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MEMORANDUM REPORT

EVALUATION OF THE KPRL MANAGEMENT PROPOSAL FOR MODIFICATION OF THE MOMBASA REFINERY

TECHNICAL ASSISTANCE PROJECT

FOR

MINISTRY OF ENERGY AND REGIONAL DEVELOPMENT

OF KENYA

July 1984

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MEMORANDUM REPORT

A. INTRODUCTION

In March 1984, the Management of KPRL presented the Government and industry shareholders with a first phase proposal for upgrading the Mombasa Refinery which involves:

- Improvement of operations and fractionation efficiency by revamping and combining the two existing CDUs to operate in series, but involving a reduction in maximum refinery crude capacity.

- The installation of a Merox sweetening unit for kerosene treating. At present, all kerosene is hydrotreated either as a kerosene-minus overhead stream in Complex I or in a separate HDS unit in Complex II.

- Some improvement in LPG recovery.

This memorandum report first considers the technical advantages of the above modification proposal. Secondly, we have calculated a series of material balances for a wide variety of crude processing schemes including:

- A No-Investment case
- The KPRL proposal

- The thermal cracker proposal.

The material balance calculations have been made assuming a variety of crude slates.

Thirdly, an economic analysis has been made to compare the gross refinery margins in 1990 and 1995 in order to assess the relative economic attraction of the alternative modification and crude slate options. The economic analysis has been undertaken using a variety of price assumptions to test the robustness of the various technical and operational options.

B. TECHNICAL REVIEW

1. Technical Advantages of the KPRL Proposal

a. Merox

A Merox unit is cheap to install and the process is less costly to operate and more energy efficient than the hydrotreating it replaces. However, since Merox sweetening does not actually reduce sulfur content (it merely converts foul-smelling sulfur compounds like mercaptans to less malodorous disulfides) it will be necessary for the refinery to produce and market two grades of kerosene. A relatively high sulfur content jet fuel (0.3 percent weight sulfur max) will be produced exclusively by Merox treating. A lower sulfur content illuminating kerosene (0.15 percent sulfur content) will be produced by Merox

treating from low sulfur crudes such as Murban, but will require HDS treating if it is produced from higher sulfur crudes such as Arab Mix.

The refinery now produces only a single grade of hydrotreated kerosene which meets the very low sulfur specification for illuminating kerosene, in spite of the fact that this accounts for only 20 percent of the total kerosene demand. The result is that jet fuel (which has a higher sulfur spec and which accounts for the other 80 percent of kerosene demand) is "over-refined" and there is a considerable "giveaway" of lower sulfur content material. The Merox proposal will correct this situation and will reduce total refining costs.

One possible concern with the KPRL proposal is the potential future growth in the demand for illuminating kerosene which, according to our 1983 study, could account for up to 28 percent of total kerosene demand by 1995 (in Kenya and the contiguous markets) or 26 percent of total Kenya only demand (see ADL's March 1983 report Tables I-8 and I-17).

The Merox unit forms an integral and essential part of the total KPRL proposal. However, revamping of the CDUs to take naphtha-minus instead of kerosene-minus overhead from the CDU I tower will eliminate a large part of the existing kerosene treating capacity in the refinery. Since all kerosene must be treated (sweetened) before sale, the lost treating capacity has to be replaced by installing new kerosene treating facilities. At the same time, provided the Merox is of sufficiently large capacity it will be possible to release the existing kerosene HDS unit in Complex II for LGO treating (see below).

b. Elimination of Obsolete Unit

It is understood from KPRL that operation of the (obsolete) kerosene-minus hydrotreater and associated "three product tower" in Complex I has always been unsatisfactory, and the proposed conversion of this unit to a naphtha-minus operation (similar to the newer Complex II) would be a beneficial change. Although not finally decided at the time (March 1984) of ADL's most recent visit to Mombasa it is possible that the Complex I hydrotreater may be shut down entirely and replaced by the more satisfactory Complex II unit. KPRL estimated that the Complex II naphtha minus hydrotreating unit might have to operate at 140 percent of design capacity. It is noted, however, that in the formal Board Paper, the Complex II HDS Unit is proposed to be shut down. Although we raised this issue with KPRL by telex, no response has yet been received. While this issue may only be resolved once the detailed engineering study of the revamp is undertaken, we urge that units which might ultimately prove valuable in meeting longer term demand (possibly when running a heavier crude slate) should not be prematurely scrapped.

c. Improved AGO Yield

A brief explanation of the methods used for estimating product yields at Mombasa is necessary before detailing the AGO yields used in the various studies.

Yield data for the KPRL refinery is normally taken from the "Mombasa Refinery Data Book," a copy of which was made available to ADL. SIPM

have indicated that a new edition based on a computer-based simulation of the refinery and the resulting crude oil yields will soon be issued. This data book, which is as much a commercial as a technical document provides deemed product yields for various crude oils and for several processing alternatives. In view of the large demand for kerosene and the relatively low demand for motor gasoline, especially in the Kenya-only market, the Data Book yields which should be considered are the so-called MIG/MAK (minimum gasoline and maximum kerosene) yields. As an example, a copy of page 1.0030 of the Data Book, covering Arabian Light crude oil, is included as Table 1 of this memorandum.

The yields of LGO given in the Data Book refer to material with percent max sulfur content which is the spec for AGO in Kenya. For certain light, low-sulfur crudes such as Abu Dhabi Murban, however, the yield of LGO is determined not by sulfur content but by the ASTM 90 percent recovery temperature, currently 365°C max, and by ASTM end-point, currently 400°C max. For other, higher-sulfur crudes, such as Arab Light, the yield of LGO is severely restricted by sulfur content. However, provided that adequate desulfurization (i.e. HDS) capacity is available, the yield of LGO can be dramatically increased up to the limit set by the 90 percent point and by the end-point. For Arab Light LGO, the increase is from 11.0 percent to 18.1 percent on crude oil as shown in Table 2 (page 1.130 of the Data Book.)

The increased yield of LGO is obtained by desulfurizing the full-range LGO in the existing Complex II kerosene HDS unit. However, in the present refinery, this unit is primarily required to treat kerosene, and

TABLE 1

CRUDE	ARABIAN LIGHT CRUDE OIL SPECIFIC GRAVITY 20/4°C : 0.853			
MODE	MIG / MAK		MAG / MAK	
INTAKE MT/SD	HIGH 11,600	LOW 7,000	LOW 11,600	LOW 7,000
Yield % Wt				
Gas	0.6	0.6	0.6	0.6
Butane	0.9	0.9	0.9	0.9
Tops	3.6	3.6	3.6	3.6
Naphtha	8.5	8.5	12.4	12.4
Kerosene	17.1	18.1	12.6	13.0
Light Gasoil	12.5	11.0	14.6	14.7
Heavy Gasoil	10.0	14.5	8.5	12.0
Long Residue	46.8	42.8	46.8	42.8

EAST AFRICAN OIL REFINERIES LIMITED MOMBASA KENYA	CRUDE OIL DISTILLATION UNITS	JANUARY 1982	REFINERY PROCESSING DATA
		1.0030	

TABLE 2

At low throughputs Complex II Kerosene Hydrotreater can be used to desulphurise gasoil in addition to treating Kerosene. The gasoil desulphurised allows upgrading of heavy gasoil to Automotive Gasoil. At High Intake this upgrading is nil. At Low Intake the following heavy gasoil (% weight of crude) can be upgraded to Automotive Gasoil.

CRUDE OIL	% WEIGHT	CRUDE OIL	% WEIGHT
Iranian Light	6.0	Arabian Medium	6.2
Iranian Medium	6.1	Kuwait	6.5
Arabian Light	7.1	Abu Al Bukoosh	7.1
Qatar Marine	4.3	Dubai	6.2
Qatar Dukhan	5.9	Arabian Heavy	3.5
Zakum	5.1	Murban	–
Basrah Light	5.1		

EAST AFRICAN OIL REFINERIES LIMITED MOMBASA KENYA	GASOIL DESULPHURISATION FACILITIES	JANUARY 1982 1.130	REFINERY PROCESSING DATA

spare capacity for treating LGO only becomes available at low crude intakes to the refinery (as noted at the top of page 1.130). For Arabian Light crude, low refinery intake means below 7,000 MT/SD or 2.345 million tons per year.

A significant advantage of the proposed KPRL scheme is that the Merox unit can treat most, if not all, of the total kerosene (depending on the crude being run), and thus the Complex II HDS unit will be released for the treatment of LGO thus increasing the yield of AGO. At high intake levels of Murban or equivalent light crudes, it is probable that the entire existing Complex II HDS capacity (in the order of 800 MT/SD) would be available for treating full-range LGO derived from the heavier part of the crude oil mix.

If the modified refinery has to treat heavier crudes, such as a 25 percent Murban/75 percent Arab Mix, some of the existing Complex II HDS capacity would have to be used to make illuminating grade kerosene (assumed to be 20 percent of the total demand). This in turn would reduce the HDS capacity available for treating AGO and hence would reduce the effective yield of AGO. Typical data, as estimated by ADL for Arab Mix alone and for a 25 percent Murban blend, are shown in Table 3.

d. Capacity of Existing HDS Unit

The maximum capacities of the Complex II HDS unit (as given to ADL in September 1982) are 800 MT/SD for kerosene and 500 MT/SD for LGO. However, in our discussions in March 1984, SIPM indicated that a test

TABLE 3

KPRI PROPOSAL
RESULTS OF OPERATION ON HEAVIER CRUDES

	Arab Mix					25% Murban/75% Arab Mix			
	% Wt	Max Throughput			% Wt	Max Throughput		Reduced Throughput	
		MT/SD	% Wt	MT/SD	% Wt	MT/SD	% Wt	MT/SD	% Wt
Crude Oil		10000		8700		1750		7410	
(10^3MT/Yr)		(3350)		(2915)		(1266)		(2486)	
Total Kero	17.89	1789		1556	19.12	1864		1418	
Kero to HDS Unit	3.58 (1)	358		311	1.91 (2)	186		142	
LGO (Light, 1%S)	11.03	1103		960	14.31	1395		1062	
LGO (Hvy., 1%S)	9.74	974		847	7.30	712		542	
Total LGO	20.77	2077		1807	21.61	2107		1604	
HDS, Kero		358		311		186		142	
HDS, LGO (Hvy)		442		489		614		542	
HDS, Total Capacity: (6)		800		800		800		684	
Kero-Jet Fuel (3)		1431		1245		1492		1134	
Kero-Illum: (4)		358		311		372		284	
Kero-Total		1789		1556		1864		1418	
AGO-Total (1%S)		1545	15.45	1449	16.66	2009	20.61	1604	21.61
LGO to Fuel Oil (5)		532	5.32	358	4.11	98	1.01	nil	--
Total LGO		2077	20.77	1807	20.77	2107	21.61	1604	21.61

Notes:

(1) Assumed that all Illuminating Kerosene must be HDS treated to 0.15%S. Balance to Merox.
(2) Assumed only half the Illuminating Kerosene must be HDS treated to 0.15%S.
(3) Jet fuel is 80% of total kerosene.
(4) Illuminating Kerosene is 20% of total.
(5) Meets ASTM Dist. Spec. for AGO but no spare HDS capacity available.
(6) HDS (existing) capacity assumed 800 MT/SD for kero and LGO.

run on this unit, charging a mixture of LGO and refinery slops (sulfur content 1.7 percent) was successfully treated (to 0.7 percent sulfur) at a rate of 1100 MT/SD. As a result SIPM now suggest using 1,000 MT/SD as the LGO capacity of the unit. However, to be conservative, we have used 800 MT/SD max for both kerosene and LGO as the basis for the calculations in Table 3.

e. Improved Fractionation

SIPM believe that if the KPRL Proposal is implemented, the yield of LGO (meeting AGO specs for ASTM 90 percent point and/or for cloud point) will be increased due to improved fractionation, by an estimated 3 percent weight on crude oil, over and above the yields given under Low Intake in the Data Book plus the additional yields given on page 1.130. as discussed above. Furthermore, they believe that this additional yield of LGO will be obtained up to the (somewhat reduced) maximum capacity of the modified refinery. For a 50 percent Murban slate, the maximum refinery capacity will be reduced from 10,500 MT/SD (as in the Data Book with the present configuration of two CDUs running in parallel) to 9,500 MT/SD (for the proposed KPRL scheme with the two CDUs running in series).

In September 1982, ADL was advised that debottlenecking of the CDUs had been studied by SIPM and that a detailed revamp scheme was to be implemented in the near future (as noted on page II-4 of ADL's March 1983 report). ADL was advised that the Low Intake yields in the Data Book could be assumed to apply up to the maximum refinery input, and

that the yield of LGO meeting revised AGO specs could be increased somewhat above the figures shown on page 1.130 of the Data Book, provided that adequate LGO HDS treating capacity was made available. The net result was that the actual yields used by ADL in the March 1983 study were somewhat above the new yields now claimed for the proposed KPRL scheme. A comparison is shown in Table 4 for Arab Mix crude.

Table 4 also shows that an extremely poor yield (only 12.5 percen weight) of LGO meeting the 1 percent sulfur spec is obtained at the High Intake rate from the existing CDU configuration. At this High Intake rate, no surplus capacity for treating LGO is available on the Complex II HDS unit. The improvement in LGO yield when processing Arab Mix with the new KPRL configuration at corresponding maximum refinery capacities was shown in Table 3 as 15.45 percent weight versus 11.03 percent weight.

The maximum yields of LGO meeting the AGO sulfur spec of 1.0 percent weight max can be summarized as follows based on Table 3:

	Yield of AGO on Crudes (% Weight)	
	100 % Arab Mix	25% Murban/75% Arab Mix
Max Refinery Capacity	15.45	20.61
1990 Demand, Kenya Only	16.66	21.61

TABLE 4

AGO YIELDS FROM CDU'S
Arab Mix Crude Slate)

Product	Data Book High Intake (%wt)	Data Book Low Intake (4) (%wt)	ADL Report (1983) (%wt)	KPRL Proposal (1984) (%wt)
Naphtha Minus (Min)	14.7	13.3	13.3	13.3
Kerosene (Max)	15.5	17.9	17.9	17.9
Light Gasoil				
a) To 1% S	12.5	11.0	11.0	11.0
b) Additional yield if run at 90% ASTM*	--	6.8 (2)	10.3 (1)	6.8 (2)
c) Improved Fract.:	--	--	--	3.0 (3)
Total LGO	12.5	17.8	21.3	20.8
Heavy Gasoil	9.2	6.9	3.4	3.9
Long Residue	48.1	44.1	44.1	44.1
Total	100.0	100.0	100.0	100.0

Notes:

(1) Estimate supplied by Asst. Manager Technical Dept. at KPRL refinery to ADL representatives in Sept. 1982 in Mombasa. Figure takes account of a then-proposed CDU debottlenecking (which was never made). Limits 90% at 365°C, EP 400°C.

(2) From KPRL Data Book, Page 1.130.

(3) Estimated figure by SIPM given to ADL representative in March 1984 in The Hague. Takes into account proposed CDU modification (towers in series, etc.)

(4) Below 7000 MT/SD = 2345 X 10^3 MT/Yr.

*90% ASTM spec is 365° max.

The variation of yield with refinery capacity is particularly noticeable when processing the heavier crudes. For a 50 percent Murban blend the yield of specification LGO is largely independent of refinery throughput. This is because the full capacity of the existing HDS unit is available for treating LGO since illuminating kerosene can be made directly from segregated Murban crude.

f. Summary

The KPRL scheme results in higher yields of specification LGO than the present refinery configuration, especially when running lighter crudes. When processing heavier crudes the improvement is less significant. However, as with the present configuration, it will be uneconomic to process crude slates such as a 100 percent Arab mix slate in either configuration without installing conversion capacity such as a thermal cracker and additional LGO HDS capacity.

We believe it is reasonable to expect that the additional 3 percent weight yield of specification LGO on crude can actually be achieved by improved fractionation. In discussions with SIPM in the Hague (March, 1984) it was apparent that a fairly detailed assessment had been undertaken, although detailed calculations were not made available to ADL. There are several favorable factors which support the SIPM contention regarding the yield improvement:

Vapor loading on the CDU I tower is reduced by operating to a naphtha-minus rather than a kerosene-minus overhead.

The number of trays involved is more or less doubled by operating the towers in series and this should improve fractionation.

The second tower is operated under some vacuum which reduces the required operating temperature.

Finally, while vapor loading is reduced, the vacuum operation will increase vapor velocity. Operation at reduced maximum refinery capacity will assist and we recommend that modifications to the two heaters, and to the crude pre-heat trains must be considered. These issues should be considered in the detailed engineering studies which are the first stage in the implementation of this project.

One advantage of the KPRL scheme is that all kerosene will be obtained as a single stream (top sidestream in the Complex I tower). Another advantage is that LGO is obtained in two streams; a light, presumably low-sulfur LGO as a second sidestream on Complex I tower, and a heavier higher-sulfur LGO stream as overhead from the Complex II tower. In general, only the heavier LGO stream will need to be HDS treated, thus reducing the actual quantity of oil to be processed in the HDS unit, although not necessarily reducing the total quantity of sulfur to be removed. In fact, total sulfur recovery may be somewhat increased due to the higher yield of specification LGO in the KPRL scheme

2. Reduction in Maximum Refinery Capacity

An apparent disadvantage of the KPRL modification proposal is that it will somewhat reduce the maximum volume of crude oil that the refinery can process. However, this issue is less important than that of running the refinery in an economic manner since assuming the marketing companies will make lighter crudes available at attractive price differentials compared to heavier crudes, then the KPRL modification will pay off in terms of lower cost and more efficient operation and will provide higher yields of middle distillates.

Required refinery throughput running a 50 percent Murban/50 percent Arab mix crude slate will not exceed the maximum of 3185 thousand MT/year through 1990. By 1995, if the full Kenya plus contiguous market demand is to be supplied however, imports of 45,000 MT/year of AGO would be required (as shown in Table C-3).

In 1995 total product demand for Kenya and the contiguous markets is only 2.48 million tons per year. To supply this demand, it would, in general, be uneconomic to process more than say 3.1 or 3.2 million tons per year of crude oil which might result in between 500,000 or 600,000 tons per year of surplus fuel oil for export. When processing a 50/50 mix of light and heavy crudes, this maximum crude throughput would not be exceeded. However, heavier crude slate such as 25 percent Murban/75 percent Arab Mix would necessitate the installation of heavy fuel oil conversion facilities such as a thermal cracker.

The critical issue in the longer term planning of KPRL's operations is therefore the availability and relative prices of the light and heavy Middle East crudes and the future evolution of refined product prices, particularly middle distillates and heavy fuel oil. This issue is addressed further in Section D of this memorandum.

3. Compatability of KPRL Modification With Eventual Installation of a Thermal Cracker

An important technical question is whether the KPRL scheme is fully compatible with operating the refinery on Arab Mix or similar crude and installing the necessary thermal cracking and HDS units should this be considered economic in the future. ADL has considered this and concludes that the proposed KPRL scheme combined with a thermal cracker would represent a slight improvement on the Option 3A modification considered in ADL's earlier analyses. As noted above, the yields of middle distillates are very similar and the addition of the Merox unit (to replace the current kerosene hydrotreating) will improve the overall operating efficiency. A Merox unit was not included in ADL's Option 3A since at the time only a single grade of kerosene of low sulfur content was being considered. The assumption that two grades of kerosene (one of higher sulfur content) can be marketed has only been recently proposed (and apparently accepted) by the marketing companies. Since this is an essential feature of the KPRL proposal, it is critical that the Ministry verify its acceptability to the marketing companies and Kenya Pipeline Company.

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ADL's Option 3A was based on the assumption discussed above that the CDU's would be debottlenecked to improve yields of specification LGO This has not been done and thus the yields used in ADL's evaluation of Option 3A were optimistic. To some extent, of course, poor yields on the CDU can be corrected in the thermal cracker although this would involve installing a larger TGU unit in most cases.

The KPRL scheme is considered to be compatible with operating the refinery on Arab Mix or similar crudes and installing the necessary thermal cracker and HDS units. There is reason to believe, however, that the thermal cracker capacity should be somewhat increased, as compared with ADL's Option 3A, by including excess HGO (over IDO requirements) and also the VGO from the bitumen plant in the feed to the thermal cracker. Some reduction in total fuel oil (and thus of surplus fuel oil for export) should result. The limit is set by fuel oil viscosity and the availability of suitable cutter stock. Refinery fuel should then be the bottoms from the thermal cracker. It is felt as a result of recent calculations that if a thermal cracker is installed in conjunction with the KPRL scheme, it would be possible to reduce crude oil charge (for Kenya plus contiguous market in 1995) from the 3.15 million tons per year estimated for Arthur D. Little's Option 3A, to about 3.05 million tons per year, with a corresponding reduction in surplus fuel oil for export

Finally, one beneficial effect of the KPRL scheme would be to reduce hydrogen demand due to replacing HDS treating of straight-run kerosene by the Merox. The reduction is estimated to be of the order of 20

percent thus reducing estimated hydrogen utilization from 80 percent (for Option 3A) to perhaps 65 percent (see page II-21 of ADL's March 1983 report). This reduction is unlikely to be sufficient to eliminate the need for the package hydrogen plant recommended for Option 3A, but further study is required.

4. Technical Conclusion

We recommend to the Ministry that the detailed design of the KPRL proposal should be based on the understanding that the proposal represents Phase 1 of a two-phase modification of the refinery which is expected to eventually have to run heavier crudes. Phase II will include thermal cracking and additional LGO HDS capacity. We also recommend that the new facilities should be sized and designed on the basis of supplying the full Kenya plus contiguous market product demand, based on 1995 estimated demand, running Arab Mix crude.

However, the detailed design of the KPRL proposal based on Arab mix crude should determine if any bottlenecks would occur if a lighter crude slate were used. A lighter crude slate might be between 50 and 80 percent Murban-type, light Middle Eastern crude with the balance Arab Light Mix type crude. The most difficult issue relating to the design study is that of the level of demand and the capacity of the new units. We recommend that the design basis should not be restricted to 1990 and Kenya only demand but rather that it should be based on 1995 and Kenya plus contiguous market demand. The Government must ensure that the refinery meets demand in its natural markets (i.e. those for which

Mombasa is the logical lowest cost supply source). The design should also take into account the eventual installation of a thermal cracker which will likely have to be installed in the 1990 to 1995 period. Thus, the design of the Phase I modification should take into account, irrespective of the short to medium term crude slate, the eventual necessity of installing a thermal cracker and additional HDS facilities and of running a heavier crude slate.

This recommendation will affect primarily the revamp of the CDUs, including heat recovery, fired heaters, tray loadings, etc. In addition, the Merox unit should be sized at a sufficiently high capacity for the heavier crude slate.

We do not believe that this design basis for the KPRL modification will result in a significantly higher initial capital cost. However, if the detailed study indicates that such a design basis would result in a substantial increase in capital cost then a careful review of market conditions should be undertaken prior to a final decision, so as to ensure that the chosen design basis is in the national interest

C. MATERIAL BALANCES

Material balances were developed for 56 different scenarios and were used as the basis for the economic analysis to compute the net costs of supplying the Kenya market. The material balances included four crude slates and six process options including a no investment option. Material balances were developed for both the 1990 and 1995 product

demands for both the Kenya only market and the Kenya plus contiguous markets. A summary of all 56 scenarios considered is given in Table 5 The material balances (i.e., oil import and export requirements) which were developed for all the scenarios are shown in tabular form in Appendix A. The assumed maximum refinery capacity is also shown in Appendix A.

Figures 1, 2 and 3 show a comparison of the material balances for selected cases in graphical form. (For simplicity, the LPG deficiency has not been shown on the graphs; refer to Appendix C for actual data.) Figure 1 shows the 1990 Kenya only market which is the smallest demand case considered, and Figure 2 shows the 1995 Kenya plus contiguous markets which was the largest demand case considered. Figures 1 and 2 only compare the no investment option with the KPRL project option. Figure 3 shows the impact of five different process options for a 25% Murban crude slate for the largest product demand case (Kenya plus contiguous markets in 1995).

From Figure 1 it can be seen that the KPRL project, which could conceivably be completed by 1990, would significantly reduce the crude oil imports required to meet the product demand and hence also the volume of surplus fuel oil exports. The fuel oil exports would be reduced by 119 MMT/Yr for a 95% Murban crude slate and by 402 MMT/Yr for the 25% Murban crude slate. The motor gasoline surplus would also be reduced. The effect of crude slate is also clearly shown in Figure 1 since the lightest crude slate (95% Murban) requires 664 MMT/Yr less crude to meet demand than the heavier. 25% Murban case in both cases

TABLE 5

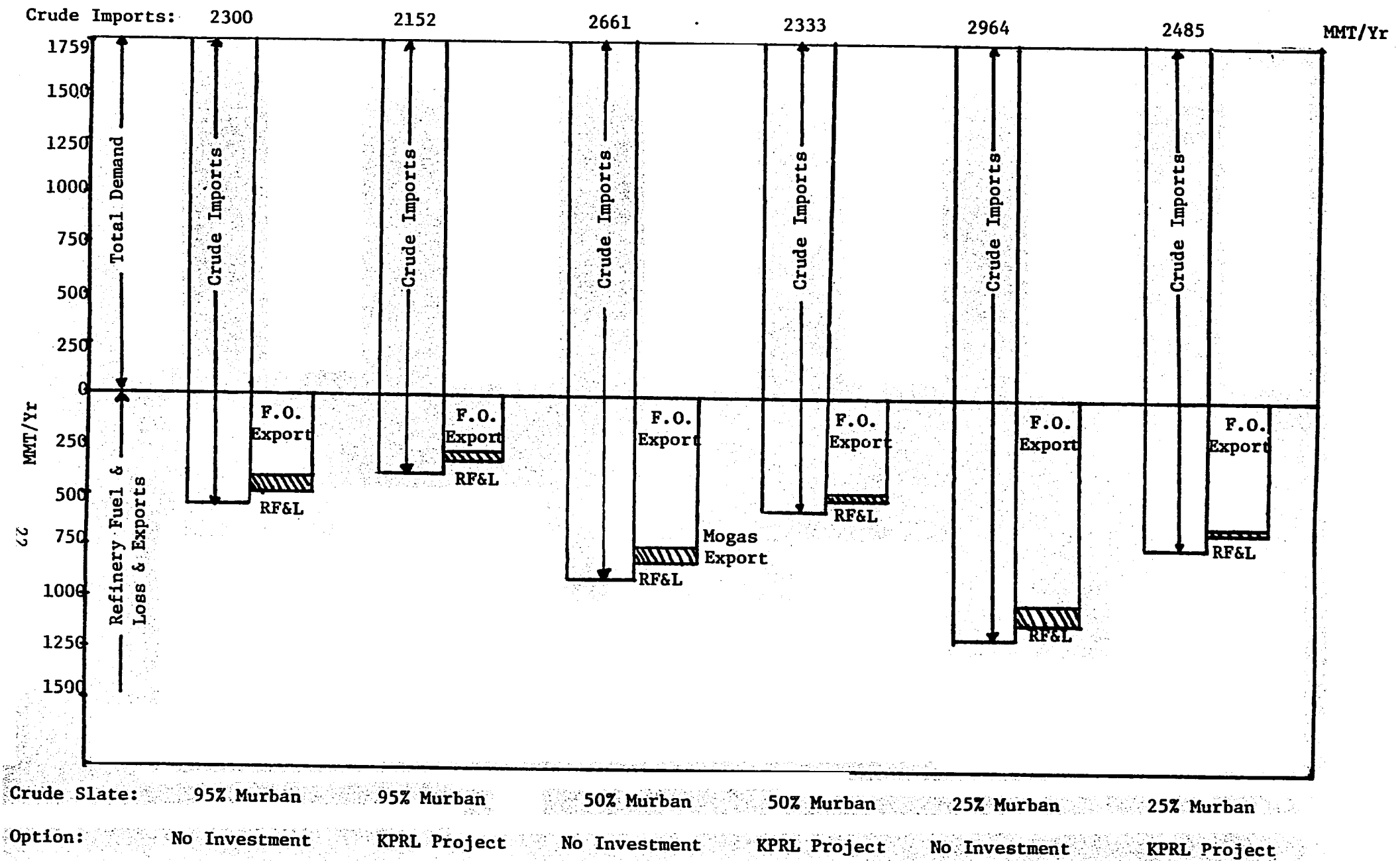
SCENARIOS USED FOR ECONOMIC ANALYSIS

95% Murban	50% Murban	25% Murban	Arab Mix
No Investment Kenya only market: 1990 & 1995* Kenya plus contiguous: 1990 & 1995*	No Investment	No Investment	
KPRL Project	KPRL Project	KPRL Project	
	ADL Phase 1 HDS Only	ADL Phase 1 HDS Only	
		ADL Phase 2 HDS + Thermal Cracking Unit + H_2 Plant	ADL Phase 2, HDS + Thermal Cracking Unit + H_2 Plant
	KPRL + HDS (No Merox)	KPRL + HDS (No Merox)	KPRL + HDS (No Merox)
			KPRL + Thermal Cracking Unit + HDS + H_2 Plant

* Similar for all scenarios

COMPARISON OF KENYA ONLY MARKET

1990 MATERIAL BALANCES FOR NO INVESTMENT OPTION VS. KPRL PROJECT



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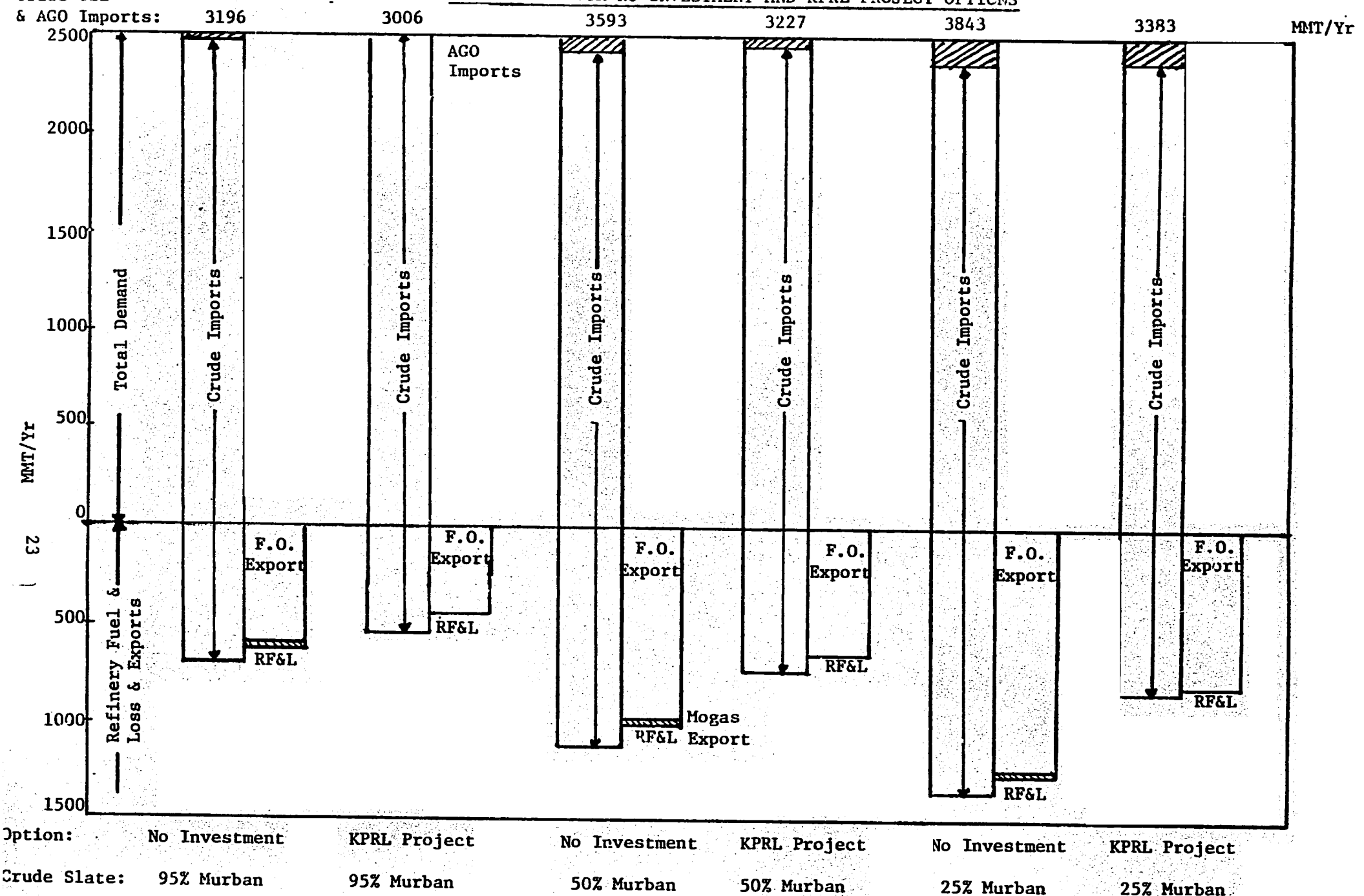
COMPARISON OF KENYA PLUS CONTIGUOUS MARKETS

1995 MATERIAL BALANCES FOR NO INVESTMENT AND KPRL PROJECT OPTIONS



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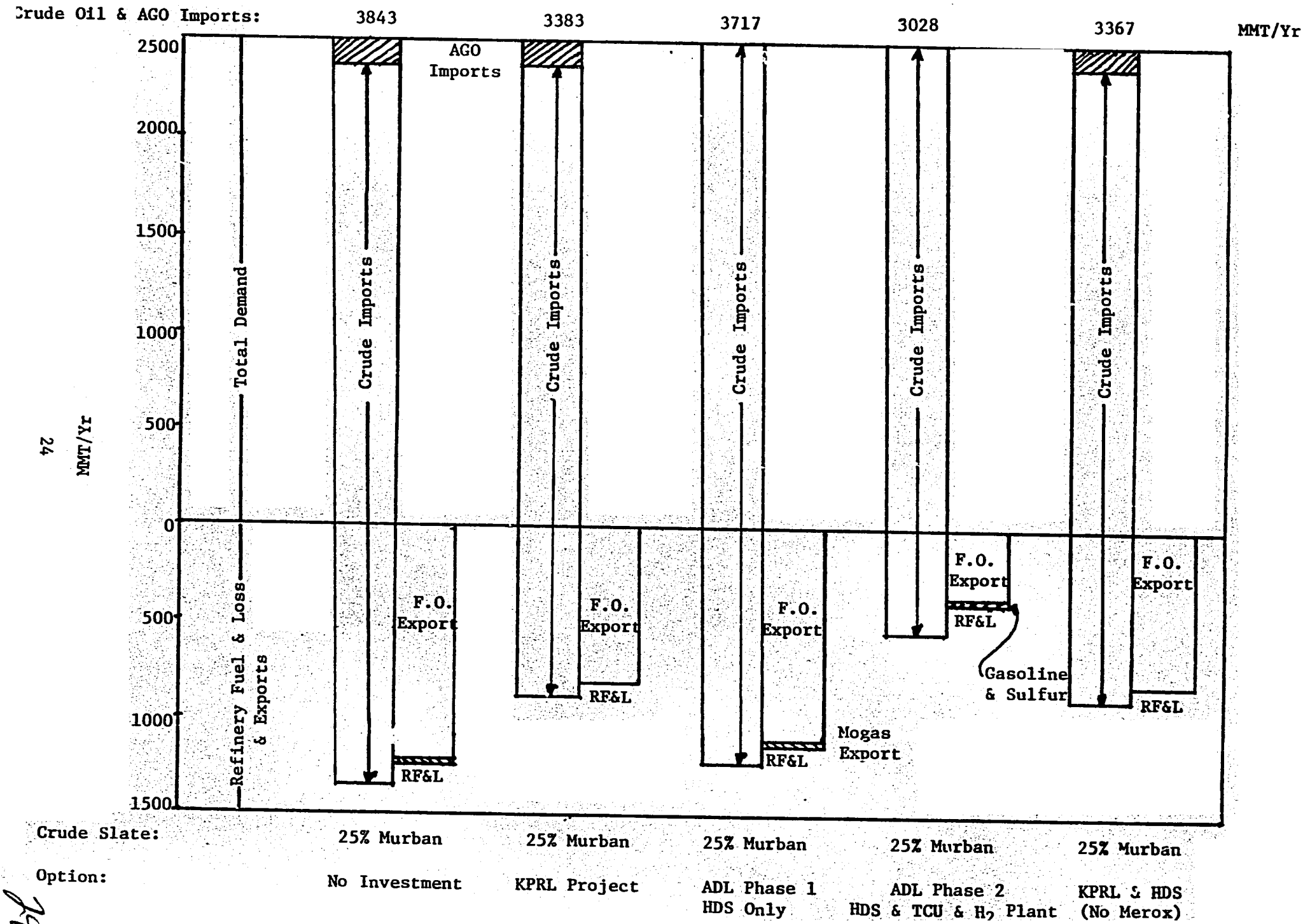
COMPARISON OF KENYA PLUS CONTIGUOUS MARKETS

1995 MATERIAL BALANCES FOR FIVE OPTIONS WITH 25% MURBAN CRUDE SLATE



with no investment. 333 MMT/Yr less crude will be required to meet demand in the KPRL project option cases (again comparing the lightest with the heaviest crude slates).

1995 product demand in Kenya is about 9% higher than 1990 demand. However, if the contiguous markets are also included in 1995, the demand on the refinery is increased by 42%. Figure 2 shows a comparison of the 1995 material balances for both the no investment case and the KPRL modification option for Kenya plus contiguous market demand. In the six scenarios shown, AGO must be imported because the crude unit is unable to run enough crude to meet white product demand. The KPRL option again reduces the crude oil import requirements and hence the surplus fuel oil exports over the no investment case. Also AGO imports will be less under the KPRL option

Figure 3 compares the 1995 material balances for five different process options assuming a 25% Murban crude slate and Kenya plus contiguous market demand. The no investment case requires the most crude oil and also the largest volume of surplus fuel oil for export. The KPRL option will reduce the volume of crude oil imports and surplus fuel oil exports; it will slightly reduce the volume of imported AGO and will eliminate the surplus motor gasoline. The Phase 1 option studied by ADL does not change the current crude unit configuration, but adds an HDS unit for LGO. Under this option, the volumes of crude oil imports and surplus fuel oil exports are higher than in the KPRL option but AGO imports would be eliminated. The most technically complex (but also the most effective option in terms of reducing crude volumes and exports of

surplus fuel oil) is ADL's Phase 2 option which includes an HDS unit, a thermal cracker, a H_2 plant and a sulfur recovery unit. This option reduces crude oil imports to 3,038 thousand tons per year and eliminates the need for AGO imports. This option also includes sulfur production. Fuel oil exports are significantly reduced to 344 thousand tons per year because the cracker converts a significant portion of the fuel oil into saleable middle distillates.

The KPRL project with an HDS unit (instead of a Merox unit) shows a slight reduction in the amount of crude oil and AGO imports and fuel oil exports over the case including a Merox unit but given current crude and product prices this additional investment is unlikely to be warranted. The ADL Phase 1 option requires more crude oil than the KPRL project with an HDS unit, but the ADL Phase 1 option does not require imports of AGO but does have higher fuel oil exports. The main difference between ADL's Phase 1 option and the KPRL plus HDS option is that the KPRL project assumes the crude units will be run in series which will improve fractionation efficiency.

The KPRL process option with the Merox unit would allow the refinery to more effectively meet Kenya only market demand in 1990 than the no investment option, but the situation becomes much more constrained by 1995 particularly if the refinery must meet demand in Kenya and the contiguous markets. Imports of AGO would be required to meet product demand. Even if the KPRL project included an HDS unit rather than a Merox unit, the material balance changes would be extremely small. A thermal cracker would be required to make a significant impact because

it converts some of the excess fuel oil into lighter products, thus significantly improving the refinery's material balance.

D. ECONOMIC ANALYSIS

This section presents an economic analysis of the alternative modification options to show how each option compares with base cases involving either refinery shut-down and product imports or no further investment in the refinery. Importantly, we have distinguished between the incremental benefits resulting from each element of the investment alternatives.

This section of the memorandum report first provides details of the assumptions made, then presents the results of the economic analysis and finally provides overall conclusions regarding KPRL's Proposal for modification of the refinery.

1. Assumptions

The economic analysis has been made using alternative sets of prices presented in Table 6 (in 1983 $/metric tons) as follows:

> Spot prices as reported by Platt's Oilgram for April 2, 1984 (when this analysis was originally made). The crude prices used are for Arab Light crude oil fob the Arabian Gulf, $28.40/Bbl and for Abu Dhabi Murban, $28.70/Bbl.

TABLE 6

1990 PRODUCT PRICE ASSUMPTIONS

(1983 $/Metric Ton)

	Spot (Platt's Oilgram 4/2/84) (FOB Arab Gulf)	March 1984 Forecast (FOB Arab Gulf)	Fall 1983 Forecast (CIF Mombasa)	Low Price Differentials (FOB Arab Gulf)
LPG	245.00	153.70	464.60	168.00
Mogas	274.00	245.95	316.80	198.90
Kero	285.00	241.95	306.70	226.00
AGO	240.00	220.10	287.10	205.40
HSFO	170.00	138.95	189.00	159.65
HSFO	174.00(1)	141.90(1	181.25(2)	141.90(1)

(1) CIF Singapore

(2) FOB Mombasa

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- The price forecast developed by ADL in the Fall 1983 and presented to the Government in our February 1984 meetings -- Arab Light: $30.30/Bbl and Murban $31.90/Bbl (fob the Arabian Gulf).

- A revised 1990 forecast which reflects ADL's March 1984 forecast -- Arab Light: $24.00/Bbl and Murban $25.45/Bbl (fob the Arabian Gulf).

- A new set of 1990 prices with very low differentials between light and heavy products and between the light and heavy Middle Eastern crudes (Arab Light $24.00/Bbl and Murban $24.25/Bbl). This case has been prepared to approximate Shell's price forecast. Unfortunately, our discussions wit Shell in London on March 23 (and subsequently by telephone) did not permit us to confirm whether these results reflect those actually used by Shell (and KPRL's management) since they declined to provide us with specific price data. Shell has confirmed, however, that it believes there will be much lower differentials between light and heavy crude oil prices, and also (by implication) much lower product price differentials. In fact, Shell sees little chance that relative crude prices will change from today's levels. These pricing issues are of fundamental importance to the economics of secondary processing at Mombasa and we shall return to them later. In any event, this final price set is an attempt to simulate Shell's prices.

In our March 1983 report and subsequent update studies, we have also found that the contiguous markets are of critical importance to the profitability of the alternative modification options. We have therefore looked at the economics of the modification proposals under the two sets of market conditions.

We understand that SIPM used a refinery linear programming optimization model in their analysis of KPRL's options, and that the model chooses which products to supply to these contiguous markets and in what volumes. While we agree that in the best of all possible worlds this is how KPRL would be run, we must express some concern that in practical terms, this degree of exactitude in planning may not be particularly helpful, either regarding the market demand which can or should be met by the refinery, or regarding the refinery's crude oil diet. We have thus preferred to use some selected cases in which the contiguous market demand must either be met, or not, in this way hoping to better portray the reality of Mombasa operations.

2. Economic Results

Detailed results are provided in terms of the net oil costs to meet market demand and the implied gross refinery margins under the four sets of price assumptions and for the 56 scenarios described in Section C above, in Appendix Table D-1 to D-5. Tables 7 and 8 summarize some of these results for Kenya only and for Kenya plus the contiguous markets, focusing on the incremental benefits of the KPRL proposal and the late addition of a thermal cracker.

TABLE 7

TOTAL COST OF OIL TO KENYA IN 1990

(Million 1983 $)

	Spot Prices (April 2, 1984)	High Price Differentials (ADL's Fall 1983 Forecast)	Medium Price Differentials (ADL's March 1984 Forecast)	Very Low Price Differentials
Product Imports	440	488	390	370
No investment (50% Murban/50% Arab Mix)	435	477	385	362
KPRL proposal (50% Murban/50% Arab Mix)	420	462	370	352
KPRL proposal + TGU* (100% Arab Mix)	409	439	350	347
Incremental Savings				
No investment over Product Imports	5	11	5	8
KPRL proposal over No Investment	15	15	15	10
KPRL + TGU over KPRL proposal	11	23	20	5
KPRL + TGU over Product Imports	31	49	40	23

*TGU - Thermal Gasoil Unit (Shell terminology) or Thermal Cracker

TABLE 8

TOTAL COST OF OIL TO KENYA AND CONTIGUOUS MARKETS IN 1990

(Million 1983 $)

	Spot Prices (April 2, 1984)	High Price Differentials (ADL's Fall 1983 Forecast)	Medium Price Differentials (ADL's March 1984 Forecast)	Very Low Price Differentials
Product Imports	555	616	494	465
No investment (50% Murban/50% Arab Mix)	553	606	491	459
KPRL proposal (50% Murban/50% Arab Mix)	533	585	471	446
KPRL proposal + TGU* (100% Arab Mix)	519	557	445	440
Incremental Savings				
No investment over Product Imports	2	10	3	6
KPRL proposal over No Investment	20	21	20	13
KPRL + TGU over KPRL proposal	14	28	26	6
KPRL + TGU over Product Imports	36	59	49	25

*TGU - Thermal Gasoil Unit (Shell terminology) or Thermal Cracker

Considering first Table 7 and the early April spot prices, our analysis shows that the gross refinery margin (GRM) in 1990 is positive at $5 million (constant 1983$). Thus before deducting investment return and operating costs, it would be preferable to run the refinery to meet Kenyan demand. When these costs are deducted, a negative net margin for refining versus product imports will result thus indicating that the refinery should be shut-down on purely economic grounds. A further $15 million benefit results from installing the KPRL project and a further $11 million from installing the thermal cracker compared to the KPRL proposal. Thus of the total benefit of $31 million (KPRL and TGU versus Product Imports), $5 million should be attributed to having the refinery, $15 million to installing the KPRL proposal and $11 million the thermal cracker benefit. Thus almost half of the benefits of the TGU installation can be achieved with the KPRL proposal.

It can also be seen that the benefits attributed to the KPRL proposal are robust across a wide range of price assumptions ($10-15 million) and do not vary greatly. By contrast the incremental benefits provided by the thermal cracker are volatile and range between $5 million and $23 million, depending upon the price assumption used. With a required investment of about $140 million (expressed in instantaneous 1983$), a 12.5% return on Average Capital Employed, and higher operating costs, the refinery would require incremental revenues (or annual capital charge) of the order of $28 million per year to be an attractive investment. Only in the high price differential case, do the benefits approach this level.

If the refinery also supplies the contiguous markets (Table 8), the benefits of the KPRL proposal will increase by roughly 30% (to $13-20 million) but incremental benefits of the thermal cracker in most cases will remain below the $28 million (annual capital charge) break-even level.

Although this analysis has been made for only one year, the capital charge concept enables us to consider the lifetime economic conditions required to support the investment. It is clear that medium or high price differentials will be required to support a thermal cracker on an incremental basis. It is also clear that in a price crisis, such as occurred in 1979/1981, the cracker would pay off handsomely. On the other hand, if low price differentials persist over a very long period (as Shell believes), then the investment is unlikely to pay off. Of course, it must also be remembered that as the material balance continues to deteriorate over time, then the economics of fuel oil upgrading will improve. This impact is not reflected in the one year analysis presented in this memorandum report.

3. Overall Conclusions Regarding KPRL's Proposal for Modification

Substantial savings can be achieved by implementing KPRL's proposal if the refinery is to be kept running. ADL's analysis shows that the

estimated investment of about $16 million (in money of the day)* can be paid out in slightly more than one year. However, when compared with product imports, the gross refinery margins are below existing processing revenues including operating expenses, asset depreciation and profits, and therefore will be insufficient to recover the new investment needed to combine the two distillation units and to install a Kero-Merox unit. Thus, as has already been recognized, the refinery is not economic, if the processing fee is maintained at its current level.

The use of the Mombasa refinery to supply the contiguous markets will improve this situation provided the processing fee charged to the marketing companies supplying these countries is above the refinery's variable costs and provided that incremental surplus fuel oil can be disposed of at reasonable price levels, or that such markets are prepared to pay the higher prices for white products which are required to cover crude oil and processing costs.

In summary, based on this one year analysis, KPRL's proposal is certainly justified provided the Government decides to keep the refinery open. Nevertheless, rapidly increasing middle distillate demand will

*It must be recognized that this is only a very preliminary estimate of the required investment.

create increasing volumes of surplus fuel oil for export and we believe that it is likely to be in Kenya's long term interest to continue to most carefully review the implementation of a thermal cracker, which is the only effective way of resolving the fundamental imbalance problem.

Our technical review of KPRL's proposal clearly demonstrates that the combining of the two existing crude distillation units (and the addition of a Kero-Merox unit) can readily be followed by the installation of a thermal cracker, when this is merited by the refinery's economics. The timing of the second stage of investment is a complex issue and is affected by a number of factors, the most important of which is future world oil prices. A major concern is that the industry has shown historic cyclicality and that investment in secondary processing has now virtually ceased. Thus, by the early 1990s, we believe differentials are again likely to increase (particularly if crude prices stabilize) and the timing of the installation of further investment at Mombasa will be critical if exposure to very high product prices is to be avoided. We understand, however, the reluctance now expressed by the industry shareholders but believe the Government must continue to insist on a commitment to review the thermal cracker again by late 1985/early 1986 at the latest. By this time, the influence of new Mid-East refined product exports on the world market and prices will be clearer and at least some of the current uncertainty may have been resolved.

APPENDIX

TABLE C-1

REFINERY MAXIMUM CAPACITY (MM TONNE/YR)

	NO INVESTMENT		KPRL
CRUDE SLATE	MAXIMUM[3]	CUT POINT[4]	MAXIMUM
95% Murban	3,182	2,345	3,010[2],[5]
50% Murban	3,518	2,345	3,182[1]
25% Murban	3,718	2,345	3,266[2]
Arab Mix	3,920	2,345	3,350[2]

(1) Supplied by KPRL and assumed to be maximum throughput.

(2) Estimated by ADL.

(3) Data from KPRL Data Book (for "High Intake" operation)

(4) Cut-point (capacity) between "Low Intake" and "High Intake" in Data Book.

(5) Original data supplied by KPRL was 2480, but this seemed out of line with other data.

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TABLE C-2
1990 MATERIAL BALANCES (MM TONNES/YR)

CRUDE SLATE:	95%[1] MURBAN	95%[1] MURBAN	50% MURBAN	50% MURBAN	25% MURBAN	25% MURBAN	25%[5,6] MURBAN	50%[5] MURBAN	ARAB MIX	25% MURBAN	ARAB[10] MIX	ARAB MIX	25% MURBAN	50% MURBAN
OPTION:	NO INVESTMENT	KPRL PROJECT	NO INVESTMENT	KPRL PROJECT	NO INVESTMENT	KPRL PROJECT	ADL PHASE 1 HDS ONLY	ADL PHASE 1 HDS ONLY	ADL PHASE 2 HDS + TGU + H_2 PLANT	ADL PHASE 2 HDS + TGU + H_2 PLANT	KPRL OPTION + TGU + HDS + H_2 PLANT	KPRL + HDS (NO MEROX)	KPRL + HDS (NO MEROX)	KPRL + HDS (NO MEROX)
KENYA PLUS MARKET														
Crude Oil	2,837	2,669	3,282	2,922	3,655	3,126	3,296	3,148	2,850	2,695[9]	2,800	3,350	3,097	2,921
AGO Import[3]	–	–	–	–	–	–	–	–	–	–	–	6	–	–
Mogas Surplus	18	–	27	–	37	–	–	8	–	–	–	–	–	–
Fuel Oil Export[2]	514	371	928	611	1,277	805	968	819	449[8]	305	402	1,031	778	610
LPG Deficiency[4]	8	10	2	5	–	2	1	3	–	–	–	–	3	5
Sulphur Prod.	–	–	–	–	–	–	–	–	15	13	15	–	–	–
KENYA ONLY MARKET														
Crude Oil	2,300	2,152	2,661	2,333	2,964	2,485	2,661	2,552	2,190[7]	2,230[7]	2,155	2,628	2,455	2,330
AGO Import[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mogas Surplus	70	48	77	35	85	29	50	62	–	55	–	8	26	34
Fuel Oil Export[2]	404	285	746	474	1,022	620	773	656	277	274	254	767	594	467
LPG Deficiency[4]	11	13	6	9	3	7	6	7	–	–	–	5	7	9
Sulphur Prod.	–	–	–	–	–	–	–	–	12	10	12	–	–	–

1 Cloud pt. problems are not expected by KPRL for the AGO for 95% Murban, although KPRL lab is testing a cloud pt. depressant from ESSO.
2 Facilities for Shell's SWIM Pour Pt. depressant are currently being installed for fuel oil.
3 "AGO Imports" may be partly "Kero Inputs".
4 LPG deficiencies may be corrected by proposed new improved C_4 recovery project. No data available.
5 Max. refinery throughput is same as for no investment case since there is no charge to the CDU's in this option.
6 Yields are based on Data Book, "Low Intake" with LGO yield limited by 90% ASTM temperature (365°C) and not by sulfur content.
7 The cut-point is capacity between "High" and "Low Intake" is 2345 MM tonne/yr. Hence these case(s) can use "Low Intake" which was adopted in original ADL study.
8 Figure slightly modified from original study.
9 Figure slightly modified from previous study to allow for "High Intake" yields.
10 Results are slightly better than original ADL 3A material balance due to improved CDU fractination. Presence of merox unit will reduce operating cost and improve H_2 balance, although not enough to eliminate H_2 plant.

TABLE C-3
1995 MATERIAL BALANCES (MM TONNES/YR)

CRUDE SLATE:	95% MURBAN	95% MURBAN	50% MURBAN	50% MURBAN	25% MURBAN	25% MURBAN	25% MURBAN	50% MURBAN	ARAB MIX	25% MURBAN	ARAB MIX	ARAB MIX	25% MURBAN	50% MURBAN
OPTION:	NO INVESTMENT	KPRL PROJECT	NO INVESTMENT	KPRL PROJECT	NO INVESTMENT	KPRL PROJECT	ADL PHASE 1 HDS ONLY	ADL PHASE 1 HDS ONLY	ADL PHASE 2 HDS + TGU + H_2 PLANT	ADL PHASE 2 HDS + TGU + H_2 PLANT	KPRL OPTION + TGU + HDS + H_2 PLANT	KPRL + HDS (NO MEROX)	KPRL + HDS (NO MEROX)	KPRL + HDS (NO MEROX)
KENYA PLUS MARKET														
Crude Oil	3,182	3,006	3,518	3,182	3,718	3,266	3,717	3,518	3,185	3,028	3,130	3,350	3,266	3,182
AGO Import	14	-	75	45	125	117	-	18	-	-	-	186	101	45
Mogas Surplus	41	15	30	-	18	-	18	29	-	10	-	-	-	-
Fuel Oil Export	581	424	971	650	1,224	801	1,098	915	499	344	446	950	785	650
LPG Deficiency	14	15	8	11	5	9	5	8	-	-	-	8	9	11
Sulphur Prod.	-	-	-	-	-	-	-	-	17	14	17	-	-	-
KENYA ONLY MARKET														
Crude Oil	2,548	2,384	2,948	2,584	3,283	2,753	2,948	2,827	2,390	2,420	2,345	2,911	2,720	2,581
AGO Import	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mogas Surplus	100	77	108	61	117	56	78	92	-	75	-	32	52	61
Fuel Oil Export	463	328	835	533	1,145	699	864	735	314	277	275	864	665	530
LPG Deficiency	17	18	11	14	7	12	10	12	-	-	-	10	12	14
Sulphur Prod.	-	-	-	-	-	-	-	-	13	10	13	-	-	-

1 No cloud pt. problem is expected by KPRL for AGO with 95% Murban, although KPRL lab is testing cloud pt. depressant (ESSO).
2 "AGIO Inputs" mayu be partly "Kero Inputs".
3 Facilities are currently being installed for Shell's Swim Pour pt. depressant.
4 This deficiency may be corrected by proposed new improved C_4 recovery project. No data available.
5 Maximum refinery throughput is same as for the No Investment case since there is no change to DCU's in this option.
6 Yields are based on Data Book "Low Intake" with LGO yield limited by 90% ASTM temperature (356°C) and not by sulphur content.
7 The cut-point in capacity between "High Intake" and "Low Intake" is 2345 MM tonne/yr. Hence this case can use "Low Intake" which was adopted in original
8 Figures slightly modified from original study.
9. Case 3A modified to take into account the use of "High Intake" yields at CDUs. The TGU is 8% higher in capacity (Kenya plus market, 1995).
10. Figures slightly modified from previous study to allow for "High Intake" yields.
11. Results are slightly better than original ADL 3A material balance due to improved CDU fractionation. Presence of Merox unit will reduce operating cost
12. HDS unit will be approximately: 1860 MT/SD (1075 Kero + 785 LGO).

MARKETING COMPANIES NET OIL COSTS

In addition to the crude slate each scenario is described with one of the following labels:

- N.I. - No Investment case.
- KPRL - combination of the two CDU's plus Merox unit.
- HDS - Arthur D. Little Option 2 (hydrodesulfurization unit).
- TGU + - Arthur D. Little Option 3A (thermal gas oil unit plus a package hydrogen plant).
- KPRL, TGU+ - the modified Option 3A, including the combination of the existing crude units, the Merox, the TGU, a small HDS unit + H_2 facilities.
- Combi, HDS - (the HDS unit) combination of the two CDU's plus Arthur D. Little's Option 2.

NET OIL COSTS AND REFINERY MARGINS

(SPOT PRICES*)
(Million 1983 $)

	Kenya Plus Contiguous Market				Kenya Only			
	1990		1995		1990		1995	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Product Imports	555.3	-	620.6	-	439.9	-	478.8	-
95% Murban N.I.	546.5	8.8	611.7	8.9	432.2	7.7	471.8	7.00
KPRL 95% Murban	535.6	19.7	595.9	24.7	425.2	14.7	463.8	15.0
50% Murban N.I.	552.7	2.6	614.0	6.6	434.5	5.4	475.2	3.0
KPRL 50% Murban	533.1	22.2	595.8	24.8	420.3	19.6	459.6	19.2
25% Murban N.I.	556.0	(0.7)	615.6	5.0	439.9	-	480.2	1.4
KPRL 25% Murban	532.2	23.1	593.7	26.9	420.5	19.4	458.8	20.0
HDS 25% Murban	540.9	14.4	605.4	15.2	426.7	13.2	466.6	12.2
HDS 50% Murban	544.8	10.5	609.4	11.2	430.0	9.9	470.1	8.7
TGU+, Arab Mix	521.8	33.5	583.6	37.0	412.4	27.5	448.1	30.7
TGU+, 25% Murban	523.7	31.6	585.6	35.0	415.7	24.2	450.6	28.2
KPRL, TGU+, Arab Mix	519.2	36.1	581.0	39.6	408.9	31.0	445.2	33.6
Combi, HDS, Arab Mix	530.4	24.9	590.9	29.7	421.1	18.8	459.4	19.4
Combi, HDS, 25% Murban	530.9	24.4	592.4	28.2	419.2	20.7	458.5	20.3
Combi, HDS, 50% Murban	533.1	22.2	595.8	24.8	421.1	18.8	459.5	19.3

[1] Net oil costs to each market
[2] Gross refinery margins.
* Platts' Prices 4/2/84.

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NET OIL COSTS AND REFINERY MARGINS

(Fall 1983 Price Forecast)*

(Million 1983 $)

	Kenya Plus Contiguous Market				Kenya Only			
	1990		1995		1990		1995	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Product Imports	616.3	-	760.3	-	488.4	-	586.8	-
95% Murban N.I.	611.0	5.3	759.7	0.6	483.9	4.5	586.4	0.4
KPRL 95% Murban	600.2	16.1	743.5	16.8	476.2	12.2	577.0	9.8
50% Murban N.I.	605.7	10.6	749.7	10.6	476.6	11.8	579.3	7.5
KPRL 50% Murban	585.2	31.3	729.0	31.3	462.1	26.3	562.2	24.6
25% Murban N.I.	601.1	15.2	743.7	16.6	475.6	12.8	577.1	9.7
KPRL 25% Murban	577.1	39.2	720.1	40.2	456.6	31.8	554.9	31.9
HDS 25% Murban	586.0	30.3	730.3	30.0	462.7	25.7	563.0	23.8
HDS 50% Murban	597.5	18.8	743.7	16.6	472.0	16.4	573.6	13.2
TGU+, Arab Mix	560.0	56.3	699.7	60.6	442.9	45.5	537.7	49.1
TGU+, 25% Murban	568.5	47.8	709.2	51.1	450.6	37.8	544.7	42.1
KPRL, TGU+, Arab Mix	557.4	58.4	696.9	63.4	439.2	49.2	534.4	52.4
Combi, HDS, Arab Mix	567.2	49.1	709.9	50.4	451.3	37.1	549.0	37.8
Combi, HDS, 25% Murban	575.8	40.5	718.4	41.9	455.3	33.1	544.8	42.0
Combi, HDS, 50% Murban	585.2	31.1	729.0	31.3	462.0	26.4	562.0	24.8

[1] Net oil costs to each market.
[2] Gross refinery margins.
* See Arthur D. Little report of March 1984.

Arthur D. Little, Inc.

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NET OIL COSTS AND REFINERY MARGINS

(March 1983 Price Forecast)

(Million 1983 $)

	Kenya Plus Contiguous Market		Kenya Only	
	1990		1990	
	(1)	(2)	(1)	(2)
Product Imports	493.5	-	390.0	-
95% Murban N.I.	491.6	1.9	388.1	1.9
KPRL 95% Murban	480.5	13.0	380.3	9.7
50% Murban N.I.	490.7	2.8	385.1	4.9
KPRL 50% Murban	470.5	23.0	370.3	19.7
25% Murban N.I.	489.6	3.9	386.6	3.4
KPRL 25% Murban	465.4	28.1	366.8	23.2
HDS 25% Murban	474.3	19.2	373.3	16.7
HDS 50% Murban	482.9	12.6	380.4	9.6
TGU+, Arab Mix	447.2	46.3	352.9	37.1
TGU+, 25% Murban	453.7	39.8	359.7	30.3
KPRL, TGU+, Arab Mix	444.7	48.8	349.7	40.3
Combi, HDS, Arab Mix	458.8	34.7	363.5	26.5
Combi, HDS, 25% Murban	463.9	29.6	365.5	24.5
Combi, HDS, 50% Murban	470.5	23.6	370.9	19.1

[1]Net oil costs to each market.
[2]Gross refinery margin

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NET OIL COSTS AND REFINERY MARGINS

(April 1984 Low Price Forecast)
(Million 1983 $)

	Kenya Plus Contiguous Market 1990		Kenya Only 1990	
	(1)	(2)	(1)	(2)
Product Imports	465.4	-	369.6	-
95% Murban N.I.	455.9	9.5	362.1	9.5
KPRL 95% Murban	449.8	15.6	357.0	12.6
50% Murban N.I.	458.8	6.6	362.0	7.6
KPRL 50% Murban	445.5	19.9	352.2	17.4
25% Murban N.I.	459.3	6.1	364.8	4.8
KPRL 25% Murban	443.9	21.5	351.5	18.1
HDS 25% Murban	449.2	16.2	355.6	14.0
HDS 50% Murban	452.9	12.5	358.9	10.7
TGU+, Arab Mix	441.3	24.1	349.7	19.9
TGU+, 25% Murban	443.2	22.2	353.1	16.5
KPRL, TGU+, Arab Mix	439.6	25.8	347.0	22.6
Combi, HDS, Arab Mix	441.3	24.1	351.1	18.5
Combi, HDS, 25% Murban	443.0	22.4	350.7	18.9
Combi, HDS, 50% Murban	445.4	20.0	352.9	16.7

Note: Rotterdam refinery margin at variable cost

[1] Net oil costs to each market
[2] Gross refinery margin.