

4. Dolomitic-limestone

Consumption of ground dolomite-limestone is at a rate of 0.25 tons per ton of CAN (26%).

Cost of mining is taken at K4 per ton while transport and handling cost will be at an average K4 per ton, totalling K8 per ton of limestone quarried delivered at the factory.

5. Bags

Imported fertilizer products are usually packed in woven poly-propylene bags having a poly-ethylene inner bag. Products granulated in the plant of OPTICHEM are packed in low density poly-ethylene bags with open mouths which are closed by heat-sealing. (Thickness: 200 microns; measurements : 23 x 35.5 inches; 800 gauge).

They perform well under local conditions of storage, handling and transport.

This type of bag is locally manufactured by Plastic Products Limited (a subsidiary of the Malawi Development Corporation).

Present capacity is about 1 million bags a year, against an annual requirement of 2.4 million bags once the fertilizer factory attains full capacity.

The current sales price is 31.53 t per bag, which is taken as unit price for cost calculation.

6. Direct manpower

Salaries, wages and benefits of personnel are treated as a fixed cost item as is customary in a capital intensive industry like a fertilizer plant. Labour, apart from bagging operations, is usually permanently employed and not laid off in slack periods.

The cost of manpower has been dealt with in a previous section. It is estimated at K603,000 per annum during the first 6 years of operation and at K355,540 per annum in later years, once expatriate staff has been replaced by local personnel. A 30% bonus for benefits and security payments is included in the above figures.

7. Overheads

Cost items under this heading include office supplies, communications, rents, contractual services, transport, public relations, land lease, etc. They were computed as a 50% surcharge of manpower inputs which will amply cover all anticipated expenditure of the nature referred to above.

8. Maintenance/repairs

Maintenance and repairs are taken at 2.0% on initial book value of civil works, amounting to K2,097 million and of value of delivered machinery and equipment, amounting to K36.956 million, totalling K39,052 million.

Spare parts, included in the capital cost estimate, is equivalent to three years' supplies of maintenance materials (K0.6 million per year).

9. Depreciation

The economic life of the plant is taken as 14 years. Assets to be depreciated include total installed cost (K54 million) minus non-depreciable assets like land, site preparation (K0.535 million), pre-operational expenses (K0.275 million), totalling K53.19 million.

Annual depreciation charges (14 years straight line) amount to

$\frac{53.19}{14}$ = 3.8 million, or 7% per year.

10. Land lease and insurance

There is very little freehold land in Malawi. So-called Customary Land is acquired by the Government from the local villages for industrial purposes and leased to industries. Terms of the lease are from 20 to 99 years at a rate of K750 to K1,000 per hectare per year and this charge is included under administrative overheads.

Insurance payments to cover damage to machinery equipment and buildings is taken as 0.5% of relevant book value, i.e. installed project costs minus cost of site preparation and pre-operating expenses (K53.19 million).

ANNEX : 3

WORKING CAPITAL CALCULATION AT 1979 PRICES [1]

(K)

		Total
1. Inventory		
(a) Chemicals	One year supply	2,788
(b) Catalysts	One year supply	160,418
(c) Bags	30 days supply	69,120
(d) Spare parts [2]		
(e) Limestone	30 days supply	21,600
(f) Work in progress	5 operating days ammonia output (600 tons) at K244/ton	146,400
(g) Finished product inventory	15 operating days production of CAN (5,400 tons) at K109	588,600
2. Accounts receivable	30 operating days production of CAN (10,800 tons) at K175 [3]	1,890,000
3. Minimum operating cash balance	5% of production costs excluding depreciation	457,861
4. Gross working capital		3,336,787
5. Accounts payable	30 operating days production of CAN (10,800 tons) at K109	1,177,200
6. Net working capital required		2,159,587

1. Based on 100% capacity utilization (e.g. 330 operatings days/year)
2. Included in the capital costs
3. 1979 sales price of CAN ex store Limbe.

ANNEX : 4

DOLOMITE-LIMESTONE RESOURCES

Malawi is well endowed with limestones and most of them are dolomitic and hence have usefulness as filler in the production of calcium ammonium nitrate.

Some of the more important magnesium limestone occurrences in Malawi are summarized in the table below.

Location	Area	Quantity or extent of available limestone	Analysis % CaO	MgO	S_1O_2	Loss on ignition
Matope	Middle Shire/ Kirk Range	About 650,000 tons	30-32	19-20	<10	
Lirangwe	"	Extensive	22-32	18-22	< 1	42-47
Kapiri Hill	"	Extensive	28.7	21.7		
Chuzi	Chikwawa	Beds up to 1.5 m thick				

Of the four main deposits, those of Matope and Lirangwe are the nearest to Walkers Ferry, the possible site of the fertilizer plant complex.

The Lirangwe occurrence is situated about 38 km from Blantyre, 5 km North East of Lirangwe Township and 25 km to the East of Walkers Ferry. The Deposit is highly dolomitic and two types occur, one with less than 10% calcite, the other with 25% to 40% calcite. The more dolomitic type, which is common at the southern end of the outcrop, has a medium to coarse grained texture and a creamy white colour. Serpentine is the only macroscopic impurity. The more calcitic type, from the northern end contains more silicate impurity but less than 1%.

The Lirangwe deposit is variable in thickness but averages about 50 m and has a total strike length of about 2 km. Reserves are estimated at over 0.5 m tons. The quarry has easy access and is being exploited for lime burning. Lime is sold under contract to the Ministry of Works for building purposes. Cost of quarrying materials has been given as K3-4 / ton

The Matope deposit is located near Matope bridge close to the south eastern bank of the Shire River at some 20 km to the north of Walkers Ferry.

The occurrence is highly dolomitic. It contains silicate impurities in variable and relatively high quantities but generally less than 10% of the rock.

The main deposit stretches as a band of variable thickness (0-18 m) over a distance of 2 km. Reserves up to 650,000 are estimated to be available for quarrying within 30 m of the surface. The cost of quarrying is estimated at K4 per ton. Yet, because of its lower silicate content, the Lirangwe dolomite should be preferred as a filler for CAN production.

In addition there is the Nkalazi group of dolomitic limestones, less than 3 km to the east and 10 km to the south east of Walkers Ferry. For this very little information on quality and quantities is available. Once a decision on the fertilizer project is taken further detailed exploratory work would become expedient because of the vicinity of the occurrences near the site of the plant.

ANNEX : 5

BY-PRODUCTS

The main by-products of ammonia manufacture via the water-electrolysis and air-separation route is oxygen (O_2).

Oxygen is an industrial gas and is used for bleaching purposes, welding, metal cutting, thermic launching of cement, etc. There are about 400 consumers of industrial oxygen in Malawi, which together purchased in 1978/79 a total of 6 million cuf of gas (162,160 NM^3) equivalent to 230 tons of gas at an average price of K15 per 300 cuf (K1.5 per kg). Industrial Gases Limited (IGL) is the major supplier of industrial gases in Malawi. According to their projections the market for oxygen will reach some 227,000 NM^3 or O_2 by 1980/81 and most likely some 270,000 NM^3 or 380 tons of oxygen gas by 1985/86 (8 to 10% increase per year). An additional and potential customer of oxygen gas may become the Viphya Pulp Project. Using oxygen instead of chlorine as a bleaching agent would reportedly require some 50 tons of O_2 per day.

Co-product oxygen is produced by both the water-electrolysis and the air-separation route at a rate of 1,665 NM^3 or 1,166 kg per ton of ammonia manufactured.

	Co-product oxygen per ton of ammonia	
	kg	NM^3
Electrolysis (g)	1,412	988
Air separation (l)	253	178
Total	1,665	1,166

When the fertilizer project is operating at design capacity, i.e. 120 tons of NM_3 per day, the production of co-product oxygen will amount to 8.325 tons per hour or 200 tons per day. Thus the entire oxygen market of Malawi would be served by 2-3 days production of the plant.

Because of the small size of the market in Malawi for industrial oxygen, no installations for filling cylinders are planned at this stage and no credit is given for oxygen co-product in cost calculations.

PART III. The Financial and Economic Evaluation

TABLE OF CONTENTS

	PAGE
I. FINANCIAL EVALUATION	1
1. Basis of Analysis	1
2. Project Viability	3
II. ECONOMIC EVALUATION	6
1. Foreign Exchange Savings	6
2. Other Economic Benefits	7
III. SUMMARY AND CONCLUSIONS	8
IV. RECOMMENDATIONS	9
V. INTRODUCTION	10
APPENDICES	
1. Selling Price for Calcium Ammonium Nitrate (CAN:26%N)	11
2. Break-even Analysis	12
3. Profit Break-even Point	13
4. Simple Rate of Return	14
5. Internal Rate of Return Calculation : Base Case	15
6. " : Alternative : A	16
7. " : Alternative : B	17
8. " : Alternative : B1	18
9. " : Alternative : B2	19
10. " : Alternative : B1 + 2	20
11. Foreign Exchange Savings	21

I. FINANCIAL EVALUATION

1. Basis of Analysis

The financial return on the investment capital is the ultimate criterion to determine whether the project is commercially viable. Consequently, the profitability analysis to be carried out will essentially consist of assessing the ratio between the profit and the capital to be invested in the proposed project. Since it is unknown at this stage how the project will ultimately be financed, the analysis will be prepared of the total investment and as if the project would be implemented without outside financing. Such a procedure is a way (a) to assess the economic value of the project for the enterpreneur and to compare the earning power of the project with prevailing opportunity cost of capital*, (b) to judge project alternatives on their own merits, assuming equal conditions for financing and (c) to indicate the conditions of loan financing such as the schedule of loan repayment as well as the maximum interest rate which could be paid without creating any losses for the project proposal.

The measures for evaluation used in this analysis are:-

1. The Break-even Point
2. The Internal Rate of Return

and 3. The Pay-Back Period

The Pay-Back Period is defined as the period required to recuperate the original investment outlay through earnings of the project.

The Break-Even Point (B.E.P.) determines the point at which sales revenues equal production costs.

The Internal Rate of Return (I.R.R.) is the discount rate at which the present value of cash inflows is equal to the present value of cash out-flows. It is the rate at which the present worth of the benefits to be derived from the project equals the present worth of the cost. In other words it represents the return over the economic life of the project to the resources engaged in the project or the rate of interest at which money could be borrowed to build the plant and be exactly repaid by the trading profit.

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* The weighted average of the borrowing rate for funds in the international and local market plus an acceptable price-earning ratio for equity financing.

The procedure for calculating the I.R.R. is to compute cash flows and to discount them to determine by trial and error the rate at which present values are zero.

Depreciation is not deducted as a cost in cash flow statements, as discounted measures of project worth automatically take care of provisions for re-investments. Further and major assumptions used in the preparation of cash flow statements are the following:-

1. Rated production capacity (at 100% capacity utilisation) is 112800 metric tons of CAN (26%N) per year and is based on a design capacity of 15 MTPD and 330 operating days per calender year.

2. The project will start production towards mid 1983 namely 30 months from initiation (early 1981).
   Production build-up will, in conformity with domestic market demand, increase gradually from a capactiy utilization rate of 30% in 1983 to 100% in the 9th year of operation (i.e. 1991 in the 11th year from initiation).

3. The economic life of the project is taken as 14 years, which includes the initial years of construction.

4. Capital* and operating costs (manufacuring cost minus depreciation) are taken from Part II, Chapter 2 of this study and represent values prevailing at the time of appraisal.

   Correspondingly all price, costs and benefit figures in the cash flow statements are expressed in constant 1979 terms.

5. The price for electricity is assumed to be 1.5 tambala per KWH (See Part II, Chapter 2: Electricity charges, Page 37)

6. The ex-factory price for CAN is taken as K175 per metric ton of bagged product (see appendix I) and is free of excise duty.

7. Income tax of 45 per cent to be paid by any manufacturing or trading company in Malawi is supposed to be waved.

8. The total capacity outlay is supposed to be disbursed entirely during the 30 months construction period and in conformity with the implementation schedule for the project i.e. 1st year: 30%; 2nd year: 50%; 3rd year (6 months) ; 20%.

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* Machinery and equipment is supposed to be imported duty-free.

2. Project Viability

The profitability analysis (Appendices: 2 - 4) indicate that the proposed fertilizer project will start to break-even at a capacity utilization of around 40%.

The B.E.P. is relatively low which is unusual for highly capital intensive projects. It illustrates the predominant effect of the relatively high level of variable costs (electricity) in relation to fixed costs. A low B.E.P is convenient since it renders the project less vulnerable to changes in the level of production (sales). Furthermore, it enables the project to start making a profit at a relatively low level of capacity utilization. On the other hand, the relatively small difference between unit sales price and variable unit cost (electricity) renders the project a rather modest earning power potential. This is first of all demonstrated by the fact that the B.E.P. is very sensitive to changes in the unit sales price. A 10% reduction in sales revenues per unit of output immediately increases the B.E.P. from 40 to 48%.

A preliminary indication of the profitability of the project is provided by the simple rate of return (SRR). Based on the assumed selling price of K175 and estimated manufacturing cost of K109 per ton, the SRR is 13.9%. The return drops by 1% in case of a reduction in selling price of K4.9 per ton is applied. This approximate calculation naturally overestimates the average earning power potential of the project; because the plant will take at least 9 to 10 years to achieve full output.

This discounted cash flow method therefore provides a more accurate assessment of the project's earning capacity.

The I.R.R. before tax is 11.58% (Appendix 4) in real terms.

It confirms that the overall earning power potential of the project is modest to low when compared with going opportunity cost assumptions i.e. 15%. Besides the pay back period, i.e. 8 - 9 years, is a rather long period to recover original investments. Thus in the event that a substantial part of the investments has to be financed with outside loans, the project will barely be in a position to support interest rates higher than 10 per cent. Furthermore without the facility of deferred repayment of loans, it will be impossible to achieve a debt service coverage ratio of at least 1.5 during the first 7 to 8 years of plant operation.

It is obvious that any less favourable assumptions as mentioned above and in particular a reduction in the selling price of CAN would increase the time needed to meet financial obligations and would render the project not sufficiently viable commercially to attract funds.

Sensitivity tests have been conducted to determine the effects on the rate of return of

1. An extended capital disbursement schedule (slower investment build-up)

2. Improved capacity utilization (accelerated production/sales build-up) and subsequently the effects of

3. A variable cost decrease by 10%
and

4. A sales revenue (price) decrease by 10%

The result of the analysis are given in the appendices 5 - 9 and are summarised below.

SENSITIVITY TESTS ON THE INTERNAL RATE OF RETURN

		%	Pay-back Period (Years)
1.	Base Case	11.56	8.9
2.	Alternative A : Slower Investment build-up	12.70	8.3
3.	Alternative B : Optimum capacity utilization	13.30	8.1
4.	Alternative B1: Optimum capacity utilization including a 10% decrease in variable cost	15.36	7.8
5.	Alternative: B2: Optimum capacity utilization including a 10% reduction in sales revenues	9.86	9.2
6.	Alternative B1 + 2: Optimum capacity utilization including a 10% reduction in both variable cost and sales price.	11.18	8.8

Alternative A (Appendix 5)

The project would allow for a slower build-up of investments because the number of electrolyser units required can be adjusted to developments in demand for fertilizer products. (See Part II, Chapter 2 Page 62, 63).

Distributing the capital outlay for the electrolyser battery over the entire economic life of the project would improve the I.R.R. by 1.14% to 12.7%. But it would hardly affect an improvement in the profit break-even or pay-back period. The project is therefore moderately sensitive to lower investment build-up.

Alternative B (Appendix 6)

Production (sales) build-up to optimum rates of capacity utilization would include a substantial improvementof the I.R.R. to 13.3%. From a technical and operational point of view, it is quite feasible to increase the rate of capacity utilization from 30% in the first year of operation (6 months of production) to 100% in the 4th year of operation.

Simultaneously, the period required to recover the amount of original investments will be brought down from almost 9 to 8 years. In case of loan financing it would nonetheless be necessary to carefully adjust the loan payment schedule to cash inflows in order not to endanger the liquidity position of the project.

It is clear that alternative B offers a greater attractiveness than alternative A as a measure to improve the earning power capacity of the project.

The increase in output over the economic life of the project would be 87,900 tons or only 7.3%, for which outlets have to be found in the local market or across the border in Zambia or Mocambique during the first 3 years of operation.

Alternative B1 (Appendix 7)

A combination of optimum and technically feasible rates of capacity utilization during the initial years of plant operation and a reduction in electricity cost from 1.5 to 1.32 tambala per KWH (equal to a reduction in variable cost of 10%) will increase the I.R.R. to 15.36%. On the basis of a price of 0.88 tambala per KWH, which equalizes the unit cost of electricity supply from an own hydro-power station, the I.R.R. will be 20 per cent.

At such a rate of return, the project will not fail to attract funds in case outside financing would be required.

Alternative B2 (Appendix 8)

A reduction of 10% in sales revenues as induced by a decrease in the sales price from K175 to K157.5 per ton which almost equals the subsidized price level at which CAN has been distributed to small holders during 1979/80, would lower the I.R.R. immediately to below 10%, in spite of optimum capacity utilization.

Alternative B1 + 2

Optimum capacity utilization in combination with a 10% reduction in both variable cost and sales revenues would render the project an earning power of just over 11%.

It is obvious that the profitability of the project is very sensitive to changes in sales prices and electricity cost.

Optimum capacity utilization in combination with a sales price of not less than K175 per ton of bagged product and an electricity cost of around 0.88 tambala per KWH would under the assumption of tax exemption, enable the project to attain an earning power sufficiently high to attract the funds for financing at normal commercial terms.

II. ECONOMIC EVALUATION

1. Foreign Exchange Savings

At 100% capacity utilization, the plant will produce some 118800 tons of CAN per annum. If imported, this output would involve some K20,79 million in foreign currency expenditure per annum (1979 price basis).

The total foreign currency component of operating costs (plus capital charges) is estimated at about K944,246 (K4,516,346) per annum, which leaves savings in foreign exchange of K19.85 million (16.27 million) per annum (See appendix 10).

Comparison of the local currency costs incurred and the annual savings in foreign exchange indicate that only K0.41 (0.52) will have to be spent to save K1.00 of foreign exchange.

Because of the very high level of domestically available inputs, especially electricity, foreign exchange savings per ton of CAN amount to K167 (137) or 95.5 (78.3) per cent of the 1978-79 import value, which is economically extremely favourable.

In addition, the estimated foreign exchange financing required for the project i.e. about K50 million, can be more than covered in less than 3 years of operation at full production.

2. Other Economic Benefits

By its high demand for electricity, the project will put to profitable use the large off-peak power availability of the country's electricity company, ESCOM, for which there is no alternative outlet.

The project will therefore have a great impact on ESCOM's capacity utilization of power generation facilities and consequently on the economics of operation. The additional cash flow generated by income from the fertilizer project will substantially improve the financial position of ESCOM who have financed the purchase of their assets by foreign borrowings.

Fertilizer manufactured domestically and entirely from local sources of raw materials and utilities will provide price and supply wise, a salient element of stability to agricultural production, the mainstake in the country's economy.

Furthermore, the unmeasured economic benefits of management and technical training, make this project particularly attractive for Malawi.

SUMMARY AND CONCLUSIONS

1. The market for nitrogenous fertilizer in Malawi has developed from some 13,000 tons of nitrogen in the 1972/73 cropping season to 17,200 tons of nitrogen in 1978/79 at a compound annual rate of about 5 per cent.

2. In the context of the market structure and in line with the prevailing agricultural policies, it is anticipated that consumption will continue to increase at more or less the same rate of growth in the coming 10 years to reach some 22,000 tons of nitrogen in 1983 and 33,000 tons of nitrogen by 1991/92.

3. Consistent with the projections for developments in demand, it is proposed to install ammonia and calcium ammonium nitrate (CAN - 26%N) manufacturing facilities with a rated capacity of 120 and 360 tons per day respectively (or alternatively ammonium nitrate - 33.5%N rated capacity 280 MTPD).

4. Coal and water power are the two resources to manufacture ammonia in Malawi independently from foreign supplies of raw materials.

5. The economics of producing ammonia from water-power are distinctly better than producing it from coal. Against capital cost of K550,000 per daily ton of installed capacity as required for the coal-gasification route, stands K270,000 only for the water-electrolysis process. Cost of manufacturing ammonia via coal gasification will amount to not less than K353 per ton, while producing ammonia via the water-electrolysis process will cost about K244 per ton. Besides, a hydro-power based plant is considerably more simple to operate than a coal-based plant.

6. The area around Walkers Ferry should be considered as the preferred location for the plant, as the cost involved for infrastructure and site development are the least among the alternative possibilities. Besides the adjacency of Nkula Power Station will ensure continuity of supplies and facilitate daily operations.

7. The electrolytic-hydrogen based project will have an annual output of 118,800 tons of CAN (26%N) when operating at full capacity during 330 days per calender year.

8. Project costs are estimated at K56.2 million including K2.16 million as working capital. The foreign exchange component of the investment outlay will be approximately K50 million.

9. The cost of manufacturing CAN is estimated at K109 per ton product once the plant attains full capacity utilization.

10. The earning power as calculated by discounted cash flows over the economic life of the project (14 years) at constant 1979 values is estimated at 11.56% before tax while the profit break-even point is reached at 40% capacity utilization.

11. The profitability of the project can be substantially improved to 15.36% by optimum capacity utilization during the initial years of operation, combined with a reduction in electricity cost from 1.5 tambala to 1.32 tambala per KWH, and to 20%, in the case of a unit cost for power supply at 0.88 tambala.

12. Stability in both supplies and prices for nitrogenous fertilizers, in addition to substantial savings in foreign currency and a significantly improved capacity utilization of the country's power generation facilities, are the salient economic benefits to be derived from a domestic industry based on the country's abundant hydro-power resources.

RECOMMENDATIONS

1. The project is recommended for implementation because its technical feasibility is evident and the benefits to be derived from it are significant for the country as a whole.

2. Since the cost of electricity is the determinant factor in regard to financial viability, it is recommended that a decision on this matter is taken at the highest policy-making level and with the shortest possible delay.

3. For this purpose a small working group of experts should be established to work out an electricity price, being appropriate to the interest of both ESCOM and the Fertilizer Project.

4. Responsibility for the realisation of the project should be delegated to specific organisations or institutions as a first step to the setting up of a fertilizer company.

INTRODUCTION

The Government of Malawi requested UNIDO early 1979 to undertake a comprehensive feasibility study on the possibility of manufacturing nitrogenous fertilizers from local natural resources and to attest the viability of such a venture (terms of reference attached).

The study was undertaken by F.J.E. Van Dierendonck, Fertilizer Industry Consultant who was based in Malawi from 28th July 1979 until 31st January, 1980. The study is in three volumes i.e.:-

Part I : The Fertilizer Market
Part II : Chapter 1 Ammonia Manufacture
: Chapter 2 Ammonia Nitrate Manufacture

Part III : The Financial and Economics Evaluation of the Project.

Part I of the study was completed in Lilongwe at the Ministry of Agriculture and Natural Resources, Part II at the premises of the Geological Survey at Zomba and Part III in Blantyre in collaboration with Press (Holdings) Malawi.

Appendix 1:

SELLING PRICE FOR CALCIUM AMMONIUM NITRATE (CAN:26%N)

The ex-factory price used for the profitability calculations is taken as K175 per metric ton of bagged CAN (26%N), which is equal to the F.O.R./F.O.T. price ex-store Limbe as prevalent during the 1979/80 cropping season. This is a commercial price derived from computing the costs of imports (CIF), inland forwarding, handling etc, and by adding service charges (see Part I: The Fertilizer Market, Page 22). The subsidized retail price of ADMARC to small holders in the current cropping season has been fixed at K155 per ton.

World market prices for nitrogenous fertilizers i.e. urea, AN/CAN, SA are directly related to the prices for petroleum products (Naphta, Fuel-Oil) and natural gas (See Part II: Chapter 1 the Fertilizer Project, Page 2). The rate of increase in crude oil and nitrogenous fertilizer prices as experienced since 1973, is reflected and will continue to be determined by the oil price policies of the OPEC.

TREND IN WORLD MARKET PRICES (F.O.B) FOR NITROGENOUS FERTILIZER PRODUCTS (1970 - '79) ON A PER-TON NITROGEN BASIS.

YEAR	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
US DOLLARS	109	96	147	234	763	326	250	261	304	359

As a matter of fact there is little prospect of a decline in AN/CAN prices on the world market and in price levels for nitrogenous fertilizers in general, due to continuously increases in oil prices and because of anticipated supply deficits as investments in new fertilizer capacity have remained modest in recent years.

Appendix 2:

BREAK-EVEN ANALYSIS

Break-even analysis determines the point at which sales revenues equal production costs. The break-even point (B.E.P.) can also be defined as the capacity utilization at which sales revenues and production costs match each other.

The B.E.P. is calculated algebraically by making use of the following equation:

$$\text{B.E.P.} = \frac{\text{Fixed Costs}}{\text{Sales revenues} - \text{Variable costs}} \times 100$$

As interest payments on loans are not included, the fixed costs are in our case, the same for every volume of production and remain constant during the entire economic life of the project.

Thus, the profit B.E.P. of the proposed project is estimated at 40% of its capacity (47658 tones of CAN), which is graphically represented in figure 17.

A reduction of 11.8% in electricity cost (from 1.5 tambala to 1.323 tambala per KWH) which equals a 10% reduction in variable costs, hardly effects the B.E.P., which in this case /lowered to 37.9%. On the other hand, / would be a reduction of 10% in sales revenues would immediately result in an increase of the B.E.P. to 47.8%.

Appendix 3:

SIMPLE RATE OF RETURN

The simple rate of return (SRR) is defined as the ratio of the trading profit in a normal year of full production to the original investment outlay (fixed assets, pre - production capital expenditure and working capital).

If the trading profit as in our case is taken as annual sales revenues minus manufacturing costs. The S.R.R. is

$$\frac{20,790,000 - 12,957,226}{56,200,000} \times 100 = 13.9\%$$

A reduction of only K4.9 per ton in selling price i.e. from K175 to K170.1 drops the SRR by 1%.

Appendix 4:

INTERNAL RATE OF RETURN

BASE CASE

YEAR	CALENDER YEAR	CAPACITY UTILIZATION 1/	PRODUCTION MT	CAPITAL DISBURSEMENT %	CAPITAL DISBURSEMENT TOTAL 1000 K	OPERATING COSTS K1000 2/	SALES REVENUES K1000	GROSS CASH FLOW K1000	CUMULATIVE CASH FLOW K1000	DISCOUNT FACTOR 11%	PRESENT VALUE K1000	DIS-COUNT FACTOR 12%	PRESENT VALUE K1000
-1	1981	–	–	30	17000	–	–	-17000	-17000	0.901	-15300	0.893	-15181
-2	1982	–	–	50	28200	–	–	-28200	-45200	0.811	-22870	0.797	-22475
-3	1983	30	35640	20	11000	3854	6237	- 8617	-53817	0.731	- 6299	0.712	- 6135
4	1984	71	84348	–	–	6960	14761	7801	-46016	0.659	5141	0.636	4961
5	1985	75	89100	–	–	7264	15593	8329	-37687	0.593	4939	0.567	4694
6	1986	78	92664	–	–	7491	16216	8725	-28962	0.535	4668	0.507	4424
7	1987	83	98604	–	–	7870	17256	9386	-19576	0.482	4524	0.452	4242
8	1988	87	103356	–	–	8172	18087	9915	- 9661	0.434	4303	0.404	4006
9	1989	91	108108	–	–	8475	18919	10444	783	0.391	4084	0.361	3770
10	1990	96	114048	–	–	8654	19958	11104	11887	0.352	3909	0.322	3575
11	1991	100	118800	–	–	9157	20790	11633	23520	0.317	3688	0.288	3350
12	1992	100	118800	–	–	9157	20790	11633	35153	0.286	3327	0.257	2990
13	1993	100	118800	–	–	9157	20790	11633	46786	0.258	3001	0.229	2664
14	1994	100	118800	–	7414 3/	9157	20790	19047	58419 4/	0.232	4419	0.205	3905
			1201068								1534		-1210

1) See Part II: Chapter 2 Page 62

2) Excluding Depreciation, Financial Charges and Taxes on profits

3) Salvage Value :
working capital at 100% 2160
buildings/housing at 60% 1558
scrap value equipment at 10% CIF 3606
Total (K1000) 7414

4) Salvage value not included

RESULTS ANALYSIS

a) $I.R.R. = 11 + \frac{1534\ (12 - 11)}{1534 + 1210} = 11.56$

b) Pay Back period = 8.9 years.

INTERNAL RATE OF RETURN
ALTERNATIVE : A

Appendix 5:

YEAR	CAPACITY UTILIZATION	PRODUCTION MT	CAPITAL DISBURSEMENT [1] %	TOTAL (K1000)	OPERATING COSTS (K1000)	SALES REVENUES (K1000)	GROSS CASH FLOW (K1000)	CUMULATIVE CASH FLOW (K1000)	DISCOUNT FACTOR 13	PRESENT VALUE	DISCOUNT FACTOR 12	PRESENT VALUE
-1	-	-	26.2	14932	-	-	-14932	-14932	0.885	-13215	0.893	-13334
-2	-	-	44.3	24887	-	-	-24887	-39819	0.783	-19487	0.797	-19835
-3	30	35640	17.7	9955	3854	6237	- 7572	-47391	0.693	- 5247	0.712	- 5391
4	71	84348	-	-	6960	14761	+ 7801	-39590	0.613	+ 4782	0.636	+ 4961
5	75	89100	-	-	7264	15593	8329	-31262	0.543	4523	0.567	+ 4723
6.	78	92664	1.63	917	7491	16216	7808	-23456	0.48	3748	0.507	3959
7	83	98604	1.63	917	7870	17256	8469	-14984	0.425	3599	0.452	3828
8	87	103356	1.63	917	8172	18087	8998	- 5986	0.376	3383	0.404	3635
9	91	108108	1.63	917	8475	[illegible]	9527	3541	0.333	3173	0.361	3439
10	96	114048	3.261	1834	8354	19958	9270	12811	0.295	2735	0.322	2985
11	100	118800	1.63	917	9157	20790	10716	23527	0.261	2797	0.287	3076
12	100	118800		-	9157	20790	11633	35160	0.231	2687	0.257	2990
13	100	118800		-	9157	20790	11633	46793	0.204	2373	0.229	2664
14	100	118800		7414 [2]	9157	20790	19047 [2]	58426 [3]	0.181	3448	0.205	3905
		1201068								-701		+1605

1) Cost of instalment per electrolyser unit is estimated at K0.917 million

2) Including salvage value: K7414 million

3) Excludes salvage value

RESULTS ANALYSIS

a) I.R.R.: $12 + \frac{1605 \times 1}{1605 + 701} = 12.70$

b) Pay back period = 8.3 years

INTERNAL RATE OF RETURN

ALTERNATIVE : B

Appendix 6:

YEAR	CAPACITY 1/ UTILIZATION	PRODUCTION 2/ MT	CAPITAL DISBURSEMENT %	CAPITAL DISBURSEMENT ToTal (K1000)	OPERATING COSTS (K1000)	SALES REVENUES (K1000)	GROSS CASH FLOW (K1000)	CUMULATIVE CASH FLOW	DISCOUNT FACTOR 12	PRESENT VALUE	DISCOUNT FACTOR 14	PRESENT VALUE
-1	–	–	30	17000	–	–	-17000	-17000	0.893	-15181	0.877	-14909
-2	–	–	50	28200	–	–	-28200	-45200	0.797	-22475	0.769	-21686
-3	30	35640	20	1[illegible]00	3054	6237	- 8617	-53817	0.712	- 6135	0.675	- 5816
-4	70	83160	–	–	6884	14553	+ 7669	-46148	0.636	+ 4877	0.592	4540
5	85	100980	–	–	8021	17672	9651	-36497	0.567	+ 5472	0.519	5009
6	100	118800	–	–	9157	20790	11633	-24864	0.507	+ 5886	0.456	5305
7	100	118800	–	–	9157	20790	11633	-13231	0.452	5258	0.400	4653
8	100	118800			9157	20790	11633	- 1598	0.404	4700	0.351	4083
9	100	118800			9157	20790	11633	+10035	0.361	4200	0.308	3583
10	100	118800			9157	20790	11633	+21668	0.322	3746	0.270	3141
11	100	118800			9157	20790	11633	33301	0.288	3350	0.237	2757
12	100	118800			9157	20790	11633	44934	0.257	2990	0.208	2420
13	100	118800			9157	20790	11633	56567	0.229	2664	0.182	2117
14	100	118800		7414 3/	9157	20790	19047 3/	68200 4/	0.205	3905	0.160	3048
		1288980								+3257		-1755

1) Optimum capacity utilization as technically feasible

2) Total output during economic life time of project is 7.3% higher as compared with base case.

3) Salvage value included

4) Salvage value not included

RESULTS ANALYSIS

a) $\text{I.R.R.}: 12 + \frac{3257\,(14 - 12)}{3257 + 1755} = 13.3$

b) Pay back period = 8.1 years.

INTERNAL RATE OF RETURN

ALTERNATIVE B1

Appendix 7:

YEAR	CAPACITY UTILIZATION	PRODUCTION MT	CAPITAL DISBURSEMENT (K1000)	OPERATING COST (K1000) 1/	SALES REVENUES (K1000)	GROSS CASH FLOW (K1000)	CUMULATIVE CASH FLOW (K1000)	DISCOUNT FACTOR 14	PRESENT VALUE	DISCOUNT FACTOR 16	PRESENT VALUE
-1	-	-	17000	-	-	-17000	-17000	0.877	-14909	0.862	-14654
-2	-	-	28200	-	-	-28200	-45200	0.769	-21686	0.743	-20953
-3	30	35640	11000	3627	6237	- 8390	-53590	0.675	- 5663	0.641	- 5378
4	70	83160	-	6354	14553	+ 8199	-45391	0.592	+ 4854	0.553	+ 4534
5	85	100980	-	7377	17673	10296	-35095	0.519	+ 5344	0.476	4901
6	100	118800	-	8400	20790	12390	-22705	0.456	+ 5650	0.41	5080
7	100	118800	-	8400	20790	12390	-10315	0.400	4956	0.354	4386
8	100	118800	-	8400	20790	12390	2075	0.351	4349	0.305	3779
9	100	118800	-	8400	20790	12390	14465	0.308	3816	0.263	3259
10	100	118800	-	8400	20790	12390	26855	0.270	3345	0.227	2813
11	100	118800	-	8400	20790	12390	39245	0.237	2936	0.195	2416
12	100	118800	-	8400	20790	12390	51635	0.208	2577	0.168	2082
13	100	118800	-	8400	20790	12390	64025	0.182	2255	0.145	1797
14	100	118800	7414 2/	8400	20790	19809 2/	76415 3/	0.160	3169	0.125	2476
		1288980							+7278		-3462

1) Fixed costs (minus depreciation = 1580900) + (Variable cost - 10%) x capacity utilization factor
A 10% reduction in variable cost conforms with a 11.8% reduction in electricity cost from 1.5t to 1.32t per KWH

2) Salvage value (included)

3) Salvage Value excluded

RESULT ANALYSIS

a) $\text{I.R.R.} = 14 + \frac{7278\,(16 - 14)}{7278 + 3462} = 15.36$

b) Pay back period = 7.8 years

INTERNAL RATE OF RETURN

ALTERNATIVE B2

Appendix 8:

YEAR	CAPACITY UTILIZATION	PRODUCTION MT	CAPITAL DISBURSEMENT (K1000)	OPERATING COSTS (K1000)	SALES REVENUES 1) (K1000)	GROSS CASH FLOW (K1000)	CUMULATIVE CASH FLOW (K1000)	DISCOUNT FACTOR 10	PRESENT VALUE	DISCOUNT FACTOR 9	PRESENT VALUE
-1	–	–	17000	–	–	-17000	-17000	0,909	-15453	0,917	-15589
-2	–	–	28200	–	–	-28200	-45200	0,826	-23293	0,842	-23744
-3	30	35640	11000	3854	5613	- 9241	-54441	0,751	- 6940	0,772	- 7134
4	70	95160		6884	13098	+ 6214	-48227	0,603	+ 4244	0,708	4400
5	85	100980		8021	15905	+ 7884	-40343	0,621	+ 4896	0,650	5125
6	100	118800		9157	18711	9554	-30789	0,564	5388	0,596	5694
7	100	118800		9157	18711	9554	-21235	0,513	4901	0,547	5226
8	100	118800		9157	18711	9554	-11681	0,467	4462	0,502	4796
9	100	118800		9157	18711	9554	- 2127	0,424	4051	0;46	4395
10	100	118800		9157	18711	9554	7427	0,386	3688	0,422	4032
11	100	118800		9157	18711	9554	16981	0,351	3354	0,388	3707
12	100	118800		9157	18711	9554	26535	0,319	3048	0,356	3401
13	100	118800		9157	18711	9554	36089	0,290	2771	0,326	3115
14	100	118800	7414 2/	9157	18711	16968 2/	45643 3/	0,263	4463	0,299	5073
		1288980							-420		+2497

1) On the basis of a 10% decrease in sales price namely K157.5 per ton as compared with K175 for the base case.

2) Salvage value (included)

3) Salvage Value not included

RESULT ANALYSIS

a) $\text{I.R.R.} = 9 + \frac{2497\ (10 - 9)}{2497 + 420} = 9.86$

b) Pay back period = 9.2 years.

Appendix 9

INTERNAL RATE OF RETURN

ALTERNATIVE B1 + 2

YEAR	CAPITAL DISBURSEMENT	OPERATING COSTS (K1000)	SALES REVENUES (K1000)	GROSS CASH FLOW (K1000)	CUMULATIVE CASH FLOW (K1000)	DISCOUNT FACTOR 10	PRESENT VALUE	DISCOUNT FACTOR 12	PRESENT VALUE
-1	17000	-	-	-17000	-17000	0.909	-15453	0.893	-15181
-2	28200	-	-	-28200	-45200	0.826	-23293	0.797	-22475
-3	11000	3627	5613	- 9014	-54214	0.751	- 6770	0.712	- 6418
4		6354	13098	+ 6744	-47470	0.683	4606	0.636	+ 4209
5		7377	15905	+ 8528	-38942	0.621	5296	0.567	4835
6		8400	18711	+10311	-28631	0.564	5815	0.507	5228
7		8400	18711	10311	-18320	0.513	5290	0.452	4661
8		8400	18711	10311	- 8009	0.467	4815	0.404	4166
9		8400	18711	10311	2302	0.424	4372	0.361	3722
10		8400	18711	10311	12613	0.386	3980	0.322	3320
11		8400	18711	10311	22924	0.351	3619	0.288	2970
12		8400	18711	10311	33235	0.319	3289	0.257	2650
13		8400	18711	10311	43546	0.29	2990	0.229	2361
14	7414 1/	8400	18711	17725 1/	53857 2/	0.263	4662	0.205	3634
							+3218		-2238

1) Salvage Value (Included)

2) Salvage Value (Not included)

RESULT ANALYSIS

a) $I.R.R. = 10 + \frac{3218\ (12 - 10)}{3218 + 2238} = 11.18$

b) Pay back period = 8.8 years

Appendix 10:

ANNUAL FOREIGN EXCHANGE SAVINGS AND EFFECTIVENESS OF IMPORT SUBSTITUTION
(BASED ON 100% CAPACITY UTILIZATION)

	ANNUAL COSTS (kwacha's)
1. OPERATING COSTS 1/	
a. Foreign currency component	
Catalysts	160,418
Chemicals	2,788
Maintenance Materials	781,040
Sub-total	944,246
b. Local currency component	
Electricity 2/	6,415,200
Dolomite Limestone	237,600
Bags 2/	760,320
Manpower 3/	355,940
Overheads	177,970
Insurance	265,950
Sub-total	8,212,980
c. Total Operating Costs	9,157,226
2. VALUE OF ANNUAL PRODUCTION	
At K175 per ton 4/	20,790,000
3. GROSS FOREIGN EXCHANGE SAVINGS (2 - 1a) (Exclusive capital charges 5/)	19,845,754 (16,270,654)
4. EFFECTIVENESS OF IMPORT SUBSTITUTION (1b : 3)	0.41 (0.52)

1) Taken from Part II Chapter 2 Page 94.
2) Assumed to be local currency cost exclusively.
3) Excluding additional cost of foreign technical assistance.
4) Equal to CIF Beira + transit cost to Limbe, assumed to be in foreign currency entirely.
5) Figures in brackets indicate net annual foreign exchange savings from the project assuming 14 years annuity on foreign exchange investment outlay.

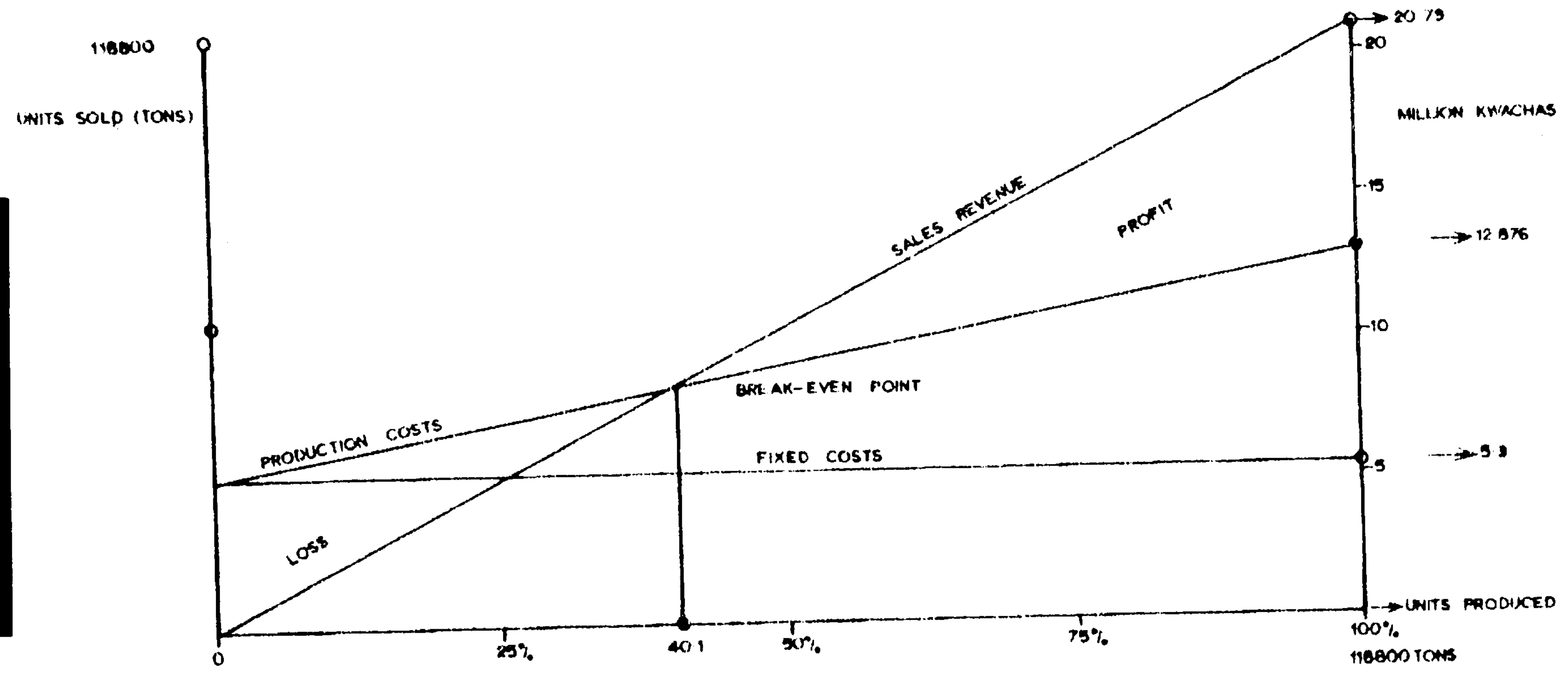

FIGURE 17 THE PROFIT BREAK-EVEN POINT AT CONSTANT 1979 VALUES