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COMPETITIVE ECONOMICS OF UNITED STATES AND FOREIGN REFINING

December 1979

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COMPETITIVE ECONOMICS OF UNITED STATES AND FOREIGN REFINING

Prepared For

UNITED STATES DEPARTMENT OF ENERGY

For PACE

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A

INTRODUCTION

The Pace Company Consultants & Engineers, Inc. was requested by the United States Department of Energy's Office of Oil and Gas Policy to analyze the relative competitiveness of United States and foreign refineries in supplying product to the United States East Coast once United States crude oil prices reach world levels. In this study we present the 1980 and 1985 economics for the following types of existing United States Gulf Coast and foreign export refineries which represent the incremental product supply sources to the United States East Coast.

Location	Type	Thousand Barrels Per Stream Day
Caribbean	Hydroskimming	400
Rotterdam	Hydroskimming	300
Gulf Coast	Hydroskimming	20
Gulf Coast	Low Conversion	50
Gulf Coast	High Conversion	100
Gulf Coast	High Conversion	335

For 1985 we have also calculated the economics for new refineries built to serve the United States East Coast market in the following locations:

- Caribbean
- Rotterdam
- East Coast
- Gulf Coast
- Mexico
- Middle East

In order to bracket the conversion level of a new refinery built to serve the United States refined products market in the mid-1980s, both high and low conversion operations have been considered.

The reference case comparison of the economics of existing and new United States and foreign export refineries presented in this study is based on Pace's assessment of the most likely relative product values. Possible variations in the variables affecting relative refinery economics are treated as sensitivity cases. In the cases for existing refineries, charges for capital, including depreciation, are excluded from the comparative economics. The economic comparison of the new refinery locations considered is based on a 10 percent after tax return on investment.

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SUMMARY AND CONCLUSIONS

CONCLUSIONS

- The existing Caribbean export refineries are at a competitive advantage relative to all United States Gulf Coast refineries except the very large, high conversion facilities. The advantage ranges from a minimum of $0.45 per barrel to a maximum of $2.14 per barrel (1978 United States dollars) in 1980 with United States crude oil prices at world levels (Figure B-1).

- The existing European export refineries are also at a competitive advantage relative to the hydroskimming and low conversion United States Gulf Coast refineries (Figure B-1). Higher crude oil and product transportation costs reduce the European export refinery's competitive advantage compared to its Caribbean counterpart.

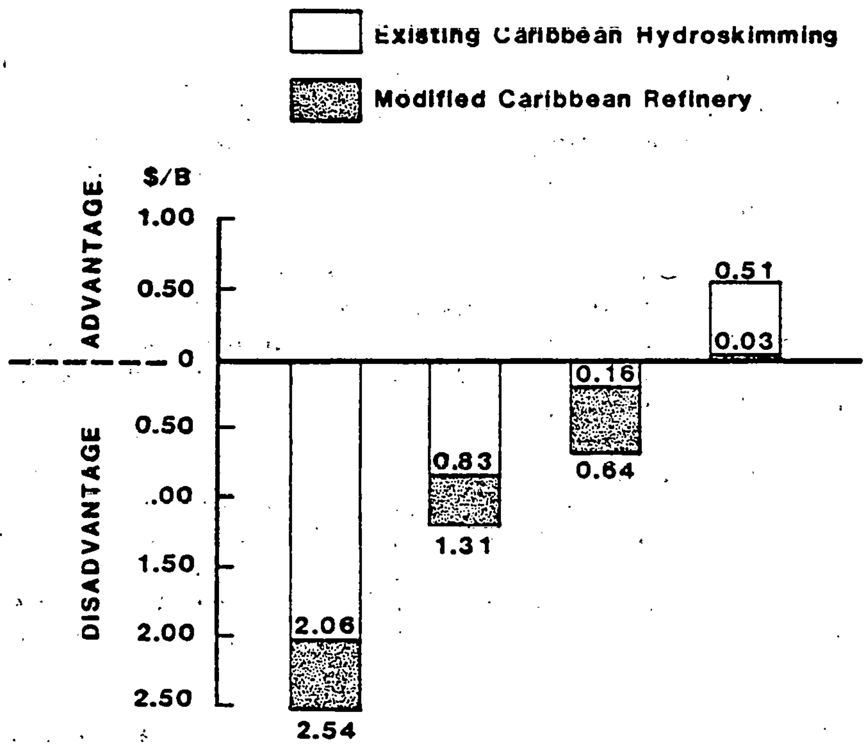
- The Caribbean and Rotterdam refiner's competitive position would be significantly enhanced with the addition of conversion facilities to increase gasoline and distillate yields (Figure B-2). The advantage in 1985 would increase to a maximum of $2.54 per barrel (1978 dollars).

- Higher crude oil and product transportation costs due to natural port limitations and the Jones Act are key factors determining the United States Gulf Coast refiner's competitive position. These locational disadvantages in addition to United States emission standards account for $1.42 and $0.94 per barrel of the competitive advantage of the Caribbean and European export refineries, respectively.

- New United States refineries are at an even greater disadvantage relative to foreign competition. Caribbean and Mexican locations are the most attractive for a new refinery with lower income and ad valorem taxes in addition to the locational factors cited previously. Mexico also has potentially cheap natural gas for refinery fuel. Taken together, these factors give a new Mexican or Caribbean refinery about a $2.00 to $3.00 per barrel advantage relative to a United States East or Gulf Coast location.

FIGURE B-2

COMPETITIVENESS OF U.S. GULF COAST REFINERIES
1985 REFERENCE CASE
(1978 U.S. DOLLARS)



U.S. Gulf Coast Refinery:

Size (MBPSD)	20	50	100	335
Conversion Level	Hydro-skimming	Low	High	High

SUMMARY

Existing Refineries

The relative competitiveness of existing United States Gulf Coast and foreign hydroskimming export refineries in supplying product to the United States East Coast varies depending upon both the size and amount of conversion processing in the refineries. Key basis items to the comparative economics presented in this study are listed in Table B-1. The relative economics of the four Gulf Coast refinery types considered compared to both a typical Caribbean and Rotterdam hydroskimming export facility for 1980 and 1985 are derived in Tables B-2 and B-3, respectively. Product gross margins which indicate the relative competitiveness of the existing refineries in the early 1980s—with United States crude oil prices at world levels—compare as shown in Figure B-1.

All the Gulf Coast refiners except the large, high conversion type facilities are at an economic disadvantage. The hydroskimming scheme typical of the Caribbean and Rotterdam export refineries produces a larger percentage of the lower valued residual products compared to a refinery that has invested in conversion processing. The greater relative yield of the higher priced gasoline and distillates thus improves the competitive position of the high conversion United States Gulf Coast refineries, partially or fully offsetting locational disadvantages.

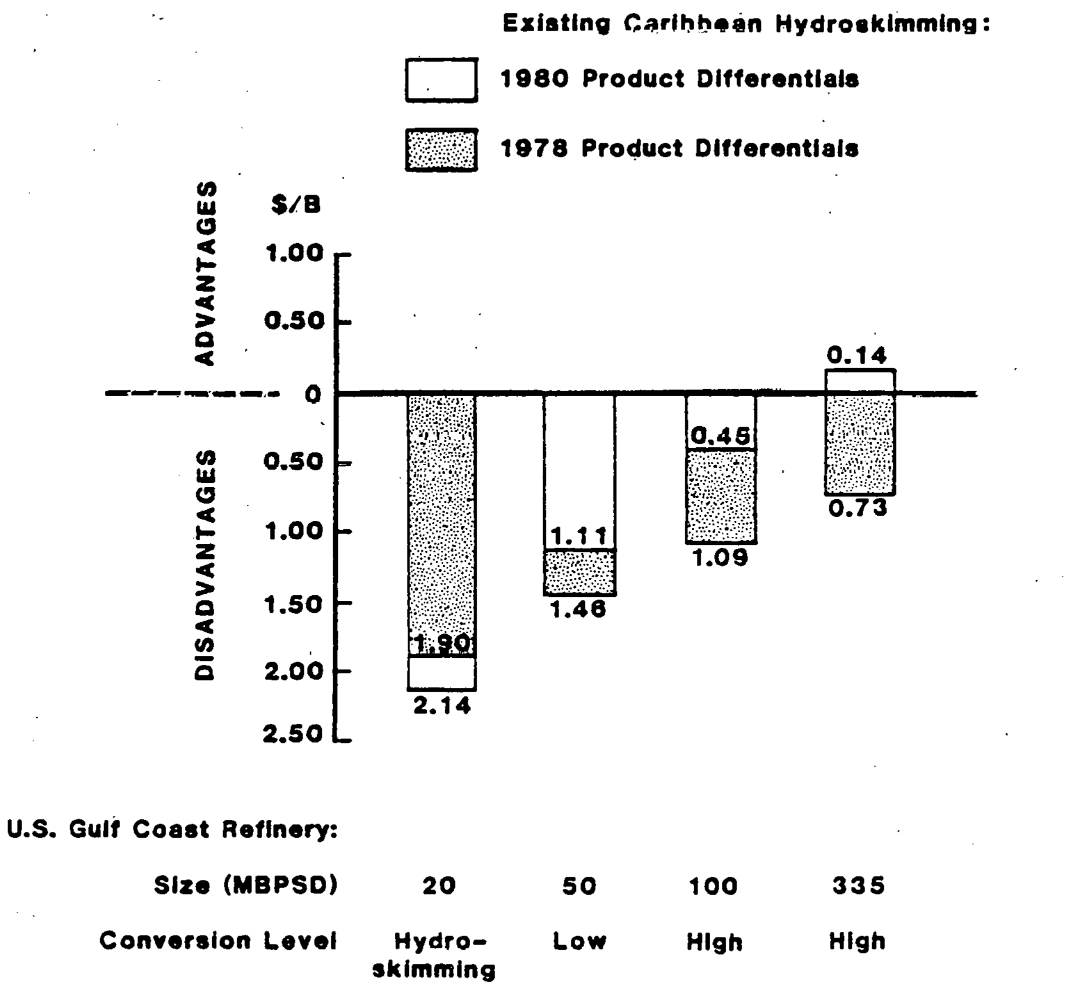
Although time required for project planning and construction precludes any major modification of the existing foreign export refineries in the early 1980s (particularly in light of the uncertainty in United States import tariff policy), conversion facilities could be added by 1985. The relative economics of existing United States Gulf Coast refineries and a modified existing Caribbean refinery are shown in Table B-4. Capital charges equivalent to a 10 percent straight line depreciation plus a 10 percent return on investment for the new facilities are included as costs in the economics for the modified Caribbean refinery. As illustrated in Figure B-2, the product margins show that the addition of conversion facilities would significantly improve the competitiveness of the Caribbean export refineries.

The product gross margins for the existing United States Gulf Coast refineries are the values **relative** to their Caribbean and Rotterdam competition. The negative values shown for the lower conversion United States refineries do not necessarily mean that these refineries will be operating at a loss. Product prices will reach the levels so that the increments of supply required to meet demand are profitable. Pace estimates that 1 to 1.5 million barrels per day of product will be available from the Caribbean export refineries (excluding the Virgin Islands and Puerto Rico). Another 4 to 5 million barrels per day of product will be available from spare capacity in OECD Europe in the 1980 to 1990 period. Therefore, with United States petroleum demand expected to increase at less than 1.5 percent per year over the next decade, the low conversion United States Gulf Coast refineries will likely face stiff competition from the Caribbean and European export refineries, which would tend to keep their **absolute** product margins depressed.

FIGURE B-3

COMPETITIVENESS OF U.S. GULF COAST REFINERIES PRODUCT PRICE DIFFERENTIALS SENSITIVITY

(1978 U.S. DOLLARS)



Product Price Differentials Sensitivity

The price differentials between refined products can radically affect the competitive position between existing high conversion refineries and the hydroskimming operation characteristic of the foreign export refineries. Refined product price differentials are highly volatile and difficult to forecast. Therefore, because of the variations in the product slates of the existing refineries studied, the assumption as to the relative prices of the different product categories is a critical factor to the economic comparison.

Refined product price differentials in our Reference Case economics reflect historic **world** levels adjusted to account for expected market factors in the 1980 to 1985 period. The crude oil price controls program has also skewed product price differentials in the United States. With the large volume of residual fuel oil imports, residual fuel oil prices in the New York Harbor are set by the delivered price of similar quality, heavy Venezuelan crude oil. However, with crude oil price controls, gasoline and distillate prices have been tied to lower United States oil prices, whereas residual fuel oil prices have been determined by world crude oil prices. Therefore, the differential between light products (gasoline and distillates) has been much less in the New York Harbor than in other world markets.

The key factor to the relative prices of light products and residual fuel oil is the relative availability of light crude oil—which contains a larger percentage of gasoline and distillate fractions—and heavy crude oil. In 1979 the tight supply of light crude oil, aggravated by the Iranian crisis, has resulted in a widening of the differential between the higher sulfur residual fuel oil grades and light products on the United States East Coast. The supply of light crude oil is expected to remain tight throughout the 1980s, with the light crude oils retaining a high market premium.

Over the long term with equilibrium conditions, conversion economics would set the relative prices of light and heavy crude oil, i.e., light products and residual fuel oil. However, Pace considers it unlikely that sufficient cracking and desulfurization capacity will be installed to allow conversion economics to be the price setting mechanism by 1985. Therefore, market factors are expected to keep the price between high sulfur (3.0 weight percent sulfur) residual and unleaded gasoline at the $10.00 to $11.00 per barrel range with United States crude oil prices at world levels in the 1980 to 1985 period. Reference Case 1980 and 1985 product price differentials assumed compare with actual 1978 and 1979 differentials as shown in Table B–5.

Because of the uncertainty in future product price differentials, the relative economics of the existing refineries studied were calculated based on 1978 differentials as a sensitivity case. The 1980 economics for the United States Gulf Coast refineries relative to the Caribbean hydroskimming operation on the basis of actual 1978 New York Harbor differentials compare with that with Pace's forecast 1980 differentials as shown in Figure B–3.

With 1978 product price differentials, all United States Gulf Coast refiners (even the large, high conversion facilities) are at a substantial competitive disadvantage. The effect of product price differentials is of less importance to the hydroskimming or low conversion Gulf Coast refineries because the product yields approximate those of Caribbean or Rotterdam operations.

Pace considers it unlikely that the differential between gasoline and residual fuel oil will narrow to 1978 levels. However, the 1978 product price differentials sensitivity illustrates how significant relative product prices are to the competitiveness of United States conversion refineries with the foreign hydroskimming refineries.

Locational Factors

The analysis of the competitiveness of existing United States and foreign refineries presented in this study considers all the factors affecting the relative economics, including differences in refinery size, complexity, and product yields. There are fundamental locational advantages/disadvantages due to natural port limitations, the Jones Act, and United States emission standards.

Crude oil and product transportation cost differences account for a large portion of the cost advantage shown for the Caribbean and Rotterdam export refineries. Crude oil costs for Caribbean and Rotterdam refineries are significantly lower compared to that for United States Gulf Coast refiners due to their access to a deepwater port. The increased cost of foreign crude oil due to natural port limitations for United States Gulf Coast refiners ranges from $0.20 per barrel for African oils to $0.60 per barrel for Middle East crude oils.

A deepwater port is currently under construction off the coast of Louisiana—Louisiana Offshore Oil Port, Incorporated (LOOP). Utilization of the LOOP facilities will vary among the Gulf Coast refiners. Crude oil transportation costs in the Reference Case economics presented in this study are **not** based on use of a Gulf Coast superport. However, LOOP charges, now estimated at $0.37 per barrel, will offset some of the savings to Gulf Coast refiners.

The United States Jones Act effectively creates a separate tanker market which determines product transport costs for United States refiners from the world market for foreign refiners. The tanker rates assumed in the Reference Case economics are also provided in Table B-1.

In 1979 there has been a significant surge in world tanker rates, particularly in the 30,000 to 80,000 DWT size range which can be accommodated in United States ports. Voyage (spot) charter rates have exceeded the Worldscale (W.S.) 300 level. Crude oil and product stockpiling have been a contributing factor. Rates for United States flagships also rose early in 1979, but settled back to the American Rate (A.R.) 200 to 225 range by mid-year, due to an easing in requirements for Alaskan oil transported through the Panama Canal.

In response to the tight market conditions, there has been a burst of orders in 1979 for 30,000 to 80,000 DWT tankers in the world market. With a one to two year construction period, Pace forecasts charter rates to settle back to an average W.S. 150 and W.S. 109 for clean and dirty vessels, respectively, by the time United States crude oil prices reach world levels. Also by the early 1980s, the LOOP facility (with the capability to handle 1.4 million barrels per day of crude oil) is scheduled to be in operation which will reduce the use of these smaller vessels for crude oil transshipment from Caribbean terminals.

With world charter rates for 30,000 to 80,000 DWT vessels at an average W.S. 300 compared to A.R. 200 for American flagships, the **product** transportation cost advantage of the Caribbean and Rotterdam refineries would be essentially eliminated. However, the higher cost for transshipment of Middle East crude oil from Caribbean offloading terminals would increase United States Gulf Coast refiners' average **crude oil** transport costs by about $0.60 per barrel.

The locational disadvantages of United States Gulf Coast refiners relative to those in the Caribbean and Europe, based on Pace's 1980 forecast of United States and world tanker rates, is shown in the table which follows. The sensitivity of the crude oil/product transportation cost comparison to world rates for 30,000 to 80,000 DWT vessels at an average W.S. 300 is also provided.

Locational Cost Differences
(1978 U.S. Dollars Per Barrel)

U.S. Gulf Coast Refinery Advantage/(Disadvantage)	Pace Forecast 1980 Reference Case		W.S. 300 Sensitivity Case	
	Caribbean	Rotterdam	Caribbean	Rotterdam
Crude Oil Transport	(0.50)	(0.45)	(1.10)	(1.05)
Product Transport	(0.80)	(0.30)	(0.10)	(1.00)
Subtotal	(1.30)	(0.75)	(1.20)	(0.05)
Emission Restrictions*	(0.12)	(0.12)	(0.12)	(0.12)
Other Operating	(0.00)	(0.02)	(0.00)	(0.02)
Total	(1.42)	(0.94)	(1.32)	(0.19)

* Out of pocket costs only

The locational cost differences shown are for the same refinery in all three locations. Except for relatively small differences, the comparison is independent of refinery size and complexity.

In the W.S. 300 Sensitivity Case, the effect on the European refiner's competitive position is much larger than that for the Caribbean refiner because of the greater distance by which products must be shipped in the small tankers.

The mode of transporting product from the United States Gulf Coast to the East Coast is also a key factor in the transportation cost comparison. The Reference Case economics presented in this study are based on tanker movement for all products.

Although over 70 percent of the gasoline and distillates transported from the Gulf Coast to the East Coast is via pipeline, almost one million barrels per day move by water. Currently the product pipelines joining the regions are operating at full capacity during most of the year. Access to these pipelines varies by refinery. Pipeline tariffs are about half that for tanker movement at A.R. 200. Therefore, actual average transportation cost for individual Gulf Coast refiners could be as much as $0.70 per barrel lower than shown in this study if pipelines are used for product movements.

New Refineries

With the limited petroleum demand growth now expected coupled with the substantial surplus of foreign refining capacity, it can be questioned whether a new refinery in the United States could be justified. In addition, the conversion level of a new refinery built to serve the United States refined products market in the mid-1980s is not certain. We have simulated both high and low conversion operations to bracket the possible range.

The comparative economics of the new 1985 refineries in the locations considered are relative to a new East Coast refinery yielding a 10 percent after-tax return on investment (ATROI). The economics are presented relative to the United States East Coast location to show what economic subsidy would be required to ensure that a new refinery built to supply growth in the United States East Coast products market would be located within the region. The comparison of the after-tax return on investment indicates the relative advantage or disadvantage of the various locations. The 1985 Reference Case net operating margin, total refinery investment, and return on investment for the new refinery types and locations considered are summarized in Table B-6.

The criteria for establishing the return on investment required to justify construction of a new refinery often vary by location. Factors to be considered are:

- Stability of the local government
- Possibility of nationalization of assets
- Uncertainty in future import/export policies of the countries concerned.

A 10 percent ATROI is considered the typical requirement for most refinery projects. The difference in the 1985 Reference Case net operating margins and that yielding a 10 percent ATROI for the new refineries is summarized as follows:

Competitive Position of New Refineries at 10% ATROI
(1978 U.S. Dollars Per Barrel)

Refinery Type	Advantage/(Disadvantage) High Conversion	Advantage/(Disadvantage) Low Conversion
United States East Coast	0	0.12
United States Gulf Coast	(0.14)	(0.14)
Caribbean	2.00	1.82
Rotterdam	0.37	0.35
Mexico	3.07	2.35
Middle East	0.12	(0.12)

Key factors and sensitivities in the advantages/disadvantages of each refinery location are discussed in the following.

United States Gulf Coast

With the cost differences established in the 1985 Reference Case, the United States Gulf Coast is a less favorable location for a new foreign crude oil based refinery to serve the United States East Coast compared with an East Coast location. Higher product transportation costs, boosted by Jones Act tanker requirements, offset lower investment and operating costs.

Caribbean

Lower taxes are the major advantage a Caribbean location offers a refiner. Higher refinery fuel sulfur levels are permitted in the Caribbean resulting in lower desulfurization requirements, which in turn decrease total refinery investment, fuel, and hydrogen requirements. United States environmental and safety regulations account for \$0.20 to \$0.26 of the cost advantage for the Caribbean refinery location.

Rotterdam

The new United States East Coast and Rotterdam refineries are essentially competitive, with the Rotterdam refiner having only a \$0.35 to \$0.40 per barrel advantage. Higher product transportation costs offset lower crude oil, operating, and capital costs for the Rotterdam refinery.

Mexico

Key factors to the economic advantage of the Mexican refinery are:

- Pricing of Mexican crude oil
- Use of low-valued natural gas to supplement refinery fuel gas
- Income tax treatment.

The pricing of Mexican crude oil is not certain at present. In the Reference Case economics presented in this study, we have set the value of Mexican Isthmus at the delivered price of Saudi Light in Rotterdam less transportation from Mexico.

The availability of low-valued natural gas to supplement refinery fuel gas provides the Mexican refinery with a $0.32 to $0.40 per barrel cost advantage. We have not included an income tax in the new Mexican refinery economics. With a nationalized oil industry, all refinery gross profits would essentially accrue to the government. Justification of a new export refinery would likely be based on an adequate return on investment to the government. A 10 percent rate of return (equivalent to a 10 percent ATROI of a private company) is a likely criterion. The positive effects of new refinery construction and operation on area industrialization would likely also be considered.

Middle East

The new United States East Coast and Middle East refineries are essentially competitive. Using the same criteria for a government-owned Middle East refinery as that for a government-owned Mexican refinery, we have not included an income tax in the new Middle East refinery economics. Higher refinery investment costs offset income tax and other cost advantages.

TABLE B-1

KEY BASIS ITEMS

- Comparative economics for the existing refineries is based on the relative gross margin, i.e., product revenues less crude oil and other out-of-pocket costs.
- Comparative economics for the new refineries is based on the net operating margin, i.e., gross margin less depreciation and income taxes. The net operating margin equivalent to a simple 10 percent after-tax return on investment is compared for each new refinery location.
- Refinery costs and revenues are annual figures expressed per barrel of crude oil throughput with 350 stream days per year.
- Product prices are assumed to be uncontrolled. No existing crude oil or product import tariffs are included in the economics.
- Costs are typical of each refinery type and location.
- Refinery fuel is not included in the operating cost category. Refinery fuel consumption is accounted for in determining the yield of product to sales.
- Average tanker charter rates for key size groups are as follows:

	1980	1985
Foreign Flagships		
30,000 - 80,000 DWT		
Dirty	109	109
Clean	150	150
80,000 - 150,000	65	90
VLCC/ULCC	50	64
United States Flagships		
30,000 - 80,000 DWT		
Dirty	200	200
Clean	200	200

- Gasoline pool tetraethyl lead content is limited to 0.5 g/gal in all United States refinery simulations for 1980 and 1985.

TABLE B-2

COMPARATIVE ECONOMICS - EXISTING REFINERIES
1980 REFERENCE CASE
(1978 U.S. Dollars Per Barrel)

	U.S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Economics Relative to Caribbean Hydroskimming				
Costs:				
Feedstock*	(0.94)	(1.39)	(1.37)	(1.24)
Operating	(0.35)	(0.59)	(0.50)	(0.51)
Product Transport	(0.86)	(0.84)	(0.81)	(0.78)
Subtotal	(2.15)	(2.82)	(2.68)	(2.53)
Product Slate Value- New York Harbor	0.01	1.71	2.23	2.67
Gross Margin	(2.14)	(1.11)	(0.45)	0.14
Economics Relative to Rotterdam Hydroskimming				
Costs:				
Feedstock*	(0.55)	(1.00)	(1.00)	(0.85)
Operating	(0.36)	(0.60)	(0.51)	(0.52)
Product Transport	(0.35)	(0.33)	(0.30)	(0.27)
Subtotal	(1.26)	(1.93)	(1.81)	(1.64)
Product Slate Value- New York Harbor	(0.20)	1.50	2.04	2.46
Gross Margin	(1.46)	(0.43)	0.23	0.82

* Includes Butanes

TABLE B-3

COMPARATIVE ECONOMICS - EXISTING REFINERIES
1985 REFERENCE CASE
(1978 U.S. Dollars Per Barrel)

	U.S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Economics Relative to Caribbean Hydroskimming				
Costs:				
Feedstock*	(0.94)	(1.35)	(1.32)	(1.21)
Operating	(0.35)	(0.59)	(0.50)	(0.51)
Product Transport	(0.86)	(0.84)	(0.81)	(0.78)
Subtotal	(2.15)	(2.78)	(2.63)	(2.50)
Product Slate Value-New York Harbor	0.09	1.95	2.47	3.02
Gross Margin	(2.06)	(0.83)	(0.16)	0.51
Economics Relative to Rotterdam Hydroskimming				
Costs:				
Feedstock*	(0.50)	(0.91)	(0.88)	(0.77)
Operating	(0.35)	(0.59)	(0.50)	(0.51)
Product Transport	(0.35)	(0.33)	(0.30)	(0.27)
Subtotal	(1.20)	(1.83)	(1.68)	(1.55)
Product Slate Value-New York Harbor	(0.16)	1.70	2.22	2.76
Gross Margin	(1.36)	(0.13)	0.54	1.21

* Includes Butanes

TABLE B-4

COMPARATIVE ECONOMICS - EXISTING REFINERIES
MODIFIED CARIBBEAN REFINERY 1985 SENSITIVITY CASE
(1978 U.S. Dollars Per Barrel)

	U.S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Economics Relative to Modified Caribbean Hydroskimming				
Costs:				
Feedstock*	(0.55)	(0.96)	(0.93)	(0.82)
Operating	(0.10)	(0.35)	(0.25)	(0.26)
Product Transport	(0.83)	(0.81)	(0.78)	(0.75)
Subtotal	(1.48)	(2.11)	(1.96)	(1.83)
Product Slate Value-New York Harbor	(1.92)	(0.06)	0.46	1.00
Gross Margin	(3.40)	(2.17)	(1.50)	(0.83)
Capital Charges				
Depreciation	0.43	0.43	0.43	0.43
10% ATROI	0.43	0.43	0.43	0.43
	0.86	0.86	0.86	0.86
Net	(2.54)	(1.31)	(0.64)	0.03

TABLE B-5

REFINED PRODUCT PRICE DIFFERENTIALS
NEW YORK HARBOR
(1978 U.S. Dollars Per Barrel)

	Actual*		Pace Reference Case	
	1978	1979	1980	1985
Premium Gasoline	0.15	0.13	0.21	0.21
Unleaded Gasoline (Base)	0.0	0.0	0.0	0.0
Regular Gasoline	(1.14)	(1.45)	(1.47)	(1.68)
Kerosene/Jet-A	(1.17)	(1.12)	(1.34)	(1.26)
No. 2 Fuel Oil	(1.93)	(3.17)	(2.44)	(2.52)
Residual Fuel Oil				
0.3 wt.% S	(3.42)	(3.05)	(3.02)	(3.36)
1.0 wt.% S	(4.42)	(6.23)	(7.20)	(7.78)
3.0 wt.% S	(6.14)	(10.21)	(10.08)	(10.92)

* Based on average annual terminal prices

TABLE B-6

NEW REFINERY ECONOMICS SUMMARY
1985 REFERENCE CASE
(1978 U.S. Dollars)

	Total Refinery Investment (Million Dollars)	Net Operating Margin (Dollars per Barrel)	After Tax ROI (Percent)
Low Conversion			
U.S. East Coast	650	1.36	11.0
U.S. Gulf Coast	555	0.92	8.5
Caribbean	621	3.00	25.5
Rotterdam	535	1.37	13.5
Mexico	629	3.55	29.5
Middle East	891	1.58	9.5
High Conversion			
U.S. East Coast	839	1.60	10.0
U.S. Gulf Coast	713	1.22	9.0
Caribbean	802	3.53	23.0
Rotterdam	683	1.67	13.0
Mexico	800	4.59	30.0
Middle East	1002	2.03	11.5

C

PROCESSING CONFIGURATIONS

EXISTING REFINERIES

We simulated the 1980 and 1985 operation of the following types of existing refineries:

Location	Size (MBPSD)	Description
United States Gulf Coast	20	Hydroskimming
	50	Low Conversion
	100	High Conversion
	335	High Conversion
Caribbean	400	Hydroskimming
Rotterdam	300	Hydroskimming

Refineries in each of the United States Gulf Coast refinery categories considered are documented in Table C-1. Some of the refineries listed in Table C-1 are inland and do not directly sell products into the United States East Coast market. However, these refiners sell products into their local markets in competition with refiners whose alternative market is the United States East Coast. Therefore, the economics of these inland refineries are also affected by the United States East Coast market. As shown, the conversion level of Gulf Coast refineries increases as the size of the refinery increases. A number of the small refineries are essentially hydroskimming facilities built by owners of local domestic crude oil supplies to supply local markets. Many of these refineries also supply feedstock to lube oil and asphalt operations. Many of the refiners in the 15 to 30 thousand barrels per stream day size range have gasoline reforming capabilities. We have included limited reforming capability in the Hydroskimming—20 MBPSD refinery simulation.

Most of the refineries in the Low Conversion—50 MBPSD category are owned by independent refiners. The independents also account for a number of the High Conversion—100 MBPSD type refineries. However, most of the large, integrated Gulf Coast refinery facilities belong to the major oil companies. Processing configurations of the United States Gulf Coast refinery types considered are typical of the refineries in each category. Refinery petrochemical operations have been excluded in our simulations.

The majority of the surplus capacity in the Caribbean represents a large hydroskimming operation. Visbreaking and a large portion of the vacuum gas oil hydrotreating are dedicated to Venezuela crude oil processing and are currently operating at capacity, essentially representing a baseload operation. Since these Caribbean conversion facilities were installed specifically to process Venezuelan oil and are a major outlet for that country's crude oil exports, it can be assumed that Venezuelan crude oil pricing will be such to maintain current operations.

The primary objective of this study is to assess the ability of United States refiners to compete with spare foreign refining capacity, i.e., a hydroskimming operation in the Caribbean, once United States crude oil prices equate to world levels. Therefore, in our simulation of the operation of surplus Caribbean refining capacity, we have excluded from consideration the following units in Lago Oil and Transport Company's Aruba refinery and Shell Curacao's facility which are dedicated to Venezuelan crude oil processing.

	Unit Capacity (MBPSD)	
	Lago-Aruba	Shell-Curacao
Crude Oil Distillation	300	160
Vacuum Distillation	120	
Visbreaking	210	90
Distillate HDS	32	40
Vacuum Gas Oil HDS	105	-

The Caribbean hydroskimming refinery simulated includes limited reforming and vacuum gas oil hydrotreating capabilities. The nominal capacity of 400 MBPSD for the Caribbean hydroskimming refinery represents economics of scale typical in the Caribbean export facilities. Even with a majority of the Venezuelan crude oil processing considered as a separate operation, common maintenance crews, supervisory/administrative staffs, and other offsite facilities result in average costs for the hydroskimming operation typical of that for a 400 MBPSD facility.

The majority of the export refineries in the Netherlands are also large hydroskimming facilities with gasoline reforming. The Shell Nederland NV Pernis refinery is the only export facility with catalytic or thermal cracking. The typical Rotterdam export refinery simulated includes reforming, but no cracking or vacuum gas oil desulfurization facilities.

The configurations for the existing refinery simulations are provided in Table C-2.

NEW REFINERIES

The following new refinery locations are considered in this study:

- United States East Coast
- United States Gulf Coast
- Caribbean
- Rotterdam
- Mexico
- Middle East

The conversion level of a new refinery built to serve the United States refined products market in the mid-1980s is not certain. We have simulated both a high and low conversion operation for refinery locations considered to bracket the possible range.

We allowed the Pace Refinery LP Model to optimize the processing unit utility for each refinery location and conversion type. Limitations placed on the new refineries' operation which affect the processing configuration are:

- Only unleaded gasoline production - no use of tetraethyl lead.
- No sales of naphtha - this increases reforming to produce unleaded gasoline.
- Distillate fuel oil sulfur levels were restricted to 0.2 weight percent to match typical 1985 United States East Coast product requirements - this determines distillate hydrotreating requirements.
- The residual fuel oil pool mix by sulfur grade was required to match expected 1985 East Coast consumption requirements as shown in the following table:

Wt. % S	Percent
0.30	14
0.50	22
0.75	11
1.00	44
3.00	9
	100

Resultant new refinery configurations for each location are provided in Table C-3. Variations in processing unit sizes in each location are due to differences in crude oil slates and refinery fuel sulfur restrictions.

TABLE C-1

UNITED STATES GULF COAST REFINERIES BY TYPE

	Crude Capacity		MBPSD					
	MBPCD	MBPSD	Catalytic Reforming	Aklylation	Catalytic Cracking	Hydrocracking	Delayed Coking	Other Thermal Cracking
Hydroskimming - 20 MBPSD								
Existing Capacity/January 1, 1979								
Adobe Refining Corp./La Blanca, Tx.	5.0	5.0	-	-	-	-	-	-
Amerada-Hess Corp./Purvis, Miss.	30.0	31.5	5.4	5.2	16.2	[illegible]	7.0	-
Bayou State Oil Corp./Hosston, La.	5.0	5.0	-	-	-	-	-	-
Berry Petroleum/Stevens, Ark.	2.9	3.0	-	-	-	-	-	-
Calcasieu Refining Ltd./Lake Charles, La.	6.0	6.0	-	-	-	-	-	-
Calumet Refining Co./Princeton, La.	2.4	2.4	-	-	-	-	-	-
Canal Refining Co./Church Point, La.	6.4	6.5	-	-	-	-	-	-
Carbonit Refining, Inc./Hearne, Tx.	10.0	11.0	-	-	-	-	-	-
Clairborne Gasoline Co./Hibon, La.	6.5	6.7	-	-	-	2.3	-	-
Cotton Valley Solvents/Cotton Valley, La.	11.0	11.2	-	-	-	-	-	-
Cross Oil & Refining Co./Smackover, Ark.	8.6	8.8	-	-	-	-	-	-
Dorchester Refining Co./Mt. Pleasant, Tx.	26.0	29.5	5.0	2.4	10.0	-	-	-
Eddy Refining Co./Houston, Tx.	3.5	3.5	-	-	-	-	-	-
Ergon Refining, Inc./Vicksburg, Miss.	10.0	10.0	-	-	-	-	-	-
Erickson Refining Co./Port Neches, Tx.	30.0	32.0	-	-	-	-	-	-
Evangeline Refining Co., Inc./Jennings, La.	5.0	5.0	0.6	-	-	-	-	-
Flint Chemical Co./San Antonio, Tx.	1.2	1.4	-	-	-	-	-	-
Gulf Oil Corp./Venice, La.	28.7	29.1	18.0	-	-	11.5	-	-
Gulf States Oil & Refining Co./ Corpus Christi, Tx.	12.5	12.5	-	-	-	-	-	-
Hill Petroleum Co./Krotz Springs, La.	10.1	10.7	-	-	-	-	-	-
Howell Corp./San Antonio, Tx.	3.0	3.0	1.3	-	-	-	-	-
Hunt Oil Co./Tuscaloosa, Ala.	28.5	29.9	5.5	-	-	-	-	-
Independent Refining Corp./Winnie, Tx.	16.0	15.4	7.7	-	-	3.[illegible]	-	-
La Jet, Inc./St. James, La.	20.0	21.0	-	-	-	-	-	-
Longview Refining Co./Longview, Tx.	8.8	9.0	5.5	-	-	-	-	-
MacMillan Ring-Free Oil Co./ Norphlet, Ark.	4.4	4.5	-	-	-	-	-	-
Marion Corp./Theodore, Ala.	25.0	26.0	4.5	-	-	-	-	-
Mobile Bay Refinery Co./Chickasaw, Ala.	28.0	30.0	3.0	-	-	-	-	-
Mt. Airy Refining Co./Mt. Airy, La.	13.6	14.2	-	-	-	-	-	-
Pioneer Refining Ltd./Nixon, Tx.	4.9	5.0	-	-	-	-	-	-
Quitman Refining Co./Quitman, Tx.	6.0	5.7	-	-	-	-	-	-
Rancho Refining Co./Donna, Tx.	1.2	1.1	-	-	-	-	-	-
Saber Refining Co./Corpus Christi, Tx.	20.0	21.0	-	-	-	-	-	-
Sector Refining Co./Tucker, Tx.	9.7	10.0	-	-	-	-	-	-
Sentry Refining, Inc./Corpus Christi, Tx.	10.0	10.0	-	-	-	-	-	-
Shepherd Oil, Inc./Mermentau, La.	10.0	10.0	-	-	-	-	-	-
Sigmor Refining Co./Three Rivers, Tx.	22.8	24.0	8.5	-	-	-	-	-
South Hampton Refining Co./Silsbee, Tx.	20.5	22.5	4.0	-	-	-	-	-
Texas Asphalt & Refining Co./Euless, Tx.	5.0	6.0	-	-	-	-	-	-
Thriftway, Inc./Graham, Tx.	1.8	2.5	-	-	-	-	-	-
Tipperary Corp./Ingleside, Tx.	6.5	6.5	-	-	-	-	-	-
T & S Refining, Inc./Jennings, Tx.	10.2	11.0	-	-	-	-	-	-
Southland Oil Co./Humberton, Miss.	5.7	6.6	-	-	-	-	-	-
Southland Oil Co./Sandersville, Miss.	11.0	12.5	-	-	-	-	-	-
Southland Oil Co./Yazoo City, Miss.	3.8	4.5	-	-	-	-	-	-
Vulcan Refining Co./Cordova, Ala	10.6	11.4	-	-	-	-	-	-
Warrior Asphalt Co./Holt, Ala.	2.9	3.0	-	-	-	-	-	-
Winston Refining Co./Fort Worth, Tx.	20.0	20.5	1.7	-	3.4	-	-	-
Subtotal	550.7							

Table C-1
Page Two

	Crude Capacity MBPCD	Crude Capacity MBPSD	Catalytic Reforming (MBPSD)	Aklylation (MBPSD)	Catalytic Cracking (MBPSD)	Hydrocracking (MBPSD)	Delayed Coking (MBPSD)	Other Thermal Cracking (MBPSD)
Additions/1979-1980								
Lake Charles Refining Co./ Lake Charles, La.	28.0	30.0	8.0	-	-	-	-	30.0
Calcasieu Refining Ltd./Lake Charles, La.	4.0	4.0	-	-	-	-	-	-
Cross Oil & Refining Co./Smackover, Ark.	2.0	2.0	-	-	-	-	-	-
International Processors/St. Rose, La.	28.8	30.0	-	-	-	-	-	-
Harbor Refining/Derby, Tx.	5.0	5.0	-	-	-	-	-	-
Gulf States/Corpus Christi, Tx.	7.5	7.5	-	-	-	-	-	-
Refinery Services/Westwego, La.	10.0	10.0	-	-	-	-	-	-
Ergon Refining Inc./Vicksburg, Miss.	19.0	20.0	-	-	-	-	-	-
Pioneer Refining Ltd./Nixon, Tx.	5.0	5.0	-	-	-	-	-	-
Tipperary Refining Corp./Ingleside, Tx.	10.0	10.0	-	-	-	-	-	-
La Jet Inc./St. James, La.	29.0	31.0	-	-	-	-	-	-
Burnside Refining/Burnside, La.	35.0	37.0	-	-	-	-	-	-
Placid Refining Co./Mont Belvieu, Tx.	12.0	12.0	-	-	-	-	-	-
Hill Petroleum/Krotz Springs, La.	30.0	30.0	12.0	-	-	-	-	-
Novex Refining Inc./Oiltanking, Tx.	10.0	10.0	-	-	-	-	-	-
Subtotal	235.3							
TOTAL	786.0							
Low Conversion - 50 MBPSD								
Existing Capacity/January 1, 1979								
Atlas Processing Co./Shreveport, La.	45.0	47.4	10.0	-	-	-	-	-
Charter International Oil Co./Houston, Tx.	65.0	70.0	13.5	4.5	40.0	-	-	10.0
Louisiana Land & Exploration Co./ Seraland, Ala.	41.3	40.0	13.1	-	-	-	-	-
Marathon Oil Co./Texas City, Tx.	66.0	68.0	8.0	11.0	38.0	-	-	-
Placid Refining Co./Port Allen, La.	34.2	36.0	5.5	-	-	-	-	-
Sun Co., Inc./Corpus Christi, Tx.	57.0	60.0	24.0	7.3	25.0	-	7.7	-
Texaco, Inc./Port Neches, Tx.	47.0	49.0	-	-	-	-	-	-
Tosco Corp./El Dorado, Ark.	47.0	48.3	5.8	4.5	15.5	-	-	-
Subtotal	402.5							

Table C-1
Page Three

	Crude Capacity		MBPSD					
	MBPCD	MBPSD	Catalytic Reforming	Aklylation	Catalytic Cracking	Hydrocracking	Delayed Coking	Other Thermal Cracking
Additions/1979-1980								
Atlas Processing Co./Shreveport, La.	25.0	26.2	2.0	-	-	-	-	-
La Gloria Oil & Gas Co./Tyler, Tx.*	45.9	46.4	15.6	4.7	16.5	-	24.0	3.0
Howell Corp./Corpus Christi, Tx.	53.0	55.0	9.5	-	-	1.0	-	-
Placid Refining Co./Port Allen, La.	5.0	6.0	-	3.6	16.5	-	-	-
Uni Refining Inc./Ingleside, Tx.*	40.5	42.5	12.0	5.2	17.0	-	-	-
Subtotal	169.4							
TOTAL	571.9							

High Conversion - 100 MBPSD

	MBPCD	MBPSD	Catalytic Reforming	Aklylation	Catalytic Cracking	Hydrocracking	Delayed Coking	Other Thermal Cracking
Existing Capacity/January 1, 1979								
American Petrofina, Inc./Port Arthur, Tx.	90.0	110.0	22.0	2.5	34.0	-	-	10.0
Crown Central Petroleum Co./ Houston, Tx.	100.0	103.0	22.0	10.0	50.0	-	9.5	-
Murphy Oil Corp./Meraux, La.	92.5	95.4	23.0	3.0	10.5	-	-	-
Tenneco Oil Co./Chalmette, La.	115.0	120.0	35.0	5.0	22.0	18.0	9.0	-
Texaco, Inc./Convent, La.	140.0	146.0	30.0	12.5	70.0	-	-	12.0
Texas City Refining Co./Texas City, Tx.	119.6	130.0	11.0	-	35.0	-	-	-
Southwestern Refining Co./ Corpus Christi, Tx.	120.0	122.5	30.0	4.0	12.0	-	-	-
Union Oil Co./Beaumont, Tx.	120.0	125.0	36.0	4.2	38.0	-	-	-
Subtotal	897.1							
Additions/1979-1980								
Union Oil Co./Beaumont, Tx.	30.0							
Subtotal	30.0							
TOTAL	927.1							

Table C-1
Page Four

	Crude Capacity MBPCD	Crude Capacity MBPSD	Catalytic Reforming (MBPSD)	Aklylation (MBPSD)	Catalytic Cracking (MBPSD)	Hydrocracking (MBPSD)	Delayed Coking (MBPSD)	Other Thermal Cracking (MBPSD)
High Conversion - 335 MBPSD								
Existing Capacity/January 1, 1979								
Amoco Oil Co./Texas City, Tx.	415.0	432.0	134.0	31.0	184.0	42.0	33.5	-
Atlantic Richfield/Houston, Tx.	363.0	381.0	95.0	9.0	76.0	-	30.0	-
Cities Service Co./Lake Charles, La.	291.0	303.0	46.0	33.0	125.0	-	28.0	-
Coastal States Petrochemical Co./ Corpus Christi, Tx.	185.0	193.0	35.0	2.5	19.0	-	12.0	-
Exxon Co., U.S.A./Baytown, Tx.	640.0	668.0	148.0	26.0	145.0	21.0	-	-
Exxon Co., U.S.A./Baton Rouge, La.	500.0	540.0	83.0	29.8	154.8	25.0	50.0	-
Gulf Oil Co./Belle Chasse, La.	195.9	202.0	37.5	28.4	78.0	-	16.0	-
Gulf Oil Co./Port Arthur, Tx.	334.5	342.0	65.0	20.0	120.0	15.0	30.0	-
Marathon Oil Co./Garysville, La.	200.0	205.0	37.5	21.5	75.0	-	-	-
Mobil Oil Corp./Beaumont, Tx.	325.0	335.0	102.0	12.0	114.0	29.0	27.0	-
Shell Oil Co./Deer Park, Tx.	285.0	310.0	68.0	7.9	70.0	-	-	85.0
Shell Oil Co./Norco, La.	230.0	240.0	46.0	13.5	10.0	24.0	18.0	47.0
Texaco/Port Arthur, Tx.	406.0	423.0	60.0	15.0	135.0	15.0	-	18.0
Champlin Petroleum Co./ Corpus Christi, Tx.	155.0	159.0	31.3	17.6	65.0	-	-	-
Chevron, U.S.A./Pascagoula, Miss.	280.0	290.0	90.0	9.2	56.0	68.0	-	-
Subtotal	4,805.0							
Additions/1979-1980								
Dow Chemical Co./Brazosport, Tx.	200.0	210.0	-	-	-	-	-	-
Continental Oil Co./Lake Charles, La.*	165.0	168.0	18.5	4.5	30.6	-	8.5	7.0
Good Hope Refineries Inc./ Good Hope, La.*	185.0	195.0	34.5	-	80.0	-	-	-
Phillips Petroleum Co./Sweeney, Tx.*	185.0	190.0	36.0	10.5	85.5	-	-	-
Subtotal	735.0							
TOTAL	5,540.0							

* Change in refinery category with crude capacity expansion

TABLE C-2

REFINERY MODEL CONFIGURATION - EXISTING REFINERIES
(Percent of Crude Oil Distillation Capacity)

	Caribbean Hydro-skimming 400 MBPSD	Rotterdam Hydro-skimming 300 MBPSD	U.S. Gulf Coast Hydro-skimming 20 MBPSD	U.S. Gulf Coast Low Conversion 50 MBPSD	U.S. Gulf Coast High Conversion 100 MBPSD	U.S. Gulf Coast High Conversion 335 MBPSD
Crude Oil Distillation	100.0	100.0	100.0	100.0	100.0	100.0
Vacuum Crude Distillation	27.5	-	20.4	28.7	28.0	41.9
Reforming						
Cyclic	-	-	-	-	-	10.3
Semi-Regenerative	6.3	10.7	11.0	22.0	23.0	11.9
Alkylation (Product)	-	-	-	5.0	5.0	5.4
Catalytic Cracking	-	-	0	19.0	21.0	27.6
Hydrocracking	-	-	-	-	-	5.4
Delayed Coking	-	-	-	-	4.0	6.9
Hydrotreating						
Naphtha	6.3	10.2	10.5	18.4	19.4	16.5
Distillate	3.8	5.1	-	-	3.3	3.5
Vacuum Gas Oil	10.9	-	-	-	0.8	6.0

TABLE C-3

REFINERY MODEL CONFIGURATION - NEW REFINERIES
(Percent on Crude Oil Distillation Capacity)

Conversion Type:	U.S. East Coast 150 MBPSD Low	U.S. East Coast 150 MBPSD High	U.S. Gulf Coast 150 MBPSD Low	U.S. Gulf Coast 150 MBPSD High	Caribbean 150 MBPSD Low	Caribbean 150 MBPSD High	Rotterdam 150 MBPSD Low	Rotterdam 150 MBPSD High	Mexico 150 MBPSD Low	Mexico 150 MBPSD High	Mid East 150 MBPSD Low	Mid East 150 MBPSD High
Crude Oil Distillation	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Vacuum Crude Distillation	8.0	36.5	8.0	36.5	8.0	36.0	8.0	36.0	16.5	36.5	20.0	8.5
Reforming												
Cyclic	24.5	28.5	24.5	28.5	24.0	28.5	24.0	28.5	27.5	30.0	23.5	26.0
Semi-Regenerative	-	-	-	-	-	-	-	-	-	-	-	-
Alkylation (Product)	-	6.0	-	6.0	-	6.0	-	6.0	-	7.5	-	4.5
Catalytic Cracking	-	21.5	-	21.5	-	21.5	-	21.5	-	26.0	-	10.0
Hydrotreating												
Naphtha	24.5	26.5	24.5	26.5	24.0	26.5	24.0	26.5	27.5	28.0	23.5	23.5
Distillate	19.0	18.5	19.0	18.5	20.0	18.5	20.0	18.5	19.5	21.0	22.5	21.0
ARDS	37.5	41.0	37.5	41.0	34.5	37.5	34.5	38.0	37.5	40.5	40.0	40.5

D

CRUDE OIL

CRUDE OIL SLATE AND QUALITY

Pace set the crude oil slates for the existing and new refineries studied considering the following factors:

- Historical supply sources
- Distribution of declining local production
- Expected trends in foreign crude oil availability by source and quality
- Product slate requirements

Crude oil slates for the refineries studied are documented in Tables D-1 and D-2. Key points are discussed in the following section.

Existing Caribbean Hydroskimming Refinery

Caribbean hydroskimming operations are based on a blend of Middle East and African crude oils. Low sulfur fuel oil requirements determine the use of sweet African crude oil. As discussed previously, we have excluded the majority of Venezuelan crude oil processing in our definition of the Caribbean hydroskimming operation.

In 1978, Caribbean export refineries operated at 60 to 65 percent of capacity. Crude oil consumption by source is typically as follows:

Current Caribbean Export Refineries
Aggregate Crude Oil Slate

Crude Oil Source	MBPCD	Percent: With Venezuelan Oil	Percent: Without Venezuelan Oil
Venezuelan	1,450	70	-
Middle East	200	10	33
African/Indonesian	175	9	29
Trinidad	100	5	17
Other	125	6	21
	2,050	100	100

Source: Pace

We have assumed that the Caribbean export refineries will use a blend of Middle East and African crude oils when increasing their hydroskimming operations to capacity output. We optimized the split between the high sulfur Middle East crude oils and the lighter, low sulfur African crude oils to yield a product slate typical of current hydroskimming operations. The yield of low sulfur residual oil was also specified consistent with the United States East Coast low sulfur fuel requirements. The resultant crude oil mix is summarized in the following table:

Existing Caribbean Hydroskimming Refinery
Crude Oil Slate: 1980-1985

	Percent	°API	Wt.%S
Sour Crude Oil			
Middle East	65	32.5	2.1
Venezuelan	10	26.3	1.5
Subtotal	75	31.7	2.0
Sweet African Crude Oil	25	36.2	0.2
Total	100	32.8	1.5

Existing Rotterdam Hydroskimming Refinery

The Rotterdam hydroskimming refinery's crude oil slate requirements are similar to its Caribbean counterpart. Historically refineries in the Netherlands have also operated on a mix of Middle East and African crude oils:

Netherlands Crude Oil Imports
(Percent)

	1976	1977	1978
Middle East	76	77	74
African	17	17	20
North Sea	-	3	1
Others	7	3	5
	100	100	100

Source: Oil and Energy Trends

As with the Caribbean hydroskimming refinery, we optimized the split between the high sulfur Middle East and the lighter, low sulfur African crude oils to yield a product slate typical of current Rotterdam hydroskimming operations. The resultant crude oil slate for a capacity operation is summarized in the following table:

Existing Rotterdam Hydroskimming Refinery
Crude Oil Slate: 1980-1985

	Percent	°API	Wt.% S
Sour Middle East Crude Oil	85	35.9	1.4
Sweet African Crude Oil	15	36.2	0.2
	100	36.0	1.2

The large hydroskimming refineries in Western Europe have operated at 65 to 70 percent of capacity over the past several years with local European markets the primary outlet for products. To meet base level area product requirements, the Rotterdam hydroskimming refinery has a higher yield of gasoline and distillates compared with its Caribbean counterpart. On the other hand, because the United States East Coast fuel oil market is the Caribbean export refineries' primary outlet, their overall residual fuel oil yield is higher. As a result the crude oil slate at the Rotterdam hydroskimming refinery is a higher quality compared to the Caribbean.

Existing United States Gulf Coast Refineries

The source and quality of the crude oil processed by individual refineries on the United States Gulf Coast are related to the following factors:

- Conversion level of the refinery
- Location of the refinery
- Age of the refinery

A number of the small and medium-sized refineries on the United States Gulf Coast area were built specifically to process local crude oil production. Since 1975 crude oil production in PADD 3 has declined at an average rate of 4.5 percent per year. Pace forecasts PADD 3 crude oil production in 1980 to represent only 89 percent of that in 1975. The expected increase in PADD 3 refineries' dependence on foreign crude oil is shown in the following table:

PADD 3 Crude Oil Slate
(Percent)

	Actual 1976	Actual 1977	Actual 1978*	Pace Forecast 1980	Pace Forecast 1985
Domestic	69.2	61.3	59.8	56.0	54.0
Foreign	30.8	38.7	40.2	44.0	46.0
Total	100.0	100.0	100.0	100.0	100.0

* Based on 10 month average

Source: Energy Data Reports: PAD Districts Supply/Demand, Quarterly

In setting the crude oil slate for the PADD 3 refinery categories studied, we assumed that many of the smaller refineries will preferentially maintain a larger share of the available area crude oil production. Many of these refineries are owned by the independent producers in the area and/or are landlocked with no access to foreign crude supplies. To balance the higher fraction of domestic crude oil use in the smaller refineries, foreign crude oil use in the medium and large size refinery types was set at that level required to net an overall PADD 3 crude oil mix consistent with that forecast for the 1980 to 1985 period. The resultant crude oil slates for each refinery category are summarized in the following table:

Existing U.S. Gulf Coast Refineries
Crude Oil Slate: 1980-1985

	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Crude Oil Mix (% of Total)				
Texas/Louisiana Sour Mix	43.1	31.7	19.2	19.2
Texas/Louisiana Sweet Mix	48.9	36.3	21.8	21.8
Alaskan North Slope	-	-	2.4	10.5
Domestic Subtotal	92.0	68.0	43.4	51.5
Middle East Mix	-	-	5.4	30.8
African Mix	8.0	32.0	51.2	17.7
Foreign Subtotal	8.0	32.0	56.6	48.5
Total	100.0	100.0	100.0	100.0
Crude Slate Quality				
Percent Sour Crude Oil	43.1	31.7	27.0	60.5
Avg. wt. % S	0.70	0.58	0.54	0.96
Avg. °API	34.1	35.0	35.0	33.7

Crude oil imports for the small and medium size refineries in 1977 and 1978 were primarily low sulfur African crudes. Because these refineries do not have the desulfurization facilities in place or under construction to process a significant amount of Middle East crude oils, we have restricted crude oil imports in the Hydroskimming 20 MBPSD, Low Conversion-50 MBPSD, and High Conversion-100 MBPSD refinery categories to the low sulfur grades.

We have also assumed that the average large, high conversion refinery of the United States Gulf Coast will be processing over 35 thousand barrels per calendar day of Alaskan North Slope crude oil by 1980, backing out an equivalent amount of high sulfur Middle East crude oils.

New 1985 Refineries

The basis for selection of the 1985 crude oil slate for the new refineries studied can be summarized as follows:

- The new United States East Coast and Gulf Coast refineries were assumed to operate solely on imported oil. The foreign oil slate was set equivalent to Pace's forecast of the typical 1985 import mix to the areas.
- The crude oil slate for the new Caribbean and Rotterdam refineries was set identical to that for the new United States refineries.
- The new Mexican refinery was assumed to operate 100 percent on Mexican Isthmus crude oil.
- The new Middle East refinery was assumed to operate on the following mix of Saudi Arabian crude oils.

	Percent
Saudi Arabian Light	65
Saudi Arabian Berri	8
Saudi Arabian Medium	11
Saudi Arabian Heavy	16
	100

The crude oil blend and average qualities for the new 1985 refineries are summarized in the following table:

New Refineries
Crude Oil Slate - 1985
(Percent)

	United States Caribbean Rotterdam	Mexican	Middle East
Sour Crude Oil			
Middle East Mix	50	-	100
Mexican Isthmus	15	100	-
Subtotal	65	100	100
Sweet Crude Oil			
African Mix	30	-	-
North Sea	5	-	-
Subtotal	35	-	-
Total	100	100	100
Crude Slate Quality			
Avg. °API	34.0	33.3	32.7
Avg. wt. % S	1.3	1.5	2.0

CRUDE OIL COSTS

The delivered cost of crude oil varies among the refineries studied depending on the refinery location, crude oil source and quality, and means and cost of transporting the crude. Average crude oil costs for the refineries examined in this study are derived in Tables D-3 through D-5 and summarized in the following table:

Average Crude Oil Cost
(1978 U.S. Dollars per Barrel)

Refinery Type	1980	1985
Existing:		
Caribbean Hydroskimming	13.83	14.09
Rotterdam Hydroskimming	14.22	14.53
U.S. Gulf Coast-		
No Conversion-20 MBPSD	14.77	15.03
Low Conversion-50 MBPSD	14.80	15.06
High Conversion-100 MBPSD	14.80	15.06
High Conversion-335 MBPSD	14.72	14.98
New:		
U.S. East Coast Refinery	-	14.70
U.S. Gulf Coast Refinery	-	14.70
Caribbean Refinery	-	14.25
Rotterdam Refinery	-	14.35
Mexican Refinery	-	13.65
Middle East Refinery	-	12.79

The basis for the determination of the average cost of crude oil for each refinery type is as follows:

- Average 1978 FOB postings were used for the foreign crude oils. Changes in the differential between sweet and sour crude oil prices are examined as a sensitivity case. Any across-the-board increases in foreign crude oil prices in real terms (constant 1978 dollars) which do not alter the sweet/sour differential will not significantly affect the relative economics of the refineries studied.
- An exception was made for Mexican Isthmus crude oil. In 1978 the FOB Mexican Isthmus price of $13.10 translated to a significantly lower delivered price on the United States Gulf Coast compared to the similar quality Saudi Arabian Light. In this study we adjusted the FOB price of Mexican Isthmus crude oil to more accurately reflect its true market value. The FOB price was set at the delivered price of Saudi Arabian Light in Rotterdam less transportation from Mexico via a Very Large Crude Carrier (VLCC):

Mexican Isthmus FOB
(1978 U.S. Dollars per Barrel)

	1978	1980	1985
Saudi Light FOB Price	12.70	12.70	12.70
Transport Ras Tanura to Rotterdam	1.11	1.17	1.51
Transport Dos Bocas to Rotterdam	(0.56)	(0.59)	(0.76)
Mexican Isthmus FOB Price	13.25	13.28	13.45

- Transportation costs from the crude oil loading port to the appropriate discharging port were calculated based on the composite vessel size for the route and corresponding charter rate. Pace's forecast of escalation of Worldscale (W.S.) rates in real terms for each shipment mode was used to determine 1980 and 1985 transport costs (in 1978 United States dollars).
- An average 11 cents per barrel unloading charge was used for all foreign oils.
- We have assumed that United States domestic oil will be priced against the delivered price of foreign oil of similar quality. With the basis for deriving the delivered price of foreign oil as outlined previously, we set the wellhead price of sweet and sour PADD 3 crude oil production equivalent to the average 1978 stripper oil price for each type plus the escalation in the transportation cost of moving foreign oil to the United States Gulf Coast.
- Gathering and pipeline costs for PADD 3 crude oil production consumed in United States Gulf Coast refineries were set at an average 40 cents per barrel.
- The delivered price of Alaskan North Slope crude oil on the United States Gulf Coast was set equal to the landed price of Saudi Arabian Light less a 25 cents per barrel quality discount.
- Gathering and pipeline costs for Mexican Isthmus crude oil transported to a Mexican export refinery and Middle East crude oils transported to a Middle East export refinery were estimated at 20 cents per barrel.

The 1980 and 1985 delivered cost of foreign oil to the Caribbean, Rotterdam, United States Gulf Coast, and United States East Coast are derived in Tables D–6 through D–9. The following discharging port was assumed for each refining area:

Area	Port
Caribbean	Aruba
Rotterdam	Rotterdam
U.S. Gulf Coast	Houston
U.S. East Coast	Philadelphia

Refinery gate prices for PADD 3 crude oil production consumed in United States Gulf Coast refineries are provided in Table D-10. The differences in the transportation cost of foreign crude oils is a key factor to the relative economics of United States and offshore refineries. Increases in the delivered price of foreign oil will vary among the refineries studied depending on the crude source and the typical transportation mode to the receiving port. Details of Pace's basis for the transportation costs presented in this study are provided in the following discussion.

Middle East Crude Oils

Transportation via a VLCC (very large crude carrier) is the common means of moving Middle East crude oils to Caribbean and Western European ports. Middle East crude oils destined for United States ports are usually shipped to a Caribbean entrepot and off-loaded into smaller vessels for transshipment to United States ports. This is the basis for the transportation costs for Middle East crudes presented in this study.

VLCCs Charter Rate

The composition of the VLCC and ULCC (ultra large crude carriers) fleet is as follows as of June 30, 1978.

	No.	Percent of Existing Fleet
Total Existing VLCC + ULCC Fleet		
Petroleum company owned vessels	252	35
Privately owned vessels	462	65
	714	100
Private Fleet - Extent of Time Charters		
Charters expiring before 1980	93	13
Chartered beyond 1980	195	27
Free of charters	174	25
	462	65
Extent of Lay-up		
Petroleum company owned vessels	4	1
Privately owned - time chartered until 1980	2	0
Privately owned - time chartered beyond 1980	12	2
Privately owned - free of all charters	83	11
	101	14
On Order with Delivery Scheduled for		
1978	10	1
1979	10	1
1980	1	0
1981	1	0
1982	1	0
	23	3

We consider it doubtful that additional VLCCs will be ordered until a Worldscale rate in the 70 to 80 range is established and full speed operations are resumed. We determined the average 1980 and 1985 cost to move crude oil via VLCC on the basis of the composite Worldscale rate for the existing fleet considering the following charter types:

- Petroleum company owned vessels
- Time charters
- Voyage (spot) charters

We developed a supply/demand balance for VLCCs through 1985 to forecast the escalation of the charter rates. We assumed a 3.0 percent per year growth in crude oil movement via VLCC. Early scrapping or loss was estimated at three vessels per year with an average scrapping age of 18 years. We also assumed that the Worldscale rate for voyage charters would not reach the level equivalent to a full economic return on a new vessel until the VLCC surplus is reduced to 3.5 percent of the fleet.

Currently most of the VLCC and ULCC vessels are engaged in slow steaming operations with an average speed of 11.5 knots compared to a design speed of 16 knots. This 38 percent reduction in speed is equivalent to some 45 million tons hidden tanker carrying capacity. As shown in Table D-11 the continuation of an 11.5 knot average vessel speed through 1982, laid-up vessels as a percentage of the total fleet will drop to the 3.5 percent level. However, realistically by 1981 the speed of the available fleet should begin to increase. Based on the assumption of a 3.0 percent per year growth in VLCC crude oil movements through 1985, followed by a 1.0 percent per year rate (with a 16.0 knot maximum vessel speed) new vessels will not be required until 1988. With a two year delivery date, the W.S. 70 rate, representing recovery of all voyage, operating, and investment costs, should be reached by 1986. The buildup of the Worldscale rate for all economic recovery is summarized in the following:

	Equivalent W.S.	
Vessel Size D.W.T.	250,000	500,000
Capital (0% DCF) costs	17.9	17.9
Operating costs	12.8	11.0
Voyage costs	24.7	20.0
Total at 0% DCF	55.4	48.9
Adjustment to 15% DCF	18.0	18.0
Total at 15% DCF	73.4	66.9

It should be noted that orders will only be placed when it can be clearly seen that W.S. 70 is going to be achieved on a reasonably long-term basis.

The derivation of the composite VLCC/ULCC equivalent Worldscale rate from our forecast of the rate for the major charter types considered is summarized in the following:

VLCC Charter Rates

	Actual 1978		Forecast 1980		Forecast 1985	
	W.S.	Percent	W.S.	Percent	W.S.	Percent
Petroleum Company Vessels	48	39	48	37	60	33
Time Charters:						
1-2 Years	25	15	38	14	70	4
3-5 Years	33	1	39	1	70	5
8 Years	70	29	70	27	70	33
Voyage Charters	27	16	35	21	60	25
Composite	47	100	50	100	64	100

Petroleum Company Owned Vessels

While slow steaming at 11.5 knots, companies are considered to be operating at 0 percent DCF at W.S. 48 until 1981.

The rate for these vessels is allowed to rise steadily to W.S. 70 by the late 1980s.

Time Charters - 1 to 2 Years

The charter rate was allowed to climb to W.S. 70 by 1983 indicating the tightening of the tanker supply.

Time Charters - 3 to 5 Years

Time charters affected for this category during the 1977 to 1978 period ranged W.S. 33.9 to 34.7. We show escalation to W.S. 70 by 1984.

Time Charters - 8 Years

Up to 1980 these charters were fixed prior to the 1973 embargo at W.S. 70. No recent 8-year charters have been reported. However, we have assumed owners are aware of the longer-term situation, and that a rate of W.S. 70 would be fully justified by 1983. It is possible that the rates between 1980 and 1983 might be in the W.S. 60 range which would have the effect of reducing the average rate by about 3 points during these years.

Voyage Charters

Historic voyage charter rates are documented below:

Year	W.S.
1976	29
1977	24
1978	27

As discussed previously, voyage charter rates must reach W.S. 70 by 1986 to provide the necessary economic incentive to justify new tanker construction. We have allowed the voyage charter rates to rise steadily from W.S. 27 in 1978 to W.S. 70 by 1986.

Transshipment Costs

For Middle East crude oils shipped to the United States via Caribbean transshipment terminals we have assumed the following charges:

Transshipment Charges
(1978 U.S. Dollars Per Barrel)

	1980	1985
Terminal Charges	0.16	0.16
Losses	0.09	0.07
Demurrage	0.03	0.03
Total	0.28	0.25

Typical Caribbean terminal charges are:

- 18 cents per barrel including loading and unloading costs and storage for 10 days with a penalty of one cent per barrel per day if this time is exceeded.
- 10 cents per barrel for loading across the dock.

A 250 thousand DWT vessel can be unloaded within 24 hours and a 50 thousand DWT vessel loaded in 12 hours. It should be possible to schedule the arrival of these two vessels together so that the transshipment cost is reduced to:

- one 50 thousand DWT vessel at 10 cents per barrel
- four 50 thousand DWT vessels at 18 cents per barrel
- at an average 16.4 cents per barrel

By 1984 all vessels entering United States ports will be required by the Department of Transportation and United States Coast Guard regulations to use a new system for the cleaning of cargo tanks. This tank cleaning system comprises a crude oil washing (COW) instead of water washing and is only permitted to be used in conjunction with inert gas blanketing system (IGS). There is also an alternative to COW which requires the building of vessels with fully segregated ballast tanks, but this is more expensive. It is almost certain that the application of COW and IGS systems will also be required by Caribbean ports.

The tank cleaning systems will not only reduce pollution but will have a marked effect on cargo losses which are quite significant in transshipment operations.

COW plus IGS reduce transportation losses on average from 0.5 to 0.3 volume percent. We have assumed that by 1983 all vessels engaged in transshipment operations will operate with COW plus IGS. The value of the crude oil losses in the transshipment operations, including storage losses of one percent, is assumed to be as follows:

Transshipment Cargo Losses
(1978 U.S. Dollars)

	Per Barrel Loaded
1980	0.09
1985	0.07

It is difficult to maintain a transshipment operation to the extent that the vessels are fully employed in the three operations of loading, shipment and unloading. Some idle time for company owned or time chartered vessels and demurrage for voyage chartered vessels is almost inevitable, particularly since the latter is typically engaged in a series of six to ten day round trip voyages. We have estimated average demurrage costs to be three cents per barrel.

Transshipment Vessels Charter Rate

United States Gulf Coast and Atlantic ports are limited to receiving vessels sized less than 70 thousand to 80 thousand DWT. Typical average fleet composition is shown in the following table:

Transshipment Fleet Composition (Percent)			
Fleet Composition	U.S. Atlantic Coast Ports	U.S. Gulf Coast Ports	U.S. Average
30 - 39,999 DWT	35	30	33
40 - 49,999 DWT	20	25	22
50 - 59,999 DWT	20	30	25
60 - 69,999 DWT	15	10	13'
70 - 79,999 DWT	10	5	7
Total %	100	100	100
Weighted Average DWT	49,500	48,500	48,900

The world fleet in the 30 thousand to 80 thousand DWT size range, age ownership, scrapping and new buildings on order are provided in Table D-12. The average age of the fleet is 12.5 years and about one-third of the vessels will need to be replaced within five years. Because the proportion of vessels in lay-up is relatively small, the spot charter market has become sensitive to supply/demand imbalances. Orders for 65 new vessels are currently being filled. During the last half of 1978, spot charter rates rose 20 to 50 percent above the level required to justify new construction. During 1979 spot charter rates have risen above W.S. 300. In our forecast we have assumed that additional orders will be placed to ensure a balanced charter situation. However, because a large fraction of the 30 thousand to 80 thousand DWT size range are company owned, long-term charter rates will temper surges in voyage charter rates. Also by the early 1980s the Louisiana Offshore Oil Port, Inc. (LOOP) should be in operation, reducing the requirements for transshipment vessels. We have assumed that in 1980 and 1985 the composite Worldscale rate will average that for full recovery of capital costs equivalent to the long-term charter rate. Our forecast for transshipment vessel charter rates typical for the 1980 to 1985 period is summarized in the following table:

Transshipment Vessels Charter Rates

Vessel Size	1980-1985 (W.S.)	1980-1985 (Percent)
30,000-40,000	123	33
40,000-50,000	112	22
50,000-60,000	106	25
60,000-70,000	90	13
70,000-80,000	84	7
Composite	109	100

African Crude Oils

Because the large Caribbean and Rotterdam refiners are located adjacent to deepwater ports, the average vessel size used to transport African crude oils to Caribbean and Rotterdam ports is considerably larger than that for the voyage to United States ports. The typical composition of the fleet for transport of African oils for 1978 compares as shown in the following.

Fleet Composition
(Percent)

Vessel Size Range (DWT)	U.S. Atlantic Gulf Coast Ports	Caribbean & Rotterdam Ports
30,000 - 50,000	9	2
50,000 - 80,000	52	16
Subtotal	61	18
80,000 - 100,000	17	8
100,000 - 150,000	21	56
VLCC	1	18
Total	100	100

As discussed previously, vessels in the 30 thousand to 100 thousand DWT size range are expected to remain in tight supply. Worldscale rates for all charter types are expected to be equivalent to full recovery of capital costs.

However, about 10 percent of the vessels in the 100 thousand to 150 thousand DWT size range were in lay-up during 1978. Eight new vessels are scheduled to be delivered before 1981. We have assumed that through 1985 new additions in this size category will be in line with demand growth, and with normal scrapping the surplus will be reduced to 5 percent.

The actual 1978 and forecast 1980 and 1985 Worldscale rates for 30 thousand to 100 thousand DWT and 100 thousand to 150 thousand DWT vessels are compared in Table D-13. The composite rate for the fleet carrying African crude oils to United States, Caribbean, and Rotterdam ports is provided in the following table:

African Crude Oil Transport
Composite Charter Rate

	Worldscale Rate		
Port	Actual 1978	Forecast 1980	Forecast 1985
United States	75	81	87
Caribbean, Rotterdam	59	64	83

Mexican Crude Oil

Because of the shallow waters off the Mexican coast, crude oil exported to the United States has been shipped primarily in vessels in the 30 thousand to 50 thousand DWT size range. An offshore single point mooring system which can accommodate VLCCs is currently under construction at Dos Bocas with completion scheduled by the early 1980s.

We have estimated the cost to transport Mexican crude oil to the markets considered in this study on the following basis:

- Transport to both Caribbean and Rotterdam ports will be in VLCCs.
- Average vessel size and charter rates for movement to the United States Gulf Coast and East Coast were assumed to be similar to that for transshipment vessels from the Caribbean.

TABLE D-1

CRUDE OIL SLATE
EXISTING REFINERIES: 1980-1985

	Caribbean Hydro-skimming 400 MBPSD (Percent)	Rotterdam Hydro-skimming 300 MBPSD (Percent)	United States Gulf Coast			
			Hydro-skimming 20 MBPSD (Percent)	Low Conversion 50 MBPSD (Percent)	High Conversion 100 MBPSD (Percent)	High Conversion 335 MBPSD (Percent)
Sour Crude Oil						
Saudi Arabian Mix	50.0	40.0	-	-	5.4	14.9
Iranian Light	3.6	-	-	-	-	6.7
Iranian Heavy	-	3.5	-	-	-	-
Abu Dhabi Murban	-	41.5	-	-	-	6.0
Kuwait Export	11.4	-	-	-	-	3.2
Tia Juana Medium	10.0	-	-	-	-	-
Tx./La. Sour Mix	-	-	43.1	31.7	19.2	19.2
Alaskan North Slope	-	-	-	-	2.4	10.5
Subtotal	75.0	85.0	43.1	31.7	27.0	60.5
Sweet Crude Oil						
Nigerian Mix	17.5	10.5	4.5	13.0	29.8	12.4
Libyan Es Sider	7.5	4.5	1.5	19.0	21.4	5.3
North Sea Ekofisk	-	-	2.0	-	-	-
Tx./La. Sweet Mix	-	-	48.9	36.3	21.8	21.8
Subtotal	25.0	15.0	56.9	68.3	73.0	39.5
Total Crude Oil	100.0	100.0	100.0	100.0	100.0	100.0
Avg. Crude Oil Qualities						
°API	32.8	36.0	34.1	35.0	35.0	33.7
Wt. % S	1.5	1.2	0.7	0.6	0.5	1.0

TABLE D-2

CRUDE OIL SLATE
NEW HIGH AND LOW CONVERSION REFINERIES: 1985

	U.S. East Coast 150 MBPSD (Percent)	U.S. Gulf Coast 150 MBPSD (Percent)	Caribbean 150 MBPSD (Percent)	Rotterdam 150 MBPSD (Percent)	Mexico 150 MBPSD (Percent)	Middle East 150 MBPSD (Percent)
Sour Crude Oil						
Saudi Arabian Mix	30.0	30.0	30.0	30.0	-	100.0
Iranian Light	5.0	5.0	5.0	5.0	-	-
Abu Dhabi Murban	5.0	5.0	5.0	5.0	-	-
Kuwait Export	10.0	10.0	10.0	10.0	-	-
Mexican Isthmus	15.0	15.0	15.0	15.0	100.0	-
Subtotal	65.0	65.0	65.0	65.0	100.0	100.0
Sweet Crude Oil						
Nigerian Mix	21.0	21.0	21.0	21.0	-	-
Libyan Es Sider	9.0	9.0	9.0	9.0	-	-
North Sea Ekofisk	5.0	5.0	5.0	5.0	-	-
Subtotal	35.0	35.0	35.0	35.0	0.0	0.0
TOTAL CRUDE OIL	100.0	100.0	100.0	100.0	100.0	100.0
Avg. Crude Oil Qualities						
°API	34.0	34.0	34.0	34.0	33.3	32.7
Wt. % S	1.3	1.3	1.3	1.3	1.5	2.0

TABLE D-3

CRUDE OIL COST
EXISTING FOREIGN REFINERIES
(1978 U.S. Dollars)

	Caribbean Hydroskimming			Rotterdam Hydroskimming		
		Cost MM$			Cost MM$	
	MBPSD	1980	1985	MBPSD	1980	1985
Saudi Arabian Mix	200.0	962.9	985.3	120.0	582.8	597.2
Iranian Light	14.4	70.4	72.1	-	-	-
Iranian Heavy	-	-	-	10.5	50.6	51.9
Abu Dhabi Murban	-	-	-	124.5	632.1	646.5
Kuwait Export	45.6	214.5	219.7	-	-	-
Nigerian Mix	70.0	355.2	359.9	31.5	160.3	162.5
Libyan Es Sider	30.0	151.7	153.8	13.5	67.2	67.9
Tia Juana Medium	40.0	181.9	182.1	-	-	-
	400.0	1936.6	1972.9	300.0	1493.0	1526.0
Avg. Landed Crude Oil Price ($/Bbl)		13.83	14.09		14.22	14.53

TABLE D-4

CRUDE OIL COST
EXISTING U.S. GULF COAST REFINERIES
(1978 U.S. Dollars)

	Hydroskimming			Low Conversion			High Conversion			Large High Conversion		
		Cost MM$			Cost MM$			Cost MM$			Cost MM$	
	MBPSD	1980	1985	MBPSD	1980	1985	MBPSD	1980	1985	MBPSD	1980	1985
Saudi Arabian Mix	-	-	-	-	-	-	5.4	27.4	28.0	50.0	254.1	259.2
Iranian Light	-	-	-	-	-	-	-	-	-	22.5	116.3	118.7
Abu Dhabi Murban	-	-	-	-	-	-	-	-	-	20.0	105.9	107.9
Kuwait Export	-	-	-	-	-	-	-	-	-	10.7	53.1	54.2
Nigerian Mix	0.9	4.7	4.7	6.5	33.9	34.4	29.8	155.4	157.1	41.5	216.3	218.1
Libyan Es Sider	0.3	1.5	1.6	9.5	49.1	49.7	21.4	110.6	112.9	17.8	91.7	92.2
North Sea Ekofisk	0.4	2.1	2.1	-	-	-	-	-	-	-	-	-
Alaskan North Slope	-	-	-	-	-	-	2.4	12.1	12.5	35.2	176.9	180.5
Tx./La. Sweet Mix	9.8	52.2	53.1	18.1	96.5	98.3	21.8	116.3	118.5	73.0	389.5	396.9
Tx./La. Sour Mix	8.6	42.9	43.7	15.9	79.6	81.1	19.2	96.2	98.1	64.3	322.1	328.7
Total	20.0	103.4	105.2	50.0	259.1	263.5	100.0	518.0	527.1	335.0	1725.9	1756.4
Avg. Landed Crude Oil Price ($/Bbl)		14.77	15.03		14.80	15.06		14.80	15.06		14.72	14.98

TABLE D-5

CRUDE OIL COST
NEW 1985 REFINERIES
(1978 U.S. Dollars)

	U.S. East Coast		U.S. Gulf Coast		Caribbean		Rotterdam		Mexico		Middle-East	
	MBPSD	Cost MM$ 1985	MBPSD	Cost MM$ 1985	MBPSD	Cost MM$ 1985	MBPSD	Cost MM$ 1985	MBPSD	Cost MM$ 1985	MBPSD	Cost MM$ 1985
Saudi Arabian Mix	45.0	233.4	45.0	233.3	45.0	221.7	45.0	224.2	-	-	150.0	671.5
Iranian Light	7.5	39.6	7.5	39.6	7.5	37.6	7.5	38.0	-	-	-	-
Abu Dhabi Murban	7.5	40.5	7.5	40.5	7.5	38.6	7.5	39.0	-	-	-	-
Kuwait Export	15.0	76.1	15.0	76.0	15.0	72.2	15.0	73.0	-	-	-	-
Nigerian Mix	31.5	163.6	31.5	165.0	31.5	162.0	31.5	162.6	-	-	-	-
Libyan Es Sider	13.5	69.2	13.5	70.1	13.5	69.2	13.5	67.8	-	-	-	-
North Sea Ekofisk	7.5	38.2	7.5	38.8	7.5	38.5	7.5	36.9	-	-	-	-
Mexican Isthmus	22.5	111.1	22.5	108.5	22.5	108.3	22.5	111.9	150.0	716.6	-	-
Total	150.0	771.7	150.0	771.8	150.0	748.1	150.0	753.4	150.0	716.6	150.0	671.5
Avg. Landed Crude Oil Price ($/Bbl)		14.70		14.70		14.25		14.35		13.65		12.79

TABLE D-6

CRUDE OIL PRICE DERIVATION
CARIBBEAN REFINERIES
(1978 U.S. Dollars per Barrel)

1980

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Abu Dhabi Murban	Kuwait
FOB Price	12.70	13.22	12.32	12.02	12.81	13.26	12.22
Transportation to Aruba	1.06	1.03	1.08	1.09	1.10	1.02	1.10
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	13.87	14.36	13.41	13.22	14.02	14.39	13.43

African/South American Crude Oils	Nigerian Forcados	Nigerian Bonny Lt.	Libya Es Sider	Tia Juana Medium	North Sea
FOB Price	13.62	13.87	13.68	12.72	13.69
Transportation to Aruba	0.65	0.64	0.66	0.16	0.66
Offloading	0.11	0.11	0.11	0.11	0.11
Total	14.38	14.62	14.45	12.99	14.46

1985

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Abu Dhabi Murban	Kuwait
FOB Price	12.70	13.22	12.32	12.02	12.81	13.26	12.22
Transportation to Aruba	1.37	1.33	1.39	1.41	1.42	1.32	1.42
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	14.18	14.66	13.82	13.54	14.34	14.69	13.75

African/South American Crude Oils	Nigerian Forcados	Nigerian Bonny Lt.	Libya Es Sider	Tia Juana Medium	North Sea	Mexican Isthmus
FOB Price	13.62	13.87	13.68	12.72	13.69	13.45
Transportation to Aruba	0.84	0.83	0.86	0.18	0.85	0.22
Offloading	0.11	0.11	0.11	0.11	0.11	0.11
Total	14.57	14.81	14.65	13.01	14.65	13.78

TABLE D-7

CRUDE OIL PRICE DERIVATION
ROTTERDAM REFINERIES
(1978 U.S. Dollars Per Barrel)

1980

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Iranian Heavy	Abu Dhabi Murban	Kuwait
F.O.B. Price	12.70	13.22	12.32	12.02	12.81	12.49	13.26	12.22
Transportation to Rotterdam	1.17	1.14	1.19	1.21	1.21	1.23	1.13	1.21
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	13.98	14.47	13.62	13.34	14.13	13.83	14.50	13.54

African/South American Crude Oils	Nigerian Forcados	Nigerian Bonny Lt.	Libya Es Sider	North Sea
FOB Price	13.62	13.87	13.68	13.69
Transportation to Rotterdam	0.69	0.68	0.44	0.19
Offloading	0.11	0.11	0.11	0.11
Total	14.42	14.66	14.23	13.99

1985

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Iranian Heavy	Abu Dhabi Murban	Kuwait
FOB Price	12.70	13.22	12.32	12.02	12.81	12.49	13.26	12.22
Transportation to Rotterdam	1.51	1.47	1.54	1.56	1.56	1.59	1.46	1.56
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	14.32	14.80	13.97	13.69	14.48	14.19	14.83	13.89

African/South American Crude Oils	Nigerian Forcados	Nigerian Bonny Lt.	Libya Es Sider	North Sea	Mexican Isthmus
FOB Price	13.62	13.87	13.68	13.69	13.45
Transportation to Rotterdam	0.89	0.88	0.58	0.225	0.76
Offloading	0.11	0.11	0.11	0.11	0.11
Total	14.62	14.86	14.37	14.05	14.21

TABLE D-8

CRUDE OIL PRICE DERIVATION
U.S. GULF COAST REFINERIES-FOREIGN CRUDE OIL
(1978 U.S. Dollars Per Barrel)

1980

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Abu Dhabi Murban	Kuwait
FOB Price	12.70	13.22	12.32	12.02	12.81	13.26	12.22
Transportation to Aruba	1.06	1.03	1.08	1.09	1.10	1.02	1.10
Transshipment Terminal Charges	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Transportation to Houston	0.47	0.46	0.48	0.49	0.47	0.46	0.47
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	14.62	15.10	14.27	13.99	14.77	15.13	14.18

African/South American Crude Oils	Nigerian Forcadose	Nigerian Bonny Lt.	Libya Es Sider	North Sea
FOB Price	13.62	13.87	13.68	13.69
Transportation to Houston	1.05	1.03	0.97	0.92
Offloading	0.11	0.11	0.11	0.11
Total	14.78	15.01	14.76	14.72

1985

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Abu Dhabi Murban	Kuwait
FOB Price	12.70	13.22	12.32	12.02	12.81	13.26	12.22
Transportation to Aruba	1.37	1.33	1.39	1.41	1.42	1.32	1.42
Transshipment Terminal Charges	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Transportation to Houston	0.47	0.46	0.48	0.49	0.47	0.46	0.47
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	14.91	15.38	14.56	14.29	15.07	15.41	14.48

African/South American Crude Oils	Nigerian Forcados	Nigerian Bonny Lt.	Libya Es Sider	North Sea	Mexican Isthmus
FOB Price	13.62	13.87	13.68	13.69	13.45
Transportation to Houston	1.12	1.11	1.05	0.98	0.25
Offloading	0.11	0.11	0.11	0.11	0.11
Total	14.85	15.09	14.84	14.78	13.81

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TABLE D-9

CRUDE OIL PRICE DERIVATION
U.S. EAST COAST REFINERY
(1978 U.S. Dollars Per Barrel)

1980

Persian Gulf Crude Oils	Arabian Light	Arabian Berri	Arabian Medium	Arabian Heavy	Iranian Light	Iranian Heavy	Abu Dhabi Murban	Kuwait
FOB Price	12.70	13.22	12.32	12.02	12.81	12.49	13.26	12.22
Transportation to Rotterdam	1.37	1.33	1.39	1.41	1.42	1.44	1.32	1.42
Transshipment Terminal Charges	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Transportation to Philadelphia	0.48	0.47	0.49	0.50	0.48	0.49	0.47	0.49
Offloading	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Total	14.92	15.39	14.57	15.30	15.08	14.79	15.42	14.50

African/South American Crude Oils	Nigerian Forcados	Nigerian Bonny Lt.	Libya Es Sider	North Sea	Mexican Isthmus
FOB Price	13.62	13.87	13.68	13.69	13.45
Transportation to Philadelphia	0.99	0.98	0.85	0.76	0.55
Offloading	0.11	0.11	0.11	0.11	0.11
Total	14.72	14.96	14.64	14.56	14.11

TABLE D-10

CRUDE OIL PRICE DERIVATION
U.S. GULF COAST REFINERIES-DOMESTIC CRUDE OIL
(1978 U.S. Dollars)

	°API	Wt.%S	Price ($/Bbl) 1980	Price ($/Bbl) 1985
Texas/Louisiana Sour·Mix				
West Texas Sour	34.6	1.40	13.69	13.69
West Texas Intermediate	39.8	0.49	14.85	14.85
East Texas Hawkins	26.6	2.45	12.88	12.88
Average Wellhead Price	34.6	1.35	13.82	13.82
Foreign Crude Oil Freight Cost Escalation Adjustment			0.09	0.35
Gathering and Pipeline Charges			0.40	0.40
Average Refinery Gate Price			14.31	14.57
Texas/Louisiana Sweet Mix				
East Texas Sweet	39.1	0.25	14.83	14.83
Central Texas Conroe	34.6	0.10	14.84	14.84
Louisiana Offshore Empire	30.5	0.30	14.66	14.66
South Louisiana Southline	34.5	0.23	14.74	14.74
Average Wellhead Price	33.5	0.21	14.75	14.75
Foreign Crude Oil Freight Cost Escalation Adjustment			0.09	0.35
Gathering and Pipeline Charges			0.40	0.40
Average Refinery Gate Price			15.24	15.50

TABLE D-11

VLCC - ULCC SUPPLY/DEMAND BALANCE

End of Year	Original Fleet	Cumulative Loss/Damage/ Scrap	Available Fleet	Vessels Required @11.5 knots	Laid-Up & Idle		Fleet in Active Service @ 16.0 Knots	
					No.	Percent	No.	Percent*
1978	724	1	723	624	99	13.5	-	-
1979	734	4	730	646	84	11.5	-	-
1980	735	7	728	668	60	8.0	-	-
1981	736	10	726	688	38	5.0	-	-
1982	737	13	724	707	25	3.5	19	3
1983	737	16	721	728	25	3.5	79	11
1984	737	20	717	749	25	3.5	140	20
1985	737	24	713	771	25	3.5	204	29
1986	737	27	710	782	25	3.5	239	34
1987	737	44	693	794	25	3.5	284	41
1988	737	112	625	806	25	3.5	506	81
1989	737	182	555	818	25	3.5	555	100
1990	737	252	485	830	25	3.5	485	100

* Calculated percentage at 16.0 knots with balance at 11.5 knots (slow steaming)

TABLE D-12

FLEET CHARACTERISTICS
30,000 - 80,000 DWT

Existing Fleet	30,000/ 40,000	40,000/ 50,000	50,000/ 60,000	60,000/ 70,000	70,000/ 80,000	30,000/ 80,000
Petroleum company owned vessels	169	94	66	33	49	411
Privately owned vessels	267	61	92	92	83	595
Total	436	155	158	125	132	1006
Average age (years)	10.5	16.5	15.0	13.0	11.5	12.5
Scrapping (as of June 1978)	66	66	43	43	43	109
New buildings (through 1980)	30	5	13	11	8	67

TABLE D-13

CHARTER RATES
FOR
AFRICAN CRUDE OIL TRANSPORT

	Percent of Total	Worldscale Rate Actual 1978	Worldscale Rate Forecast 1980	Worldscale Rate Forecast 1985
30,000-100,000 DWT				
Petroleum Company Vessels/ Long-term charters	38	106	106	106
Time Charters:				
1-2 Years	12	83	83	83
3-5 Years	27	91	91	91
Voyage Charters	23	88	105	106
Composite	100	95	99	102
100,000-150,000 DWT				
Petroleum Company Vessels/ Long-term Charters	10	67	67	67
Time Charters:				
1-2 Years	25	54	60	90
3-5 Years	35	60	60	90
Voyage Charters	30	46	60	90
Composite	100	55	61	88

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REFINED PRODUCTS

PRODUCT SLATES AND QUALITIES

Product slates and qualities presented in this study for existing refineries represent typical annual yields for each type. We adjusted historical product slates to account for changing product demand patterns, product specifications, and feedstock quality. Local product consumption requirements were also considered. Resultant product slates for the existing refineries considered in this study are documented in Tables E–1 and E–2.

As discussed previously, we have assumed that the new refineries studied are to serve primarily the United States East Coast refined products market. Two product slates were considered for both a high and low conversion operation to bracket the range in product growth pattern in this market. Product slates for the new 1985 refineries are provided in Table E–3.

Typical current quality specifications for United States, Caribbean, and European refined products markets are provided in Table E–4. For all new refineries considered, all products were assumed to meet United States quality requirements expected for 1985.

Important factors to the product slates for each of the refinery types considered are highlighted in the following text.

Existing Caribbean Hydroskimming Refinery

Currently Caribbean hydroskimming refineries provide product for both local and export markets. By 1980 local consumption requirements will likely absorb most of the gasoline which can be produced. Octane requirements for gasoline in the Caribbean are considerably lower than in the United States. In addition, there are no restrictions on the use of tetraethyl lead (TEL) or other gasoline additives. Therefore, the Caribbean refiner can significantly increase the gasoline yield from his hydroskimming operation by optimizing additives use. The Caribbean hydroskimming operation simulated in this study does produce a small amount of regular gasoline for export when operating at capacity in 1980. Gasoline pool qualities compare as shown in the following table:

Existing Caribbean Hydroskimming Refinery
Gasoline Pool Yield and Quality

	Percent On Crude	RON	MON	TEL (cc/gal)
Caribbean Regular	6.0	85.2	80.2	1.3
Caribbean Premium	4.0	95.0	89.2	2.8
U.S. Regular	0.9	94.0	89.1	2.8
Total Pool	10.9	89.5	84.3	2.0

Currently a large portion of the naphtha surplus (in excess of that which can be blended into the gasoline pool) is consumed in Puerto Rican petrochemical operations. If the Caribbean refineries operate at capacity, the additional naphtha produced would have to be exported from the region. Naphtha yield shown for the Caribbean hydroskimming operation represents the minimum level.

Excluding local bunker fuel consumption, the majority of the distillates and residual fuel oil production is exported from the area. Jet-A production was required to meet the specifications for international carriers. Product qualities for fuel oil production for the Caribbean hydroskimming refinery simulated in this study were set at that for the United States East Coast market. Fuel oil yield and average sulfur content are summarized in the following table:

Existing Caribbean Hydroskimming Refinery
Fuel Oil Pool Yield and Quality

	Percent on Crude	Wt.%S
Diesel/Distillate Fuel Oil	16.5	0.20
Residual Fuel Oil		
0.3-0.5 Wt.%S	13.8	0.45
1.0-3.0 Wt.%S	39.0	2.30
Average Residual	52.8	1.85

The Caribbean hydroskimming refinery typically blends some distillate fractions with residuum in order to meet low sulfur fuel oil requirements on the United States East Coast. In our simulation of this operation, over 38 thousand barrels per stream day of distillate range material is blended into the residual fuel oil pool. This material could be marketed as distillate. However, disposition of the resulting large amount of high sulfur residual oil would certainly pose a problem.

Existing Rotterdam Hydroskimming Refinery

Currently the large hydroskimming refineries in Western Europe are operating at 60 to 65 percent of capacity with a large fraction of their product marketed within the region. We have assumed that when operating at capacity in the 1980–1985 period, the area demand will still consume most of the gasoline which can be produced. In contrast to the Caribbean, most European countries have imposed restrictions on gasoline TEL levels. We restricted gasoline pool lead levels to 1.6 cc per gallon which represents typical area regulations. Gasoline pool qualities are summarized in the following table:

Existing Rotterdam Hydroskimming Refinery
Gasoline Pool Yield and Quality

	Percent On Crude	RON	MON	TEL (cc/gal)
European Regular	9.0	92.0	86.9	1.6
European Premium	4.3	99.0	90.9	1.6
Total Pool	13.3	94.3	88.2	1.6

Naphtha use as a petrochemical feedstock will continue to face competition from LPG and gas oil in the 1980 to 1985 period in both European and export markets. Naphtha yield was minimized in both the Caribbean and Rotterdam hydroskimming operation.

European distillate and residual fuel oil sulfur restrictions are not as rigid as those for the United States East Coast market. Commercial gas oil sulfur levels typically range from 0.2 to 0.3 weight percent sulfur (an 0.25 weight percent average was used in this study). Low sulfur fuel oil production also is significantly lower for the European hydroskimming operation compared with the Caribbean counterpart, with the latter geared more to serve the United States East Coast market requirements. Distillate fuel oil yield, on the other hand, is greater, as only a relatively small amount is blended into the residual pool to produce low sulfur residual fuel oil. Fuel oil yield and the average sulfur content are summarized in the following table:

Existing Rotterdam Hydroskimming Refinery
Fuel Oil Pool Yield and Quality

	Percent on Crude	Wt.% S
Gas Oil/Diesel	30.0	0.25
Residual Fuel Oil		
0.5 wt.% S	2.0	0.50
1.0-3.0 wt.% S	37.7	2.60
Average Residual Oil	39.7	2.30

Jet-A production was also required to meet specifications for international carriers.

Existing United States Gulf Coast Refineries

The existing United States refineries studied show a wide variation in product yields corresponding to the range in conversion levels. Gasoline yield is determined primarily by the reforming, alkylation, and cracking capabilities of the refinery. Gasoline yield ranges from 11 percent for the Hydro-skimming—20 MBPSD refinery to over 44 percent for the High Conversion 335 MBPSD refinery. We have set the gasoline mix by grade and pool TEL level to reflect expected 1980 and 1985 requirements as shown in the following table:

Existing United States Gulf Coast Refineries
Gasoline Pool Composition

	Minimum Specification		Pool Mix Percent	
	RON	MON	1980	1985
U.S. Premium Gasoline*	100.0	93.0	6.5	-
U.S. Unleaded Gasoline	94.0	87.0	48.2	75.0
U.S. Regular Gasoline*	93.0	85.0	45.3	25.0
	93.9	86.5	100.0	100.0

Maximum TEL Level, 1980 - 1985	
cc/gal	0.47
g/gal	0.50

* Leaded grades

Naphtha surplus to that which can be blended into the gasoline pool is sold as product. Naphtha yield was minimized in the 20, 50, and 100 MBPSD refinery categories. A number of the large Gulf Coast refineries have adjacent heavy feedstock (naphtha and gas oil) ethylene plants. We fixed the naphtha yield in the High Conversion – 335 MBPSD refinery at 5.0 percent on crude to account for the average petrochemical feedstock requirements in this size category. Distillate and residual products yields also vary significantly with the conversion level, as shown in the following:

Existing United States Gulf Coast Refineries
Fuel Oil Pool Yield and Quality

	Diesel/No. 2 Oil		Total Residual Products*	
	Percent On Crude	Wt.%S	Percent On Crude	Wt.%S
Hydroskimming-20 MBPSD	24.0	0.2	52.7	1.1
Low Conversion-50 MBPSD	27.8	0.2	32.7	1.1
High Conversion-100 MBPSD	25.1	0.2	22.3	1.5
High Conversion-335 MBPSD	20.8	0.4	20.1	1.7

* Including lubes, waxes, greases, petroleum coke, asphalt feedstocks, plus refinery fuel.

Feedstocks for production of lubes, waxes, and greases are included in the 1.0 weight percent sulfur residual fuel oil pool in our refinery simulations. Bunker fuel and asphalt stock are included in the 3.0 weight percent sulfur residual fuel oil pool. It should be noted that the residual fuel oil category in Energy Information Administration (EIA) and American Petroleum Institute (API) data publications includes only No. 6 fuel oil production (including refinery fuel) plus bunkers.

Catalytic cracking in the Low Conversion—50 MBPSD refinery results in refinery results in increased yield of both gasoline and distillates relative to the Hydroskimming—20 MBPSD refinery. Increased cracking and coking capabilities of the high conversion refineries allow cracking of distillate stocks to produce additional gasoline and jet fuel material. However, the overall yield of distillate fuel is lowered as shown previously. In addition, distillate range material is also blended into the residual fuel oil pool to lower sulfur levels to a marketable level. In 1978 the sulfur content of PADD 3 residual fuel oil (No. 6 oil plus bunkers) averaged 1.6 to 1.7 weight percent. We limited the sulfur content of the residual fuel oil pool in the High Conversion—335 MBPSD refinery to a 1.7 weight percent maximum to maintain current average PADD 3 levels.

New 1985 Refineries

For each of the new refinery locations considered, product slates were determined for both high and low conversion operations. Product yields for the two operations compare as shown in the following table:

New 1985 Refineries Product Slate
(Percent Crude Oil)

	Low Conversion	High Conversion
Gasoline	23.0-27.2	32.5-50.7
Kerosene/Jet-A	0.0- 2.7	0.0- 7.2
Diesel/No.2 Fuel Oil	23.4-25.9	16.1-27.6
Residual Products*	39.6-44.6	22.6-35.4
LPG	2.4- 3.8	2.7- 3.3

* Excluding plant fuel oil

The differences in the yields between refineries at the same conversion level are attributable to differences in the crude oil slates and refinery fuel sulfur restrictions. Limitations placed on refinery fuel sulfur levels are:

	Maximum wt.% S
United States	0.5
Rotterdam	3.0
Caribbean	no restriction
Mexico	no restriction
Middle East	no restriction

Product specifications were set at those expected to prevail in the United States East Coast fuels market in 1985. All gasoline production was assumed to be unleaded. Pace forecasts average unleaded gasoline octane levels to increase in response to market requirements. Unleaded gasoline qualities are as follows:

Unleaded Gasoline Octane—1985

	Averages
RON	93.8
MON	85.8
R+M/2	89.8

No sale of naphtha as product was allowed. Distillate fuel oil levels were set at 0.2 weight percent sulfur. Residual fuel oil production by sulfur grade was required to match Pace's forecast of 1985 PADD 1 residual products demand mix as shown in the following table:

United States PADD 1 Residual Products	
Wt. % S	Percent
0.30	14
0.50	22
0.75	11
1.00	44
3.00	9
	100

REFINED PRODUCT VALUES

Refined Product Price Differential

The relative values placed on gasoline, distillates, and residual fuel oils become a major factor to the relative economics of the refineries studied. In this study, we have compared refinery margins based on projected netback prices for product sales in the United States East Coast refined products market. United States Gulf Coast refineries and foreign imports supply about 75 percent of the refined products consumed on the United States East Coast. United States Gulf Coast refineries supply most of PADD 1's deficit in gasoline and distillates. Gasoline and distillate prices on the United States East Coast have reflected values on the United States Gulf Coast plus transportation to the region.

Residual fuel oil consumption has been concentrated on the East Coast with area demand accounting for 40 to 50 percent of the United States total. Large volumes of foreign imports have been required to supply United States East Coast residual fuel oil demand. For this reason, fuel oil prices on the United States East Coast have reflected world levels corresponding to crude oil prices significantly higher than in the United States. As a result the differential between gasoline and residual fuel oil in the United States has been significantly less than in other world markets. Average annual refined product price differentials for the New York Harbor compare with those for Rotterdam and Singapore market as shown in Table E-5.

Pace considers it likely that with United States crude oil price decontrol, gasoline and distillates will reflect the domestic crude oil price escalation while residual fuel oil prices, previously at world levels in the New York Harbor market, will increase by a significantly smaller amount. Pace's forecast of United States East Coast refined product price differentials with United States crude oil prices at world levels in 1980 and 1985 is provided in the following:

Refined Product Price Differentials
New York Harbor
(1978 U.S. Dollars Per Barrel)

	Actual		Pace Forecast	
	1977	1978	1980	1985
Premium Gasoline	0.21	0.15	0.21	0.21
Unleaded Gasoline	Base			
Regular Gasoline	(0.74)	(1.14)	(1.47)	(1.68)
Light Naphtha (C5/160)	N/A	N/A	N/A	(3.40)
Full Range Naphtha	(1.89)	(1.93)	(1.60)	(1.89)
Kerosene/Jet-A	(0.98)	(1.17)	(1.34)	(1.26)
No. 2 Fuel Oil	(1.36)	(1.93)	(2.44)	(2.52)
Residual Fuel Oil				
0.3 wt.% S (low pour)	(1.41)	(3.42)	(3.02)	(3.36)
0.5 wt.% S (low pour)	(1.84)	(3.78)	(3.44)	(3.78)
1.0 wt.% S	(2.45)	(4.42)	(7.20)	(7.78)
3.0 wt.% S (bunkers)	(3.94)	(6.14)	(10.08)	(10.92)

* Based on average annual terminal prices

Caribbean and European gasoline grades were valued relative to United States premium, unleaded, and regular gasoline, considering the octane rating and lead levels of the grades. Octane number, lead levels, and the differential values of the gaosline grades considered are provided in the following table for reference.

Gasoline Quality Price Differentials

	Octane		TEL	Differential (1978 U.S.$/Bbl)	
	RON	MON	(cc/gal)	1980	1985
U.S. Premium	100.0	93.0	2.8	0.21	0.21
U.S. Unleaded	93.0	85.0	0.0	-	-
U.S. Regular	94.0	87.0	2.8	(1.47)	(1.68)
Caribbean Premium	95.0	89.0	2.8	(0.05)	(1.05)
Caribbean Regular	85.0	80.0	2.8	(1.60)	(1.60)
European Premium	99.0	89.0	1.6	(0.05)	(0.05)
European Regular	92.0	82.0	1.6	(1.25)	(1.25)

We have equated the value of asphalt unit feedstock to that of 3.0 weight percent sulfur residual fuel oil. The green coke produced in the high conversion United States refineries is 2 to 3 weight percent sulfur coke—considered anode quality material. Green coke prices for anode quality ranged $50 to $60 per ton on the United States Gulf Coast during 1978. In this study we have set anode quality green coke value at $60 per ton. Sulfur is valued at $40 per ton.

LPG Prices

Historically, propane and butanes have been priced at a premium relative to distillate fuel oil on a heating value basis in many world markets. However, as shown in Table E-6, the premium value commanded by propane has been decreasing over the past several years. Considering the number of new gas plants expected to come onstream worldwide during the early 1980s, we have assumed that the price of propane will be less than equivalent to the netback price of distillate fuel oil on a heating value basis.

Because of normal butane's value as gasoline blendstock and isobutane's value as a feedstock in gasoline alkylate production, butanes should continue to be priced at a premium relative to distillate fuel oil through the early 1980s. However, as new world supplies come onstream, coupled with an expected decline in gasoline demand, butane prices should decline to near equivalency with distillate fuel oil on a heating value basis by 1985.

Pricing of LPG relative to No. 2 fuel oil is summarized in the following.

LPG/Distillate Heating Value Ratio*

	1980	1985
Propane	0.85	0.75
Normal Butane	1.35	1.05
Iso Butane	1.63	1.18

* Gross BTU basis

Product Transportation Costs To New York Harbor

The costs to move product from each of the refineries studied to New York Harbor terminals are summarized in Table E-7. Our outlook for the charter rates for product carriers is summarized in the following.

Foreign Clean Product Carriers

Essentially all of the clean cargo vessels from Caribbean and Rotterdam refineries to Atlantic ports are in the 20 thousand to 35 thousand DWT size range with an average vessel size of 29 thousand DWT. These vessels are presently fully employed and operated at average W.S. 150 during 1978. Rates increased steadily throughout 1978 as new buildings barely kept up with scrapping. At present 46 percent of the fleet is between 15 and 20 years old with an average age of 12 years. Also, because in the short haul type of trade close coordination of requirement is required, a large majority of the charters are either company or time chartered vessels. Only 14 percent of 1978 movement represented voyage charters.

Between 1980 and 1990 the charter rates will depend largely on the extent of scrapping and new building. We expect supply to just keep up with demand so that charter rates will represent full recovery of capital costs on a new vessel. Derivation of the Worldscale rate which will provide a full capital cost recovery is shown in the following table:

Foreign Clean Cargo Vessel Economics
(Equivalent 1978 Worldscale)

Vessel Size DWT	20,000	25,000	30,000	35,000
Fixed Direct Costs	65.7	55.0	45.1	41.7
Bunkers & Port Charges	52.8	51.0	48.8	43.1
Capital Costs	48.7	44.0	40.0	38.2
Total Costs, W.S.	167.2	150.0	133.9	123.0

On this basis we have assumed that Worldscale rates will average Worldscale 150 for the 1980 to 1985 period.

Foreign Residual Fuel Oil Carriers

For movements of residual fuel oil from Caribbean and Rotterdam ports, the fleet composition is similar to that for crude oil transshipment vessels from the Caribbean terminals. The Worldscale rate forecast for these vessels should also apply to residual fuel oil movements from these regions.

United States Flagships

The supply of United States flag vessels for product movement is currently very tight due to two key factors:

- The number of new United States tankers under construction since 1973 has been quite small.
- Movement of Alaskan crude oil through the Panama Canal to the United States Gulf Coast has reduced tanker availability for product movements.

Mexican Refinery Product

The cost to move product from the new 1985 Mexican refinery was calculated on the same basis as that outlined previously for the Caribbean and Rotterdam refineries.

Middle East Refinery Product

We have assumed that for the long haul from the Middle East refinery to the United States East Coast, product will be moved in 50 thousand to 80 thousand DWT vessels. The Worldscale rate expected to apply to such carriers is provided in the following:

	W.S.
Actual 1978	83
Forecast 1980	92
Forecast 1985	99

United States East Coast Refinery Product

We have included a $0.21 to $0.27 per barrel product transportation cost in the total product costs of a new United States East Coast refinery. With the particularly difficult siting restrictions in the heavily populated areas of the United States East Coast, it is likely that a new refinery would be located a considerable distance from major product markets.

Product movements from the United States Gulf Coast to East Coast ports are in 20 thousand to 40 thousand DWT vessels. The present age and scheduled new building of the United States fleet in this size range are provided in the following:

United States Product Vessels

Size Range 20,000 to 35,000 D.W.T.

Year Built	Number of Vessels	Tonnage Thousand DWT
1958 and earlier	86	2,386
1959 to 1971	21	652
1972 to 1973	0	0
1974	4	110
1975	5	137
1976 to 1978	0	0
Total	116	3,174

New Buildings 20,000 to 35,000 DWT

Delivery Date	Number of Vessels	Tonnage Thousand DWT
1978 (July to Dec.)	1	30
1979	1	30
1980	2	60

As shown in the preceding, about 75 percent of the fleet in this size range is more than ten years old and thus a high scrapping rate is likely over the next five years. However, the tanker tonnage on order does not reflect the serious problem of obsolescence in the present fleet. The number of vessels engaged in grain movements which are suitable for petroleum product transport has been reduced from 33 vessels in late 1977 to less than 17 vessels by late 1978 (590 thousand DWT).

The administration has the power to permit the use of foreign vessels on a voyage-by-voyage basis if it can be shown that no United States flag carriers are available. However, as discussed previously, foreign vessels idle in the 20 thousand to 40 thousand size range represent less than 5 percent of the total fleet. This represents a minimum lay-up level below which charter rates can be expected to rise rapidly. Therefore, rising transport costs for United States coastal trade appear certain.

The voyage charter market represents about 10 percent of the total charters for United States product carriers. The remainder are primarily company owned and long-term charters with very few short-term charters. The voyage charter rates for both clean and dirty cargo movements have increased from American Tanker Rate (AR) 130 to 136 in 1976 to an average AR 165 in 1978, reflecting the tightening in supply. As shown in the following table, voyage charter rates have risen to the level which represents full recovery of capital costs on new construction.

United States Product Vessel Economics

Year Commissioned	1974	1975	1976	1977
Building Price, $/DWT	343	474	531	605
Costs, AR Equivalent				
Fixed Direct Costs	46.2	52.4	58.0	63.3
Bunkers & Port Charges	23.6	24.9	25.5	26.7
Total Direct Costs	69.8	77.3	83.5	90.0
Capital Costs	31.5	43.6	48.5	55.8
Total Costs	101.3	120.9	132.0	145.8

With increasing costs in real terms we expect AR 200 to be representative of company owner time and voyage charters in the 1980 to 1985 period. However, if appropriate action is not taken shortly to boost construction of new United States product carriers, rates could easily jump to AR 250 to 300 by the early 1980s.

New York Harbor Prices–Reference Case

In the 1980 Reference Case analysis of the existing refineries, we have determined the New York Harbor prices which net back a break-even operation for the Caribbean hydroskimming refinery—with the 1980 refined product price differentials as forecast previously. This simulates the situation in which there is substantial spare capacity in 1980, and the offshore refineries could force market prices down to the break-even point for a large hydroskimming operation. This approach allows us to determine the economic advantage/disadvantage of the offshore hydroskimming refineries relative to the United States Gulf Coast refineries considered.

In 1985 we have set the reference level New York Harbor prices at that required to net back a 20 percent before tax return on investment for a new high conversion United States East Coast refinery (with the 1985 refined product price differentials as forecast previously).

The Reference Case 1980 and 1985 New York Harbor prices used in this study are provided in the following table:

New York Harbor Prices-Reference Case
(1978 U.S. Dollars per Barrel)

	Actual 1978	Reference Case 1980	Reference Case 1985
Gasoline			
U.S. Premium	17.86	20.56	-
U.S. Unleaded	17.71	20.35	23.75
U.S. Regular	16.57	18.88	22.07
Caribbean Premium*	-	19.30	22.70
Caribbean Regular*	-	18.75	22.15
European Premium*	-	20.30	23.70
European Regular*	-	19.10	22.50
Full Range Naphtha	15.78	18.75	21.86
Kerosene/Jet-A	16.54	19.01	22.49
Distillate Fuel Oil/Gas Oil	15.78	17.91	21.23
Residual Fuel Oil			
0.3 wt.% S	14.29	17.33	20.39
0.5 wt.% S	13.93	16.91	19.97
1.0 wt.% S	13.29	13.15	15.97
3.0 wt.% S	11.57	10.27	12.83
Propane	11.34	10.10	10.52
Normal Butane		17.60	16.22
Isobutane		20.39	17.50
Mixed Butanes		18.21	16.23

* Equivalent value in New York Harbor

Refinery gate netback prices (New York Harbor price less transportation) for all products of each of the refineries considered are provided in Table E-8.

TABLE E-1

1980 PRODUCT SLATE* - EXISTING REFINERIES
(Percent on Crude Oil)

	Caribbean Hydroskimming 400 MBPSD	Rotterdam Hydroskimming 300 MBPSD	United States Gulf Coast Hydroskimming 20 MBPSD	United States Gulf Coast Low Conversion 50 MBPSD	United States Gulf Coast High Conversion 100 MBPSD	United States Gulf Coast High Conversion 335 MBPSD
Premium Gasoline	4.0	9.0	0.9	2.3	2.4	2.9
Unleaded Gasoline	-	-	6.0	16.9	18.0	20.1
Regular Gasoline	6.9	4.3	6.4	15.9	16.9	21.4
Total Gasoline	10.9	13.3	13.3	35.1	37.3	44.4
Naphtha/JP-4	6.6	8.7	6.4	2.5	4.0	5.0
Kerosene	-	-	-	-	1.9	1.9
Jet-A	8.0	3.5	-	-	7.1	7.1
Distillate Oil	15.7	21.1	22.6	25.7	23.8	19.8
Diesel	0.8	8.9	1.3	1.7	1.3	1.0
Total Naphtha/Distillates	31.1	42.2	30.3	29.3	38.1	34.8
Residual Fuel Oil						
0.3 wt. % S	5.0	-	-	-	-	-
0.5 wt. % S	8.8	2.0	-	-	2.6	2.9
1.0 wt. % S	13.7	8.0	43.4	29.3	6.4	3.9
3.0 wt. % S	24.5	29.0	6.4	-	9.0	7.0
Total Residual Fuel Oil	52.0	39.0	49.0	29.3	18.0	13.8
Asphalt Stock	-	-	1.0	1.0	1.0	1.0
Petroleum Coke	-	-	-	-	1.0	1.6
LPG	2.0	2.1	2.0	2.2	2.6	2.9
Sulfur	0.1	0.0	0.0	0.0	0.0	0.1

* Does not include refinery fuel

TABLE E-2

1985 PRODUCT SLATE* - EXISTING REFINERIES
(Percent on Crude Oil)

	Caribbean Hydroskimming 400 MBPSD	Rotterdam Hydroskimming 300 MBPSD	United States Gulf Coast			
			Hydroskimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Premium Gasoline	4.0	9.0	0.0	0.0	0.0	0.0
Unleaded Gasoline	-	-	9.3	25.4	27.1	32.3
Regular Gasoline	6.9	4.3	3.2	8.7	9.3	11.0
Total Gasoline	10.9	13.3	12.5	34.1	36.4	43.3
Naphtha/JP-4	6.6	8.7	7.2	3.6	4.9	6.2
Kerosene	-	-	-	-	1.9	1.9
Jet-A	8.0	3.5	-	-	7.1	7.1
Distillate Oil	15.7	21.1	22.6	25.7	23.8	19.8
Diesel	0.8	8.9	1.3	1.7	1.3	1.0
Total Naphtha/Distillates	31.1	42.2	31.1	29.9	39.0	36.0
Residual Fuel Oil						
0.3 wt. % S	5.0	-	-	-	-	-
0.5 wt. % S	8.8	2.0	-	-	2.6	2.9
1.0 wt. % S	13.7	8.0	43.4	29.3	6.4	3.9
3.0 wt. % S	24.5	29.0	6.4	-	9.0	7.0
Total Residual Fuel Oil	52.0	39.0	49.8	29.3	18.0	13.8
Asphalt Stock	-	-	1.0	1.0	1.0	1.0
Petroleum Coke	-	-	-	-	1.0	1.6
LPG	2.0	2.1	2.0	2.2	2.6	2.9
Sulfur	0.1	0.0	0.0	0.0	0.0	0.1

* Does not include refinery fuel

TABLE E-3

1985 PRODUCT SLATE* - NEW REFINERIES
(Percent on Crude Oil)

Conversion Type:	U.S. East Coast 150 MBPSD Low	High	U.S. Gulf Coast 150 MBPSD Low	High	Caribbean 150 MBPSD Low	High	Rotterdam 150 MBPSD Low	High	Mexico 150 MBPSD Low	High	Mid East 150 MBPSD Low	High
Unleaded Gasoline	26.8	45.8	26.8	45.8	26.7	45.8	26.7	45.8	27.2	50.7	23.0	32.5
Total Gasoline	26.8	45.8	26.8	45.8	26.7	45.8	26.7	45.8	27.2	50.7	23.0	32.5
Kerosene/Jet-A	1.4	0.6	1.4	0.6	2.7	0.5	2.7	0.5	-	7.2	-	-
Distillate Fuel Oil	25.9	26.6	25.9	26.6	25.5	27.6	25.5	27.6	23.4	16.1	23.6	26.0
Total Distillates	27.3	27.2	27.3	27.2	28.2	28.1	28.2	28.1	23.4	23.3	23.6	26.0
Residual Fuel Oil												
0.3 wt. % S	5.8	3.4	5.8	3.4	5.7	3.3	5.7	3.3	6.4	3.6	6.5	5.1
0.5 wt. % S	11.0	6.4	11.0	6.4	10.8	6.1	10.8	6.1	12.1	6.7	12.1	9.7
1.0 wt. % S	19.7	11.4	19.7	11.4	19.5	11.1	19.4	11.1	21.7	12.0	21.8	17.3
3.0 wt. % S	3.8	2.2	3.8	2.2	3.7	2.1	3.7	2.1	4.2	2.3	4.2	3.3
Total Residual Fuel Oil	40.3	23.4	40.3	23.4	39.7	22.6	39.6	22.6	44.4	24.6	44.6	35.4
LPG	2.4	2.7	2.4	2.7	2.4	2.7	2.6	2.7	3.2	3.3	3.8	2.7
Sulfur	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.5	0.5	0.6	0.6

*Does not include refinery fuel.

TABLE E-4

REFINED PRODUCT SPECIFICATIONS

	Typical Current			Forecast 1985
	Caribbean	Rotterdam	U.S. Gulf Coast	U.S. East Coast
Premium Gasoline				
Research Octane Number (Min.)	95.00	99.00	100.00	-
Motor Octane Number (Min.)	-	89.00	93.00	-
Lead Additives, cc/gal (Max.)	2.82	1.60	2.82	-
Reid Vapor Pressure, psi (Max.)	9.00	10.50	10.00	-
Volume Percent Evaporated at:				
212°F (Min.)	40.00	50.00	43.00	-
(Max.)	55.00	-	58.00	-
356°F (Min.)	90.0	90.00	90.00	-
Unleaded Gasoline				
Research Octane Number (Min.)	-	-	93.00	93.80
Motor Octane Number (Min.)	-	-	85.00	85.80
Lead Additives, cc/gal (Max.)	-	-	-	-
Reid Vapor Pressure, psi (Max.)	-	-	10.00	10.00
Volume Percent Evaporated at:				
212°F (Min.)	-	-	43.00	43.00
(Max.)	-	-	58.00	58.00
356°F (Min.)	-	-	90.00	90.00

continued . . .

TABLE E-4 continued

	Typical Current			Forecast 1985
	Caribbean	Rotterdam	U.S. Gulf Coast	U.S. East Coast
Regular Gasoline				
Research Octane Number (Min.)	85.00	92.00	94.00	-
Motor Octane Number (Min.)	-	82.00	87.00	-
Lead Additives, cc/gal (Max.)	2.82	1.60	2.82	-
Reid Vapor Pressure, psi (Max.)	9.00	10.50	10.00	-
Volume Percent Evaporated at:				
212°F (Min.)	40.00	50.00	43.00	-
(Max.)	55.00	-	58.00	-
356°F (Min.)	90.00	90.00	90.00	-
Commercial Jet-A				
Density, lbs/bbl:				
(Max.)	290.20	290.20	290.20	290.20
(Min.)	271.10	271.10	271.10	271.10
Sulfur, Weight Percent	0.20	0.20	0.20	0.20
Freeze Point, °F (Max.)	-50	-50	-50	-50
ASTM Smoke Point, MM (Min.)	25.00	25.00	25.00	25.00
Volume Percent in the 285/350°F Range (Max.)	10.00	10.00	10.00	10.00
Volume Percent Evaporated at 400°F (Min.)	20.00	20.00	20.00	20.00
Kerosene				
Sulfur, Weight Percent	0.10	0.10	0.10	0.10
Pour Point, °F (Max.)	-20	-20	-20	-20
ASTM Smoke Point, MM (Min.)	25.00	25.00	22.00	22.00
Volume Percent in the 285/350°F Range (Max.)	10.00	10.00	10.00	10.00
Volume Percent Evaporated at 400°F (Min.)	20.00	20.00	20.00	20.00

continued . . .

TABLE E-4 continued

	Typical Current			Forecast 1985
	Caribbean	Rotterdam	U.S. Gulf Coast	U.S. East Coast
Diesel				
Density, Lbs/Bbl (Min.)	290.00	290.00	290.00	290.00
(Max.)	300.00	300.00	300.00	300.00
Sulfur, Weight Percent	0.30	0.30	0.30	0.20
Pour Point, °F (Max.)	-5.00	-5.00	-5.00	-5.00
Volume Percent in the 285/350°F Range (Max.)	15.00	15.00	15.00	15.00
Diesel Index (Min.)	53.00	53.00	53.00	53.00
Flash Point, °F (Min.)	150.00	150.00	150.00	150.00
Distillate Fuel Oil/Gas Oil				
Density, Lbs/Bbl (Min.)	290.00	290.00	290.00	290.00
(Max.)	300.00	300.00	300.00	300.00
Sulfur, Weight Percent	0.20	0.25	0.40	0.20
Pour Point, °F (Max.)	-5.00	-5.00	-5.00	-5.00
Volume Percent in the 285/350°F Range (Max.)	15.00	15.00	15.00	15.00
Diesel Index (Min.)	50.00	53.00	50.00	50.00
Flash Point, °F (Min.)	150.00	150.00	150.00	150.00
Residual Fuel Oil (0.3 wt. % S)				
Sulfur, Weight Percent	0.30	-	-	0.30
Pour Point, °F (Max.)	60.00	-	-	60.00
Viscosity SSU @ 100°F (Min.)	120.00	-	-	120.00
(Max.)	240.00	-	-	240.00

continued . . .

TABLE E-4 continued

	Typical Current			Forecast 1985
	Caribbean	Rotterdam	U.S. Gulf Coast	U.S. East Coast
Residual Fuel Oil (0.5 wt. % S)				
Sulfur, Weight Percent	0.5	0.5	0.5	0.5
Pour Point, ^{o}F (Max.)	60.0	60.0	60.0	60.0
Viscosity SSU @ 100^{o}F (Min.)	150.0	150.0	150.0	150.0
(Max.)	370.0	370.0	370.0	370.0
Residual Fuel Oil (1.0 wt. % S)				
Sulfur, Weight Percent	1.0	1.0	1.0	1.0
Pour Point, ^{o}F (Max.)	100.0	100.0	100.0	100.0
Viscosity, SSU @ 100^{o}F (Min.)	250.0	250.0	250.0	250.0
(Max.)	500.0	500.0	500.0	500.0
Residual Fuel Oil (3.0 wt. % S)				
Sulfur, Weight Percent	3.0	3.0	3.0	3.0
Pour Point, ^{o}F (Max.)	100.0	100.0	100.0	100.0
Viscosity SSF @ 122^{o}F (Max.)	200.0	200.0	200.0	200.0
Plant Fuel Oil				
Sulfur, Weight Percent	None	3.0	0.75	0.5

TABLE E-5

HISTORIC REFINED PRODUCT PRICE DIFFERENTIALS
(Current U.S. Dollars per Barrel)

	New York Harbor Terminal Prices			Rotterdam Barge Prices			Singapore Cargo Prices		
	1976	1977	1978	1976	1977	1978	1976	1977	1978
Premium Gasoline	0.39	0.21	0.15		Base			Base	
Unleaded Gasoline		Base		N/A	N/A	N/A	N/A	N/A	N/A
Regular Gasoline	(0.42)	(0.74)	(1.15)	(1.62)	(1.16)	(1.23)	(1.89)	(1.89)	(1.89)
Kerosene/Jet-A	(1.39)	(0.98)	(1.18)	(2.05)	0.10	(1.22)	(2.73)	(2.65)	(2.65)
Distillate Fuel Oil/Gas Oil	(2.36)	(1.36)	(1.93)	(2.97)	0.50	(2.52)	(3.78)	(3.61)	(3.61)
Residual Fuel Oil									
0.3 wt.% S (low pour)	(1.99)	(1.41)	(3.42)	-	-	-	-	-	-
0.5 wt.% S (low pour)	(2.59)	(1.84)	(3.78)	-	-	-	-	-	-
1.0 wt.% S	(3.26)	(2.45)	(4.42)	(6.17)	(3.41)	(6.56)	-	-	-
3.0 wt.% S (bunkers)	(4.58)	(3.94)	(6.14)	(7.14)	(4.79)	(8.25)	(8.29)	(7.89)	(8.29)

TABLE E-6

HISTORICAL PROPANE PRICES
(Current U.S. Dollars)

	U.S. Gulf Coast	U.S. East Coast	Rotterdam	Venezuela
1978				
Propane, ¢/gal.	22.8	27.0	26.9	24.1
Distillate Fuel Oil, ¢/gal.	34.5	37.6	40.5	36.6
Propane Premium, %	0.0	8.6	0.0	0.0
1977				
Propane, ¢/gal.	22.2	26.8	26.4	27.4
Distillate Fuel Oil, ¢/gal.	33.7	36.2	37.2	35.4
Propane Premium, %	0.0	12.0	7.4	17.3
1976				
Propane, ¢/gal.	16.7	23.2	25.7	26.7
Distillate Fuel Oil, ¢/gal.	29.7	29.9	33.5	32.9
Propane Premium, %	(15.0)	17.4	16.0	22.8

TABLE E-7

REFINED PRODUCT TRANSPORTATION COSTS
(1978 U.S. Dollars Per Barrel)

	Tanker Movement to New York Harbor											
	Caribbean		Rotterdam		U.S. Gulf Coast		U.S. East Coast		Mexico		Mid-East	
	1980	1985	1980	1985	1980	1985	1980	1985	1980	1985	1980	1985
Premium Gasoline	0.58	0.58	1.07	1.07	1.27	1.27	-	0.21	-	0.64	-	1.77
Unleaded Gasoline	0.58	0.58	1.07	1.07	1.27	1.27	-	0.21	-	0.64	-	1.77
Regular Gasoline	0.58	0.58	1.07	1.07	1.27	1.27	-	0.21	-	0.64	-	1.77
Naphtha/JP-4	0.58	0.58	1.07	1.07	1.27	1.27	-	0.21	-	0.64	-	1.77
Kerosene/Jet-A	0.64	0.64	1.19	1.19	1.40	1.40	-	0.23	-	0.71	-	1.95
Diesel/Distillate Fuel Oil	0.66	0.66	1.23	1.23	1.45	1.45	-	0.24	-	0.73	-	2.02
Residual Fuel Oil												
0.3 wt. % S	0.49	0.49	0.91	0.91	1.46	1.46	-	0.25	-	0.54	-	2.10
0.5 wt. % S	0.49	0.49	0.91	0.91	1.46	1.46	-	0.25	-	0.54	-	2.10
1.0 wt. % S	0.51	0.51	0.96	0.96	1.55	1.55	-	0.26	-	0.57	-	2.19
3.0 wt. % S	0.53	0.53	0.98	0.98	1.58	1.58	-	0.27	-	0.59	-	2.27

TABLE E-8

REFINED PRODUCT NET-BACK VALUES*
(1978 U.S. Dollars Per Barrel)

	Caribbean 1980	Caribbean 1985	Rotterdam 1980	Rotterdam 1985	U.S. Gulf Coast 1980	U.S. Gulf Coast 1985	U.S. East Coast 1980	U.S. East Coast 1985	Mexico 1980	Mexico 1985	Mid-East 1980	Mid-East 1985
Gasoline												
U.S. Premium	19.98	-	--	-	19.29	-	-	-	-	-	-	-
U.S. Unleaded	19.77	23.17	-	22.68	19.08	22.48	-	23.54	-	23.11	-	21.98
U.S. Regular	18.30	21.49	-	-	17.61	20.80	-	-	-	-	-	-
Caribbean Premium	18.72	22.12	-	-	-	-	-	-	-	-	-	-
Caribbean Regular	18.17	21.57	-	-	-	-	-	-	-	-	-	-
European Premium	-	-	19.23	22.63	-	-	-	-	-	-	-	-
European Regular	-	-	18.03	21.43	-	-	-	-	-	-	-	-
Full Range Naphtha	18.17	21.28	17.68	20.79	17.48	20.59	-	-	-	-	-	-
Kerosene/Jet A	18.37	21.85	17.82	21.30	17.61	21.09	-	22.26	-	21.78	-	20.54
Distillate Fuel Oil/Gas Oil	17.25	20.57	16.68	20.00	16.46	19.78	-	20.99	-	20.50	-	19.21
Residual Fuel Oil												
0.3 wt. % S	16.84	19.90	16.42	19.48	15.87	18.93	-	20.14	-	19.85	-	18.29
0.5 wt. % S	16.42	19.48	16.00	19.06	15.45	18.51	-	19.72	-	19.43	-	17.87
1.0 wt. % S	12.64	15.46	12.19	15.01	11.60	14.42	-	15.71	-	15.40	-	13.78
3.0 wt. % S	9.74	12.30	9.29	11.85	8.69	11.25	-	12.56	-	12.24	-	10.56
Asphalt Stock	-	-	-	-	8.69	11.25	-	-	-	-	-	-
Petroleum Coke ($/Ton)	-	-	-	-	60.00	60.00	-	-	-	-	-	-
Propane	9.32	9.76	8.69	9.11	9.15	9.57	-	10.24	-	9.68	-	8.20
Normal Butane	16.74	15.36	16.00	14.62	16.36	15.10	-	15.91	-	15.27	-	13.60
Iso-Butane	19.53	16.64	18.79	15.90	18.92	16.32	-	17.19	-	16.55	-	14.88
Mixed Butanes	17.38	15.87	16.61	14.63	16.88	15.08	-	15.92	-	15.22	-	13.61

* From sales to the New York Harbor

F

OPERATING COSTS

COST SUMMARY

Operating costs on a per barrel of crude oil throughput basis vary among refiners depending upon the following factors:

- Processing complexity
- Size
- Age
- Location

Operating costs for the refineries studied are provided in Tables F-1 and F-2. Cost categories are discussed in the following text.

Salaries and Wages

For each of the United States refinery types considered in this study, Pace estimated typical current manpower staffing based on data provided in the National Petroleum Refiners Association's (NPRA) "Collective Bargaining Manual." Most United States refineries are overstaffed compared to the actual manpower requirements of the process units. This is particularly true of the older, large facilities of the major oil companies which typically employ 1.5 to 2.0 times the personnel required to run an equivalent new refinery. One reason is that as the process unit control system has become significantly more automated and sophisticated, the oil companies have been reluctant to eliminate operator jobs due to labor relations considerations. Many of these large refineries are the product of several expansions with duplication of many of the process units. This reduces the economies of scale associated with increased size. Also, the major oil companies have a much larger technical staff involved with research and development projects compared with the smaller independent refiners.

Pace's estimate of typical manpower staffing for actual United States Gulf Coast refineries in the categories considered in this study is provided in Table F-3. It should be noted that in estimating manpower, personnel associated with lubes facilities, chemicals manufacture, and some thermal cracking operations in the smaller refineries were excluded. This allows consistency with the refinery configurations considered in this study.

Manpower information for Caribbean and European export refineries is not as extensive as that available for United States refineries. Based on our conversations with refiners in these two key export refinery regions, we have estimated manpower usage and costs for Caribbean and Rotterdam refiners.

The typical number of operators employed per shift and supervision and technical support for the existing refinery categories considered in this study compare as shown below:

Manpower Comparison

	Hourly-Operations (Men Per Shift)			Supervision/Technical* (Total Salaried)		
	Actual Avg	Pace Min.	Factor	Actual Avg	Pace Min.	Factor
U.S. Gulf Coast						
Small, Hydroskimming	12	12	1.00	16	23	0.71
Small, Low Conversion	30	30	1.00	45	57	0.79
Medium, High Conversion	41	37	1.11	60	71	0.85
Large, High Conversion	71	57	1.25	241	109	2.21
Caribbean Hydroskimming	95	-	-	264	-	-
Rotterdam Hydroskimming	75	-	-	190	-	-

*Excluding Maintenance Supervision

Annual operating labor costs were estimated based on the following wage rates:

Wage Rate Bases - Existing Refineries
(1978 U.S. Dollars)

	$/Hour
U.S. Gulf Coast	9.10
Caribbean	7.20
Rotterdam	8.00

Annual costs for salaried supervision, technical, and non-exempt support personnel were calculated based on an average annual salary of $25,000 for the United States and $22,000 in the Caribbean and Rotterdam. Benefits and plant administration costs were estimated at 50 percent of the total of operating labor wages plus salaries. We have assumed that manpower costs will not escalate in real terms between 1978 and 1985.

Total manpower costs for the existing refineries studied compare as shown below:

Salaries and Wages - Existing Refineries
(1978 U.S. Dollars Per Barrel)

Refinery Type	
U.S. Gulf Coast	
Hydroskimming - 20 MBPSD	0.33
Low Conversion - 50 MBPSD	0.32
High Conversion - 100 MBPSD	0.21
High Conversion - 335 MBPSD	0.14
Caribbean Hydroskimming	0.13
Rotterdam Hydroskimming	0.13

For the new refineries considered for 1985, we have estimated operating labor requirements based on Pace's estimate of the manpower requirements of an equivalent new refinery on the United States Gulf Coast. Operating labor requirements of the processing units are provided in Table F-4. Differences in labor productivity in the United States and foreign locations were considered in setting wage rates. The base wage rates, productivity factors, and the adjusted wage rate for the new refineries considered are shown below:

Wage Rate Basis - New Refineries
(1978 U.S. Dollars)

Location	Base Wage $/Hour	Productivity*	Adjusted Wage $/Hour
U.S. Gulf Coast	9.10	1.00	9.10
U.S. East Coast	9.50	0.90	10.60
Caribbean	7.20	0.90	8.00
Rotterdam	8.00	1.00	8.00
Mexico	7.20	0.90	8.00
Middle East	4.85	0.40	12.10

* United States Gulf Coast equals 1.0

The base wage rates and productivity factors shown above were based on data published by the National Labor Relations Board and the Department of Commerce. Salaries for supervision, technical, and non-exempt support personnel were estimated at 60 percent of operating labor wages for the new refineries. Total manpower costs for the new 1985 refineries studied compare as shown below:

Salaries and Wages - New Refineries
(1978 U.S. Dollars Per Barrel)

	Low Conversion	High Conversion
U.S. East Coast	0.11	0.17
U.S. Gulf Coast	0.09	0.14
Caribbean	0.09	0.12
Rotterdam	0.09	0.12
Mexico	0.09	0.12
Middle East	0.13	0.18

UTILITIES

Utilization of conversion processing and desulfurization facilities directly determines utilities consumption. Fuel, power, and makeup water requirements for each refinery type considered are provided in Table F–5.

In the economics presented in this study, fuel consumption is not categorized directly as an operating cost. With the exception of the new Mexican refinery, fuel required is supplied by fuel gas and fuel oil produced within the refinery. The net reduction in the overall refinery product yield to sales accounts for fuel cost. In the case of the new Mexican refinery we have allowed the refinery to purchase natural gas to provide for refinery fuel requirements in excess of that which can be supplied by internal refinery fuel gas. Due to the surplus of natural gas in Mexico, purchased natural gas was valued at $0.35 per million BTU (equivalent to residual fuel oil at $2.20 per barrel). The ability to supplement refinery fuel gas production with relatively cheap natural gas provides the Mexican refinery with a significant economic advantage.

Energy consumption in the new 1985 refineries reflects the energy conservation measures incorporated into the design of new refinery equipment. In comparing the energy consumption of the new refineries with the existing refineries studied, it should be noted that the additional residual desulfurization incorporated in these new refinery prototypes adds 30 to 50 million BTU per barrel to total refinery fuel consumption.

United States refiners have made significant progress since 1973 in reducing refinery fuel use. However, due to investment and/or downtime constraints, there is still potential remaining for improvement in many refineries. Based on data provided to the American Petroleum Institute, refinery fuel use in the United States varies from low levels of 210 million BTUs per barrel of crude oil to over 700 million BTUs per barrel.

Residual desulfurization also boosts power use in the new refineries. The ARDS units account for power consumption of 2.35 to 2.55 kilowatt hours per barrel of crude oil. Power costs were estimated to be as follows:

Power Costs
(1978 U.S. Dollars)

	U.S. Cents Per KWH
U.S. East Coast	3.0
U.S. Gulf Coast	3.0
Caribbean	4.0
Rotterdam	4.0
Mexico	1.8
Middle East	1.8

It is expected that power costs for United States mainland locations will be lower than Caribbean locations due to increased use of nuclear power and continued use of some natural gas. Caribbean locations will likely depend primarily on the more expensive use of residual fuel oil for power generation. Power costs in the oil producing regions of Mexico and the Middle East are significantly reduced by the availability of associated natural gas for power generation.

Makeup water for steam generation and cooling water facilities was valued at $0.15 per thousand gallons in all locations.

MAINTENANCE AND PLANT SUPPLIES

Maintenance costs are a function of refinery equipment and labor costs. Typically labor accounts for 60 to 65 percent of the total maintenance costs.

Based on Pace's experience we have estimated annual maintenance charges to be equivalent to 4 percent of onsite investment and 2 percent of offsite investment for both existing (replacement cost basis) and new refineries. Plant supplies were estimated at 8 percent of total maintenance costs.

Actual annual average maintenance costs for United States refiners in 1978 compare with that estimated for the existing United States refineries as shown in the following:

Maintenance Costs-United States Refineries
(1978 U.S. Dollars Per Barrel)

Existing U.S. Gulf Coast Refineries - Pace Estimate	
Hydroskimming-20 MBPSD	0.21
Low Conversion-50 MBPSD	0.29
High Conversion-100 MBPSD	0.28
High Conversion-335 MBPSD	0.29
Actual U.S. 1978	
Range	0.17-0.55
Average	0.29

Additional residual fuel oil desulfurization also boosts maintenance charges for the new refineries studied. Maintenance costs are higher on the United States East Coast compared to the Gulf Coast due to both higher labor and materials costs. Maintenance costs are also relatively higher for Mexican, Caribbean, and Middle East refinery locations due to the scarcity of skilled labor and the fact that materials must be transported longer distances to the refineries.

CATALYST AND CHEMICALS CONSUMPTION

Catalyst and chemicals usage includes catalyst consumption in processing units and gasoline additives. Catalysts and chemical costs for the refineries studied are provided in Table F–6. With the decline in leaded gasoline production by 1985, we show gasoline additives use also declining significantly in the new 1985 refineries. The increase in other catalyst and chemicals use in the new refineries is also attributable to the ARDS unit.

TAXES AND INSURANCE

Ad valorem taxes and insurance were calculated as 2 percent of the investment in plant facilities for all locations except where investment incentive legislation provided exemptions from taxes, or where the refinery was government owned. In these instances one percent was used for insurance coverage. Depreciation was added on a straight-line ten year basis. Income taxes vary considerably between locations with some locations providing total exemptions from income taxes as an investment incentive. The following shows the ad valorem taxes, insurance rates, and income tax percentages used in this study.

Tax Rates

Location	Taxes & Insurance % of Plant Investment	Income Tax Rate % of Gross Profit
U.S. Gulf Coast	2	50
U.S. East Coast	2	50
Rotterdam	2	48
Caribbean	1	0
Mexico	1	0
Middle East	1	0

TABLE F-1

OPERATING COST SUMMARY - EXISTING REFINERIES
(1978 U.S. Dollars Per Barrel)

	Caribbean 400 MBPSD	Rotterdam 300 MBPSD	United States Gulf Coast: Hydroskimming 20 MBPSD	United States Gulf Coast: Low Conversion 50 MBPSD	United States Gulf Coast: High Conversion 100 MBPSD	United States Gulf Coast: High Conversion 335 MBPSD
Salaries and Wages	0.13	0.13	0.33	0.32	0.21	0.14
Utilities	0.06	0.05	0.07	0.12	0.13	0.17
Maintenance/Supplies	0.15	0.12	0.21	0.29	0.28	0.29
Catalyst and Chemicals	0.05	0.05	0.04	0.12	0.14	0.17
Ad Valorem Taxes and Insurance	0.04	0.07	0.13	0.17	0.17	0.17
	0.43	0.42	0.78	1.02	0.93	0.94

TABLE F-2

OPERATING COST SUMMARY - NEW REFINERIES
(1978 U.S. Dollars Per Barrel)

Conversion Type:	U.S. East Coast 150 MBPSD Low	High	U.S. Gulf Coast 150 MBPSD Low	High	Caribbean 150 MBPSD Low	High	Rotterdam 150 MBPSD Low	High	Mexico 150 MBPSD Low	High	Middle East 150 MBPSD Low	High
Salaries and Wages	0.11	0.17	0.09	0.14	0.09	0.12	0.09	0.12	0.09	0.12	0.13	0.18
Utilities	0.14	0.14	0.14	0.14	0.18	0.17	0.18	0.17	0.09	0.08	0.10	0.10
Maintenance/Supplies	0.33	0.45	0.28	0.38	0.32	0.45	0.25	0.37	0.34	0.47	0.49	0.59
Catalyst and Chemicals	0.08	0.12	0.08	0.12	0.08	0.11	0.08	0.11	0.08	0.12	0.09	0.10
Taxes and Insurance	0.20	0.27	0.17	0.22	0.10	0.13	0.16	0.21	0.10	0.13	0.15	0.17
	0.86	1.15	0.76	1.00	0.77	0.98	0.76	0.94	0.70	0.92	0.96	1.14

TABLE F-3

TYPICAL EXISTING U.S. REFINERY MANPOWER

Conversion Level Refinery Size (MBPSD)	Hydro-skimming (0 35)	Low (35 70)	High (70 120)	High (150 650)
Hourly				
Operations	50	127	167	299
Maintenance	23	87	135	284
Subtotal	73	214	302	583
Supervision/Technical				
Operations	16	46	60	241
Maintenance Supv.	4	15	24	50
Subtotal	20	61	84	291
Plant Administration	6	17	21	35
Total Employees	99	292	407	909

TABLE F-4

PROCESSING UNIT MANPOWER REQUIREMENTS

	Men Per Shift
Crude Oil Distillation	2
Vacuum Distillation	1
Reformer	2
Alkylation	2
Catalytic Cracking	4
Hydrotreaters	
Naphtha	1
Distillate	1
ARDS	2
Hydrogen Plant	1
Saturated Gas Plant	2
Unsaturated Gas Plant	2
Sulfur Plant	2
Steam Generation	2
Cooling Water System	1

Other helpers @ 35 percent of total for process units

TABLE F-5

FUEL AND UTILITIES CONSUMPTION

Refinery Type	Fuel* (MBTU/B)	Power (KWH/B)	Make-up Water (Gal/B)
Existing			
Caribbean Hydroskimming	235	1.47	26
Rotterdam Hydroskimming	220	1.20	17
U.S. Gulf Coast			
Hydroskimming - 20 MBPSD	235	2.07	19
Low Conversion - 50 MBPSD	355	3.70	39
High Conversion - 100 MBPSD	375	3.85	42
High Conversion - 335 MBPSD	425	5.32	46
New - High Conversion - 150 MBPSD			
U.S. East Coast	280	4.68	23
U.S. Gulf Coast	280	4.68	23
Caribbean	275	4.31	22
Rotterdam	275	4.34	22
Mexican	310	4.32	26
Middle East	270	4.90	19
New - Low Conversion - 150 MBPSD			
U.S. East Coast	200	4.68	13
U.S. Gulf Coast	200	4.68	13
Caribbean	200	4.41	13
Rotterdam	200	4.44	13
Mexican	210	4.79	15
Middle East	210	5.15	15

* Excluding cat cracker coke production

TABLE F-6

CATALYSTS AND CHEMICALS COST
(1978 U.S. Dollars Per Barrel)

Refinery Type	Gasoline Additives	Other	Total
Existing			
Caribbean Hydroskimming	0.04	0.01	0.05
Rotterdam Hydroskimming	0.04	0.01	0.05
U.S. Gulf Coast			
Hydroskimming - 20 MBPSD	0.02	0.02	0.04
Low Conversion - 50 MBPSD	0.04	0.08	0.12
High Conversion - 100 MBPSD	0.04	0.10	0.14
High Conversion - 335 MBPSD	0.05	0.12	0.17
New - High Conversion - 150 MBPSD			
U.S. East Coast	0.01	0.11	0.12
U.S. Gulf Coast	0.01	0.11	0.12
Caribbean	0.01	0.10	0.11
Rotterdam	0.01	0.10	0.11
Mexican	0.01	0.11	0.12
Mid-East	0.01	0.09	0.10
New - Low Conversion - 150 MBPSD			
U.S. East Coast	0.01	0.07	0.08
U.S. Gulf Coast	0.01	0.07	0.08
Caribbean	0.01	0.07	0.08
Rotterdam	0.01	0.07	0.08
Mexican	0.01	0.07	0.08
Mid-East	0.01	0.08	0.09

G

REFINERY INVESTMENT

CAPITAL REQUIREMENTS

The following categories were considered in determining the total capital investment required for the refineries studied:

- Onsite investments
- Offsite investments
- Additional environmental costs
- Paid-up royalties
- Initial inventory of catalysts and chemicals
- Working capital
- Land

PLANT INVESTMENT

Total plant investment includes onsite, offsite, and additional environmental construction costs. Onsite investment refers to capital required for the processing units and accounts for the following:

- Engineering
- Equipment and materials
- Labor and supervision
- Contractor overhead and field expenses

Offsite investments include utilities and storage facilities. Capital investment for utilities (cooling water systems, steam generation facilities, air, and electrical distribution) typically ranges between 20 to 40 percent of total onsite investment. The cost of these facilities is related to the conversion level of the refinery—the more processing the greater the utilities requirements on a per barrel of crude oil distillation capacity.

Tankage required is determined primarily by the refinery's crude oil distillation capacity. We have estimated total refinery storage tank shell capacity to be equivalent to 70 days of crude oil throughput capacity for the large existing Caribbean hydroskimming, Rotterdam hydroskimming, United States Gulf Coast high conversion refineries, as well as all the new 1985 refineries. This would provide for storage of approximately a one month supply of crude oil and one month of refined product production. The heavy dependence of these refineries on foreign crude supplies has increased storage requirements.

For the smaller United States Gulf Coast refineries, local crude oil production transported by pipeline has accounted for a larger fraction of their crude oil supplies. These refineries on average do not have as much tankage as the larger refineries which rely heavily on foreign crude oil shipments. We have estimated storage tank shell capacity for the existing United States Gulf Coast refineries to be as follows:

	Storage (Days of Crude)
Hydroskimming - 20 MBPSD	50
Low Conversion - 50 MBPSD	55
High Conversion - 100 MBPSD	60
High Conversion - 335 MBPSD	70

The tanks were estimated to cost an average $5.00 per barrel of shell capacity.

We have also included in the offsite cost category an investment equivalent to 35 percent of total onsite investment to account for the following additional plant investment items:

- Piping, transfer systems, and crude receiving facilities
- Product loading racks
- Buildings
- Fire protection systems
- Railroad track and equipment
- Site preparation (grading, roads, etc.)
- Waste disposal sewers, separators, and storage tank dikes

Environmental restraints are considerably tighter in the United States. The capital required to comply with environmental regulations is estimated at an additional 7.5 percent of onsite investment for United States locations to account for the following requirements:

- Secondary and tertiary waste water treatment facilities
- Natural storm runoff treatment facilities
- Electrostatic precipitators for particulate matter removal.

A tail gas clean-up unit for the sulfur plant is included in the onsite investment for the sulfur plant for the Rotterdam and United States refineries studied.

Onsite and offsite investments were determined based on Pace investment curves for mid-1978 construction at United States Gulf Coast locations. Investment requirements are generally greater for the large, major oil companies compared with average costs for the independent refiners. The fewer number of people involved in project decisions tends to lower construction costs for the independents. Also, material specifications are often more strict for the majors. Experience in foreign countries indicates that government owned refineries are significantly more expensive than those of the major oil companies. The investment estimates provided in this study represent an average of that for the major and independent oil companies.

Appropriate location factors were then applied to the base Gulf Coast investment to obtain the required investment in other locations. The location factors used, shown in the following, are Pace estimates based on previous experience.

Location	Location Factor
U.S. Gulf Coast	1.00 (base)
U.S. East Coast	1.20
Caribbean	1.25
Rotterdam	1.00
Mexico	1.20
Middle East	1.75

Plant investment estimates presented in the base case analysis of this study assume no inflation in construction costs through 1985 in real terms (i.e., no inflation above general currency inflation).

FIXED AND TOTAL INVESTMENT

Fixed investment was calculated as the sum of plant investment plus paid-up royalties. Total investment includes fixed investment plus initial inventories of catalysts and chemicals, working capital, and land.

Initial inventories of catalysts and chemicals represent initial reactor catalyst charges and chemical inventories for all process units.

Working capital was calculated as 50 percent of the total storage volume valued at the average refinery gate crude oil price plus six weeks out-of-pocket operating expenses.

Land for refinery construction was also included as an investment with the land valued as follows for the various locations:

Location	Cost ($M/acre)
U.S. Gulf Coast	6.0
U.S. East Coast	9.0
Caribbean	4.0
Rotterdam	9.0
Mexico	0.0
Middle East	0.0

It was assumed that refineries in Mexico or the Middle East would be built on government owned land and no cost was assigned.

Total investments required for the refineries considered in this study are derived in Tables G-1 through G-3. Total investments on a per barrel of crude oil capacity (stream day basis) compare as summarized in Table G-4.

In general the cost of a refinery increases as the conversion level increases. Size of the refinery is also a factor.

TABLE G-1

REPLACEMENT INVESTMENT
EXISTING REFINERIES
(1978 U.S. Dollars)

	Caribbean Hydroskimming		Rotterdam Hydroskimming		United States Gulf Coast: Hydroskimming 20 MBPSD		United States Gulf Coast: Low Conv. 50 MBPSD		United States Gulf Coast: High Conv. 100 MBPSD		United States Gulf Coast: High Conv. 335 MBPSD	
	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$
Onsite Investment												
Crude Oil Distillation	400.0	94.0	300.0	70.5	20.0	9.5	50.0	18.0	100.0	23.5	335.0	74.5
Vacuum Distillation	110.0	39.0	-	-	4.5	3.0	15.0	7.0	35.0	14.0	140.0	52.5
Reforming												
Semi Regenerative	25.0	20.5	32.0	30.5	2.2	4.0	11.0	13.0	[illegible]	23.5	40.0	36.5
Cyclic	-	-	-	-	-	-	-	-	-	-	34.5	39.0
Alkylation (Product)	-	-	-	-	-	-	2.5	5.0	5.0	8.5	18.0	25.0
Catalytic Cracking	-	-	-	-	-	-	9.5	24.5	[illegible]	38.0	93.0	120.0
Hydrocracking	-	-	-	-	-	-	-	-	-	-	18.0	25.0
Delayed Coking	-	-	-	-	-	-	-	-	4.0	13.0	[illegible]	44.0
Hydrotreating												
Naphtha	25.0	10.5	45.0	19.0	4.0	3.0	11.0	6.0	[illegible]	10.0	58.0	22.5
Distillate	15.0	19.5	40.0	36.5	-	-	-	-	11.0	16.0	51.0	54.5
Vacuum Gas Oil	50.0	22.5	-	-	-	-	-	-	-	-	20.0	15.0
Saturated Gas Plant	11.0	8.0	10.0	7.5	1.0	1.5	2.5	3.0	[illegible]	4.5	20.0	12.0
Unsaturated Gas Plant	-	-	-	-	-	-	3.0	3.5	[illegible]	6.5	29.0	15.5
Merox Treating	108.0	5.5	102.0	5.0	6.0	0.5	17.0	1.5	38.0	2.5	118.0	5.5
Sulfur Plant (Ton/SD)	210	13.0	36.0	5.0	0.5	0.5	11.0	2.5	[illegible]	2.5	203.0	15.5
Total Onsite		232.5		174.0		22.0		82.0		162.5		557.0
Offsite Investment												
Utilities		72.0		54.0		7.5		13.0		36.0		91.0
Tankage		140.0		105.0		5.0		18.0		30.0		117.5
Other Offsites		81.0		61.0		8.5		23.5		57.0		195.0
Additional Environmental		-		-		1.5		3.0		12.0		41.5
Total Offsites		293.0		220.0		22.5		68.5		135.0		445.0
Total Onsite & Offsites		525.5		394.0		44.5		149.5		297.5		1002.0
Location factor		x 1.25		x 1.0		x 1.0		x 1.0		x 1.0		x 1.0
Plant Investment		657.0		394.0		44.5		14[illegible].5		297.5		1002.0
Royalties		2.5		3.0		0.5		[illegible]		5.0		19.5
Fixed Investment		659.5		397.0		45.0		15[illegible].0		302.5		1021.5
Initial Inventory of Catalysts and Chemicals		5.5		4.0		0.5		[illegible]		2.5		13.0
Working Capital		199.0		154.0		9.0		2[illegible].0		48.0		184.0
Land		8.0		18.0		6.0		9.0		12.0		18.0
Total Investment		872.0		573.0		60.5		182.0		362.5		1238.5

TABLE G-2

NEW REFINERY INVESTMENT
LOW CONVERSION

	U.S. East Coast		U.S. Gulf Coast		Caribbean		Rotterdam		Mexico		Mid-East	
	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$
Onsite Investment												
Crude Oil Distillation	150.0	29.5	150.0	29.5	150.0	29.5	150.0	29.5	150.0	29.5	150.0	29.5
Vacuum Distillation	12.0	6.0	12.0	6.0	12.0	6.0	12.0	6.0	25.0	10.5	30.0	12.5
Cyclic Reforming	36.5	40.0	36.5	40.0	36.0	40.0	36.0	40.0	41.0	44.0	35.0	39.0
Hydrotreating												
Naphtha	37.0	13.5	37.0	13.5	36.5	13.0	36.5	13.0	41.0	14.0	35.0	12.5
Distillate	28.5	29.0	28.5	29.0	29.5	29.5	29.5	29.5	29.0	29.5	33.5	32.5
ARDS	56.0	85.0	56.0	85.0	51.5	81.0	52.0	81.5	56.5	86.0	60.0	89.5
Hydrogen Plant	8.5	6.5	8.5	6.5	6.0	5.0	6.5	5.5	12.0	7.5	23.0	10.0
Saturated Gas Plant	8.0	6.5	8.0	6.5	8.0	6.5	8.0	6.5	10.0	7.5	9.5	7.5
Merox Treating	35.0	2.5	35.0	2.5	35.0	2.5	35.0	2.5	27.5	2.0	26.0	2.0
Sulfur Plant (TON/SD)	244.0	17.0	244.0	17.0	226.0	14.0	216.0	16.0	301.0	16.5	408.0	20.0
Total Onsite		235.5		235.5		227.0		230.0		247.0		255.0
Offsite Investment												
Utilities		53.0		53.0		52.0		52.5		55.5		56.5
Tankage		52.5		52.5		52.5		52.5		52.5		52.5
Other Offsites		82.0		82.0		79.5		80.5		86.5		89.5
Additional Environmental		17.5		17.5		-		-		-		-
Total Offsites		205.0		205.0		184.0		185.5		194.5		198.5
Total Onsites & Offsites		440.0		440.0		411.0		415.5		441.5		453.5
Location Factor		x 1.2		x 1.0		x 1.25		x 1.0		x 1.2		x 1.75
Plant Investment		528.0		440.0		514.0		415.5		530.0		793.5
Royalties		8.5		8.5		8.5		8.5		12.0		9.0
Fixed Investment		536.5		448.5		522.5		424.0		542.0		802.5
Initial Inventory of Catalysts and Chemicals		9.5		9.5		9.5		9.5		10.5		10.5
Working Capital		82.0		81.5		79.5		79.5		76.0		78.0
Land		22.5		15.5		10.0		22.5		0.0		0.0
Total Investment		650.5		554.5		621.5		535.5		628.5		891.0

TABLE G-3

NEW REFINERY INVESTMENT
HIGH CONVERSION

	U.S. East Coast		U.S. Gulf Coast		Caribbean		Rotterdam		Mexico		Mid-East	
	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$	MBPSD	MM$
Onsite Investment												
Crude Oil Distillation	150.0	29.5	150.0	29.5	150.0	29.5	150.0	29.5	150.0	29.5	150.0	29.5
Vacuum Distillation	55.0	28.0	55.0	20.0	54.0	20.0	54.0	20.0	54.5	20.0	32.0	13.0
Cyclic Reforming	39.5	42.5	39.5	42.5	39.5	42.5	39.5	42.5	42.0	45.0	35.0	39.0
Alkylation (Product)	9.0	14.0	9.0	14.0	9.0	14.0	9.0	14.0	11.0	16.5	4.0	7.0
Catalytic Cracking	32.0	48.5	32.0	48.5	32.0	48.5	32.0	48.5	39.0	54.5	15.0	31.5
Hydrotreating												
Naphtha	39.5	14.0	39.5	14.0	39.5	14.0	39.5	14.0	42.0	14.5	35.0	13.0
Distillate	28.0	28.5	28.0	28.5	27.5	28.0	27.5	28.0	31.5	31.5	31.5	31.5
ARDS	61.5	92.0	61.5	92.0	56.5	86.0	57.0	86.5	60.5	90.0	61.0	90.5
Hydrogen Plant (MMSCF/SD)	9.0	6.5	9.0	6.5	5.5	5.0	6.0	5.5	15.0	8.0	24.0	10.0
Saturated Gas Plant	9.0	7.0	9.0	7.0	9.0	7.0	9.0	7.0	10.5	8.0	9.5	7.5
Unsaturated Gas Plant	11.0	8.0	11.0	8.0	11.0	8.0	11.0	8.0	14.0	9.5	5.0	4.5
Merox Treating	37.0	2.5	37.0	2.5	39.0	2.5	39.0	2.5	20.5	1.5	28.0	2.0
Sulfur Plant (TON/SD)	273.0	18.5	273.0	18.5	254.0	14.5	256.0	17.5	334.0	17.5	415.0	20.0
Total Onsite		331.0		330.0		319.5		323.5		348.0		299.0
Offsite Investment												
Utilities		66.0		66.0		65.5		66.0		70.0		59.0
Tankage		52.5		52.5		52.5		52.5		52.5		52.5
Other Offsites		115.5		115.5		112.0		113.0		121.0		104.5
Additional Environmental		25.0		25.0		-		-		-		-
Total Offsites		259.0		259.0		230.0		231.5		243.5		216.0
Total Onsites & Offsites		590.0		590.0		549.5		555.0		579.5		515.0
Location Factor		x 1.2		x 1.0		x 1.25		x 1.0		x 1.2		x 1.75
Plant Investment		708.0		590.0		687.0		555.0		695.5		901.0
Royalties		14.0		14.0		13.5		13.5		15.0		11.0
Fixed Investment		722.0		604.0		700.5		568.5		710.5		912.0
Initial Inventory of Catalysts and Chemicals		11.0		11.0		10.5		10.5		12.0		11.0
Working Capital		84.0		83.5		81.0		81.0		77.5		79.0
Land		22.5		15.0		10.0		22.5		0.0		0.0
Total Investment		839.5		713.5		802.0		682.5		800.0		1002.0

TABLE G-4

TOTAL REFINERY INVESTMENT
(1978 U.S. Dollars)

Existing Refineries	Crude Capacity MBPSD	Total Investment MM$	Total Investment $/BPSD
Caribbean Hydroskimming	400	872.0	2180
Rotterdam Hydroskimming	300	573.0	1910
U.S. Gulf Coast-			
Hydroskimming	20	60.5	3025
Low Conversion	50	182.0	3640
High Conversion	100	362.5	3625
High Conversion	335	1236.5	3690
New Refineries-Low Conversion			
U.S. East Coast	150	650.5	4335
U.S. Gulf Coast	150	554.5	3700
Caribbean	150	621.5	4145
Rotterdam	150	535.5	3570
Mexican	150	628.5	4190
Mid-East	150	891.0	5940
New Refineries-High Conversion			
U.S. East Coast	150	839.5	5595
U.S. Gulf Coast	150	713.5	4755
Caribbean	150	802.0	5345
Rotterdam	150	682.5	4550
Mexican	150	800.0	5335
Mid-East	150	1002.0	6680

H

DISCUSSION

EXISTING REFINERIES

The 1980 Reference Case gross and net operating margins for the existing United States Gulf Coast and foreign refineries are provided in Table H–1. As outlined previously, the 1980 margins are keyed to the Caribbean hydroskimming refinery operating at the break-even level. The margins show that the Hydroskimming—20 MBPSD, Low Conversion—50 MBPSD, and High Conversion—100 MBPSD United States Gulf Coast refineries are at an economic disadvantage relative to both the Caribbean and Rotterdam hydroskimming export refineries.

In exporting product to the United States East Coast, the Caribbean hydroskimming operation has about a $0.65 to $0.70 per barrel economic advantage compared to the Rotterdam hydroskimming refinery. However, it should be noted that variations in the relative world tanker rates for crude oil and product transport will affect the relative competitiveness of the Caribbean and Rotterdam hydroskimming refineries.

Key factors to the relative economics of the existing refineries studied are:

- Location
- Scale of operation
- Product transportation rates
- Conversion level

Differences in the economics of the four Gulf Coast refinery types relative to the Caribbean hydroskimming refinery are summarized in the following:

Economics Relative to Caribbean Hydroskimming
1980 Reference Case
(1978 U.S. Dollars Per Barrel)

	U. S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Costs:				
Feedstock*	(0.94)	(1.39)	(1.37)	(1.24)
Operating	(0.35)	(0.59)	(0.50)	(0.51)
Product Transport	(0.86)	(0.84)	(0.81)	(0.78)
Subtotal	(2.15)	(2.82)	(2.68)	(2.53)
Product Slate Value - New York Harbor	0.01	1.71	2.23	2.67
Gross Margin	(2.14)	(1.11)	(0.45)	0.14

* Crude oil plus purchased butanes

Key factors and possible variations in the differences in the above categories are outlined in the following.

Feedstock Costs

Crude oil costs for the large Caribbean and Rotterdam hydroskimming refineries are significantly lower than for United States Gulf Coast refineries due to their location adjacent to a deepwater port. United States Gulf Coast ports are typically limited to 70 thousand to 80 thousand DWT vessels. The increased cost of foreign crude oil due to port limitations for United States Gulf Coast refineries is shown in the following:

Crude Oil Transportation Cost Sensitivity
United States Gulf Coast Refineries
(1978 U.S. Dollars per Barrel)

Crude Source	1980 Reference Case	Deepwater Port Sensitivity	Cost Reductions
Middle East	1.77-1.85	1.15-1.23	0.62
North Africa	0.97	0.77	0.20
West Africa	1.04	0.82	0.22

Operating Costs

Operating costs vary among the refineries depending upon the size and conversion level of the refineries. Manpower costs are significantly greater for the smaller Gulf Coast refineries compared with the offshore large hydro-skimming units due primarily to the smaller scale of operation. Utilities, maintenance, and catalyst/chemical charges are determined by the conversion level of the refinery. Increases in these costs for the higher conversion United States Gulf Coast refineries should be offset by higher product revenues.

Ad valorem taxes are determined by the location of the refinery. Generally most of the Caribbean export refineries have arrangements with the local governments which eliminate or lower the ad valorem tax burden.

Product Transport

As discussed previously, the Jones Act requires that vessels transporting product from United States locations must be United States flagships. This regulation effectively creates a separate tanker market which determines product transport costs for United States refiners from the international market for foreign refiners. Over the past year there has been a very large surge in world tanker rates, particularly in the "handy size" 30 thousand to 80 thousand DWT size range which can be accomodated in United States ports. Voyage charter rates in the international market exceeded W.S. 300. Rates for United States flagships also surged early in 1979, but settled back to the AR 200 - 225 range by mid year due to an easing in requirements for Alaskan oil transport through the Panama Canal.

In response to the tight market and pending stiff international antipollution measures, there has been a dramatic burst of orders during 1979 for 80 thousand tonners. With a one to two year construction period, Pace forecasts rates for foreign product carriers to United States ports to settle by the early 1980s to an average of W.S. 150 and W.S. 109 for clean and dirty carriers, respectively. Also a large number of the vessels in the 30 thousand to 80 thousand DWT size range are petroleum company owned. Therefore, long-term charter rates will temper surges in voyage charter rates in the determination of average transport costs.

On the other hand, although rates for United States flagships have been above the level for full recovery of capital costs since 1978, uncertainty about long term requirements, particularly with respect to Alaskan oil movement, has caused orders for new United States tankers to lag demand growth. Therefore, American flagship rates of AR 250 and 300 could quite possibly prevail during the early 1980s.

A detailed discussion of the world and United States tanker markets for product carriers is provided in Section E.

Based on Pace's forecast of the relative world and United States tanker rates, the Jones Act significantly penalizes Gulf Coast refiners in competing in the East Coast products market. The impact of the United States Jones Act on the product transportation costs for United States Gulf Coast refiners is derived in the following:

Impact of Jones Act on U.S. Gulf Coast Refinery Economics
(1978 U.S. Dollars Per Barrel)

	U. S. Gulf Coast Refinery			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Average Product Transport to United States East Coast:				
1980 Sensitivity Case - World Rate	0.59	0.61	0.62	0.62
1980 Reference Case - AR 200	1.42	1.39	1.36	1.33
Net Increase/(Decrease)	(0.83)	(0.78)	(0.74)	(0.71)

As shown in the preceding table, product tanker rates for movement to the United States East Coast in Jones Act vessels are more than double that for the same voyage at world rates. The regulation increases Gulf Coast refiners product costs by about $0.70 to $0.85 per barrel.

Over the next couple of years, shifts in the relative rates of United States and foreign tankers are probable. The sensitivity of the comparison to a continuation of current world rates at W.S. 300 and an increase in American flagship rates to AR 300 is derived in Table H-2 and summarized in the following:

Product Transport Cost Comparison
Sensitivity to Relative World/U.S. Rates
(1978 U.S. Dollars Per Barrel)

World Rate*	U.S. Rate	Product Transport Cost U.S. Gulf Coast to East Coast Increase/(Decrease) @ World Rate
W.S. 150/109	AR 200	(0.71)-(0.83) Pace Forecast
W.S. 300/300	AR 200	0.03 -(0.09)
W.S. 300/300	AR 300	(0.64)-(0.80)
W.S. 150/109	AR 300	(1.38)-(1.54)

* Clean/dirty carriers

Therefore, current world and United States voyage charter rates for 30 thousand to 80 thousand DWT tankers are about equivalent, with the Jones Act creating no disadvantage for United States refiners at present. However, if United States rates again surge to the AR 300 level, United States refiners are placed at a $0.65 to $0.80 per barrel cost disadvantage which is about the same as in the 1980 Reference Case comparison. A decline in the world rates would make the United States Gulf Coast refiner's disadvantage even more substantial.

Product Values

Because of the variations in the product slates of the existing United States and offshore refineries studied, the assumption as to the relative values of the different product categories is a critical factor to the economic comparison. As discussed previously in Section E, due to United States crude oil controls and the large volume of residual fuel oil imports into the United States East Coast, the differential between light products (gasoline and distillates) and residual fuel oil in the New York Harbor has been much less than in other world markets until recently. In 1979, the tight supply of light crude oil, aggravated by the Iranian crisis, has resulted in a widening of the differential between the higher sulfur residual fuel oil grades and light products (gasoline and distillates) on the United States East Coast. Pace forecasts the high sulfur residual price differential to remain close to 1979 levels through the 1980s with crude oil decontrol.

Refined product price differentials in our Reference Case economics reflect historic world levels adjusted to account for United States product consumption patterns. The 1980 Reference Case relative product values forecast for the New York Harbor compare with actual 1978 and 1979 differentials as shown following:

Refined Product Price Differentials
New York Harbor
(1978 U.S. Dollars per Barrel)

	Actual*		1980
	1978	1979	Reference Case
Premium Gasoline	0.15	0.13	0.21
Unleaded Gasoline	-	-	-
Regular Gasoline	(1.14)	(1.45)	(1.47)
Kerosene/Jet-A	(1.17)	(1.12)	(1.34)
No. 2 Fuel Oil	(1.93)	(3.17)	(2.44)
Residual Fuel Oil			
0.3 wt.% S	(3.42)	(3.05)	(3.02)
1.0 wt.% S	(4.42)	(6.23)	(7.20)
3.0 wt.% S	(6.14)	(10.21)	(10.08)

* Based on average annual terminal prices. The 1979 figures are based on 9 months data.

Product price differentials under decontrol cannot be predicted with certainty at present. Because of the higher yield of the high sulfur residual fuel oil grades in the hydroskimming refineries, the value placed on this product category relative to gasoline and distillates is a key assumption to the economics. As a sensitivity case we have determined the relative economics of the existing refineries studied on the basis of the actual 1978 New York Harbor differentials. The relative competitiveness of United States Gulf Coast and foreign refineries for this price differential sensitivity compare with that indicated by the Reference Case economics as summarized in the following:

Product Price Sensitivity
1978 New York Harbor Differentials
(1978 U.S. Dollars Per Barrel)

	1980 Gross Margin		
	Sensitivity Case 1978 Differentials	Reference Case	Increase/ (Decrease)
Caribbean Hydroskimming	0.0	0.0	0.0
Rotterdam Hydroskimming	(0.56)	(0.68)	0.12
U.S. Gulf Coast Refineries			
Hydroskimming - 20 MBPSD	(1.90)	(2.14)	0.24
Low Conversion - 50 MBPSD	(1.46)	(1.11)	(0.35)
High Conversion - 100 MBPSD	(1.09)	(0.45)	(0.64)
High Conversion - 335 MBPSD	(0.73)	0.07	(0.80)

As shown preceding, with residual fuel values relative to gasoline at 1978 levels, the higher conversion United States refineries become less competitive relative to the large Caribbean and Rotterdam hydroskimming refineries. Pace considers it unlikely that the differential between gasoline and residual fuel oil will narrow to 1978 levels. However, the 1978 differentials sensitivity case demonstrates how important relative product price values are to the competitiveness of United States conversion refineries with the foreign hydroskimming refineries.

Government Regulations

In addition to the product transportation cost disadvantage imposed by the United States Jones Act, federal, state, and local emission standards which limit the sulfur content of refinery fuel oil also represent an economic penalty. Refinery fuel oil levels on the United States Gulf Coast typically range from 0.75 to 1.0 weight percent sulfur, with local variations common. We have restricted refinery fuel oil levels to 0.75 weight percent sulfur for the existing Gulf Coast refineries in this study. On the other hand, plant fuel oil sulfur levels in the Caribbean and Rotterdam are typically much higher (3.0 and 3.5 weight percent sulfur, respectively). The economic disadvantage imposed on United States Gulf Coast refiners by plant fuel oil sulfur restrictions is derived in Table H-3 by comparing the 1980 Reference Case refinery net-back values of 0.75 weight percent sulfur and 3.0 weight percent sulfur residual fuel oil.

The disadvantage that the United States Jones Act, coupled with plant fuel oil sulfur restrictions, is expected to cause for United States Gulf Coast refiners is summarized in the following:

Effect of United States Regulations
1980 Reference Case
(1978 U.S. Dollars Per Barrel)

	U. S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Product Transport	(0.83)	(0.78)	(0.74)	(0.71)
Plant Fuel Oil Sulfur	(0.09)	(0.12)	(0.10)	(0.17)
Total	(0.92)	(0.90)	(0.84)	(0.88)

United States environmental regulations have also increased the capital investment requirements for United States refineries. These additional capital costs for United States refineries are discussed later in the analysis of the new refineries studied. In our comparison of existing refineries we have considered only the relative operating costs, **excluding capital charges.**

1985 Outlook

There should continue to be a considerable surplus of refining capacity through 1985, considering the United States, Western Europe, and the Caribbean as an aggregate region. Based on our 1985 Reference Case New York Harbor prices, we have determined the resultant gross and net operating margins for the existing refineries studied to be as shown in Table H-4. We foresee only relatively minor shifts in the relative gross margins of the United States and offshore refineries, as shown in the following:

Economics Relative to Caribbean Hydroskimming
1985 Reference Case
(1978 U.S. Dollars Per Barrel)

	U. S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Costs:				
Feedstock	(0.94)	(1.35)	(1.32)	(1.21)
Operating	(0.35)	(0.59)	(0.50)	(0.51)
Product Transport	(0.86)	(0.84)	(0.81)	(0.78)
Subtotal	(2.15)	(2.78)	(2.63)	(2.50)
Product Slate Value - New York Harbor	0.09	1.95	2.47	3.01
Net Difference in Gross Margin - 1985	(2.06)	(0.83)	(0.16)	0.51
- 1980	(2.14)	(1.11)	(0.45)	0.14

Shifts in the relative values of the product slates from 1980 to 1985 are the major factor to the changes in the relative gross margins.

Pace forecasts the differential between residual fuel oil and gasoline to widen through 1985 due to the shift in the United States gasoline mix to a higher percentage of unleaded. The increased demand for unleaded gasoline will require a significant amount of additional octane improvement capacity by 1985, even with a 1.6 percent per year decline in total gasoline production. Therefore, the gross margins of the United States refineries with existing conversion facilities (reforming, akylation, catalytic cracking, etc.) should improve relative to those for hydroskimming operations.

As total product demand increases, rising refinery capacity utilization should boost product margins above the break-even level. As discussed previously, the Caribbean export refineries have favorable tax arrangements with the island governments that significantly lower their income tax rate compared to a United States refinery. Income tax rates in the Caribbean range from zero to 39 percent compared to 50 percent in the United States and typically 48 percent in Western Europe. The 1985 Reference Case net operating margins (gross margin minus income taxes) for the existing United States refineries compare with that for the Caribbean and Rotterdam export refineries as shown in the following.

Comparative Net Operating Margins*
1985 Reference Case
(1978 U.S. Dollars Per Barrel)

	U. S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Caribbean Hydroskimming				
@ 0% Income Tax Rate	(2.31)	(1.69)	(1.36)	(1.02)
@ 39% Income Tax Rate	(1.31)	(0.69)	(0.36)	(0.02)
Rotterdam Hydroskimming				
@ 48% Income Tax Rate	(0.72)	(0.10)	0.23	0.57

The difference in gross margins—i.e., product margin over total refining costs—determines the relative competitiveness of refineries. However, the income tax levied is a key factor to the overall profitability of a refinery, and differences in income tax rates can affect regional capacity utilization. A large international oil company with refineries in both the Caribbean and the United States could increase overall corporate profitability by maximizing utilization of the Caribbean refining capacity.

Modified Caribbean Export Refinery

As shown previously, the margins of existing United States refineries improve substantially as the conversion level of the refinery increases. By 1985 an existing Caribbean export refinery could add conversion and desulfurization facilities to upgrade the refinery's overall product mix. Likely process unit additions and associated investment requirements are provided in Table H-5. The 1985 Reference Case operating margins for the modified Caribbean export refinery are provided in Table H-6. The relative economics of existing United States Gulf Coast refineries and the modified existing Caribbean export refineries are shown in the following:

Economics Relative to Modified Caribbean Export Refinery - 1985 Reference Case

	U.S. Gulf Coast Refinery Advantage/(Disadvantage)			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Costs				
Feedstock[1]	(0.55)	(0.96)	(0.93)	(0.82)
Operating	(0.10)	(0.34)	(0.25)	(0.26)
Product Tranposrt	(0.83)	(0.81)	(0.78)	(0.75)
Subtotal	(1.48)	(2.11)	(1.96)	(1.83)
Product Slate Value New York Harbor	(1.92)	(0.06)	0.46	1.00
Total	(3.40)	(2.17)	(1.50)	(0.83)
Capital Charges[2]				
Depreciation	0.43	0.43	0.43	0.43
10% ATROI	0.43	0.43	0.43	0.43
	0.86	0.86	0.86	0.86
Net	(2.54)	(1.31)	(0.64)	0.03

(1) Crude oil plus purchased butanes

(2) Charges for Caribbean refinery investment reflected as credit for United States refineries

The economics indicate that the addition of conversion facilities would improve the competitiveness of the Caribbean export refineries. Based on the 1985 Reference Case product price differentials, the processing unit additions would yield about a 20.5 percent annual before tax return on investment.

NEW REFINERIES

The 1985 Reference Case operating margins and return-on-investment for the low and high conversion—150 MBPSD new refineries types are derived in Tables H-7 and H-8, respectively. As outlined previously, our 1985 Reference Case New York Harbor product prices are the level required to yield a 10 percent after tax return on investment (ATROI) for a new East Coast refinery. Refined product demand growth in the United States should support new refinery construction by the mid-1980s, even considering the current foreign refining capacity surplus. The conversion level of the new refinery built to serve the United States refined products market in the mid-1980s is not certain. The two conversion levels considered for the new refineries in this study should bracket the possible range.

The 1985 Reference Case net operating margins, total refinery investment, and return on investment for the new refinery types and locations considered are summarized in Table H-9. The return on investment for a new Caribbean, Rotterdam, and Mexican refinery with either a low or high conversion operation is greater than that for either a United States East Coast or Gulf Coast refinery.

The criteria for establishing the return on investment required to justify construction of a new refinery often vary by location. Factors to be considered are:

- Stability of the local government
- Possibility of nationalization of assets
- Uncertainty in future import/export policies of the countries concerned

A 10 percent ATROI is considered the typical requirement for most refinery projects. The net operating margin required to yield a 10 percent ATROI for the new refineries considered is derived in Table H-10. The difference in the 1985 Reference Case net operating margins and that yielding a 10 percent ATROI for the new refineries is summarized as follows:

Net Operating Margin Difference*
(1978 U.S. Dollar per Barrel)

	Advantage/(Disadvantage)	
	Low Conversion 150 MBPSD	High Conversion 150 MBPSD
United States East Coast	0.12	0.00
United States Gulf Coast	(0.14)	(0.14)
Caribbean	1.82	2.00
Rotterdam	0.35	0.37
Mexico	2.35	3.07
Middle East	(0.12)	0.12

* Above the level required for a 10 percent ATROI

A comparison of the 1985 Reference Case economics of the new United States East Coast refinery with those for the other refinery locations considered is provided in Table H-11. Key factors and sensitivities in the advantages/disadvantages of each refinery location are discussed in the following.

United States Gulf Coast

With the cost differences established in the 1985 Reference Case, the United States Gulf Coast is a less favorable location for a new foreign crude oil based refinery to serve the United States East Coast compared with an East Coast location. The major disadvantage is created by the Jones Act requirement that United States flagships must be used to move product by tanker to the United States East Coast. If world rates would apply to product movements from the United States Gulf Coast to the East Coast, the Gulf Coast location would then become more economical as shown in the following:

Impact of Jones Act on New 1985 Gulf Coast Refinery
(1978 U.S. Dollars Per Barrel)

	United States Gulf Coast	
	Low Conversion 150 MBPSD	High Conversion 150 MBPSD
Product Transport to United States East Coast		
Reference Case - AR 200	1.37	1.36
Sensitivity Case - World Rates	0.60	0.62
Net Reduction	0.77	0.74
Gross Operating Margin—World Rates	2.60	3.18
Income Taxes—World Rates	1.30	1.59
Net Operating Margin—World Rates	1.30	1.59
After Tax ROI, Percent	12.0	12.0

Operating and capital costs are significantly lower on the United States Gulf Coast. Lower wage rates which affect operating, maintenance, and construction labor costs are a major factor. The capital cost advantage for the United States Gulf Coast is shown in the following:

Capital Cost Comparison
(1978 U.S. Dollars per Barrel)

	Depreciation 10% Straight Line	Profit 10% After Tax	Total
Low Conversion—150 MBPSD			
U.S. East Coast	1.02	1.24	2.26
U.S. Gulf Coast	0.85	1.06	1.91
Net Difference	0.17	0.18	0.35
High Conversion—150 MBPSD			
U.S. East Coast	1.37	1.60	2.97
U.S. Gulf Coast	1.15	1.36	2.51
Net Difference	0.22	0.24	0.46

Therefore, the lower total cost of construction provides the United States Gulf Coast location with a $0.35 to $0.46 per barrel capital cost advantage.

Caribbean

The Caribbean location provides a relatively modest $0.29 to $0.34 per barrel refining cost advantage compared to the United States East Coast. Higher refinery fuel sulfur levels are permitted in the Caribbean, resulting in lower desulfurization requirements which in turn decreases total refinery investment, fuel, and hydrogen requirements. The disadvantage imposed by United States East Coast environmental restrictions is estimated to be as follows:

Impact of United States East Coast Emission Restrictions
(1978 U.S. Dollars)

	United States East Coast	
	Low Conversion	High Conversion
Plant Investment, Million $	35.00	48.50
Associated Capital Costs, $/Bbl		
Depreciation	0.07	0.09
ATROI, 10%	0.07	0.09
Subtotal	0.14	0.18
Additional Fuel & Hydrogen, $/Bbl	0.06	0.08
Total	0.20	0.26

Lower taxes are the major advantage a Caribbean location offers a refiner. It is likely that a favorable income tax arrangement could be negotiated with the island government for a new Caribbean refinery. Based on the current range in island income tax rates of zero to 39 percent, the profitability of a new Caribbean refinery can vary as follows:

Income Tax Rate Sensitivity New 1985 Caribbean Refinery (1978 U.S. Dollars per Barrel)				
	Low Conversion		High Conversion	
Income Tax Rate	0%	39%	0%	39%
Gross Operating Margin	3.00	3.00	3.53	3.53
Income Taxes	-	1.17	-	1.39
Net Operating Margin	3.00	1.83	3.53	2.14
After Tax ROI (Percent)	25.5	15.5	23.0	14.0

Rotterdam

As shown in Table H-11, the new United States East Coast and Rotterdam refineries are essentially competitive with the Rotterdam refinery having a modest $0.35 per barrel advantage. Higher product transportation costs offset lower crude oil, operating, and capital costs for the Rotterdam refiner.

Mexico

The Mexican refinery enjoys the greatest economic advantage of the foreign refineries considered. Key factors to the economic advantage of the Mexican refinery are the following:

- Pricing of Mexican crude oil
- Use of low valued natural gas to supplement refinery fuel gas
- Income tax flexibilities.

The pricing of Mexican crude oil is not certain at present. Both the United States and Western Europe represent major markets for Mexican production. In 1978 the delivered price of Mexican Isthmus crude oil on the United States Gulf Coast was significantly below that of the similar quality Saudi Arabian Light. In the Reference Case economics presented in this study, we have set the value of Mexican Isthmus at the delivered price of Saudi Light in Rotterdam less transportation from Mexico. The netback price for sales to Rotterdam is significantly less than the equivalent netback for sales to the United States Gulf Coast.

However, in a tight crude oil sellers market, the Mexicans may receive the equivalent price for Saudi Light on the United States Gulf Coast. The effect of the latter on the value of Isthmus crude oil in a Mexican refinery is derived in Table H-12. The impact on the economics of a new refinery is summarized in the following:

Mexican Crude Price Sensitivity
(1978 U.S. Dollars per Barrel)

	Mexican Refinery	
	Low Conversion 150 MBPSD	High Conversion 150 MBPSD
Net Crude Oil Price Difference	1.10	1.10
Net Operating Margin		
1985 Reference Case	3.55	4.59
Crude Price Sensitivity Case	2.45	3.49
Return On Investment		
1985 Reference Case	29.5	30.0
Crude Price Sensitivity Case	20.0	23.0

The availability of low-valued natural gas to supplement refinery fuel gas requirements also provides the Mexican refinery with a considerable cost advantage as shown in the following:

Fuel Cost Advantage
1985 Reference Case
(1978 U.S. Dollars)

	Mexican Refinery	
	Low Conversion 150 MBPSD	High Conversion 150 MBPSD
Natural Gas Fuel Use— Equivalent BPSD of 0.5 wt.% S Residual Fuel Oil	3215	4045
Natural Gas Fuel Cost, MM$/Yr		
@ 35¢/MMBTU	2.2	2.7
@ 0.5 wt.% S Resid Value	21.9	27.5
Net Difference	19.7	24.8
$/Bbl of Crude Oil Throughput	0.38	0.47

We have not accounted for an income tax in the new Mexican refinery economics. With a nationalized oil industry, all refinery gross profits would essentially accrue to the government. Justification of a new export refinery would likely be based on an adequate return on investment to the government. A 10 percent rate of return—equivalent to a 10 percent ATROI for a private company—is a likely criterion. The positive effects of new refinery construction and operation on area industrialization would likely also be considered.

Middle East

The new United States East Coast and Middle East refineries are essentially competitive. Using the same criteria for a government-owned Middle East refinery as that for a government-owned Mexican refinery, we have not included an income tax in the new Middle East refinery economics. Higher refinery investment costs offset income tax and other cost advantages.

TABLE H-1

ECONOMIC SUMMARY
EXISTING REFINERIES - 1980 REFERENCE CASE
(1978 U.S. Dollars Per Barrel)

	Caribbean Hydroskimming 400 MBPSD		Rotterdam Hydroskimming 300 MBPSD		U. S. Gulf Coast Hydroskimming 20 MBPSD		U. S. Gulf Coast Low Conversion 50 MBPSD		U. S. Gulf Coast High Conversion 100 MBPSD		U. S. Gulf Coast High Conversion 335 MBPSD	
	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl
Feedstock Costs												
Crude Oil	(1936.6)	(13.83)	(1493.1)	(14.22)	(103.4)	(14.77)	(259.0)	(14.80)	(518.0)	(14.80)	(1725.9)	(14.72)
Butanes	-	-	-	-	-	-	(7.4)	(0.42)	(14.0)	(0.40)	(41.0)	(0.35)
Subtotal	(1936.6)	(13.83)	(1493.1)	(14.22)	(103.4)	(14.77)	(266.4)	(15.22)	(532.0)	(15.20)	(1762.9)	(15.07)
Operating Costs												
Salaries and Wages	(18.2)	(0.13)	(13.7)	(0.13)	(2.3)	(0.33)	(5.7)	(0.32)	(7.5)	(0.21)	(16.8)	(0.14)
Utilities	(8.8)	(0.06)	(5.3)	(0.05)	(0.5)	(0.07)	(2.0)	(0.12)	(4.4)	(0.13)	(19.5)	(0.17)
Maintenance/Supplies	(20.5)	(0.15)	(12.3)	(0.12)	(1.5)	(0.21)	(5.0)	(0.29)	(9.9)	(0.28)	(33.7)	(0.29)
Catalyst/Chamicals	(7.2)	(0.05)	(5.1)	(0.05)	(0.3)	(0.04)	(2.1)	(0.12)	(4.9)	(0.14)	(19.9)	(0.17)
Taxes and Insurance	(6.6)	(0.04)	(7.9)	(0.07)	(0.9)	(0.13)	(3.0)	(0.17)	(6.0)	(0.17)	(20.0)	(0.17)
Subtotal	(61.3)	(0.43)	(44.3)	(0.42)	(5.5)	(0.78)	(17.8)	(1.02)	(32.7)	(0.93)	(109.9)	(0.94)
Total Costs	(1997.9)	(14.26)	(1537.4)	(14.64)	(108.9)	(15.55)	(284.2)	(16.24)	(564.7)	(16.13)	(1876.8)	(16.01)
Product Revenues	1997.9	14.26	1466.1	13.96	93.9	13.41	264.7	15.13	548.8	15.68	1892.9	16.15
Gross Operating Margin	0.0	0.0	(71.3)	(0.68)	(15.0)	(2.14)	(19.5)	(1.11)	(15.9)	(0.45)	16.1	0.14
Income Taxes	-	-	-	-	-	-	-	-	-	-	(8.0)	(0.07)
Net Operating Margin	0.0	0.0	(71.3)	(0.68)	(15.0)	(2.14)	(19.5)	(1.11)	(15.9)	(0.45)	8.1	0.07

TABLE H-2

PRODUCT TRANSPORT COST SENSITIVITY
UNITED STATES GULF COAST REFINERY ECONOMICS
(1978 U.S. Dollars Per Barrel)

	Average Tanker Cost to U.S. East Coast			
	Hydro-skimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Current World/U.S. Rates				
W.S. 300	1.33	1.35	1.36	1.36
A.R. 200 (Pace Forecast)	1.42	1.39	1.36	1.33
Net Increase/(Decrease)	(0.09)	(0.04)	0.00	0.03
U.S. Rates @ A.R. 300				
W.S. 300	1.33	1.35	1.36	1.36
A.R. 300	2.13	2.09	2.04	2.00
Net Increase/(Decrease)	(0.80)	(0.74)	(0.68)	(0.64)
W.S. 150/109* (Pace Forecast)	0.59	0.61	0.62	0.62
A.R. 300	2.13	2.09	2.04	2.00
Net Increase/(Decrease)	(1.54)	(1.48)	(1.42)	(1.38)

* Clean/Dirty Vessel Rates - sensitivity case for W.S. 300 assumes clean and dirty rate is equivalent

TABLE H-3

IMPACT OF U.S. EMISSION RESTRICTIONS
1980 REFERENCE CASE

	United States Gulf Coast Refinery			
	Hydroskimming 20 MBPSD	Low Conversion 50 MBPSD	High Conversion 100 MBPSD	High Conversion 335 MBPSD
Plant Fuel Oil Use, BPSD				
0.75 wt. % S Residual	401	1420	2341	13512
Equivalent 3.0 wt. % S Residual	385	1365	2250	12984
Plant Fuel Oil Value, MM$/Yr.				
0.75 wt. % S Residual	1.77	6.26	10.32	59.54
3.0 wt. % S Residual	1.17	4.15	6.84	39.49
Net Difference	0.60	2.11	3.48	20.05
1978 $/Bbl of Crude Oil Throughput	0.09	0.12	0.10	0.17

TABLE H-4

ECONOMIC SUMMARY
EXISTING REFINERIES - 1985 REFERENCE CASE
(1978 U.S. Dollars Per Barrel)

	Caribbean Hydroskimming 400 MBPSD		Rotterdam Hydroskimming 300 MBPSD		U. S. Gulf Coast							
					Hydroskimming 20 MBPSD		Low Conversion 50 MBPSD		High Conversion 100 MBPSD		High Conversion 335 MBPSD	
	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl
Feedstock Costs												
Crude Oil	(1972.9)	(14.09)	(1526.0)	(14.53)	(105.2)	(15.03)	(263.5)	(15.06)	(527.1)	(15.06)	(1756.4)	(14.98)
Butanes	-	-	-	-	-	-	(6.6)	(0.38)	(12.4)	(0.35)	(38.1)	(0.32)
Subtotal	(1972.6)	(14.09)	(1525.7)	(14.53)	(105.2)	(15.03)	(270.1)	(15.44)	(539.5)	(15.41)	(1794.5)	(15.30)
Operating Costs												
Salaries and Wages	(18.2)	(0.13)	(13.7)	(0.13)	(2.3)	(0.33)	(5.7)	(0.32)	(7.5)	(0.21)	(16.8)	(0.14)
Utilities	(8.8)	(0.06)	(5.3)	(0.05)	(0.5	(0.07)	(2.0)	(0.12)	(4.4)	(0.13)	(19.5)	(0.17)
Maintenance/Supplies	(20.5)	(0.15)	(12.3)	(0.12)	(1.5)	(0.21)	(5.0)	(0.29)	(9.9)	(0.28)	(33.7)	(0.29)
Catalyst/Chemicals	(7.2)	(0.05)	(5.1)	(0.05)	(0.3)	(0.04)	(2.1)	(0.12)	(4.9)	(0.14)	(19.9)	(0.17)
Taxes and Insurance	(6.6)	(0.04)	(7.9)	(0.07)	(0.9)	(0.13)	(3.0)	(0.17)	(8.0)	(0.17)	(20.0)	(0.17)
Subtotal	(61.3)	(0.43)	(44.3)	(0.42)	(5.5)	(0.78)	(17.8)	(1.02)	(32.7)	(0.93)	(109.9)	(0.94)
Total Costs	(2033.9)	(14.52)	(1570.0)	(14.95)	(110.7)	(15.81)	(287.9)	(16.48)	(572.2)	(16.34)	(1904.4)	(16.24)
Product Revenues	2392.2	17.08	1765.1	16.81	114.2	16.31	318.3	18.19	656.0	18.74	2264.1	19.31
Gross Operating Margin	358.3	2.56	195.1	1.86	3.5	0.50	30.4	1.73	83.8	2.40	359.7	3.07
Income Taxes	-	-	(93.6)	(0.89)	(1.7)	(0.25)	(15.2)	(0.87)	(41.9)	(1.20)	179.8	1.53
Net Operating Margin	358.3	2.58	101.5	0.97	1.8	0.25	15.2	0.87	41.9	1.20	179.9	1.54

TABLE H-5

REFINERY INVESTMENT
MODIFIED EXISTING CARIBBEAN REFINERY
(1978 U.S. Dollars)

	MBPSD		
	Total	New	Million Dollars
Onsite Investment			
Crude Oil Distillation	400.0	-	-
Vacuum Distillation	171.0	61.0	22.0
Cyclic Reforming	104.5	79.5	70.0
Alkylation (Product)	-	22.0	29.0
Catalytic Cracking	-	84.0	84.5
Hydrotreating			
- Naphtha	104.5	79.5	22.0
- Distillate	73.0	58.0	46.0
- VGO	85.0	35.0	17.5
Hydrogen Plant (MMSCF/SD)	-	-	-
Saturated Gas Plant	20.0	9.0	7.0
Unsaturated Gas Plant	23.0	23.0	13.5
Merox Treating	77.0	-	-
Sulfur Plant (Ton/SD)	358.0	148.0	10.5
Total Onsite			322.0
Offsite Investment			
Utilities			64.0
Tankage			-
Other Offsites			80.5
Additional Environmental			-
Total Offsites			144.5
Total Onsites & Offsites			466.5
Location Factor			x1.25
Plant Investment			583.0
Royalties			18.5
Fixed Investment			601.5
Initial Inventory of Catalysts and Chemicals			10.5
Working Capital			4.0
Land			-
Total Investment			616.0

TABLE H-6

MODIFIED EXISTING CARIBBEAN REFINERY
1985 ECONOMICS
(1978 U.S. Dollars)

	Million Dollars	Dollars per Barrel
Feedstock Costs		
Crude Oil	(1972.9)	(14.09)
Butanes	(54.9)	(0.39)
Subtotal	(2027.8)	(14.48)
Operating Costs		
Salaries and Wages	(21.0)	(0.15)
Utilities	(15.2)	(0.11)
Maintenance/Supplies	(41.8)	(0.29)
Catalyst/Chemicals	(5.4)	(0.04)
Taxes and Insurance	(12.4)	(0.09)
Subtotal	(95.8)	(0.68)
Depreciation	(60.2)	(0.43)
Total Costs	(2183.8)	(15.60)
Product Revenues	2669.2	19.07
Gross Operating Margin	485.4	3.47
Income Taxes	-	-
Net Operating Margin	485.4	3.47

TABLE H–7

NEW REFINERY ECONOMICS
LOW CONVERSION – 1985 REFERENCE CASE
(1978 U.S. Dollars)

	U.S. East Coast		U.S. Gulf Coast		Caribbean		Rotterdam		Mexico		Middle East	
	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl
Feedstock Costs												
Crude Oil	(771.7)	(14.70)	(771.8)	(14.70)	(748.1)	(14.25)	(753.4)	(14.35)	(716.6)	(13.65)	(671.5)	(12.79)
Butanes	(2.0)	(0.04)	(1.9)	(0.04)	(1.7)	(0.03)	(1.7)	(0.03)	(0.8)	(0.01)	-	-
Fuel Gas	-	-	-	-	-	-	-	-	(2.2)	(0.04)	-	-
Subtotal	(773.7)	(14.74)	(773.7)	(14.74)	(749.8)	(14.28)	(755.1)	(14.38)	(719.6)	(13.70)	(671.5)	(12.79)
Operating Costs												
Salaries and Wages	(5.8)	(0.11)	(5.0)	(0.09)	(4.8)	(0.09)	(3.4)	(0.06)	(4.8)	(0.09)	(6.7)	(0.13)
Utilities	(7.5)	(0.14)	(7.5)	(0.14)	(9.3)	(0.18)	(9.4)	(0.18)	(4.6)	(0.09)	(5.0)	(0.10)
Maintenance/Supplies	(17.4)	(0.33)	(14.5)	(0.28)	(17.2)	(0.32)	(13.1)	(0.25)	(17.9)	(0.34)	(26.4)	(0.49)
Catalyst/Chemicals	(4.2)	(0.08)	(4.2)	(0.08)	(4.1)	(0.08)	(4.1)	(0.08)	(4.2)	(0.08)	(4.7)	(6.09)
Taxes and Insurance	(10.5)	(0.20)	(8.8)	(0.17)	(5.1)	(0.10)	(8.3)	(0.16)	(5.3)	(0.10)	(7.8)	(0.15)
Subtotal	(45.4)	(0.86)	(40.0)	(0.76)	(40.5)	(0.77)	(38.3)	(0.73)	(36.8)	(0.70)	(50.6)	(0.96)
Depreciation	(53.7)	(1.02)	(44.8)	(0.85)	(52.2)	(0.99)	(42.4)	(0.81)	(54.2)	(1.04)	(80.3)	(1.53)
Total Costs	(872.8)	(16.62)	(858.5)	(16.35)	(842.5)	(16.04)	(835.8)	(15.92)	(810.6)	(15.44)	(802.4)	(15.28)
Product Revenues	1014.7	19.33	954.3	18.18	1000.0	19.04	974.5	18.56	997.3	19.00	885.0	16.86
Gross Operating Margin	141.9	2.71	95.8	1.83	157.5	3.00	128.7	2.64	186.7	3.55	82.6	1.58
Income Taxes	(70.9)	(1.35)	(47.9)	(0.91)	-	-	(66.6)	(1.27)	-	-	-	-
Net Operating Margin	71.0	1.36	47.9	0.92	157.5	3.00	72.1	1.37	186.7	3.55	82.6	1.58
After Tax ROI (Percent)	11.0		8.5		25.5		13.5		29.5		9.5	

TABLE H-8

NEW REFINERY ECONOMICS
HIGH CONVERSION - 1985 REFERENCE CASE
(1978 U.S. Dollars)

	U.S. East Coast		U.S. Gulf Coast		Caribbean		Rotterdam		Mexico		Middle East	
	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl	MM$	$/Bbl
Feedstock Costs												
Crude Oil	(771.7)	(14.70)	(771.8)	(14.70)	(748.1)	(14.25)	(753.4)	(14.35)	(716.6)	(13.65)	(671.5)	(12.79)
Butanes	(22.4)	(0.43)	(21.2)	(0.41)	(21.8)	(0.43)	(20.8)	(0.40)	(29.8)	(0.56)	(2.4)	(0.05)
Fuel Gas	-	-	-	-	-	-	-	-	(2.7)	(0.05)	-	-
Subtotal	(794.1)	(15.13)	(793.0)	(15.11)	(769.9)	(14.66)	(774.2)	(14.75)	(749.1)	(14.26)	(673.9)	(12.84)
Operating Costs												
Salaries and Wages	(8.7)	(0.17)	(7.5)	(0.14)	(6.3)	(0.12)	(6.3)	(0.12)	(6.3)	(0.12)	(9.5)	(0.18)
Utilities	(7.5)	(0.14)	(7.5)	(0.14)	(9.2)	(0.17)	(9.2)	(0.17)	(4.1)	(0.08)	(5.0)	(0.10)
Maintenance/Supplies	(23.8)	(0.45)	(19.9)	(0.38)	(23.5)	(0.45)	(19.0)	(0.37)	(24.5)	(0.47)	(30.8)	(0.59)
Catalyst/Chemicals	(6.2)	(0.12)	(6.2)	(0.12)	(6.0)	(0.11)	(6.0)	(0.11)	(6.5)	(0.12)	(5.5)	(0.10)
Taxes and Insurance	(14.1)	(0.27)	(11.8)	(0.22)	(6.9)	(0.13)	(11.1)	(0.21)	(7.0)	(0.13)	(9.0)	(0.17)
Subtotal	(60.3)	(1.15)	(52.9)	(1.00)	(51.9)	(0.98)	(51.6)	(0.98)	(48.4)	(0.92)	(59.8)	(1.14)
Depreciation	(72.2)	(1.37)	(60.4)	(1.15)	(70.1)	(1.34)	(56.5)	(1.08)	(71.1)	(1.35)	(91.2)	(1.74)
Total Costs	(926.6)	(17.65)	(906.3)	(17.26)	(891.9)	(16.98)	(882.3)	(16.81)	(868.6)	(16.54)	(824.9)	(16.72)
Product Revenues	1094.3	20.84	1034.3	19.70	1077.0	20.51	1050.7	20.01	1109.2	21.13	931.3	17.74
Gross Operating Margin	167.7	3.19	128.0	2.44	185.1	3.53	168.4	3.20	240.6	4.59	106.4	2.03
Income Taxes	(83.8)	(1.59)	(64.0)	(1.22)	-	-	(80.8)	(1.53)	-	-	-	-
Net Operating Margin	83.9	1.60	64.0	1.22	1865.1	3.53	87.6	1.67	240.6	4.59	106.4	2.03
After Tax ROI (Percent)	10.0		9.0		23.0		13.0		30.0		11.5	

TABLE H-9

NEW REFINERY ECONOMICS SUMMARY
1985 REFERENCE CASE
(1978 U.S. Dollars)

	Total Refinery Investment (Million Dollars)	Net Operating Margin (Dollars per Barrel)	After Tax ROI (Percent)
Low Conversion			
U.S. East Coast	650	1.36	11.0
U.S. Gulf Coast	555	0.92	8.5
Caribbean	621	3.00	25.5
Rotterdam	535	1.37	13.5
Mexico	629	3.55	29.5
Middle East	891	1.58	9.5
High Conversion			
U.S. East Coast	839	1.60	10.0
U.S. Gulf Coast	713	1.22	9.0
Caribbean	802	3.53	23.0
Rotterdam	683	1.67	13.0
Mexico	800	4.59	30.0
Middle East	1002	2.03	11.5

TABLE H-10

1985 NET OPERATING MARGIN COMPARISON
(1978 U.S. Dollars Per Barrel)

	At Ten Percent ATROI	Reference Case	Net Difference
Low Conversion			
U.S. East Coast	1.24	1.36	0.12
U.S. Gulf Coast	1.06	0.92	(0.14)
Caribbean	1.18	3.00	1.82
Rotterdam	1.02	1.37	0.35
Mexico	1.20	3.55	2.35
Middle East	1.70	1.58	(0.12)
High Conversion			
U.S. East Coast	1.60	1.60	0.00
U.S. Gulf Coast	1.36	1.22	(0.14)
Caribbean	1.53	3.53	2.00
Rotterdam	1.30	1.67	0.37
Mexico	1.52	4.59	3.07
Middle East	1.91	2.03	0.12

TABLE H-11

COMPARATIVE ECONOMICS
1985 REFERENCE CASE

	Advantage/(Disadvantage) Relative to U.S. East Coast					
	U.S. East Coast	U.S. Gulf Coast	Caribbean	Rotterdam	Mexico	Middle East
LOW CONVERSION						
Out-of-Pocket Costs						
Feedstock	-	0.00	0.46	0.36	1.04	1.95
Operating	-	0.10	0.09	0.13	0.16	(0.10)
Product Transport	-	(1.15)	(0.33)	(0.79)	(0.38)	(1.70)
Subtotal	-	(1.05)	0.22	(0.30)	0.82	(0.15)
Depreciation	-	0.17	0.03	0.21	(0.02)	(0.51)
Product Slate Value - New York Harbor	-	-	0.04	0.02	0.04	(0.47)
Gross Operating Margin	-	(0.88)	0.29	(0.07)	0.84	(1.13)
Income Taxes	-	0.44	1.35	0.08	1.35	1.35
Net Operating Margin	-	(0.44)	1.64	0.01	2.19	0.22
HIGH CONVERSION						
Out-of-Pocket Costs						
Feedstock	-	0.02	0.47	0.38	0.87	2.29
Operating	-	0.15	0.17	0.17	0.23	0.01
Product Transport	-	(1.14)	(0.36)	(0.85)	(0.43)	(1.69)
Subtotal	-	(0.97)	0.28	(0.30)	0.67	0.61
Depreciation	-	0.22	0.03	0.29	0.02	(0.37)
Product Slate Value - New York Harbor	-	-	0.03	0.02	0.71	(1.40)
Gross Operating Margin	-	(0.75)	0.34	0.01	1.40	(1.16)
Income Taxes	-	0.37	1.59	0.06	1.59	1.59
Net Operating Margin	-	(0.38)	1.93	0.07	1.99	0.43

TABLE H-12

MEXICAN CRUDE OIL PRICE SENSITIVITY
(1978 U.S. Dollars Per Barrel)

1978 Reference Case - Rotterdam Netback Basis:	
Saudi Light F.O.B. Price	12.70
Transport Ras Tanura to Rotterdam	1.51
Transport Dos Bocos to Rotterdam	(0.76)
Mexican Isthmus F.O.B. Price	13.45
Sensitivity Case - U.S. Gulf Coast Netback Basis:	
Saudi Light F.O.B. Price	12.70
Transport Ras Tanura to U.S. Gulf Coast	2.10
Transport Dos Bocos to U.S. Gulf Coast	(0.25)
Mexican Isthmus F.O.B. Price	14.55
Net Difference	1.10