EPA-420-R-85-109

ESTIMATED REFINING COST IMPACT

OF

REDUCED GASOLINE VAPOR PRESSURE

- - - - - - - - -

FINAL REPORT

10 July 1985

Prepared For
Environmental Protection Agency
under Subcontract with
Southwest Research Institute

Contract No. 68-03-3162
Work Assignments 23 and 28

Bonner & Moore Management Science

2727 Allen Parkway • Houston, Texas 77019
(713) 522-6800 • TWX 910 881 2542

SWR-8501

DISCLAIMER

"This report was furnished to the Environmental Protection Agency by Bonner & Moore Management Science under subcontract to Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas, in fulfillment of Work Assignments 23 and 28 of Contract No. 68-03-3162. The contents of this report are produced herein as received from Bonner & Moore. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency."

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Paragraph Page

SECTION 3

SUMMARY OF RESULTS

SECTION 4

DETAILED RESULTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (Continued)

SECTION 1

INTRODUCTION

This report presents the results of a study of the economic impact, on the U. S. refining industry, of regulations which would reduce the vapor pressure of summer gasoline. The study was conducted under subcontract to Southwest Research Institute (SwRI) of San Antonio, Texas, the prime contractor for a work assignment project commissioned by the U. S. Environmental Protection Agency.

This study was initiated as a quick-response analysis of the refining industry costs involved in restricting vapor pressure in summer gasoline in the United States. To limit execution time and costs, only the Atlantic Coast, Mid-Continent and Gulf Coast regions were explicitly modeled and analyzed.

After interim reporting of initial results, several alternative situations or conditions were identified by the EPA as important extensions to the study. It was also decided that all results would be documented in a complete and formal manner in order to allow wider distribution of and broader access to the study than was originally envisioned.

It must be emphasized that expanding the study scope to include formal documentation did not expand the scope of the study itself, i.e., regionality remained restricted to the three-region basis as originally defined. The reader is, therefore, encouraged to review discussions of study approach and methodology (see Section 2, particularly subsection 2.3, which is a direct discussion of study limitations).

1.1 STUDY BACKGROUND

The language and content of this report assume that the reader is generally familiar with petroleum refining. The report, therefore, makes use of terms and references to processes used in petroleum refining without definition. On the other hand, the results presented do not require intimate knowledge of refining technology and can be understood with only a general knowledge of the major facets of refinery operations and their general relationship to gasoline manufacture. A brief overview of refinery operations, the importance of controlling gasoline volatility and possible means for restricting volatility are presented in subsequent paragraphs of this introduction for readers desiring a broad familiarity with the subject being analyzed.

1.1.1 Refinery Overview

Petroleum refineries are designed to separate crude oil, a complex mixture of hydrocarbon materials, into fractions with boiling ranges, combustion characteristics and other properties which are desirable in a variety of fuels, lubricants, solvents and petrochemical feedstocks. Processes are also installed and used to adjust product qualities and volumes in order to satisfy end-user demands.

In the U. S., motor gasoline is the major fuel product of refining. Its demand is normally greater than the volume of gasoline which can be distilled from most crude oils. Therefore, processes are used to thermally and catalytically "crack" or break up large hydrocarbon molecules present in distilled crude fractions, converting the less desirable fractions into materials with a boiling range within that bracketed for gasoline. Each refinery process produces a mixture of materials which makes the resultant material more or less suitable for a particular end product. Final product volume and quality are achieved by selective blending of available streams from the refining processes. Each refinery is, thus, a combination of processes whose capability varies with the kind of crude to be processed as well as the volume and quality demands for its finished products.

In general, when more restrictive product specifications are imposed (either by regulatory changes or by changes in engine design, for example), it becomes necessary to alter the conversion and blending operations to satisfy the additional requirements. Such changes normally impact the cost of manufacturing all end products, not just the product in question. It is, therefore, necessary to evaluate the overall cost impact on the entire refining operation in order to ascertain the cost of specific changes to a single product such as reduction of gasoline volatility. It is also possible for a change to be large enough to require new or expanded processes. Such large-magnitude changes involve capital expenditures as well as operating costs for the new or expanded processes.

1.1.2 Gasoline Volatility, Its Purpose and Control

To function properly as a fuel for spark-ignited internal-combustion engines, gasolines must have certain volatility characteristics. To permit easy starting of a cold engine, for example, the fuel must contain enough low-boiling hydrocarbons to provide, at ambient temperature, an air-fuel vapor mixture that is rich enough to be spark-ignited. Performance, after start-up and during and after warm-up of the engine, is also influenced by the concentrations of low-boiling constituents. If, however, the concentration of low-boiling hydrocarbons is not restricted, the fuel pump (after warm-up) may become "vapor locked" and fail to deliver enough fuel to support combustion, causing the engine to stall. Gasoline is normally blended with a volatility that is just below the level that might cause vapor lock.

With recognition that hydrocarbon emissions adversely affect air quality, evaporative losses of low-boiling hydrocarbons from vehicle fuel systems have become another reason for concern about gasoline volatility. Lowering gasoline volatility by decreasing the maximum allowable vapor pressure is one possible means of reducing evaporative losses. To do so, however, will increase the cost of manufacturing gasoline. To understand the reasons for the increased cost of low-volatility gasoline, it is helpful to review the manner by which gasoline volatility is controlled during fuel manufacture and the nature of certain relevant economic factors.

As formulated, gasoline normally contains hydrocarbons with boiling points ranging from 31 degrees Fahrenheit to approximately 400 degrees Fahrenheit.* The concentrations of hydrocarbons in this range are controlled to satisfy a variety of quality characteristics, including volatility. This control is accomplished by adjusting the refining processes which produce gasoline blend stocks and by the careful blending of these intermediate stocks to produce finished gasolines. Properties of blend stocks are determined largely by the nature of the processes involved, but can be

---

*Small amounts of hydrocarbons boiling outside this range are usually present because physical separation processes are imperfect.

varied somewhat by adjusting the operating conditions of those processes. Satisfying quality requirements of finished gasoline is, therefore, achieved primarily by controlled blending of available blend stocks and secondarily by control of operating conditions of processes by which blend stocks are made.

Two measures of volatility are used to obtain desired cold-start and warm-up characteristics in fuel. These measures are Reid Vapor Pressure (RVP)* and the temperatures below which specified percentages of the gasoline must boil.† Company-proprietary product specifications may involve the cited ASTM schedule or similar restrictions on the distillation properties of gasolines. Seasonal and regional adjustment is generally employed to account for ambient prevailing conditions. Vapor lock tendency is also controlled via a combination of vapor pressure and percent distilled at 158°F, namely,

$$VLI = RVP\ (psi) + 0.13\ (\%\ @\ 158°F).$$

This same relationship has been given the name Front-End Volatility Index (FEVI), and has been shown to relate to evaporative losses[1]. These two properties are related chiefly to the concentration of the lowest-boiling hydrocarbon constituents, namely butanes and pentanes (C_4s and C_5s) blended into gasoline. To a somewhat lesser extent, the concentration of C_6 components is also involved. Thus, control of gasoline volatility is related to the inclusion of these hydrocarbons in gasoline blend stocks.

---

*ASTM D 323
†ASTM D 439

Most refiners have access to normal butane (nC_4), both as a purchased raw material and as a refinery stream. Historically, normal butane has been available as a by-product from natural gas processing and has been priced well below gasoline. Thus, the refiner has an incentive to blend the maximum amount of butane into his gasoline as limited by vapor-lock considerations. A further incentive is the fact that normal butane has a high octane rating and thus reduces the cost of meeting octane requirements for finished gasolines.

Gasoline volatility is controlled to meet limits imposed by the average ambient temperatures of the region in which it will be sold. If gasoline volatility were restricted below present levels, refiners would further restrict the amount of low-boiling hydrocarbons in their blends. This would prevent the use of normal butane, a relatively inexpensive component, and in addition would require compensation for the octane quality which the butane would otherwise provide. The first step toward meeting more restrictive RVP limits would be to restrict (or discontinue) the blending of butane, as such. The second step would be to change processing to exclude butane presently contained in other blend stocks. This could require modification of existing separation facilities and/or the installation of new facilities to remove contained butanes. As a further step, extreme RVP limits could require removal of some C_5 components which in most cases would require new separation facilities. Not only would the refinery incur additional costs for removal of these hydrocarbons from gasoline, there also would be a loss in revenue since the rejected materials would be less valuable in their alternative dispositions. Achieving these alternate dispositions would require capital expenditures for new facilities such as storage tanks, loading racks, lines and pumps.

Finally, additional crude and adjusted processing conditions would be required to make up for the gasoline volume lost by rejecting low-boiling hydrocarbons to other dispositions and by increasing process severities to compensate for lost octane quality.

1.2 ACKNOWLEDGEMENTS

During the design and execution of this study, Mr. Cooper Smith of EPA, Ann Arbor, and Mr. Norman R. Sefer of Southwest Research Institute contributed suggestions and support and produced comments concerning final documentation. All of these efforts were helpful and are gratefully acknowledged.

1.3 REPORT ORGANIZATION

Beyond this introduction, this report contains three additional sections and six appendices. Section 2 discusses the approach taken and the methodology employed. Section 3 summarizes results obtained and Section 4 presents detailed results. Supporting information is presented in Appendices A through F. Bibliographies are included at the end of the main body of the report and with each appendix, as appropriate.

SECTION 2

APPROACH AND METHODOLOGY

An understanding of approach, premises and assumptions is important in judging the applicability of the results and in appreciating the study's inherent limitations. This section describes the general approach taken by Bonner & Moore Management Science in estimating the refining costs associated with gasoline vapor pressure reduction in the United States. General descriptions are also provided for the major study premises and assumptions.

2.1 GENERAL APPROACH AND METHODOLOGY

Estimates of the added costs associated with restricting gasoline volatility were prepared by determining the increased refining costs in each of three regions of the U. S., by using these results to estimate costs in two other regions, and by incorporating results from a recent study on vapor pressure reduction costs in California[2]. The three regions explicitly evaluated in this study are known as Petroleum Administration for Defense Districts (PADDs) 1, 2 and 3. These three regions, as well as the other two regions of concern, are mapped in Figure 2-1.

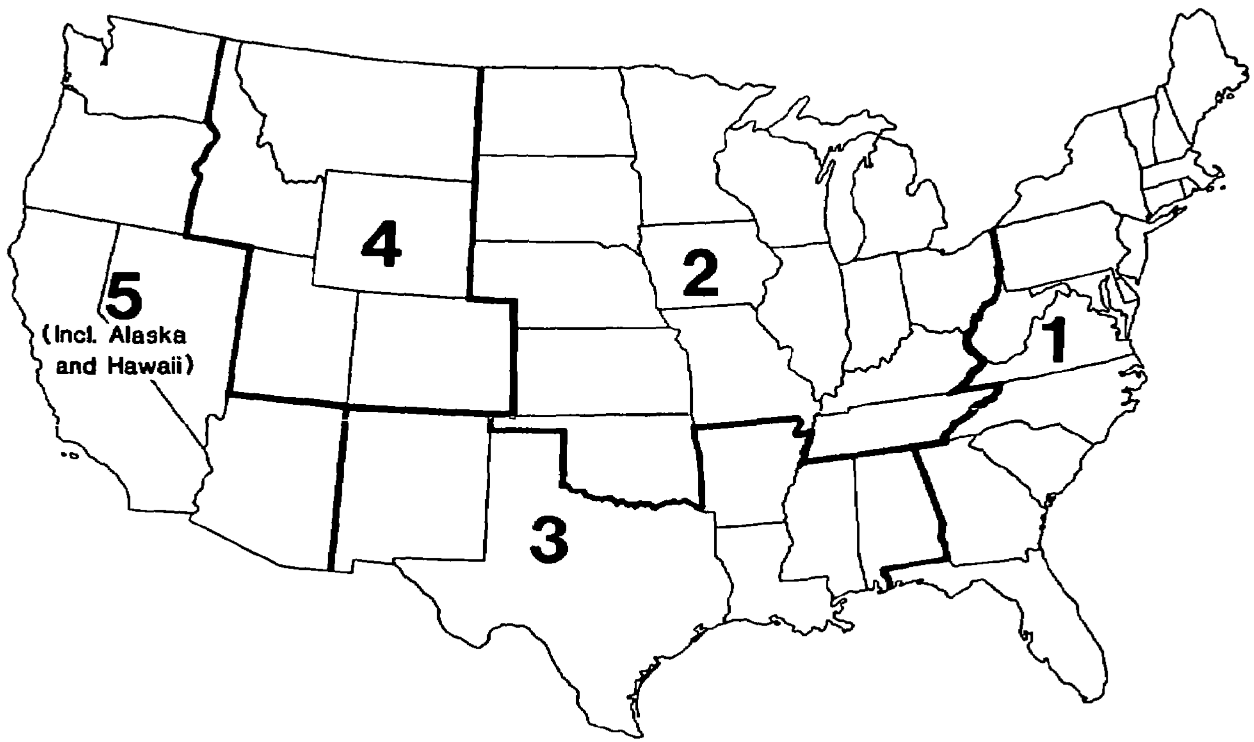

Figure 2-1. Petroleum Administration for Defense Districts (PADDs)

Mathematical (linear programming) models of the composite refining capability in PADDs 1, 2 and 3 were constructed using RPMS, a proprietary Bonner & Moore software and database system. Each model was run with gasoline vapor pressure set to correspond to current limits and, subsequently, at one and then two pounds per square inch (psi) reductions from current limitations. Differences in total refining costs, as determined from these runs, provided the desired cost estimates for each region modeled.

Results from analyses in these regions are extrapolated to national estimates by assuming that per-barrel costs for reducing gasoline vapor pressure for PADDs 4 and 5 (excluding California) would be the average of costs determined for PADDs 2 and 3, and by including results from the aforementioned study for California[2].

Three simplfying assumptions were employed to restrict the scope of the study in order to minimize time and cost of study completion. These assumptions were:

1) That national cost estimates will be sufficiently accurate if extrapolated from PADDs 1, 2 and 3 results and from the aforementioned California study.

2) That costs determined for the forecasted situation in 1990 will be indicative of long-range effects.

3) That industry-level results will be adequate for current and preliminary decision-making with respect to vapor pressure reductions. This underlying assumption precludes use of study results for decisions at the sub-regional or individual refinery levels.

Model study premises are summarized in the following paragraphs.

2.1.1 Product Demands

All products, except LPG and petroleum coke, were fixed at forecasted refining output for each region. LPG and coke were allowed to vary at prices determined from current market quotations. Forecasts of demands and refinery output are presented in Appendix A.

2.1.2 Crude Availabilities

Projections of crude supply were allocated to three classes; namely, low sulfur, high-sulfur and "swing" crudes. The swing crude was defined as a mix of 40 percent imported Arabian heavy crude oil and 60 percent imported Arabian light crude oil. Low-sulfur and high-sulfur mixes were fixed at projected volumes. The swing crude volume was allowed to vary as required by overall product output and process energy requirements. Crude oil supply forecasts are presented in Appendix B.

2.1.3 Other Raw Materials

Normal butane, iso-butane and natural gasoline volumes were defined on two bases; namely, as maxima based on recent DOE reporting and as fixed input at the same volumes defined as maxima. Details are presented in Appendix B.

2.1.4 Refinery Process Configuration

Total capacities of all major processes were imposed as maximum throughputs for each region. These throughputs were based on public information representing capacities as of 1 January 1984 (Oil & Gas Journal, March 26, 1984). Minor process capacities were allowed to take any required level at costs representing typical equipment construction. All major processes except for cat cracking of untreated feeds and light-oil hydrocracking were allowed to be built at costs typical of the sizes installed in recent years. Base configuration details are presented in Appendix E.

2.1.5 Economics

All costs and prices were set at first half 1984 values. Crudes were priced FOB the Arabian Gulf plus transportation to the East and Gulf Coasts and to the Great Lakes from the Gulf Coast. Natural gas liquids were priced according to Platt's quotations for each region. Purchased electrical power was priced according to regional quotations. No escalation to 1990 was employed, i.e., a constant 1984 dollar value was employed. Details are presented in Appendix D.

2.1.6 Product Qualities

Except for gasoline, all products were required to meet current product quality specifications as presented in Appendix C. Gasoline distillation and octanes were forced to meet current quality specifications based on the ASTM D 439 schedule (except for unleaded premium gasoline which was assigned a 93 (R+M)/2 minimum octane rating to reflect recent trends. Lead content of leaded regular was limited to 0.1 gram/gallon, maximum.

Current summer gasoline vapor pressure was determined from the ASTM D 439 schedule for seasonal and geographic volatility classes for the areas supplied by refineries in each region. This resulted in maximum summer RVP specifications of 11.50, 11.46 and 11.12 psi, respectively, for PADDs 1, 2 and 3.

Details on product specifications are presented in Appendix C.

2.2 STUDY PARAMETERS AND CASES

Certain assumptions or conditions were subjected to analysis to determine their effects on the cost of reducing gasoline vapor pressure.

2.2.1 Natural Gas Liquids Price and Consumption

As noted under the discussion of "other raw material" premises, two situations were defined for natural gas liquids (NGLs). These materials, which are produced as by-products of natural gas processing, were represented in the study models as purchased normal butane, iso-butane and natural gasoline. One NGL situation allowed the volume of each NGL to vary up to a maximum projected availability for each region (see Appendix B) at prices derived from recent market quotations (see Appendix D). Cases under this situation are noted as "open NGL" cases.

Because it would be expected that decreased demand for NGLs would depress NGL market prices, and because no study was included to determine the price elasticity of this market, a second situation was defined in which NGL purchases were forced to equal projected availabilities. This is equivalent to reducing prices to levels where refining use would be at a break-even value. Cases under this situation are noted as "fixed NGL" cases.

2.2.2 Use of Alcohols as Gasoline Blendstocks

Three kinds of alcohol use were studied. One set of cases involved blending five volume percent of a one-to-one mixture of methanol and tertiary-butyl alcohol (TBA) into each grade of gasoline. Another set of cases involved blending 7.5 volume percent of a mixture which was 2 parts methanol and 1 part TBA. The third set of alcohol cases involved blending 10 percent of gasoline-grade ethanol into each gasoline grade.* This latter situation was examined under both NGL situations. Methanol blending was examined only with NGL purchases left open.

2.2.3 Increased Gasoline Demand

One set of cases, with NGL purchases fixed at forecasted levels, was run with gasoline output from each PADD increased by 10 percent. No other major product demand was varied.

----

*Ethanol-containing blends were required to meet finished gasoline specifications (as were methanol blends) in contrast to Gasahol which is finished unleaded regular to which 10 percent ethanol has been added, and which is not, therefore, required to meet volatility restrictions.

2.2.4 Investment Restriction Cases

As stated under "Refinery Process Configuration" (Paragraph 2.1.4), each region model was equipped to represent new and expanded capacity additions. To measure the cost effect of restricting vapor pressure before planning, engineering and construction could be accomplished, a set of cases was run which prevented any major process from being added or expanded above the capacities required by each 1990 case at current summer vapor pressure limits.

2.2.5 Cat Gasoline Octane

Early case results indicated a significant decrease in the use of catalytic cracking. To test the possibility that this behavior was caused by a too-low octane quality assumption for cat gasoline, cases for PADD 3 were run which reflected an increase of one octane number in cat gasoline blending values.

2.2.6 Case Run Summary

Table 2-1 identifies the cases examined in terms of parameter selections, region and RVP level. Note that most, but not all, combinations of conditions were not included in this study.

TABLE 2-1

CASES STUDIED

	PADD 1			PADD 2			PADD 3			
Open NGL Cases	B	M	L	B	M	L	B	M	L	L-1
Standard Premises	x	x	x	x	x	x	x	x	x	
With 5% 1-to-1 MeOH-TBA	x		x	x		x	x	x	x	x
With 7.5% 2-to-1 MeOH-TBA							x		x	
With 10% EtOH				x		x	x		x	
With Incr. Cat Gaso. Octane							x	x	x	
Fixed NGL Cases										
Standard Premises	x		x	x	x	x	*		x	
With 10% EtOH	x		x	x		x	x		x	
With Incr. Gasoline Demand	x		x	x		x	x		x	
Without Capital Investment			x			x			x	

* PADD 3 base case with open NGLs used maximum NGLs available.

LEGEND:
B = Base RVP
M = Base RVP minus 1 psi
L = Base RVP minus 2 psi
L-1 = Base RVP minus 3 psi

2.3 STUDY LIMITATIONS AND AREAS EXCLUDED

Inherent in the scope, methodology and simplifying assumptions of this study are limitations in accuracy of results, in the range of applicability and in the depth of the analyses performed. Certain limitations are obvious; for example, costs which may be experienced at specific refineries could be greater or smaller than those measured in this study. Certain limitations are more subtle; for example, changes in supply logistics caused by changes in manufacturing costs have not been addressed.

Modeling assumptions embodied in the mathematical depictions of refinery technologies, while of importance, are secondary to effects caused by study assumptions and premises. Because these modeling details have been subject to repeated and nearly continuous scrutiny and improvement during the course of use in many studies, both private and public, and because the scope of this study and this document do not call for review, no further examination of process modeling will be presented except where pertinent to explaining certain results.

In addition to the general caution that industry-level model results do not reflect the extremes of specific refining situations, there are four other limitations which should be noted, namely:

1) Effects of recurring recession or rapid recovery of the U. S. economy are not recognized in forecasts of crude supply or product demand.

2) Other than increased gasoline production, changes in product demand or shifts in product demand ratios have not been examined.

3) Changes in motor gasoline demand, because of potential changes in vehicle performance, were not addressed.

4) Differences in gasoline or fuel oil grade mix among regions have been ignored.

Several areas were excluded from this study which are related to the issue of reduced gasoline volatility or to study and model premises. These exclusions do not necessarily imply lack of concern on the part of those involved in this study or lack of importance. These exclusions are listed below.

1) Deviations from assumed economics, e.g., crude costs, capital costs, or by-product prices have not been studied.

2) Major changes in crude supply or product distribution logistics have not been considered.

3) Effects of changed gasoline volatility on vehicle performance or on emissions levels were not examined.

4) Technology breakthroughs in refinery processes or in end-use of fuels were not considered.

5) Measures other than Reid Vapor Pressure for controlling gasoline volatility (e.g., front-end volatility index) were not considered.

6) Consequential changes in refinery emissions have not been considered.

7) A future limit of 0.1 gram/gallon maximum lead alkyl was imposed on leaded gasoline. No assessment of vapor pressure control costs at other lead alkyl limits was made.

8) This study assumed enough alcohol, of each type, would be available for inclusion at the prescribed concentrations in all gasolines. No attempt was made to determine how such alcohol might be supplied or the price at which it would be made available because this study is not concerned with the economics of alcohol blending.

9) Although it is theoretically possible to restrict summer vapor pressure on only that gasoline sold in critical metropolitan areas, this study does not address the potential lower manufacturing costs or the higher segregation and distribution costs of doing so.

10) If added refining costs were passed to the consumer, increased prices at the pump could decrease demand. No analysis of changes in gasoline demand was attempted.

SECTION 3

SUMMARY OF RESULTS

This section summarizes and analyzes the results obtained from this study. Detailed results from which these summaries have been prepared are presented in Section 4. Supporting material is provided in the appendices to this report.

All results are based on forecasted product demands and crude supplies for the year 1990. Economics are based on prices for the first half of 1984 and constant (non-inflated) 1984 dollar values. Refinery output to satisfy projected demands is based on historical distribution patterns, for example, Gulf Coast refineries (PADD 3) are assumed to continue to supply large volumes of products to the East Coast.

The several volatility requirements imposed on each regional model represent the volumetric weighting of volatility requirements for gasolines to each region supplied from a given refining center. Table 3-1 shows the RVP maxima using the current ASTM D 439 schedule and the maxima with one-psi and two-psi decreases for the three regions studied.

TABLE 3-1

REGIONAL RVP LIMITS

	Maximum, psi		
	Base RVP	RVP-1	RVP-2
PADD 1	11.50	10.50	9.50
PADD 2	11.46	10.46	9.46
PADD 3	11.12	10.12	9.12

These limits were applied to each of the three gasoline grades depicted in each model, namely, unleaded premium, unleaded regular, and leaded regular. All other quality limits (see Appendix C) were unchanged from case to case.

3.1 NATIONAL AND REGIONAL ESTIMATED COSTS

As described in Section 2.1, extrapolation of regional cost estimates was necessary because PADDs 4 and 5 were not included in this study. By assuming that the average cost (per barrel) for PADDs 2 and 3 is a reasonable estimate for refining costs in PADDs 4 and 5, excluding those in California, and by using results of a similar study for that state[2], national refining costs for vapor pressure control have been estimated.

Unlike the present study, that for California did not allow NGL input to vary. Furthermore, current regulations in that state limit summer gasolines to 9.0 psi maximum RVP. Since this is already more restrictive than would be required under the current ASTM schedule, it is not clear that national restrictions would affect California. Thus, national estimates have been prepared with and without costs for California's control.

3.1.1 Added Refining Costs

Table 3-2 presents per-barrel refining costs for reducing allowable maximum RVP. National costs are estimated with and without reduction costs for California. Estimates are shown with open and fixed NGL purchases. These results summarize supporting detail presented in Section 4.

TABLE 3-2

REFINING COSTS FOR REDUCING MAXIMUM RVP

($ Per Barrel of Gasoline)

	PADD 1	PADD 2	PADD 3	PADD 4 + 5 Ex Calif	Calif	Total U.S.	Total U.S. (Ex Calif)
W/NGL purchase open							
1 psi reduction	0.184	0.364	0.211	0.288*	0.50[2]	0.288	0.259
2 psi reduction	0.547	0.748	0.501	0.625*	1.08[2]	0.646	0.587
W/NGL purchase fixed							
1 psi reduction	0.187†	0.396	0.212†	0.304*	0.50[2]	0.298	0.271
2 psi reduction	0.561	0.857	0.504	0.681*	1.08[2]	0.679	0.626

----

*Estimated as average of costs for PADDs 2 and 3.

†Actual case not run, cost estimated using half the percentage increase between 2 psi reduction costs.

[2]See Bibliography, Page 4-31.

3.1.2 Effects On NGL Refining Values

It is apparent from results in Table 3-2 that costs for the two NGL situations are similar. Incremental values of NGLs, however, vary considerably in these two situations. This is illustrated by tabulation of incremental NGL values presented in Table 3-3.

As can be seen, forcing NGL purchases decreases the incremental values of individual NGLs. In general, restricting vapor pressure limits reduces the value of individual NGLs. Exceptions, primarily in PADD 2 results, are the consequences of changes in operating conditions and shifts in the NGL limits which are restricting purchases from one RVP level to the next.

It should be noted that as "incremental" values, the results in Table 3-3 apply, at best, to small volumes of these raw materials and are, therefore, useful only as indicators of pressure to change market prices. They should not be interpreted as predictions of potential market prices which might arise from future situations. What is shown, by Table 3-2, is the fact that relatively large changes in NGL prices would have small effects on the cost of vapor pressure control.

The fixed-NGL cases provide an answer to the question, "How low must NGL prices be to provide economic incentive for using the base-case volumes of NGL?" These derived NGL refining values may be lower than some alternative consumer could afford to pay and, thus, they ignore the possibility that the refiner might discontinue use of these raw materials. They do, however, provide a lower limit estimate of NGL prices and the case results reflect the cost of vapor pressure control when refining must dispose of these (low cost) potential gasoline components.

TABLE 3-3

INCREMENTAL REFINING VALUES OF NGLs

($/BBL)

	PADD-1		PADD-2		PADD-3	
	Open	Fixed	Open	Fixed	Open	Fixed
Base RVP						
Normal Butane	35.27*	35.24	24.77*	20.98	29.80*	29.80
Iso-Butane	32.03*	32.05	24.75	23.30	31.16*	31.16
Nat. Gasoline	32.52	30.03	29.12	27.41	29.51*	29.51
RVP-1 psi						
Normal Butane	28.75*	na	23.20	18.37	26.22*	na
Iso-Butane	30.51*	na	25.83*	23.46	31.14*	na
Nat. Gasoline	32.52	na	29.12	28.34	29.98*	na
RVP-2 psi						
Normal Butane	21.97	21.04	22.39	16.44	23.30	21.30
Iso-Butane	28.15	27.05	24.89*	21.69	29.04*	26.86
Nat. Gasoline	32.52	29.36	29.55*	28.95	30.01*	29.90

*Limited by maximum availability

3.1.3 Estimated Annual Costs

When applied to the volumes of gasoline forecast for each region, for a 92-day summer period, the costs in Table 3-2 produce estimated annual costs ranging from $131 million to $386 million. Table 3-4 shows the development of these costs. As noted earlier, the cost effect of forcing NGL purchases is relatively small.

3.1.4 Effect on Raw Material Requirements

Changes in crude oil requirements account for most of the costs for reducing gasoline vapor pressure. Costs associated with capital investments and changes in operating costs (less credits for by-products) account for the rest. Table 3-5 presents the changes in raw materials (crude plus NGLs) indicated from model results. As shown by the differences between values with open and fixed NGL purchases, changes in NGL input are small except in PADD 2*. Using $30.00 per barrel (approximately the average price for swing crude) for national crude costs, the national annual crude cost for a 2 psi reduction in RVP (fixed NGL purchase) would be approximately $308 million, including California, or $259 million, excluding California. This represents 80 percent of the total refining cost estimate shown in Table 3-4.

----

*PADD 2 model results consistently showed a surplus of low-boiling streams relative to gasoline demand. This suggests that crude type and/or gasoline yield would be shifted from those assumed in study forecasts by changing crude and product logistics.

TABLE 3-4

ANNUAL REFINING COSTS ESTIMATES FOR REDUCING GASOLINE RVP

	PADD 1	PADD 2	PADD 3	4 + 5 Ex Calif	Calif	Total U.S.	Total U.S. (Ex Calif)
Average 1990 Gasoline Output, MBPCD	465	1541	2844	418	710	5978	5268
Summer Gasoline Output, MBPY*	44,490†	147,400†	272,100†	39,990†	65,320	569,300	503,980
Cost of vapor pressure reduction, M$/Yr							
W/NGL purchase open							
1 psi	8,190	53,700	57,410	11,520	32,660	163,480	130,820
2 psi	24,330	110,300	136,300	24,990	70,550	366,570	296,020
W/NGL purchase fixed							
1 psi	8,320	58,370	57,690	12,160	32,660	169,200	136,540
2 psi	24,960	126,300	137,100	27,230	70,550	386,140	315,590

---

*Summer period of 92 days

†Summer gasoline output 4% greater than annual daily average

TABLE 3-5

EFFECT OF RVP REDUCTION ON RAW MATERIAL

	PADD 1	PADD 2	PADD 3	PADD 4 + 5 Ex Calif	Calif	Total U.S.	Total U.S. (Ex Calif
Open NGL							
Total Raw Material, BBL/BBL of gasoline							
1 psia reduction	0.016	0.006	0.006	0.006*	0.012[2]	0.007	0.006
2 psia reduction	0.012	0.014	0.014	0.014*	0.025[2]	0.015	0.014
Total Raw Material, BPCD							
1 psi reduction	7,490	8,520	17,090	2,510	8,520	44,110	35,590
2 psi reduction	5,730	21,170	39,690	5,850	17,750	90,190	72,440
Fixed NGL							
Total Raw Material, BBL/BBL of gasoline							
1 psi reduction	na	0.012	na	na	0.012[2]	0.009†	0.008†
2 psi reduction	0.013	0.025	0.014	0.019	0.025[2]	0.018	0.015
Total Raw Material, BPCD							
1 psi reduction	7,490††	18,960	17,070††	3,760§	8,520	55,800	47,280
2 psi reduction	6,210	38,650	40,920	7,940	17,750	111,740	93,720

----

*Average of values for PADD 2 and 3.
†Estimated by using "Open NGL" values for PADDs 1 and 3.
††Open-NGL value used in the absence of actual case results.
§Increased average per barrel value of 0.009 applied to 418 BPCD gasoline output.
[2]See Bibliography, Page 4-31.

3.1.5 Effect On Investment Requirements

After accounting for raw material costs, investment-related costs are the major part of vapor pressure control costs. Amortization, cost of capital, maintenance, insurance, local and federal taxes and cost of manpower are those associated with investment in new and expanded facilities. For purposes of this summary, the changes in investment requirements (rather than the associated costs of supporting the investment) have been prepared and are presented in Table 3-6.

Minimization of costs in the solution to each case represents a balance of capital costs, operating costs and raw material costs. Each refining situation would dictate a unique balance of its costs which would not necessarily match the balances achieved by the model solutions of this study. Thus, the added capital requirements shown in Table 3-6 must be viewed as indicative since actual needs could vary widely from those estimated in this study.

A further qualification of added investment results must be recognized. As noted in the discussion of model premises in Section 2.1, major as well as auxiliary process investment options were allowed as needed above January 1, 1984, process capabilities. Differences in process investments between a base-RVP and lower-RVP case can and do reflect, for certain processing, lower capacity-additions in the low-RVP case than required in the base-RVP case.

TABLE 3-6

ESTIMATED CAPITAL REQUIREMENTS FOR REDUCING RVP

	PADD 1	PADD 2	PADD 3	PADD 4 + 5 Ex Calif	Calif	Total U.S.	Total U.S. (Ex Calif)
Open NGL, M$/BBL of gasoline							
1 psi reduction	0.205	0.101	0.054	0.078	0.104[2]	0.098	0.083
2 psi reduction	0.165	0.187	0.112	0.150	0.223[2]	0.178	0.142
, MM$							
1 psi reduction	95.5	156.3	154.8	33.0†	146[2]	585.6	439.6
2 psi reduction	76.6	288.8	319.3	62.7†	314[2]	1061.4	747.4
Fixed NGL, M$/BBL of gasoline							
1 psi reduction	na	0.068	na	na	0.104[2]	na	na
2 psi reduction	0.151	0.136	0.100	0.118*	0.223	0.160	0.122
, MM$							
1 psi reduction	na	104.1	na	na	146[2]	na	na
2 psi reduction	70.1	209.8	316.0	49.3[2]	314[2]	959.2	645.2

----

*Estimated as average of costs for PADDs 2 and 3
†Calculated from per-barrel estimate and gasoline volume of 418 MBPCD.
[2]See Bibliography, Page 4-31.

Restated, this is the consequence of the optimal configuration for the low-RVP case not requiring more of every type of process than would be required in optimal configuration for the base-RVP case*.

3.2 PARAMETER EFFECTS

Effects of changes to certain premises on the costs of reducing RVP were examined in this study. One set of changes represents use of various alcohols as gasoline constituents. One change examines the effect of increased gasoline demand. Another examines the effect of not allowing capital investment beyond that justified for the 1990 era without RVP restriction. Finally, one set of cases was run to confirm that observed changes in utilization of catalytic cracking were not caused by inappropriate blending values assumed for cat gasolines.

Each of these parameter studies was restricted to some, but not all, combinations of RVP reduction and region. Because of missing evaluations, effects on national costs can only be assumed to approximate the same percentage change observed for a given PADD.

---

*High-severity reforming is the most notable major process that was needed to a lesser extent in low-RVP cases compared to its need in base-RVP cases.

3.2.1 Methanol-TBA Cases

All cases involving methanol-TBA blends were run with NGL purchases open. Two types of methanol-TBA mixes were examined. Eight cases examined the effect of using 5 volume-percent of a one-to-one mix of methanol-TBA. Two cases were run to examine the effect of a two-to-one mix at 7.5 volume-percent. All gasoline grades were formulated with the same specified alcohol content.

Table 3-7 summarizes the results from the one-to-one methanol-TBA cases. Costs of reducing vapor pressure when this mix of methanol-TBA is blended into all gasolines are 50, 20 and 40 percent above those for no-alcohol cases for PADDs 1, 2 and 3, respectively. These percentages weighted by the relative volumes of gasoline from each region indicate that national costs for vapor pressure reduction would be approximately 34 percent greater if all gasolines were blended with 5 percent methanol-TBA. As shown by the added raw material and added investment results in Table 3-7, both of these factors are more costly if vapor pressure restrictions are imposed in a 1-to-1 methanol-TBA environment.

Cases for PADD 3 with 1 psi and 3 psi reduction in maximum RVP were run to identify costs effects with methanol and a need to further restrict RVP. The reason for such further restriction might arise as means of compensating for the fact that vehicle operators could produce a high-vapor-pressure mixture in their fuel tanks by adding a non-alcohol gasoline to a partial tank of alcohol-containing gasoline, or vice versa. Because of the non-linear blending behavior of alcohol-hydrocarbon mixtures with respect to volatility characteristics, such occurrences would result in vehicle

TABLE 3-7

EFFECTS OF 50/50 METHANOL-TBA

(Open NGLs)

	PADD 1		PADD 2		PADD 3	
	W/O	W	W/O	W	W/O	W
Refining Cost, $/BBL of gasoline						
1 psi reduction	0.184	na	0.364	na	0.211	0.314
2 psi reduction	0.547	0.815	0.748	0.898	0.501	0.692
3 psi reduction	na	na	na	na	na	1.163
Added Raw Material, BBL/BBL of gasoline						
1 psi reduction	0.016	na	0.006	na	0.006	0.007
2 psi reduction	0.012	0.029	0.014	0.021	0.014	0.016
3 psi reduction	na	na	na	na	na	0.029
Added Investment, M$/BBL of gasoline						
1 psi reduction	0.205	na	0.101	na	0.054	0.036
2 psi reduction	0.165	0.312	0.187	0.269	0.112	0.186
3 psi reduction	na	na	na	na	na	0.255

fuel tanks containing a mixture that exceeds RVP limits even though both the alcohol-containing and non-alcohol gasolines were at, or slightly below, the allowable maximum.

In an environment where gasoline with and without methanol-TBA would be available, it could conceivably become required to blend all gasolines to a lower base RVP to overcome the above-described problem. Further reduction in RVP to combat evaporative emissions would then take place from a lower base RVP. The differences in costs between 3-psi and 1-psi reduction represents the RVP-reduction (of 2-psi) costs from a lower base. From Table 3-7, the 3-to-1 difference of $0.849 per barrel for PADD 3 is a significantly larger cost for a 2 psi reduction than the $0.692 per barrel cost shown for a 2 psi reduction from base RVP. This illustrates the fact that a given reduction in RVP is more costly for low base levels, than from a higher base level.

Cases with 2-to-1 methanol-TBA were evaluated only for PADD 3. Table 3-8, therefore, presents a comparison of like results from standard-premise and 1-to-1 methanol-TBA cases. As can be seen, vapor pressure costs for gasoline with alcohol are greater than those with alcohol-free blends. The larger concentration of the 2-to-1 mix, even though more methanol is involved, results in lower costs because the vapor-pressure blending value of this alcohol mixture (at the higher concentration) is lower than that for the 1-to-1 mix of methanol-TBA (see Appendix F) and because the increased alcohol concentration means less hydrocarbon base stock is needed.

TABLE 3-8

EFFECTS OF 2/1 METHANOL-TBA

(PADD 3)

		Methanol-TBA	
	Std. Premises	5% of 1/1 Mix	7.5% of 2/1 Mix
Cost of 2 psi Reduction, $/BBL of gasoline	0.501	0.692	0.532
Added Raw Materials, BBL/BBL of gasoline	0.014	0.16	0.009
Added Investment, M$/BBL of gasoline	0.112	0.186	0.186

3.2.2 Ethanol Cases

Five case-pairs were prepared to measure the cost of vapor-pressure reduction with 10 volume-percent ethanol.* Each pair represents cases at base RVP and at 2 psi reduction. Two pair (for PADDs 2 and 3) were run with NGL purchases open and three (for PADDs 1, 2, and 3) with NGL purchases fixed.

In every case with ethanol being blended, vapor-pressure-reduction costs were zero. The reason is simply that base-RVP cases all show gasolines being blended well below maximum RVP. Each grade was limited instead by the maximum % @ 160°F. Table 3-9 presents the predicted RVP of each gasoline pool for the base-RVP cases run in this study.

----

*This use of ethanol should not be confused with the practice of adding ethanol to finished unleaded gasoline to produce Gasahol. Ethanol-containing blends in this study are required to meet normal volatility specifications. Gasahol is not.

TABLE 3-9

PREDICTED GASOLINE POOL RVP WITH ETHANOL

(psi)

	PADD 1	PADD 2	PADD 3
Max RVP Specification	11.50	11.46	11.12
Open NGL Purchases	na	6.84	7.94
Fixed NGL Purchases	6.40	6.97	7.07

It appears from these results that lowering the allowable maximum RVP by 2 psi would impose no restriction to ethanol-containing gasoline and that base case RVPs would be well below that restriction.

The explanation of this characteristic of the ethanol cases, compared to the cases involving other alcohols depends on the relationships of blending values for vapor pressure and % @ 160°F of each type of alcohol mixture. These blending values are shown in Table 3-10*. Also shown in Table 3-10 are the contributions to blend quality of each type of alcohol, namely, the blending values times their

---

*Blending values for other properties are shown in Appendix F.

respective concentrations (as volume fractions). Maximum % @ 160°F was defined as 35 volume percent. Maximum base RVPs were 11.50 to 11.12 psi. Thus, the 1-to-1 methanol-TBA mixture accounts for approximately 24 percent of allowable RVP and 16 percent of the allowable % @ 160°F. Ethanol, on the other hand, accounts for 13 percent of the maximum RVP and 63 percent of the maximum % @ 160°F.

Without relaxing the maximum limit for % @ 160°F, gasoline blends with ethanol cannot approach current RVP limits. Unlike the other alcohol cases, this characteristic of ethanol blends means there would be no need to reduce "base" RVPs since they would be well below the lower limits considered in this study.

TABLE 3-10

ALCOHOL BLENDING VALUES

	METHANOL-TBA 1/1	METHANOL-TBA 2/1	ETHANOL
Assumed Concentration, Volume %	5	7.5	10
RVP Blending value, psi	54.0	40.0	15.0
% @ 160°F Blending value	115	175	220
Contribution to blend quality (blending value times concentration)			
RVP, psi	2.70	3.0	1.50
% @ 160°F	5.75	13.125	22.00

3.2.3 No-Investment Cases

Three cases without the ability to invest in new or expanded facilities for major processes were run to measure the impact of not having time to plan, engineer and construct such capacity. Each case assumes that capacity which was shown to be justified at current RVP limits and with NGL purchases fixed at forecasted availabilities would be in place and would have to serve for lower RVP limits. Table 3-11 presents a summary of the results from these cases (W/O) along with results for cases with (W) investment allowed.

TABLE 3-11

NO-INVESTMENT IMPACTS

(2 psi Reduction)

	PADD 1		PADD 2		PADD 3	
	W	W/O	W	W/O	W	W/O
Cost, $/BBL of gasoline	0.561	0.641	0.857	1.084	0.504	0.713
Added Raw Material, BBL/BBL of gasoline	0.013	0.020	0.025	0.036	0.014	0.024
Added Investment,						
Major processes	-0.007	-	-0.003	-	0.040	-
Auxiliary processes	0.158	0.112	0.139	0.169	0.060	0.051
Total	0.151	0.112	0.136	0.169	0.100	0.051

These results indicate that lack of time to adjust facilities for reduced volatility requirements would increase costs by 14 percent, 26 percent and 41 percent in PADDs 1, 2 and 3, respectively. Using gasoline output to weight these increases gives an estimate of 34 percent increase for national costs. As would be expected, added raw materials increase even more, namely, 54 percent, 44 percent and 71 percent for PADDs 1, 2 and 3, respectively, and the estimate of national raw material increase is 61 percent.

Added-investment results require explanation. As noted in Section 3.1.5, optimal process configurations do not have all process expansions from base capacities in the same proportions. As is illustrated by the added investment results in Table 3-11, this can lead to some subset of process expansions being less in one case than in another. In this particular instance, the process subset termed "major processes" shows a net smaller investment requirement in the low-RVP case than in the base-RVP case for PADDs 1 and 2. In addition, Table 3-11 shows that auxiliary process investments can be larger in the no-investment (of major process) situation than in the situation allowing investments.

It is important, in this context, to recognize that auxiliary process investments should be classed as operating costs. Further, it should be recognized that defining certain processes (e.g., sulfur recovery) as auxiliary was somewhat arbitrary, and in retrospect, could have been done to minimize the apparent anomaly appearing in the above results.

3.2.4 Increased Gasoline Output Cases

Three pairs of cases with NGL purchases fixed and with gasoline output requirements increased by 10 percent were run to measure the effect of this change in product demand on RVP reduction costs. Each pair consisted of a base-RVP and an RVP-minus-2 case. Results are summarized in Table 3-12.

Because of the change in divisors which is caused by increasing gasoline output, Table 3-12 shows measured effects as per-day and per-barrel-of-gasoline results. For all PADDs, daily cost for a 2-psi reduction increases. The per-barrel cost for PADD 1 decreases slightly. The three-PADD increase in daily refining cost is 11 percent. Thus, a 10 percent increase in forecasted gasoline demand would be expected to increase the national refining cost of reducing RVP by 11 percent. The average per-barrel cost, on the other hand, increases only 1.2 percent with a 10 percent demand increase.

Added raw material requirements for the 10 percent increase in gasoline output for these three regions is shown to be approximately 10,000 barrels per day above that required to adjust RVP with base case demands. The increase in gasoline demand is more easily accommodated by PADDs 1 and 2 (both show a decrease in added raw material requirements to reduce RVP at higher gasoline output) than by PADD 3. This is because PADD 1 and 2 gasoline demands are relatively easier to meet.

data.[10] Kerosene jet fuel demand for each PADD is the total jet fuel demand less the naphtha jet fuel demand.

3) Residual Fuel

The grades of residual fuel represented in this study are low sulfur (0 to 0.3 weight percent Sulfur) medium sulfur (0.31 to 1.0 weight percent Sulfur) and high sulfur (greater the 1.0 weight percent Sulfur). Grade mixes are based on the growth rates for each grade from a comprehensive study of nautral gas usage,[7] applied to 1983 production of each grade. This results in a small percentage increase in the low and medium sulfur grades at the expense of the high-sulfur grade. Because of projected increase in total residual fuel demand by 1990, individual grades of residual fuel also show increases.

TABLE 3-12

EFFECTS OF INCREASED GASOLINE DEMAND

(2 psi Reduction)

	PADD 1		PADD 2		PADD 3	
	As Forecast	+10%	As Forecast	+10%	As Forecast	+10%
Gasoline Output, MBPCD	465.0	511.5	1541.0	1695.1	2844.0	3128.4
Cost, M$PCD	261.0	261.7	1320.7	1485.6	1432.5	1607.3
$/BBL of gasoline	0.561	0.512	0.857	0.876	0.504	0.514
Added Raw Material, MBPCD	6.210	1.280	38.650	37.020	40.920	57.550
BBL/BBL of gasoline	0.013	0.003	0.025	0.022	0.014	0.018
Added Investment, MM$	70.1	189.7	209.8	380.3	316.0	2.9
M$/BBL of gasoline	0.151	0.371	0.136	0.224	0.111	0.001

The larger added investments shown for PADDs 1 and 2 when gasoline demand is increased are indicative of shifts in the balance between raw material costs and capital costs. Total added investment for these regions is approximately $23 million greater for the increased-gasoline cases but its distribution among the regions is obviously not uniform.

All of these effects must be recognized as small differences between large numbers. Even though the model behavior leading to these results, as well as the direction of change indicated by the results, are understandable and for the most part consistent with expectations, their limited accuracy and dependence on study premises and model assumptions must be recognized.

3.2.5 Cases with Increased Octane Values for Cat Gasoline

Unlike the other parameter examinations, which explored study premises, this particular investigation was made to confirm that observed model behavior was not the result of modeling assumptions about the octane blending values assigned to catalytic gasolines. Details of these cases are included with other case details in Section 4. No summary is, however, presented here. Instead, a brief discussion of the model behavior is provided.

Early model results showed cat cracking capacity to be utilized at low levels. Recognizing that this was, in part, caused by the low limit (0.1 gm/gal) on use of lead alkyl, and that cat gasoline octane values at this low level were at or below gasoline specifications, it was decided to test the effect of slightly higher blending values. Octane values of cat gasoline can be controlled to some extent by feedstock selection and by operating conditions as well as catalyst type selection. To approximate the possible improvement in blending values that use of this flexibility might achieve, cases with higher octane blending values for gasolines were run.

Results showed that even lower utilization of cat cracking capacity was needed when octane values were increased. The model behavior, for purposes of this study, was, therefore, judged acceptable.

3.3 CONCLUSIONS

Several important conclusions may be drawn from the results of this study.

3.3.1 Refiners' Cost for RVP Reduction

Possibly the most important conclusion which may be drawn from study results is that refiners' cost increase can be expected to vary according to the severity of the vapor pressure restriction and among the regions in which the gasolines are processed. Refiners' cost of reducing summer gasoline RVP could vary from 0.4 to 2.6 cents per gallon. There would undoubtedly be variations in the sub-regional areas as well, although this study did not attempt to measure costs at this level of detail.

Increased cost of gasoline with RVP restriction would not necessarily be reflected as increase in pump prices for gasoline. Costs could be absorbed at any point in the manufacturing/marketing chain and/or passed on to the consumer. Increased gasoline costs might be masked by other important influences such as the prices of crude oils or by an intense competitive situation in a particular area. The increased cost of manufacturing lower-volatility gasoline is real, however, and would represent a large cost to the economy of the U. S. Under the standard premises of this study, the national costs are estimated to be more than $315 million during the first year of restriction.

3.3.2 Natural Gas Liquids (NGL) Effects

A second conclusion is that the results of this study show that refining costs for restricting RVP are relatively insensitive to the market price of natural gas liquids (normal butane, iso-butane and natural gasoline). That is, changes in prevailing prices for natural gas liquids would not be expected to exert a significant impact on the cost of reducing vapor pressure.

On the other hand, the converse is not true. NGLs are currently significant components of gasoline, and regulations reducing the vapor pressure of gasoline will have a significant effect on the price of natural gas liquids. If these raw materials cannot be used in gasoline blending, their decreased value in alternate dispositions (probably as plant fuel) would depress their market prices.

3.3.3 Using RVP Restrictions For Emissions Control

A third important conclusion has to do with RVP measurement as a volatility control. This conclusion can be drawn from the effects of alcohol use on the cost of RVP reduction. The effect of using RVP alone as a control specication is seen most clearly in the cases using ethanol as a blend stock.

The conclusion which can be drawn from these cases is that controlling RVP alone is probably more costly and less effective than controlling a combination of vapor pressure and distillation properties. Other studies[1] have shown that Front-End Volatility Index (FEVI)* correlates much more accurately with evaporative emissions than does RVP alone.

This study defines volatility reduction as RVP reduction only. The importance of volatility restrictions other than RVP is emphasized by ethanol case results. Because of ethanol's effects on % @ 160°F, relative to its effects on RVP, all ethanol blends are limited by the maximum of 35% @ 160°F and, at 6 to 8 RVP, are well below the maximum restriction considered in this study. Using RVP alone as a means for controlling evaporative emissions limits the flexibility the refiner has in meeting volatility restrictions and thus would increase the cost of manufacturing gasoline.

Had the study models been given the flexibility of blending to FEVI limitations rather than RVP limitations alone, the measured costs for volatility reduction would have been lower in the non-alcohol cases and higher in the alcohol cases.

---

*FEVI = RVP + 0.13 (% @ 160° F).

3.4 EFFECT OF SIMPLIFYING ASSUMPTIONS

As constituted, this study was designed to estimate the refining costs of restricting summer gasoline volatility. Restrictions were defined as reduction in RVP amounting to 1 psi and 2 psi from limits currently specified by ASTM D 439. This standard defines regional summer maxima with a range of 9 psi to 11.5 psi. Thus, a 2-psi reduction would require gasoline blends with RVP specifications from 7 psi to 9.5 psi.

To simplify the study models, for purposes of reducing study cost, all gasolines from a given region were combined to represent a single volatility grade. This results in base-case RVPs of 11.50, 11.46 and 11.12 psi for PADDs 1, 2 and 3, respectively--which are at the upper end of the range of stated ASTM standard. The cost of restricting RVP is inversely proportional to the base RVP, i.e., reduction from a base of 10 RVP is more costly than a reduction from a base of 11 RVP. The simplified models, thus, tend to understate the true cost of RVP reduction.

Another simplification tends to overstate the true cost of RVP reduction. This assumption is that regional refining output of gasoline would not change if RVP restrictions were to cause shifts in regional gasoline costs.

These simplifications (along with others, as reflected in Section 2.1) introduce a degree of uncertainty into the estimated costs. Since reduction of maximum vapor pressure is only one of several alternatives which can be used for reducing hydrocarbon emissions, it is important to recognize the uncertainty of results when making comparisons with costs for other reduction methods.

3.5 ISSUES FOR FURTHER STUDY

Several issues related to this study subject are topics which deserve further investigation. Important issues are:

1) <u>PADDs 4 and 5 Costs</u>

This study estimated costs for RVP reduction in PADDS 1, 2, and 3. Costs for refining in PADDS 4 and 5 were inferred or drawn from other studies on the same subject.

2) <u>Use of Measures Other than RVP</u>

The use of FEVI or similar measures of evaporative tendency should be compared to the use of RVP as a means of volatility control.

3) <u>Impact on Product Supply</u>

The restriction of gasoline volatility will have an effect on the supply logistics of gasoline and other petroleum products. This effect should be examined since it would influence the cost of restricting gasoline volatility.

4) <u>Impact on Natural Gas Processing</u>

Restriction of RVP has the potential for major impact on the natural gas processing industry. The potential economic impact of reduced refining demand for NGLs is a cost which was not assessed in this study, but one that would occur with volatility restriction.

5) Impact on Individual Refining Situations

The possible cost extremes associated with unique refinery problems could vary considerably from the industry-level estimates derived in this study. A study of individual refining situations is, therefore, recommended.

SECTION 4

DETAILED RESULTS

This section contains selected detail for each case evaluated in this study. As shown earlier in Table 2-1, not all combinations of region, vapor pressure level and parameter situations were included. Presentation order and grouping of case results are based on region first, NGL situation second and decreasing vapor pressure limits, within a given subordinate parameter situation, third. Such ordering is, of course, arbitrary and should not be taken to imply relative significance.

Results for each case are arranged in groups, namely, operations detail, gasoline blend detail and result-differences between reduced-RVP cases and the appropriate base-RVP case. The latter is always grouped with related reduced-RVP cases except for low-RVP cases not allowing major processing investment. The appropriate base-RVP case for the low-RVP-no-investment cases is always the left-most (standard premises) case in tables containing the no-investment result.

For cases involving alcohols, gasoline volumes represent only the hydrocarbon portion of finished blends. This is because it was convenient to model the fixed alcohol content of each situation by adjusting gasoline specifications and volume demands as if refining produced gasoline which, when the appropriate alcohol is added, would satisfy finished quality and volume requirements. Predicted gasoline grade and pool qualities shown under blend detail results are, however, those for the finished fuels including the appropriate alcohol.

4.1 PADD 1 CASE RESULTS

Table 4-1 presents case results for PADD 1 with NGL purchase open. Table 4-2 presents case results with NGL purchases fixed at forecasted levels.

4.2 PADD 2 CASE RESULTS

Table 4-3 presents case results for PADD 2 with NGL purchases open. Table 4-4 presents case results with NGL purchases fixed at forecasted levels.

4.3 PADD 3 CASE RESULTS

Table 4-5 presents case results for PADD 3 with NGL purchases open. Table 4-6 presents case results with NGL purchases fixed at forecasted levels.

TABLE 4-1

PADD 1 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 1 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2
MAX. RVP (ALL GRADES), PSI	11.500	10.500	9.500	11.500	9.500
OPERATIONS DETAIL					
UTILITY PURCHASES					
CAT/CHEM, M$PCD	140.031	139.426	154.263	130.960	151.052
PWR GEN, M-KWH-PCD	5208.949	5264.535	5480.262	4931.965	5290.863
RAW MATERIAL PURCHASES, MBPCD					
LOW-SULFUR CRUDE	555.500	555.500	555.500	555.500	555.500
HIGH-SULFUR CRUDE	302.500	302.500	302.500	302.500	302.500
SWING CRUDE	232.624	240.113	240.016	209.632	223.527
PROPANE	6.620	6.620	6.620	6.620	6.620
N-BUTANE	0.950	0.950	0.000	0.000	0.000
ISO-BUTANE	5.670	5.670	4.959	5.670	0.000
NAT. GASOLINE	0.000	0.000	0.000	0.000	0.000
TOTALS	1103.864	1111.353	1109.595	1079.922	1088.147
RAW MATERIAL INCREMENTAL VALUES, $/BBL.					
LOW-SULFUR CRUDE	32.010	31.980	31.920	31.930	31.920
HIGH-SULFUR CRUDE	29.800	29.860	29.930	29.940	29.940
SWING CRUDE	29.690	29.690	29.690	29.690	29.690
PROPANE	23.850	23.850	23.850	23.850	23.850
N-BUTANE	35.270	28.750	21.970	22.030	18.810
ISO-BUTANE	32.030	30.510	28.150	28.280	24.430
NAT. GASOLINE	32.520	32.520	32.520	29.010	29.390
SELECTED PRODUCT SALES, MBPCD					
LEADED REGULAR	79.050	79.050	79.050	75.097	75.097
UNLEADED GASOLINE	302.250	302.250	302.250	287.137	287.137
UNLEADED PREMIUM	83.700	83.700	83.700	79.515	79.515
TOTAL GASOLINE	465.000	465.000	465.000	441.749	441.749

TABLE 4-1

PADD 1 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 2 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2
SELECTED PRODUCT SALES, MBPCD (CONT.)					
LIQ.PET.GAS.	36.930	38.585	37.712	33.224	35.338
SALABLE COKE (MTPCD)	22.728	27.188	22.720	22.721	22.720
GASEOUS PLANT FUEL	43.344	43.705	46.314	40.799	45.883
LIQUID PLANT FUEL	0.000	0.608	0.000	0.000	0.000
RELATIVE CASH FLOW, M$PCD	-7313.602	-7399.027	-7567.848	-6577.641	-6956.512
RELATIVE INVESTMENT, MM$	875.789	780.307	952.368	770.076	915.134
BLEND DETAILS					
RVP - LD. REG.	11.500	10.500	9.500	11.500	9.500
RVP - UNL. REG.	11.500	10.500	9.500	11.500	9.500
RVP - UNL. PRE.	11.500	10.500	9.500	11.500	9.500
RVP - POOL	11.500	10.500	9.500	11.500	9.500
VAPOR-LOCK INDEX-LD. REG.	16.033	15.050	14.050	16.050	13.813
VAPOR-LOCK INDEX-UNL. REG.	16.050	15.050	14.050	16.050	13.930
VAPOR-LOCK INDEX-UNL. PRE.	16.050	14.111	11.980	16.050	12.149
VAPOR-LOCK INDEX-POOL	16.047	14.881	13.677	16.050	13.589
%@160 DEGREES F.-LD. REG.	34.869	35.000	35.000	35.000	33.174
%@160 DEGREES F.-UNL. REG.	35.000	35.000	35.000	35.000	34.076
%@160 DEGREES F.-UNL. PRE.	35.000	27.781	19.076	35.000	20.380
%@160 DEGREES F.-POOL	34.978	33.700	32.134	35.000	31.457
%@210 DEGREES F.-LD. REG.	57.000	57.000	57.000	57.000	57.000
%@210 DEGREES F.-UNL. REG.	54.897	54.384	53.810	55.553	53.512
%@210 DEGREES F.-UNL. PRE.	50.810	46.177	41.197	52.795	42.310
%@210 DEGREES F.-POOL	54.519	53.352	52.082	55.303	52.089

TABLE 4-1

PADD 1 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 3 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2
BLEND DETAILS (CONT.)					
%@230 DEGREES F.-LD. REG.	62.973	63.023	63.191	61.881	62.388
%@230 DEGREES F.-UNL. REG.	62.459	62.594	62.293	62.446	61.430
%@230 DEGREES F.-UNL. PRE.	65.029	61.501	58.428	67.158	58.096
%@230 DEGREES F.-POOL	63.009	62.470	61.750	63.198	60.993
%@330 DEGREES F.-LD. REG.	91.837	91.964	92.158	90.747	91.130
%@330 DEGREES F.-UNL. REG.	94.613	95.011	95.188	93.914	94.492
%@330 DEGREES F.-UNL. PRE.	97.631	97.507	97.337	97.957	96.343
%@330 DEGREES F.-POOL	94.685	94.942	95.059	94.103	94.254
SPECIFIC GRAVITY-LD. REG.	0.741	0.742	0.743	0.747	0.753
SPECIFIC GRAVITY-UNL. REG.	0.751	0.751	0.752	0.757	0.762
SPECIFIC GRAVITY-UNL. PRE.	0.739	0.751	0.759	0.739	0.754
SPECIFIC GRAVITY-POOL	0.747	0.749	0.752	0.752	0.759
% AROMATICS- LD. REG.	30.830	31.032	31.055	28.741	29.997
% AROMATICS- UNL. REG.	38.162	37.880	38.327	36.247	37.847
% AROMATICS- UNL. PRE.	31.602	35.777	35.976	25.530	27.579
% AROMATICS- POOL	35.735	36.337	36.668	33.042	34.664
RESEARCH OCTANE- UNL. REG.	92.370	92.472	92.849	93.778	94.094
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	87.185	87.236	87.424	87.889	88.047
RESEARCH OCTANE- UNL. PRE.	98.500	98.500	98.500	98.500	98.515
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.500
(R+M)/2- UNL. PRE.	93.000	93.000	93.000	93.000	93.008
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.000	89.000

TABLE 4-1

PADD 1 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 4 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2
CASE DIFFERENCES					
SWING CRUDE, MBPCD		7.489	7.392		13.895
N-BUTANE, MBPCD		0.000	-0.950		0.000
ISO-BUTANE, MBPCD		0.000	-0.711		-5.670
NAT. GASOLINE, MBPCD		0.000	0.000		0.000
TOTAL RAW MATERIALS, MBPCD		7.489	5.731		8.225
LIQ. PET. GASES, LPG, MBPCD		1.655	0.782		2.114
SALABLE COKE, MTPCD		4.460	-0.008		-0.001
GASEOUS PLANT FUEL, MBPCD		0.361	2.970		5.084
LIQUID PLANT FUEL, MBPCD		0.608	0.000		0.000
CATALYST AND CHEMICALS, M$PCD		-0.604	14.233		20.092
ELECTRICAL POWER, M-KWH-PCD		55.586	271.313		358.898
CASH FLOW, M$PCD		-85.425	-254.246		-378.871
INVESTMENT, MM$		-95.482	76.579		145.058
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE					
SWING CRUDE, BBL./BBL.		0.016	0.016		0.030
TOTAL RAW MATERIALS, BBL./BBL.		0.016	0.012		0.018
CATALYST AND CHEMICALS, $/BBL.		-0.001	0.031		0.043
ELECTRICAL POWER, KWH/BBL.		0.120	0.583		0.772
CASH FLOW, $/BBL.		-0.184	-0.547		-0.815
INVESTMENT, M$/BBL.		-0.205	0.165		0.312

TABLE 4-2

PADD 1 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 1 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
MAX. RVP (ALL GRADES), PSI	11.500	9.500	11.500	9.500	11.500	9.500	9.500
OPERATIONS DETAIL							
UTILITY PURCHASES							
CAT/CHEM, M$PCD	139.688	154.793	152.376	152.376	149.797	169.872	151.471
PWR GEN, M-KWH-PCD	5203.660	5469.418	5472.324	5472.324	5624.254	5893.152	5630.004
RAW MATERIAL PURCHASES, MBPCD							
LOW-SULFUR CRUDE	555.500	555.500	555.500	555.500	555.500	555.500	555.500
HIGH-SULFUR CRUDE	302.500	302.500	302.500	302.500	302.500	302.500	302.500
SWING CRUDE	232.027	238.237	210.826	210.826	289.903	291.185	241.114
PROPANE	6.620	6.620	6.620	6.620	6.620	6.620	6.620
N-BUTANE	0.950	0.950	0.950	0.950	0.950	0.950	0.950
ISO-BUTANE	5.670	5.670	5.670	5.670	5.670	5.670	5.670
NAT. GASOLINE	0.640	0.640	0.640	0.640	0.640	0.640	0.640
TOTALS	1103.907	1110.117	1082.706	1082.706	1161.783	1163.065	1112.994
RAW MATERIAL INCREMENTAL VALUES, $/BBL.							
LOW-SULFUR CRUDE	32.010	31.910	31.770	31.770	32.020	31.950	32.770
HIGH-SULFUR CRUDE	29.810	29.940	30.030	30.030	29.800	29.960	29.930
SWING CRUDE	29.690	29.690	29.690	29.690	29.690	29.690	29.690
PROPANE	23.850	23.850	23.850	23.850	23.850	23.850	23.850
N-BUTANE	35.240	21.040	22.150	22.150	36.090	22.400	18.550
ISO-BUTANE	32.050	27.050	28.840	28.840	32.480	28.650	32.270
NAT. GASOLINE	30.030	29.360	21.630	21.630	30.730	29.220	28.920
SELECTED PRODUCT SALES, MBPCD							
LEADED REGULAR	79.050	79.050	71.145	71.145	86.955	86.955	79.050
UNLEADED GASOLINE	302.250	302.250	272.024	272.024	332.474	332.474	302.250
UNLEADED PREMIUM	83.700	83.700	75.330	75.330	92.070	92.070	83.700
TOTAL GASOLINE	465.000	465.000	418.499	418.499	511.499	511.499	465.000

TABLE 4-2

PADD 1 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 2 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
SELECTED PRODUCT SALES, MBPCD (CONT.)							
LIQ.PET.GAS.	36.898	37.646	36.180	36.180	41.454	41.318	39.003
SALABLE COKE (MTPCD)	22.718	22.720	25.363	25.363	30.950	26.887	22.720
GASEOUS PLANT FUEL	43.311	46.358	53.645	53.645	47.509	50.660	48.412
LIQUID PLANT FUEL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RELATIVE CASH FLOW, M$PCD	-7315.156	-7576.113	-6629.113	-6629.113	-8914.934	-9176.684	-7613.062
RELATIVE INVESTMENT, MM$	874.351	944.445	758.681	758.682	861.098	1050.832	926.317
BLEND DETAILS							
RVP - LD. REG.	11.500	9.500	6.272	6.272	11.500	9.500	9.500
RVP - UNL. REG.	11.500	9.500	6.537	6.300	11.500	9.500	9.500
RVP - UNL. PRE.	11.500	9.500	6.002	6.857	11.500	9.500	9.500
RVP - POOL	11.500	9.500	6.396	6.396	11.500	9.500	9.500
VAPOR-LOCK INDEX-LD. REG.	16.033	14.050	10.822	10.822	15.845	14.050	14.050
VAPOR-LOCK INDEX-UNL. REG.	16.050	14.042	11.087	10.850	16.050	14.050	14.050
VAPOR-LOCK INDEX-UNL. PRE.	16.050	11.934	10.552	11.407	16.050	11.987	12.254
VAPOR-LOCK INDEX-POOL	16.047	13.664	10.946	10.946	16.015	13.679	13.727
%@160 DEGREES F.-LD. REG.	34.869	35.000	35.000	35.000	33.422	35.000	35.000
%@160 DEGREES F.-UNL. REG.	35.000	34.940	35.000	35.000	35.000	35.000	35.000
%@160 DEGREES F.-UNL. PRE.	35.000	18.721	35.000	35.000	35.000	19.131	21.183
%@160 DEGREES F.-POOL	34.978	32.031	35.000	35.000	34.732	32.144	32.513
%@210 DEGREES F.-LD. REG.	57.000	57.000	42.828	42.828	57.000	57.000	57.000
%@210 DEGREES F.-UNL. REG.	54.847	53.798	49.092	47.913	54.538	53.883	53.487
%@210 DEGREES F.-UNL. PRE.	50.830	40.557	44.104	48.362	50.330	40.926	42.331
%@210 DEGREES F.-POOL	54.490	51.959	47.130	47.130	54.199	52.081	52.076

TABLE 4-2

PADD 1 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 3 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
BLEND DETAILS (CONT.)							
%@230 DEGREES F.-LD. REG.	62.973	63.191	46.035	46.035	63.241	63.191	63.566
%@230 DEGREES F.-UNL. REG.	62.403	62.261	54.368	52.426	62.306	62.599	61.918
%@230 DEGREES F.-UNL. PRE.	65.050	57.872	55.397	62.412	64.313	58.272	59.263
%@230 DEGREES F.-POOL	62.977	61.629	53.137	53.137	62.826	61.921	61.720
%@330 DEGREES F.-LD. REG.	91.837	92.158	81.000	81.000	92.260	92.158	93.129
%@330 DEGREES F.-UNL. REG.	94.616	95.150	92.985	91.169	94.869	95.406	95.147
%@330 DEGREES F.-UNL. PRE.	97.633	97.253	89.656	96.213	97.293	97.340	97.401
%@330 DEGREES F.-POOL	94.686	95.020	90.348	90.348	94.862	95.202	95.210
SPECIFIC GRAVITY-LD. REG.	0.741	0.743	0.760	0.760	0.743	0.754	0.748
SPECIFIC GRAVITY-UNL. REG.	0.751	0.917	0.775	0.775	0.752	0.752	0.754
SPECIFIC GRAVITY-UNL. PRE.	0.738	0.759	0.763	0.754	0.737	0.758	0.757
SPECIFIC GRAVITY-POOL	0.747	0.859	0.771	0.769	0.748	0.755	0.753
% AROMATICS- LD. REG.	30.830	31.055	23.346	23.346	31.316	31.055	34.428
% AROMATICS- UNL. REG.	38.277	38.178	36.231	38.159	38.648	37.948	39.068
% AROMATICS- UNL. PRE.	31.540	35.768	29.976	23.014	29.672	35.569	35.410
% AROMATICS- POOL	35.799	36.534	32.915	32.915	35.786	36.348	37.621
RESEARCH OCTANE- UNL. REG.	92.381	92.760	95.835	95.733	92.518	92.798	92.846
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	87.190	87.380	88.917	88.866	87.259	87.399	87.423
RESEARCH OCTANE- UNL. PRE.	98.500	98.500	98.894	98.997	98.500	98.500	98.500
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.500	87.500	87.500
(R+M)/2- UNL. PRE.	93.000	93.000	93.197	93.248	93.000	93.000	93.000
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	94.500	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	83.500	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.000	89.000	89.000	89.000

TABLE 4-2

PADD 1 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 4 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
CASE DIFFERENCES							
SWING CRUDE, MBPCD		6.210		0.000		1.282	9.087
N-BUTANE, MBPCD		0.000		0.000		0.000	0.000
ISO-BUTANE, MBPCD		0.000		0.000		0.000	0.000
NAT. GASOLINE, MBPCD		0.000		0.000		0.000	0.000
		......		......		......	......
TOTAL RAW MATERIALS, MBPCD		6.210		0.000		1.282	9.087
LIQ. PET. GASES, LPG, MBPCD		0.748		0.000		-0.136	2.105
SALABLE COKE, MTPCD		0.002		0.000		-4.063	0.002
GASEOUS PLANT FUEL, MBPCD		3.047		0.000		3.151	5.101
LIQUID PLANT FUEL, MBPCD		0.000		0.000		0.000	0.000
CATALYST AND CHEMICALS, M$PCD		15.105		0.000		20.075	11.784
ELECTRICAL POWER, M-KWH-PCD		265.758		0.000		268.898	426.344
CASH FLOW, M$PCD		-260.957		0.000		-261.750	-297.906
INVESTMENT, MM$		70.094		0.001		189.734	51.966
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE							
SWING CRUDE, BBL./BBL.		0.013		0.000		0.003	0.020
TOTAL RAW MATERIALS, BBL./BBL.		0.013		0.000		0.003	0.020
CATALYST AND CHEMICALS, $/BBL.		0.032		0.000		0.039	0.025
ELECTRICAL POWER, KWH/BBL.		0.572		0.000		0.526	0.917
CASH FLOW, $/BBL.		-0.561		0.000		-0.512	-0.641
INVESTMENT, M$/BBL.		0.151		.000		0.371	0.112

TABLE 4-3

PADD 2 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 1 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA		10 % ETHANOL	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2
MAX. RVP (ALL GRADES), PSI	11.460	10.460	9.460	11.460	9.460	11.460	9.460
OPERATIONS DETAIL							
UTILITY PURCHASES							
CAT/CHEM, MSPCD	448.173	466.478	484.387	437.110	499.933	502.000	502.000
PWR GEN, M-KWH-PCD	13633.715	14020.539	14440.496	13353.223	14342.309	14657.230	14657.230
RAW MATERIAL PURCHASES, MBPCD							
LOW-SULFUR CRUDE	2295.000	2295.000	2295.000	2295.000	2295.000	2295.000	2295.000
HIGH-SULFUR CRUDE	486.000	486.000	486.000	486.000	486.000	486.000	486.000
SWING CRUDE	219.247	225.380	229.393	181.926	219.035	153.448	153.448
PROPANE	83.630	83.630	83.630	83.630	83.630	83.630	83.630
N-BUTANE	44.750	16.219	0.000	0.000	0.000	7.442	7.442
ISO-BUTANE	34.168	36.000	36.000	19.347	0.000	36.000	36.000
NAT. GASOLINE	0.000	29.085	53.940	14.239	28.482	0.000	0.000
TOTALS	3162.795	3171.314	3183.963	3080.142	3112.147	3061.520	3061.520
RAW MATERIAL INCREMENTAL VALUES, $/BBL.							
LOW-SULFUR CRUDE	31.300	31.250	31.290	31.300	31.320	31.170	31.170
HIGH-SULFUR CRUDE	29.970	29.960	29.950	29.980	30.050	29.920	29.920
SWING CRUDE	30.420	30.420	30.420	30.420	30.420	30.420	30.420
PROPANE	20.450	20.450	20.450	20.450	20.450	20.450	20.450
N-BUTANE	24.770	23.200	22.390	22.250	18.010	23.200	23.200
ISO-BUTANE	24.750	25.830	24.890	24.750	23.510	29.820	29.820
NAT. GASOLINE	29.120	29.120	29.550	29.120	29.120	29.120	22.090
SELECTED PRODUCT SALES, MBPCD							
LEADED REGULAR	261.970	261.970	261.970	248.871	248.871	235.773	235.773
UNLEADED GASOLINE	1001.650	1001.650	1001.650	951.567	951.567	901.485	901.485
UNLEADED PREMIUM	277.380	277.380	277.380	263.510	263.510	249.642	249.642
TOTAL GASOLINE	1541.000	1541.000	1541.000	1463.948	1463.948	1386.900	1386.900

TABLE 4-3

PADD 2 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 2 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA		10 % ETHANOL	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2
SELECTED PRODUCT SALES, MBPCD (CONT.)							
LIQ.PET.GAS.	169.172	171.271	173.638	165.793	175.379	153.942	153.942
SALABLE COKE (MTPCD)	25.876	26.257	26.799	23.005	26.019	19.526	19.526
GASEOUS PLANT FUEL	119.681	123.366	131.936	117.223	133.394	153.276	153.276
LIQUID PLANT FUEL	0.000	1.422	0.000	0.000	0.000	0.000	0.000
RELATIVE CASH FLOW, M$PCD	-8607.469	-9167.957	-9759.449	-6454.891	-7838.781	-6308.906	-6308.906
RELATIVE INVESTMENT, MM$	2530.464	2686.781	2819.235	2440.437	2855.346	2599.731	2599.731
BLEND DETAILS							
RVP - LD. REG.	11.460	10.460	9.460	11.460	9.460	6.285	6.285
RVP - UNL. REG.	11.460	10.460	9.460	11.460	9.460	7.084	6.255
RVP - UNL. PRE.	11.460	10.460	9.460	11.460	9.460	6.466	9.460
RVP - POOL	11.460	10.460	9.460	11.460	9.460	6.837	6.837
VAPOR-LOCK INDEX-LD. REG.	15.994	15.010	14.010	15.695	13.847	10.835	10.835
VAPOR-LOCK INDEX-UNL. REG.	16.010	15.010	13.967	16.010	13.862	11.634	10.805
VAPOR-LOCK INDEX-UNL. PRE.	14.601	13.195	11.859	16.010	12.319	11.016	14.010
VAPOR-LOCK INDEX-POOL	15.754	14.683	13.595	15.956	13.582	11.387	11.387
%@160 DEGREES F.-LD. REG.	34.881	35.000	35.000	32.578	33.748	35.000	35.000
%@160 DEGREES F.-UNL. REG.	35.000	35.000	34.671	35.000	33.863	35.000	35.000
%@160 DEGREES F.-UNL. PRE.	24.160	21.038	18.451	35.000	21.989	35.000	35.000
%@160 DEGREES F.-POOL	33.028	32.487	31.808	34.588	31.706	35.000	35.000
%@210 DEGREES F.-LD. REG.	57.000	57.000	57.000	57.000	57.000	42.772	42.772
%@210 DEGREES F.-UNL. REG.	55.745	54.817	54.151	55.464	52.532	45.855	47.207
%@210 DEGREES F.-UNL. PRE.	43.673	41.939	40.500	52.204	43.284	48.722	43.841
%@210 DEGREES F.-POOL	53.785	52.870	52.178	55.138	51.627	45.847	45.847

TABLE 4-3

PADD 2 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 3 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA		10 % ETHANOL	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2
BLEND DETAILS (CONT.)							
%@230 DEGREES F.-LD. REG.	62.938	63.036	63.028	62.219	62.287	46.023	46.023
%@230 DEGREES F.-UNL. REG.	63.303	62.583	62.038	62.541	60.306	51.336	53.826
%@230 DEGREES F.-UNL. PRE.	59.139	58.380	58.007	66.728	60.121	61.637	52.646
%@230 DEGREES F.-POOL	62.491	61.903	61.481	63.240	60.610	52.287	52.287
%@330 DEGREES F.-LD. REG.	91.915	91.993	91.828	91.041	91.020	81.000	81.000
%@330 DEGREES F.-UNL. REG.	93.245	93.489	93.524	93.276	93.317	91.626	92.841
%@330 DEGREES F.-UNL. PRE.	97.297	97.291	97.326	97.957	97.211	95.730	91.342
%@330 DEGREES F.-POOL	93.748	93.919	93.920	93.738	93.628	90.558	90.558
SPECIFIC GRAVITY-LD. REG.	0.742	0.742	0.743	0.753	0.752	0.759	0.759
SPECIFIC GRAVITY-UNL. REG.	0.741	0.744	0.745	0.754	0.757	0.773	0.775
SPECIFIC GRAVITY-UNL. PRE.	0.757	0.759	0.759	0.739	0.759	0.742	0.735
SPECIFIC GRAVITY-POOL	0.744	0.746	0.747	0.751	0.757	0.765	0.765
% AROMATICS- LD. REG.	31.172	31.075	31.501	30.331	29.529	23.220	23.220
% AROMATICS- UNL. REG.	31.963	33.077	33.559	33.653	34.476	34.560	35.216
% AROMATICS- UNL. PRE.	37.838	36.940	35.564	25.064	30.079	16.689	14.320
% AROMATICS- POOL	32.886	33.432	33.570	31.543	32.844	29.415	29.415
RESEARCH OCTANE- UNL. REG.	92.488	92.588	92.957	93.892	94.056	95.615	95.615
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	87.244	87.544	87.478	87.946	88.028	88.808	88.808
RESEARCH OCTANE- UNL. PRE.	98.500	98.500	98.500	98.500	98.672	98.500	98.500
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.500	87.500	87.500
(R+M)/2- UNL. PRE.	93.000	93.000	93.000	93.000	93.086	93.000	93.000
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	94.500	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	83.500	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.000	89.000	89.000	89.000

TABLE 4-3

PADD 2 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 4 of 4)

	STANDARD PREMISES			5 % METHANOL-TBA		10 % ETHANOL	
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2
CASE DIFFERENCES							
SWING CRUDE, MBPCD		6.133	10.146		37.109		0.000
N-BUTANE, MBPCD		-28.531	-44.750		0.000		0.000
ISO-BUTANE, MBPCD		1.832	1.832		-19.347		0.000
NAT. GASOLINE, MDPCD		29.085	53.940		14.243		0.000
TOTAL RAW MATERIALS, MBPCD		8.519	21.168		32.005		0.000
LIQ. PET. GASES, LPG, MBPCD		2.099	4.466		9.586		0.000
SALABLE COKE, MTPCD		0.381	0.923		3.014		0.000
GASEOUS PLANT FUEL, MBPCD		3.685	12.255		16.171		0.000
LIQUID PLANT FUEL, MBPCD		1.422	0.000		0.000		0.000
CATALYST AND CHEMICALS, M$PCD		18.305	36.214		62.823		0.000
ELECTRICAL POWER, M-KWH-PCD		386.824	806.781		989.086		0.000
CASH FLOW, M$PCD		-560.488	-1151.980		-1383.890		0.000
INVESTMENT, MM$		156.317	288.771		414.909		0.000
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE							
SWING CRUDE, BBL./BBL.		0.004	0.007		0.024		0.000
TOTAL RAW MATERIALS, BBL./BBL.		0.006	0.014		0.021		0.000
CATALYST AND CHEMICALS, $/BBL.		0.012	0.024		0.041		0.000
ELECTRICAL POWER, KWH/BBL.		0.251	0.524		0.642		0.000
CASH FLOW, $/BBL.		-0.364	-0.748		-0.898		0.000
INVESTMENT, M$/BBL.		0.101	0.187		0.269		0.000

TABLE 4-4

PADD 2 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 1 of 4)

	STANDARD PREMISES			10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
MAX. RVP (ALL GRADES), PSI	11.460	10.460	9.460	11.460	9.460	11.460	9.460	9.460
OPERATIONS DETAIL								
UTILITY PURCHASES								
CAT/CHEM, MSPCD	446.447	481.772	501.436	521.869	521.869	468.775	522.191	506.768
PWR GEN, M-KWH-PCD	13399.641	13925.004	14399.129	13912.617	13912.617	14451.703	15385.379	15485.652
RAW MATERIAL PURCHASES, MBPCD								
LOW-SULFUR CRUDE	2295.000	2295.000	2295.000	2295.000	2295.000	2295.000	2295.000	2295.000
HIGH-SULFUR CRUDE	486.000	486.000	486.000	486.000	486.000	486.000	486.000	486.000
SWING CRUDE	161.025	179.989	199.678	82.321	82.321	333.717	370.734	215.773
PROPANE	83.630	83.630	83.630	83.630	83.630	83.630	83.630	83.630
N-BUTANE	44.750	44.750	44.750	44.750	44.750	44.750	44.750	44.750
ISO-BUTANE	36.000	36.000	36.000	36.000	36.000	36.000	36.000	36.000
NAT. GASOLINE	53.940	53.940	53.940	53.940	53.940	53.940	53.940	53.940
TOTALS	3160.345	3179.309	3198.998	3081.641	3081.641	3333.037	3370.054	3215.093
RAW MATERIAL INCREMENTAL VALUES, $/BBL.								
LOW-SULFUR CRUDE	31.340	31.320	31.340	31.020	31.020	31.650	31.230	31.510
HIGH-SULFUR CRUDE	29.980	30.030	30.100	29.780	29.780	30.240	30.050	29.890
SWING CRUDE	30.420	30.420	30.420	30.420	30.420	30.420	30.420	30.420
PROPANE	20.450	20.450	20.450	20.450	20.450	20.450	20.450	20.450
N-BUTANE	20.980	18.370	16.440	20.450	20.450	28.900	15.200	11.000
ISO-BUTANE	23.300	23.460	21.690	26.820	26.820	30.350	20.190	19.590
NAT. GASOLINE	27.410	28.340	28.950	20.170	20.170	29.160	29.600	25.470
SELECTED PRODUCT SALES, MBPCD								
LEADED REGULAR	261.970	261.970	261.970	235.773	235.773	288.167	288.167	261.970
UNLEADED GASOLINE	1001.650	1001.650	1001.650	901.485	901.485	1101.814	1101.814	1001.650
UNLEADED PREMIUM	277.380	277.380	277.380	249.642	249.642	305.118	305.118	277.380
TOTAL GASOLINE	1541.000	1541.000	1541.000	1386.900	1386.900	1695.099	1695.099	1541.000

TABLE 4-4

PADD 2 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 2 of 4)

	STANDARD PREMISES			10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
SELECTED PRODUCT SALES, MBPCD (CONT.)								
LIQ.PET.GAS.	166.428	172.511	174.067	155.003	155.003	176.032	180.963	185.851
SALABLE COKE (MTPCD)	21.368	22.925	24.485	14.555	14.555	35.099	38.072	24.446
GASEOUS PLANT FUEL	118.536	127.252	136.212	154.590	154.590	129.682	146.822	146.384
LIQUID PLANT FUEL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RELATIVE CASH FLOW, M$PCD	-8642.559	-9252.859	-9963.219	-6791.887	-6791.887	-13826.367	-15311.984	-10313.441
RELATIVE INVESTMENT, MM$	2663.405	2767.547	2873.169	2835.360	2835.359	2776.089	3156.390	2923.834
BLEND DETAILS								
RVP - LD. REG.	11.460	10.460	9.460	6.103	6.103	11.460	9.460	9.460
RVP - UNL. REG.	11.460	10.460	9.460	6.671	6.675	11.460	9.460	9.460
RVP - UNL. PRE.	11.460	10.460	9.460	8.850	8.837	11.460	9.460	9.460
RVP - POOL	11.460	10.460	9.460	6.967	6.967	11.460	9.460	9.460
VAPOR-LOCK INDEX-LD. REG.	16.010	15.010	14.010	10.653	10.653	16.010	14.010	13.992
VAPOR-LOCK INDEX-UNL. REG.	16.010	15.010	13.754	11.221	11.225	16.010	13.606	13.978
VAPOR-LOCK INDEX-UNL. PRE.	16.010	13.771	11.859	13.400	13.387	15.795	11.859	11.859
VAPOR-LOCK INDEX-POOL	16.010	14.787	13.456	11.517	11.517	15.971	13.360	13.599
%@160 DEGREES F.-LD. REG.	35.000	35.000	35.000	35.000	35.000	35.000	35.000	34.861
%@160 DEGREES F.-UNL. REG.	35.000	35.000	33.028	35.000	35.000	35.000	31.890	34.755
%@160 DEGREES F.-UNL. PRE.	35.000	25.469	18.451	35.000	35.000	33.344	18.457	18.457
%@160 DEGREES F.-POOL	35.000	33.284	30.739	35.000	35.000	34.702	30.001	31.839
%@210 DEGREES F.-LD. REG.	54.719	55.653	55.511	42.266	42.266	56.598	57.000	57.000
%@210 DEGREES F.-UNL. REG.	56.287	53.986	50.465	45.487	46.535	56.255	51.889	54.286
%@210 DEGREES F.-UNL. PRE.	50.676	44.862	40.500	47.951	44.165	49.615	40.438	40.438
%@210 DEGREES F.-POOL	55.011	52.627	49.529	45.383	45.383	55.118	50.697	52.255

TABLE 4-4

PADD 2 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 3 of 4)

	STANDARD PREMISES			10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
BLEND DETAILS (CONT.)								
%@230 DEGREES F.-LD. REG.	60.439	61.605	61.443	45.375	45.375	62.760	62.459	63.042
%@230 DEGREES F.-UNL. REG.	63.965	61.756	58.284	50.853	52.533	63.973	59.777	62.674
%@230 DEGREES F.-UNL. PRE.	63.639	60.023	58.007	60.496	54.430	62.923	57.954	57.954
%@230 DEGREES F.-POOL	63.307	61.418	58.771	51.657	51.657	63.578	59.905	61.887
%@330 DEGREES F.-LD. REG.	91.104	91.554	91.611	81.000	81.000	92.191	91.343	91.815
%@330 DEGREES F.-UNL. REG.	93.108	92.762	92.319	90.646	92.023	93.230	92.594	93.902
%@330 DEGREES F.-UNL. PRE.	97.550	97.359	97.326	95.082	90.112	97.507	97.319	97.319
%@330 DEGREES F.-POOL	93.567	93.384	93.100	89.805	89.805	93.823	93.232	94.162
SPECIFIC GRAVITY-LD. REG.	0.740	0.741	0.738	0.766	0.766	0.743	0.736	0.746
SPECIFIC GRAVITY-UNL. REG.	0.738	0.740	0.747	0.762	0.764	0.739	0.747	0.746
SPECIFIC GRAVITY-UNL. PRE.	0.748	0.757	0.759	0.755	0.748	0.730	0.759	0.759
SPECIFIC GRAVITY-POOL	0.740	0.743	0.748	0.762	0.762	0.738	0.747	0.748
% AROMATICS- LD. REG.	30.480	30.858	29.117	26.771	26.771	31.875	28.250	33.015
% AROMATICS- UNL. REG.	29.932	31.049	34.072	28.745	29.491	30.733	33.758	33.855
% AROMATICS- UNL. PRE.	37.446	37.327	35.564	24.383	21.689	37.584	35.396	35.396
% AROMATICS- POOL	31.378	32.147	33.498	27.624	27.624	32.160	33.117	33.989
RESEARCH OCTANE- UNL. REG.	92.293	92.370	92.611	94.979	95.472	92.527	93.210	93.167
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	87.146	87.185	87.305	88.489	88.736	87.264	87.605	87.584
RESEARCH OCTANE- UNL. PRE.	98.500	98.500	98.500	98.993	98.500	98.500	98.500	98.500
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.500	87.500	87.500	87.500
(R+M)/2- UNL. PRE.	93.000	93.000	93.000	93.247	93.000	93.000	93.000	93.000
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	94.500	94.500	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	83.500	83.500	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.000	89.000	89.000	89.000	89.000

TABLE 4-4

PADD 2 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 4 of 4)

	STANDARD PREMISES			10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
CASE DIFFERENCES								
SWING CRUDE, MBPCD		18.964	38.653		0.000		37.017	54.748
N-BUTANE, MBPCD		0.000	0.000		0.000		0.000	0.000
ISO-BUTANE, MBPCD		0.000	0.000		0.000		0.000	0.000
NAT. GASOLINE, MDPCD		0.000	0.000		0.000		0.000	0.000
TOTAL RAW MATERIALS, MBPCD		18.964	38.653		0.000		37.017	54.748
LIQ. PET. GASES, LPG, MBPCD		6.083	7.639		0.000		4.931	19.423
SALABLE COKE, MTPCD		1.557	3.117		0.000		2.973	3.078
GASEOUS PLANT FUEL, MBPCD		8.716	17.676		0.000		17.140	27.848
LIQUID PLANT FUEL, MBPCD		0.000	0.000		0.000		0.000	0.000
CATALYST AND CHEMICALS, M$PCD		35.324	54.988		0.000		53.416	60.321
ELECTRICAL POWER, M-KWH-PCD		525.363	999.488		0.000		933.676	2086.011
CASH FLOW, M$PCD		-610.300	-1320.660		0.000		-1485.617	-1670.882
INVESTMENT, MM$		104.142	209.764		-0.001		380.301	260.429
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE								
SWING CRUDE, BBL./BBL.		0.012	0.025		0.000		0.022	0.036
TOTAL RAW MATERIALS, BBL./BBL.		0.012	0.025		0.000		0.022	0.036
CATALYST AND CHEMICALS, $/BBL.		0.023	0.036		0.000		0.032	0.039
ELECTRICAL POWER, KWH/BBL.		0.341	0.649		0.000		0.551	1.354
CASH FLOW, $/BBL.		-0.396	-0.857		0.000		-0.876	-1.084
INVESTMENT, M$/BBL.		0.068	0.136		.000		0.224	0.169

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 1 of 8)

	STANDARD PREMISES			5 % METHANOL-TBA			
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 1	RVP - 2	RVP - 3
MAX. RVP (ALL GRADES), PSI	11.120	10.120	9.120	11.120	10.120	9.120	8.120
OPERATIONS DETAIL							
UTILITY PURCHASES							
CAT/CHEM, M$PCD	989.619	1032.082	1042.944	1004.179	1013.558	1051.304	1059.703
PWR GEN, M-KWH-PCD	30539.926	30993.672	31304.414	29839.547	30414.176	30968.867	31843.020
RAW MATERIAL PURCHASES, MBPCD							
LOW-SULFUR CRUDE	2578.000	2578.000	2578.000	2578.000	2578.000	2578.000	2578.000
HIGH-SULFUR CRUDE	2051.000	2051.000	2051.000	2051.000	2051.000	2051.000	2051.000
SWING CRUDE	1351.765	1368.834	1394.944	1224.337	1287.982	1318.174	1411.948
PROPANE	119.100	119.100	119.100	119.100	119.100	119.100	119.100
N-BUTANE	68.040	68.040	64.551	44.283	0.000	0.000	0.000
ISO-BUTANE	38.030	38.030	38.030	38.030	38.030	34.246	0.000
NAT. GASOLINE	150.970	150.970	150.970	150.970	150.970	150.970	129.559
TOTALS	6356.905	6373.974	6396.595	6205.720	6225.082	6251.490	6289.607
RAW MATERIAL INCREMENTAL VALUES, $/BBL.							
LOW-SULFUR CRUDE	31.610	31.650	31.650	31.650	31.700	31.710	31.610
HIGH-SULFUR CRUDE	30.030	30.030	30.070	30.030	30.040	30.070	30.110
SWING CRUDE	29.820	29.820	29.820	29.820	29.820	29.820	29.820
PROPANE	20.000	20.000	20.000	20.000	20.000	20.000	20.000
N-BUTANE	29.700	26.120	23.200	23.200	22.690	18.830	15.590
ISO-BUTANE	31.160	31.140	29.040	29.070	28.490	24.300	20.780
NAT. GASOLINE	29.480	29.950	29.980	29.500	29.770	29.590	28.640
SELECTED PRODUCT SALES, MBPCD							
LEADED REGULAR	483.479	483.479	483.479	459.305	459.305	459.305	459.305
UNLEADED GASOLINE	1848.600	1848.600	1848.600	1756.170	1756.170	1756.170	1756.170
UNLEADED PREMIUM	511.920	511.920	511.920	486.323	486.323	486.323	486.323
TOTAL GASOLINE	2843.999	2843.999	2843.999	2701.798	2701.798	2701.798	2701.798

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 2 of 8)

	STANDARD PREMISES			5 % METHANOL-TBA			
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 1	RVP - 2	RVP - 3
SELECTED PRODUCT SALES, MBPCD (CONT.)							
LIQ.PET.GAS.	276.341	282.003	284.794	272.852	276.943	287.040	298.446
SALABLE COKE (MTPCD)	141.029	142.708	144.746	130.035	134.883	136.036	143.376
GASEOUS PLANT FUEL	213.159	218.948	226.157	203.501	212.453	220.852	235.337
LIQUID PLANT FUEL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RELATIVE CASH FLOW, M$PCD	-48554.684	-49154.320	-49980.477	-44264.836	-45156.840	-46232.520	-47572.781
RELATIVE INVESTMENT, MM$	5638.352	5793.130	5957.621	5573.654	5676.159	6101.971	6298.480
BLEND DETAILS							
RVP - LD. REG.	11.120	10.120	9.120	11.120	10.120	9.120	8.120
RVP - UNL. REG.	11.120	10.120	9.120	11.120	10.120	9.120	8.120
RVP - UNL. PRE.	11.120	10.120	9.120	11.120	10.120	9.120	8.120
RVP - POOL	11.120	10.120	9.120	11.120	10.120	9.120	8.120
VAPOR-LOCK INDEX-LD. REG.	15.670	14.670	13.670	15.670	14.670	13.260	11.432
VAPOR-LOCK INDEX-UNL. REG.	15.607	14.372	12.952	15.538	14.321	12.831	11.746
VAPOR-LOCK INDEX-UNL. PRE.	14.557	12.680	11.442	15.556	13.700	12.551	10.705
VAPOR-LOCK INDEX-POOL	15.429	14.118	12.802	15.564	14.269	12.854	11.505
%@160 DEGREES F.-LD. REG.	35.000	35.000	35.000	35.000	35.000	31.848	25.474
%@160 DEGREES F.-UNL. REG.	34.515	32.704	29.477	33.986	32.315	28.548	27.892
%@160 DEGREES F.-UNL. PRE.	26.442	19.694	17.865	34.123	27.539	26.393	19.888
%@160 DEGREES F.-POOL	33.144	30.753	28.325	34.183	31.912	28.721	26.040
%@210 DEGREES F.-LD. REG.	54.911	55.359	55.978	55.553	55.863	55.907	49.936
%@210 DEGREES F.-UNL. REG.	57.000	56.056	53.666	57.000	55.734	53.547	51.222
%@210 DEGREES F.-UNL. PRE.	44.861	40.813	40.162	54.000	47.931	46.551	44.135
%@210 DEGREES F.-POOL	54.460	53.194	51.628	56.214	54.352	52.689	49.728

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 3 of 8)

	STANDARD PREMISES			5 % METHANOL-TBA			
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 1	RVP - 2	RVP - 3
BLEND DETAILS (CONT.)							
%@230 DEGREES F.-LD. REG.	61.905	62.151	62.490	61.987	62.169	61.565	56.784
%@230 DEGREES F.-UNL. REG.	63.135	62.382	60.926	63.737	62.294	61.126	58.489
%@230 DEGREES F.-UNL. PRE.	59.852	57.978	57.976	67.005	63.982	62.351	62.786
%@230 DEGREES F.-POOL	62.335	61.550	60.661	64.028	62.577	61.421	58.972
%@330 DEGREES F.-LD. REG.	93.137	92.807	92.364	92.900	92.635	91.150	90.919
%@330 DEGREES F.-UNL. REG.	91.200	90.822	90.921	91.334	91.093	90.991	90.996
%@330 DEGREES F.-UNL. PRE.	96.832	96.947	97.299	97.225	97.806	97.644	97.309
%@330 DEGREES F.-POOL	92.543	92.262	92.314	92.661	92.564	92.216	92.119
SPECIFIC GRAVITY-LD. REG.	0.748	0.747	0.745	0.758	0.757	0.756	0.768
SPECIFIC GRAVITY-UNL. REG.	0.739	0.741	0.746	0.744	0.751	0.754	0.763
SPECIFIC GRAVITY-UNL. PRE.	0.748	0.753	0.758	0.746	0.750	0.756	0.749
SPECIFIC GRAVITY-POOL	0.742	0.744	0.748	0.747	0.752	0.755	0.762
% AROMATICS- LD. REG.	34.587	33.581	32.223	33.880	33.037	31.015	35.337
% AROMATICS- UNL. REG.	31.322	31.219	32.367	27.586	30.807	30.808	35.645
% AROMATICS- UNL. PRE.	30.945	31.316	34.479	28.968	26.675	29.563	22.517
% AROMATICS- POOL	31.809	31.638	32.722	28.905	30.442	30.619	33.230
RESEARCH OCTANE- UNL. REG.	92.779	93.251	93.440	93.565	94.173	94.398	95.151
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	87.389	87.626	87.720	87.783	88.086	88.199	88.576
RESEARCH OCTANE- UNL. PRE.	98.500	98.500	98.500	98.500	98.500	98.668	98.557
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.500	87.500	87.500
(R+M)/2- UNL. PRE.	93.000	93.000	93.000	93.000	93.000	93.084	93.028
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	94.500	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	83.500	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.000	89.000	89.000	89.000

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 4 of 8)

	STANDARD PREMISES			5 % METHANOL-TBA			
	BASE RVP	RVP - 1	RVP - 2	BASE RVP	RVP - 1	RVP - 2	RVP - 3
CASE DIFFERENCES							
SWING CRUDE, MBPCD		17.069	43.179		63.645	93.837	187.611
N-BUTANE, MBPCD		0.000	-3.489		-44.283	-44.283	-44.283
ISO-BUTANE, MBPCD		0.000	0.000		0.000	-3.784	-38.030
NAT. GASOLINE, MBPCD		0.000	0.000		0.000	0.000	-21.411
		------	------		------	------	------
TOTAL RAW MATERIALS, MBPCD		17.069	39.690		19.362	45.770	83.887
LIQ. PET. GASES, LPG, MBPCD		5.662	8.453		4.091	14.188	25.594
SALABLE COKE, MTPCD		1.679	3.717		4.848	6.001	13.341
GASEOUS PLANT FUEL, MBPCD		5.789	12.998		8.952	17.351	31.836
LIQUID PLANT FUEL, MBPCD		0.000	0.000		0.000	0.000	0.000
CATALYST AND CHEMICALS, M$PCD		42.463	53.325		9.379	47.125	55.524
ELECTRICAL POWER, M-KWH-PCD		453.746	764.488		574.629	1129.320	2003.473
CASH FLOW, M$PCD		-599.636	-1425.793		-892.004	-1967.684	-3307.945
INVESTMENT, MM$		154.778	319.269		102.505	528.317	724.826
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE							
SWING CRUDE, BBL./BBL.		0.006	0.015		0.022	0.033	0.066
TOTAL RAW MATERIALS, BBL./BBL.		0.006	0.014		0.007	0.016	0.029
CATALYST AND CHEMICALS, $/BBL.		0.015	0.019		0.003	0.017	0.020
ELECTRICAL POWER, KWH/BBL.		0.160	0.269		0.202	0.397	0.704
CASH FLOW, $/BBL.		-0.211	-0.501		-0.314	-0.692	-1.163
INVESTMENT, M$/BBL.		0.054	0.112		0.036	0.186	0.255

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 5 of 8)

	7.5 % METHANOL-TBA		10 % ETHANOL		INCREASED OCTANE FOR CAT GASOLINE		
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 1	RVP - 2
MAX. RVP (ALL GRADES), PSI	11.120	9.120	11.120	9.120	11.120	10.120	9.120
OPERATIONS DETAIL							
UTILITY PURCHASES							
CAT/CHEM, M$PCD	995.303	1015.262	1082.671	1082.671	987.399	1049.586	1076.102
PWR GEN, M-KWH-PCD	29476.820	29792.566	29888.242	29888.242	30562.844	30917.461	31345.270
RAW MATERIAL PURCHASES, MBPCD							
LOW-SULFUR CRUDE	2578.000	2578.000	2578.000	2578.000	2578.000	2578.000	2578.000
HIGH-SULFUR CRUDE	2051.000	2051.000	2051.000	2051.000	2051.000	2051.000	2051.000
SWING CRUDE	1276.453	1223.438	1255.208	1255.208	1357.994	1354.932	1391.588
PROPANE	119.100	119.100	119.100	119.100	119.100	119.100	119.100
N-BUTANE	68.040	0.000	68.040	68.040	68.040	68.040	48.603
ISO-BUTANE	38.030	36.798	38.030	38.030	38.030	38.030	38.030
NAT. GASOLINE	0.000	149.816	0.000	0.000	150.970	150.970	150.970
TOTALS	6130.623	6158.152	6109.378	6109.378	6363.134	6360.072	6377.291
RAW MATERIAL INCREMENTAL VALUES, $/BBL.							
LOW-SULFUR CRUDE	31.690	31.540	31.520	31.520	31.540	31.710	31.750
HIGH-SULFUR CRUDE	30.050	30.080	30.070	30.070	29.960	30.020	30.030
SWING CRUDE	29.820	29.820	29.820	29.820	29.820	29.820	29.820
PROPANE	20.000	20.000	20.000	20.000	20.000	20.000	20.000
N-BUTANE	25.240	18.770	23.630	23.630	28.780	25.010	23.200
ISO-BUTANE	31.670	24.300	30.640	30.640	30.010	31.070	29.120
NAT. GASOLINE	27.340	28.640	28.640	28.640	29.260	29.490	29.730
SELECTED PRODUCT SALES, MBPCD							
LEADED REGULAR	447.219	447.219	435.132	435.132	483.479	483.479	483.479
UNLEADED GASOLINE	1709.955	1709.955	1663.740	1663.740	1848.600	1848.600	1848.600
UNLEADED PREMIUM	473.526	473.526	460.727	460.727	511.920	511.920	511.920
TOTAL GASOLINE	2630.700	2630.700	2559.599	2559.599	2843.999	2843.999	2843.999

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 6 of 8)

	7.5 % METHANOL-TBA		10 % ETHANOL		INCREASED OCTANE FOR CAT GASOLINE		
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 1	RVP - 2
SELECTED PRODUCT SALES, MBPCD (CONT.)							
LIQ.PET.GAS.	268.041	275.896	253.121	253.121	283.442	283.291	287.440
SALABLE COKE (MTPCD)	132.660	129.265	129.677	129.677	131.043	140.915	144.228
GASEOUS PLANT FUEL	197.890	206.995	215.434	215.434	207.266	213.753	220.728
LIQUID PLANT FUEL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RELATIVE CASH FLOW, M$PCD	-41815.855	-43328.406	-42141.812	-42141.812	-48153.020	-48713.348	-49541.840
RELATIVE INVESTMENT, MM$	5282.888	5811.001	5870.292	5870.292	5170.381	5773.782	6010.668
BLEND DETAILS							
RVP - LD. REG.	11.120	9.120	6.074	6.114	11.120	10.120	9.120
RVP - UNL. REG.	11.120	9.120	8.861	8.170	11.120	10.120	9.120
RVP - UNL. PRE.	11.120	9.120	6.782	8.809	11.120	10.120	9.120
RVP - POOL	11.120	9.120	8.013	7.935	11.120	10.120	9.120
VAPOR-LOCK INDEX-LD. REG.	15.670	13.670	10.624	10.664	15.670	14.670	13.670
VAPOR-LOCK INDEX-UNL. REG.	15.670	13.670	13.411	12.720	15.656	14.419	13.055
VAPOR-LOCK INDEX-UNL. PRE.	15.670	13.670	11.332	13.359	14.023	12.684	11.451
VAPOR-LOCK INDEX-POOL	15.670	13.670	12.563	12.485	15.365	14.149	12.871
%@160 DEGREES F.-LD. REG.	35.000	35.000	35.000	35.000	35.000	35.000	35.000
%@160 DEGREES F.-UNL. REG.	35.000	35.000	35.000	35.000	34.896	33.070	30.270
%@160 DEGREES F.-UNL. PRE.	35.000	35.000	35.000	35.000	22.328	19.724	17.933
%@160 DEGREES F.-POOL	35.000	35.000	35.000	35.000	32.651	30.996	28.854
%@210 DEGREES F.-LD. REG.	54.429	53.600	42.414	41.326	57.000	56.119	57.000
%@210 DEGREES F.-UNL. REG.	55.118	55.242	47.278	46.378	57.000	57.000	54.974
%@210 DEGREES F.-UNL. PRE.	51.197	51.396	41.117	45.513	42.778	40.712	39.936
%@210 DEGREES F.-POOL	54.295	54.271	45.342	45.363	54.440	53.918	52.612

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 7 of 8)

	7.5 % METHANOL-TBA		10 % ETHANOL		INCREASED OCTANE FOR CAT GASOLINE		
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 1	RVP - 2
BLEND DETAILS (CONT.)							
%@230 DEGREES F.-LD. REG.	60.330	60.135	45.402	44.459	62.987	62.557	63.033
%@230 DEGREES F.-UNL. REG.	61.723	62.491	51.436	50.225	63.035	63.068	61.672
%@230 DEGREES F.-UNL. PRE.	66.910	67.225	50.727	57.583	59.591	57.952	57.917
%@230 DEGREES F.-POOL	62.420	62.943	50.283	50.569	62.407	62.060	61.227
%@330 DEGREES F.-LD. REG.	91.472	91.871	83.713	83.028	92.004	92.422	91.834
%@330 DEGREES F.-UNL. REG.	91.231	91.050	89.836	89.127	91.525	90.605	90.501
%@330 DEGREES F.-UNL. PRE.	96.720	98.000	91.729	94.976	96.952	96.819	97.013
%@330 DEGREES F.-POOL	92.260	92.440	89.136	89.143	92.583	92.032	91.900
SPECIFIC GRAVITY-LD. REG.	0.759	0.761	0.766	0.766	0.743	0.746	0.743
SPECIFIC GRAVITY-UNL. REG.	0.755	0.755	0.766	0.764	0.741	0.739	0.744
SPECIFIC GRAVITY-UNL. PRE.	0.735	0.746	0.727	0.734	0.744	0.750	0.753
SPECIFIC GRAVITY-POOL	0.752	0.754	0.759	0.759	0.742	0.742	0.745
% AROMATICS- LD. REG.	30.072	30.565	26.517	26.641	31.255	32.403	30.615
% AROMATICS- UNL. REG.	30.898	29.557	32.159	30.057	32.648	29.858	30.873
% AROMATICS- UNL. PRE.	15.845	22.485	3.243	11.384	27.216	29.443	30.284
% AROMATICS- POOL	28.048	28.422	25.995	26.115	31.433	30.215	30.723
RESEARCH OCTANE- UNL. REG.	94.220	94.774	94.810	94.997	92.480	93.059	93.434
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	88.110	88.387	88.405	88.499	87.240	87.529	87.717
RESEARCH OCTANE- UNL. PRE.	98.604	98.500	98.758	98.500	98.287	98.500	98.500
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.713	87.500	87.500
(R+M)/2- UNL. PRE.	93.052	93.000	93.129	93.000	93.000	93.000	93.000
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	93.471	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	84.529	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.003	89.000	89.000	89.000

TABLE 4-5

PADD 3 CASE RESULTS WITH OPEN NGL PURCHASES

(Sheet 8 of 8)

	7.5 % METHANOL-TBA		10 % ETHANOL		INCREASED OCTANE FOR CAT GASOLINE		
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 1	RVP - 2
CASE DIFFERENCES							
SWING CRUDE, MBPCD		-53.015		0.000		-3.062	33.594
N-BUTANE, MBPCD		-68.040		0.000		0.000	-19.437
ISO-BUTANE, MBPCD		-1.232		0.000		0.000	0.000
NAT. GASOLINE, MBPCD		149.816		0.000		0.000	0.000
		......		......		......	......
TOTAL RAW MATERIALS, MBPCD		27.529		0.000		-3.062	14.157
LIQ. PET. GASES, LPG, MBPCD		7.855		0.000		-0.151	3.998
SALABLE COKE, MTPCD		-3.395		0.000		9.872	13.185
GASEOUS PLANT FUEL, MBPCD		9.105		0.000		6.487	13.462
LIQUID PLANT FUEL, MBPCD		0.000		0.000		0.000	0.000
CATALYST AND CHEMICALS, M$PCD		19.959		0.000		62.187	88.703
ELECTRICAL POWER, M-KWH-PCD		315.746		0.000		354.617	782.426
CASH FLOW, M$PCD		-1512.551		0.000		-560.328	-1388.820
INVESTMENT, MM$		528.113		0.000		603.401	840.287
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE							
SWING CRUDE, BBL./BBL.		-0.019		0.000		-0.001	0.012
TOTAL RAW MATERIALS, BBL./BBL.		0.010		0.000		-0.001	0.005
CATALYST AND CHEMICALS, $/BBL.		0.007		0.000		0.022	0.031
ELECTRICAL POWER, KWH/BBL.		0.111		0.000		0.125	0.275
CASH FLOW, $/BBL.		-0.532		0.000		-0.197	-0.488
INVESTMENT, M$/BBL.		0.186		0.000		0.212	0.295

TABLE 4-6

PADD 3 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 1 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
MAX. RVP (ALL GRADES), PSIA	11.120	9.120	11.120	9.120	11.120	9.120	9.120
OPERATIONS DETAIL							
UTILITY PURCHASES							
CAT/CHEM, M$PCD	989.619	1042.285	1074.731	1074.731	1082.184	1096.499	1023.818
PWR GEN, M-KWH-PCD	30539.926	31368.176	29893.629	29893.629	33144.555	33783.973	32517.387
RAW MATERIAL PURCHASES, MBPCD							
LOW-SULFUR CRUDE	2578.000	2578.000	2578.000	2578.000	2578.000	2578.000	2578.000
HIGH-SULFUR CRUDE	2051.000	2051.000	2051.000	2051.000	2051.000	2051.000	2051.000
SWING CRUDE	1351.765	1392.684	1123.701	1123.701	1667.682	1725.230	1418.664
PROPANE	119.100	119.100	119.100	119.100	119.100	119.100	119.100
N-BUTANE	68.040	68.040	68.040	68.040	68.040	68.040	68.040
ISO-BUTANE	38.030	38.030	38.030	38.030	38.030	38.030	38.030
NAT. GASOLINE	150.970	150.970	150.970	150.970	150.970	150.970	150.970
TOTALS	6356.905	6397.824	6128.841	6128.841	6672.822	6730.370	6423.804
RAW MATERIAL INCREMENTAL VALUES, $/BBL.							
LOW-SULFUR CRUDE	31.610	31.700	31.510	31.510	31.620	31.670	37.050
HIGH-SULFUR CRUDE	30.030	30.070	30.060	30.060	30.030	30.070	30.510
SWING CRUDE	29.820	29.820	29.820	29.820	29.820	29.820	29.820
PROPANE	20.000	20.000	20.000	20.000	20.000	20.000	20.000
N-BUTANE	29.700	21.200	23.800	23.800	29.750	21.550	19.110
ISO-BUTANE	31.160	26.860	30.750	30.750	31.220	27.240	39.000
NAT. GASOLINE	29.480	29.870	22.630	22.630	29.500	29.750	34 790
SELECTED PRODUCT SALES, MBPCD							
LEADED REGULAR	483.479	483.479	435.132	435.132	531.827	531.827	483.479
UNLEADED GASOLINE	1848.600	1848.600	1663.740	1663.740	2033.458	2033.458	1848.600
UNLEADED PREMIUM	511.920	511.920	460.727	460.727	563.111	563.111	511.920
TOTAL GASOLINE	2843.999	2843.999	2559.599	2559.599	3128.396	3128.396	2843.999

TABLE 4-6

PADD 3 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 2 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
SELECTED PRODUCT SALES, MBPCD (CONT.)							
LIQ.PET.GAS.	276.341	285.314	250.548	250.548	295.359	302.599	286.932
SALABLE COKE (MTPCD)	141.029	144.146	119.661	119.661	165.912	170.523	141.031
GASEOUS PLANT FUEL	213.159	226.211	224.232	224.232	236.836	253.621	239.680
LIQUID PLANT FUEL	0.000	0.000	0.000	0.000	0.000	0.000	8.283
RELATIVE CASH FLOW, M$PCD	-48554.684	-49987.219	-43041.789	-43041.789	-58388.770	-59996.117	-50581.457
RELATIVE INVESTMENT, MM$	5638.352	5954.396	6273.015	6273.015	6384.724	6387.610	5782.245
BLEND DETAILS							
RVP - LD. REG.	11.120	9.120	6.262	6.262	11.120	9.120	9.120
RVP - UNL. REG.	11.120	9.120	7.703	6.778	11.120	9.120	9.120
RVP - UNL. PRE.	11.120	9.120	5.550	8.892	11.120	9.120	9.120
RVP - POOL	11.120	9.120	7.071	7.071	11.120	9.120	9.120
VAPOR-LOCK INDEX-LD. REG.	15.670	13.670	10.812	10.812	15.670	13.482	13.670
VAPOR-LOCK INDEX-UNL. REG.	15.607	12.944	12.253	11.328	15.614	12.919	12.790
VAPOR-LOCK INDEX-UNL. PRE.	14.557	11.442	10.100	13.442	14.710	11.444	11.448
VAPOR-LOCK INDEX-POOL	15.429	12.797	11.621	11.621	15.461	12.750	12.698
%@160 DEGREES F.-LD. REG.	35.000	35.000	35.000	35.000	35.000	33.552	35.000
%@160 DEGREES F.-UNL. REG.	34.515	29.410	35.000	35.000	34.572	29.226	28.234
%@160 DEGREES F.-UNL. PRE.	26.442	17.860	35.000	35.000	27.618	17.880	17.906
%@160 DEGREES F.-POOL	33.144	28.280	35.000	35.000	33.393	27.919	27.525
%@210 DEGREES F.-LD. REG.	54.911	55.978	41.640	41.640	55.016	54.245	56.539
%@210 DEGREES F.-UNL. REG.	57.000	53.658	48.771	47.268	57.000	52.967	51.990
%@210 DEGREES F.-UNL. PRE.	44.861	40.164	38.557	43.987	45.445	40.109	39.984
%@210 DEGREES F.-POOL	54.460	51.623	45.720	45.720	54.583	50.870	50.602

TABLE 4-6

PADD 3 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 3 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
BLEND DETAILS (CONT.)							
%@230 DEGREES F.-LD. REG.	61.905	62.490	44.717	44.717	61.964	61.306	62.777
%@230 DEGREES F.-UNL. REG.	63.135	60.941	54.857	52.313	63.061	60.347	59.319
%@230 DEGREES F.-UNL. PRE.	59.852	57.977	45.806	54.994	60.229	57.963	57.900
%@230 DEGREES F.-POOL	62.335	60.671	51.504	51.504	62.365	60.081	59.651
%@330 DEGREES F.-LD. REG.	93.137	92.364	81.000	81.000	93.066	92.733	92.040
%@330 DEGREES F.-UNL. REG.	91.200	90.907	92.746	90.434	91.129	91.197	91.122
%@330 DEGREES F.-UNL. PRE.	96.832	97.301	85.522	93.869	96.648	97.232	97.129
%@330 DEGREES F.-POOL	92.543	92.305	89.449	89.449	92.452	92.544	92.360
SPECIFIC GRAVITY-LD. REG.	0.748	0.745	0.760	0.760	0.748	0.750	0.743
SPECIFIC GRAVITY-UNL. REG.	0.739	0.746	0.764	0.767	0.739	0.749	0.752
SPECIFIC GRAVITY-UNL. PRE.	0.748	0.758	0.740	0.731	0.744	0.757	0.755
SPECIFIC GRAVITY-POOL	0.742	0.748	0.759	0.759	0.741	0.750	0.751
% AROMATICS- LD. REG.	34.587	32.225	23.076	23.076	34.369	34.370	31.285
% AROMATICS- UNL. REG.	31.322	32.259	29.876	31.409	31.103	33.720	35.749
% AROMATICS- UNL. PRE.	30.945	34.515	15.032	9.494	28.078	33.498	31.931
% AROMATICS- POOL	31.809	32.659	26.048	26.048	31.114	33.790	34.303
RESEARCH OCTANE- UNL. REG.	92.779	93.434	94.925	95.012	93.102	93.635	93.664
MOTOR OCTANE- UNL. REG.	82.000	82.000	82.000	82.000	82.000	82.000	82.000
(R+M)/2- UNL. REG.	87.389	87.717	88.463	88.506	87.551	87.817	87.832
RESEARCH OCTANE- UNL. PRE.	98.500	98.500	98.587	98.500	98.500	98.500	98.500
MOTOR OCTANE- UNL. PRE.	87.500	87.500	87.500	87.500	87.500	87.500	87.500
(R+M)/2- UNL. PRE.	93.000	93.000	93.043	93.000	93.000	93.000	93.000
RESEARCH OCTANE- LD. REG.	94.500	94.500	94.500	94.500	94.500	94.500	94.500
MOTOR OCTANE- LD. REG.	83.500	83.500	83.500	83.500	83.500	83.500	83.500
(R+M)/2- LD. REG.	89.000	89.000	89.000	89.000	89.000	89.000	89.000

TABLE 4-6

PADD 3 CASE RESULTS WITH FIXED NGL PURCHASES

(Sheet 4 of 4)

	STANDARD PREMISES		10 % ETHANOL		INCREASED GASOLINE		NO INVESTMENT
	BASE RVP	RVP - 2	BASE RVP	RVP - 2	BASE RVP	RVP - 2	RVP - 2
CASE DIFFERENCES							
SWING CRUDE, MBPCD		40.919		0.000		57.548	66.899
N-BUTANE, MBPCD		0.000		0.000		0.000	0.000
ISO-BUTANE, MBPCD		0.000		0.000		0.000	0.000
NAT. GASOLINE, MBPCD		0.000		0.000		0.000	0.000
TOTAL RAW MATERIALS, MBPCD		40.919		0.000		57.548	66.899
LIQ. PET. GASES, LPG, MBPCD		8.973		0.000		7.240	10.591
SALABLE COKE, MTPCD		3.117		0.000		4.611	0.002
GASEOUS PLANT FUEL, MBPCD		13.052		0.000		16.785	26.521
LIQUID PLANT FUEL, MBPCD		0.000		0.000		0.000	8.283
CATALYST AND CHEMICALS, M$PCD		52.666		0.000		14.315	34.199
ELECTRICAL POWER, M-KWH-PCD		828.250		0.000		639.418	1977.461
CASH FLOW, M$PCD		1432.535		0.000		-1607.347	-2026.773
INVESTMENT, MM$		316.044		0.000		2.886	143.893
CASE DIFFERENCES, NORMALIZED PER BARREL OF GASOLINE							
SWING CRUDE, BBL./BBL.		0.014		0.000		0.018	0.024
TOTAL RAW MATERIALS, BBL./BBL.		0.014		0.000		0.018	0.024
CATALYST AND CHEMICALS, $/BBL.		0.019		0.000		0.005	0.012
ELECTRICAL POWER, KWH/BBL.		0.291		0.000		0.204	0.695
CASH FLOW, $/BBL.		-0.504		0.000		-0.514	-0.713
INVESTMENT, M$/BBL.		0.111		0.000		0.001	0.051

<u>BIBLIOGRAPHY</u>

[1]State of California Air Resources Board, "The Feasibility and Impact of Reducing Hydrocarbon Emissions by Reducing Gasoline Volatility," December 9, 1975.

[2]Bonner & Moore Management Science, "Impact of Reducing Gasoline Volatility," 30 November 1983, Document No. CAR-8201 prepared for the California Air Resources Board.

APPENDIX A

PRODUCT DEMAND FORECASTS

APPENDIX A

PRODUCT DEMAND FORECASTS

Appendix A presents the forecasts of petroleum product demands used in this study. Forecasts were developed as a review and update of a forecast prepared for an earlier study[1]. This forecast is based on four general assumptions and six premises relating to specific products. The four general assumptions are:

1) U.S. GNP is assumed to grow at 3.5 percent per year through the 1980s.

2) Continued conservation will hold growth of energy consumption to 1.6 percent per year.

3) Petroleum-based fuels will provide a large but declining part of energy supply. From a current percentage of 43, petroleum supply will decrease to 36 percent of total energy satisfaction by 2000.

4) Crude oil prices will drop slightly in terms of real dollar value through the 1980s.

Certain premises have been used in forecasting demands for individual products. These are:

1) Gasoline consumption will decline at a slower rate than predicted in forecasts made in the preceding three to four years. Slower development, than first expected, of the penetration

of diesel-powered vehicles into new car sales is the main reason for this less rapid decline. Another factor is a lower than projected vehicular fuel economy of the new car mix. This forecast is based on diesel penetration amounting to five percent of new car sales by 1990. The recent trend toward larger, more powerful, more spacious cars will reduce the mile-per-gallon assumptions of earlier forecasts.

2) Demand projections for aviation turbine fuel has been taken from a recent forecast concentrating on middle distillate fuels[2].

3) Distillate fuels, i.e. diesel fuel and heating oil, demand will grow at a rate of 1.5 percent per year. Growth will occur because of the addition of diesel-powered cars and trucks to the automotive population. Heating oil for both residential and commercial consumption is assumed to decline during the forecast period.

4) Residual fuel oil demand is projected to increase through 1990. Between 1985 and 1990, growth is assumed to be 3.9 percent per year, with a slight decline thereafter. Potential demand variation for utility boiler fuel, in dual-fired boilers, is approximately two million barrels per day of fuel oil equivalent. With the deregulation of natural gas price, stable crude prices, surplus refining capacity and the trend toward heavier crude supply, it is expected that the balance between fuel oil and natural gas use will swing toward fuel oil.

Further, assuming no new projects for nuclear power facilities and with current projects being held up, utility power supply from nuclear plants will be lower than assumed in earlier forecasts. It is expected that this shortfall will be made up by a combination of coal-fired and dual-fired boilers in the near term and by coal-fired boilers in the longer term.

5) Automotive lube oil demand is assumed to be level through the forecast period. Industrial lube oil demand may grow slightly. Asphalt demand should grow during the period of the late 1980s in response to construction and road repair activities.

6) Miscellaneous products include specialty naphthas, petrochemical feedstocks (naphthas and light ends) and other products (petrolatums, associated oils, ramjet and rocket fuels, SNG feeds, etc.). Petrochemical feedstock demand is expected to grow at a modest rate of 2.4 percent per year. Other miscellaneous products are assumed to be level throughout the forecast period.

7) Demand for petroleum coke* will continue to be much lower than production. Excess production competes with high-sulfur coal domestically and abroad. Current and planned processing to accommodate heavy crude may be more than adequate, depending on residual fuel oil demand. There is a large potential market for petroleum coke as a fuel and over-supply offers significant incentives for its development. Projections for coke in this forecast assume a growth based on use of installed and announced coking capacity.

National forecasts, developed for this study, are presented in Table A-1. Also shown are 1983 actual consumptions of refined products and two 1984 forecasts from other sources for comparison.

Distribution of this national forecast among the five PADDs is based on maintaining the same proportions of each product demand as represented in the earlier referenced study. Product demands forecasted for each region are shown in Table A-2.

---

*Catalyst coke is consumed in the cat cracking process and is, therefore, not considered marketable and is not represented in the coke demands of this forecast.

TABLE A-1

PETROLEUM DEMAND FORECAST FOR U.S.
(MBPCD)

Product	Bonner & Moore Forecast 1985	Bonner & Moore Forecast 1990	Comparisons 1983[1] Actual	Comparisons 1984 O&GJ[2]	Comparisons 1984 IPAA[3]
Gasoline	6,500	6,000	6,643	6,640	6,563
Jet Fuels	1,140	1,240	1,042	1,075	1,081
Distillates	2,900	3,100	2,809	2,810	2,903
Residual Fuels	1,650	2,000	1,403	1,455	1,531
Lubes and Asphalts	560	610	530	na	na
Miscellaneous	575	645	547	na	na
Petroleum Coke	250	270	228	na	na
	13,575	13,865	13,202	-	-

[1]U.S. Department of Energy, Monthly Petroleum Summaries
[2]Oil and Gas Journal, January 30, 1984, page 99
[3]National Petroleum News, December 1983, page 42

TABLE A-2

FORECAST OF REFINED PRODUCT DEMANDS
(MBPCD)

		U.S.	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
1985 -	Gasoline	6,500	2,223	2,112	930	195	1,040
	Jet Fuels	1,140	441	220	130	30	319
	Distillates	2,900	1,093	905	435	104	363
	Residual Fuels	1,650	934	205	219	15	277
	Lubes and Asphalts	560	163	224	71	20	82
	Miscellaneous	250	33	65	80	-	72
	Petroleum Coke	575	49	106	375	7	38
	Total	13,575	4,936	3,837	2,240	371	2,191
1990 -	Gasoline	6,000	2,088	1,932	852	168	960
	Jet Fuels	1,240	470	238	139	40	353
	Distillates	3,100	1,128	958	505	115	394
	Residual Fuels	2,000	968	290	368	22	352
	Lubes and Asphalts	610	185	240	76	22	87
	Miscellaneous	270	23	59	106	-	82
	Petroleum Coke	645	54	116	428	8	39
	Total	13,865	4,916	3,833	2,474	375	2,267

The location and capacity of major refining centers are such that satisfying regional demands involves inter-regional product movements. Most of these movements are by pipeline, some are by tanker and barge and a lesser amount is moved by tank car and tank truck. Some product supply, particularly to PADD 1, is via import from Caribbean sources. Traditional movements among PADDs have been influenced more recently by refinery shutdowns. For this study, the projected inter-PADD movements were taken from two recent studies[6,7] and revised to account for the most recent refinery closures. Because it appears likely that further refinery closures will, if needed, involve PADD 1, previous inter-PADD movements have been revised to reflect more movements from PADD 3 to PADD 1. Application of estimated inter-PADD movements leads to the refinery output requirements shown in Table A-3. In addition to the forecasts of refinery output requirements, Table A-3 also shows 1983 actual refining supplies for each PADD.

Neither the demand projections shown in Table A-2 nor the refinery output requirements shown in Table A-3 include LPG. Although refineries produce this fuel, only a minor part of that output is produced from refinery processes. The major part must, therefore, be brought in with other raw materials such as natural gas liquids and even with crude oils. LPG actually produced in refining is a by-product since process operating decisions are rarely, if ever, made on the basis of adjusting production of LPG.

TABLE A-3

EXPECTED-GROWTH REFINERY OUTPUT REQUIREMENTS
(MBPCD)

(Sheet 1 of 2)

	U.S. Product Demand	Net Imports + Stk Drawdown - Exports - Stk Addt'n	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
1983 (Actual)*							
Gasoline	6,643	291.3	580.8	1755.5	2812.2	220.9	982.3
Jet Fuels	1,042	22.2	44.8	157.3	512.4	32.6	272.7
Distillates	2,809	245.6	265.8	604.4	1229.3	113.3	350.6
Residual Fuels	1,403	556.6	99.7	73.4	357.1	10.1	306.1
Lubes and Asphalts	530	-3.3	94.5	140.1	207.9	22.9	67.9
Miscellaneous	547	40.3	19.5	42.5	412.5	1.2	31.0
Petroleum Coke	228	-16.5	12.3	61.4	84.8	4.3	81.7
Total	13,202	1136.2	1117.4	2834.6	5616.2	405.3	2092.3
1985 (Forecast)							
Gasoline	6,500	291.0	566.0	1716.0	2750.0	215.0	962.0
Jet Fuels	1,140	23.0	49.0	172.0	561.0	36.0	299.0
Distillates	2,900	254.0	276.0	624.0	1267.0	116.0	363.0
Residual Fuels	1,650	656.0	117.0	86.0	419.0	12.0	360.0
Lubes and Asphalts	560	-4.0	100.0	148.0	220.0	24.0	72.0
Miscellaneous	575	41.0	21.0	45.0	434.0	1.0	33.0
Petroleum Coke	250	-15.0	33.0	65.0	85.0	0.0	82.0
Total	13,575	1246.0	1162	2856	5736.0	404.0	2171.0

*Source: DOE, Petroleum Supply Monthly

TABLE A-3

EXPECTED-GROWTH REFINERY OUTPUT REQUIREMENTS
(MBPCD)

(Sheet 2 of 2)

	U.S. Product Demand	Net Imports + Stk Drawdown - Exports - Stk Addt'n	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
1990 (Forecast)							
Gasoline	6,000.0	22.0	465.0	1541.0	2844.0	181.0	947.0
Jet Fuels	1,240.0	-46.0	94.0	172.0	627.0	43.0	350.0
Distillates	3,100.0	142.0	225.0	759.0	1465.0	124.0	385.0
Residual Fuels	2,000.0	723.0	135.0	215.0	553.0	22.0	352.0
Lubes and Asphalts	610.0	55.0	85.0	181.0	180.0	22.0	87.0
Miscellaneous	645.0	0.0	43.0	103.0	452.0	8.0	39.0
Petroleum Coke	270.0	-40.0	23.0	59.0	121.0	0.0	107.0
Total	13,865.0	856.0	1070.0	3030.0	6242.0	400.0	2267.0

Petroleum coke is also a refinery by-product, except in those cases where its quality and location permit its use in non-fuel applications such as anode and electrode manufacture. Coke is also produced and consumed in the cat cracking process. As shown in Tables A-2 and A-3, coke volume is based on a fuel-oil-equivalent as a means of representing coke output volumetrically. No attempt has been made to identify that part of the petroleum coke which goes to non-fuel uses. Only marketable coke is represented in the figures shown in these tables. Because a significant portion of coke production is by-product, the forecast figures really constitute estimates of consequential production, not demands.

Table A-4 shows the grade mixes used for major products, namely, motor gasoline, jet fuels and residual fuel.

1) Motor Gasoline

The motor gasoline grade mix is based on a recent forecast developed by E. I. du Pont de Nemours & Co.[8] The projected 1990 split of leaded-to-unleaded gasoline corresponded to a forecast developed by Bonner & Moore for use in an alcohol study for the U.S. Department of Energy.[9] This gasoline grade split was applied to each PADD.

2) Jet Fuel

The jet fuel grade mix is based on a recent forecast of naphtha and kerosene jet fuels.[2] The allocation of the total U. S. naphtha jet produced to each PADD is based on 1981 through 1983 actual

TABLE A-4
PRODUCT GRADE DISTRIBUTION
(%)

	PADD 1		PADD 2		PADD 3	
	1983	1990	1983	1990	1983	1990
Motor Gasoline						
Unleaded Premium	61.8	18.0	51.6	18.0	57.2	18.0
Unleaded Regular		65.0		65.0		65.0
Leaded Regular	38.2	17.0	48.4	17.0	42.8	17.0
Jet Fuel						
Naphtha Jet	41.3	26.6	18.8	18.7	18.6	19.4
Kero Jet	58.7	73.4	81.2	81.3	81.4	80.6
Residual Fuel						
Low Sulfur (0-.3 wt%)	16.3	16.0	6.9	7.0	8.3	9.0
Medium Sulfur (.3-1.0 wt%)	59.0	60.0	25.2	27.0	29.0	34.0
High Sulfur (over 1.0 wt%)	24.7	24.0	67.9	66.0	62.7	57.0

data.[10] Kerosene jet fuel demand for each PADD is the total jet fuel demand less the naphtha jet fuel demand.

3) *Residual Fuel*

The grades of residual fuel represented in this study are low sulfur (0 to 0.3 weight percent Sulfur) medium sulfur (0.31 to 1.0 weight percent Sulfur) and high sulfur (greater the 1.0 weight percent Sulfur). Grade mixes are based on the growth rates for each grade from a comprehensive study of nautral gas usage,[7] applied to 1983 production of each grade. This results in a small percentage increase in the low and medium sulfur grades at the expense of the high-sulfur grade. Because of projected increase in total residual fuel demand by 1990, individual grades of residual fuel also show increases.

APPENDIX A BIBLIOGRAPHY

[1]Bonner & Moore Management Science, "Natural Gas Consumption in U. S. Refineries," Appendix A, prepared for the Gas Research Institute under Contract No. 5083-800-0909. NTIS Document No. GRI-84/0143.

[2]Carlton R. Jones, Resource Planning Consultants, "Middle Distillates Outlook, Part 1 - Marketing Trends", presented at the API Mid-Year Refining Meeting in New Orleans, Louisiana, May 15, 1984.

[3]U.S. Department of Energy, Monthly Petroleum Summaries

[4]Oil and Gas Journal, January 30, 1984, page 99

[5]National Petroleum News, December 1983, page 42

[6]Bonner & Moore, "Impact of Alcohol fuels on the U. S. Refining Industry," prepared for the U. S. Department of Energy under contract No. DE-AC01-81CS-50007, August, 1983.

[7]Bonner & Moore, Jensen Associates - Proprietary Study of Natural Gas Deregulation.

[8]Oil & Gas Journal, "Automakers Seek Oil Product Changes," May 28, 1984, Page 46.

[9]Bonner & Moore Management Science, "Impact of Alcohol Fuels on the U. S. Refining Industry," Appendices A and F, Volume 2, prepared for the U.S. Department of Energy under Contract Number DE-AC01-81CS-500007.

[10]U. S. Department of Energy, Annual Petroleum Statement DOE/EIA-0340(81),(82) and (83)

APPENDIX B

PROJECTED CRUDE AND NGL SUPPLY

APPENDIX B

PROJECTED CRUDE AND NGL SUPPLY

Appendix B provides projections of crude oil and other raw materials supply employed in this study.

B.1 CRUDE SUPPLY

Production of crude oil and lease condensate in the United States is expected to decline throughout the remainder of the decade, from 8.7 million barrels/day in 1983 to 7.5 million barrels/day in 1990. Since product demand is expected to increase slightly through 1990, imported crude oil must increase from the 1983 level of 3 million barrels/day. Because of the expected oversupply of world crude oils of all qualities through the rest of the decade, however, increased crude oil imports should not cause the 1°-to-2° API gravity reduction in crude that some forecasters have dicted.

Table B-1 shows projected 1990 crude slates for PADDs 1, 2 and 3. The crude charge to each PADD, by source, was developed using the *Jensen/Bonner & Moore Study*[1] and by modifying some of its assumptions to reflect changed conditions. The methodology used was to project the amount of crude available from each source through 1990 and then to allocate this crude to each PADD based on historical patterns modified by changing conditions of refining capacity and product demands. Saudi Arabian crude was used as the supplemental (swing) crude.

TABLE B-1

1990 CRUDE SLATES

Sources	Representative Crudes	°API	Wt%S	Grouping	PADD 1 (MBPCD)	PADD 2 (MBPCD)	PADD 3 (MBPCD)
North Slope	North Slope	26.4	1.0	High S.	123.0		580.0
PADD 1	Citronelle	43.5	0.35	Low S.	21.0		77.0
PADD 2	Eastern Kansas	30.2	0.35	Low S.	32.0	533.0	
	Citronelle	43.5	0.35	Low S.		86.0	334.0
PADD 3	Gibson Terminal	35.8	0.46	Low S.	4.5	215.0	557.0
	Morgan City	28.5	0.20	Low S.		172.0	358.0
	Weems Arco Sour	33.4	0.90	High S.	4.5	241.0	490.0
	Camrick	39.7	0.14	Low S.		147.0	490.0
PADD 4	Wyoming Sweet	38.2	0.33	Low S.		515.0	
North Africa	Saharan Blend	44.9	0.14	Low S.	107.0	180.0	313.0
West Africa	Bonny Light	36.9	0.13	Low S.	78.0	61.5	137.0
	Forcados	28.8	0.33	Low S.	78.0	61.5	34.0
U.A.E.	Murban	39.0	0.80	High S.	16.0	47.0	115.0
North Sea	Ninian	35.2	0.46	Low S.	205.0	85.0	160.0
VZ, Trin.& Tob.	Galleota	34.1	0.22	Low S.	14.0	39.0	118.0
	Leona	24.1	1.52	High S.	60.0	8.0	55.0
Mexico	Isthmus	32.8	1.51	High S.	40.0	95.0	405.5
	Mayan	22.0	3.32	High S.	59.0	95.0	405.5
Canada	Glacier Pipeline	40.0	0.50	Low S.	16.0	200.0	
Saudi, Iran, Iraq & Kuwait	Arabian Light	32.9	1.70	Swing	88.8	45.6	679.2
	Arabian Heavy	27.0	2.82	Swing	59.2	30.4	452.8
TOTALS					1,006.0	2,857.0	5,761.0

Typical crudes, from the Bonner & Moore assay library[2], were selected to represent sources of crude oil. For foreign sources, major export crudes from the particular area were selected. To confirm these selections, these representative crudes were used with the 1983 actual volumes of crudes, by source, to each PADD and a volumetric average API gravity and weight percent sulfur were determined. These averages were compared to the actual average API gravity and weight percent sulfur of crude charge reported in the DOE "Petroleum Supply Annual." Adjustments were made, as necessary.

Table B-2 contains a comparison of the reported 1983 crude gravities and sulfur contents for each PADD with those calculated from the crude slates shown in Table B-1. The composite crude quality of the three PADDs is projected to be heavier and contain more sulfur than current crude slates but not to the degree anticipated by others. The quality changes in PADDs 1 and 2 are slight whereas the major deterioration of quality appears to be in PADD 3. Current refinery process trends are anticipating and, in a way, directing this trend. The majority of topping refineries and hydroskimming refineries in PADD 3 needing the lower-sulfur-content and lower-gravity crudes have been shut down. Complex refineries have been modified by investments in bottom-of-the-barrel upgrading and in desulfurization processes to accommodate heavy crudes such as Mayan. During the past two years, refinery shutdowns in PADD 2 represent an 18 percent decrease in refining capacity. In PADD 1, 17 percent of refining capacity has been shut down. Very little process investment has been announced for the existing refineries in PADDS 1 and 2.

TABLE B-2

COMPARISON OF AVERAGE GRAVITY AND SULFUR

OF CRUDE SLATES

	1983 ACTUAL	1990 PROJECTED
PADD 1		
API° Gravity	31.8	32.7
Weight Percent Sulfur	.95	.97
PADD 2		
API° Gravity	34.6	35.0
Weight Percent Sulfur	.89	.65
PADD 3		
API° Gravity	34.3	33.2
Weight Percent Sulfur	.87	1.18
WEIGHTED AVERAGE (PADDs 1,2,3)		
API° Gravity	34.1	33.7
Weight Percent Sulfur	.88	1.00

B.2 NGL SUPPLY

NGL supplies (LPG, normal butane, iso-butane and natural gasoline) were maintained, for purposes of this study, at 1983 levels. These levels were developed from the DOE "Petroleum Supply Annual--1983."

APPENDIX B BIBLIOGRAPHY

[1]Bonner & Moore Management Science and Jensen Associates, proprietary study of natural gas deregulation.

[2]Bonner & Moore Management Science, proprietary crude oil assay library.

APPENDIX C

PRODUCTION SPECIFICATIONS

APPENDIX C

PRODUCT SPECIFICATIONS

The specifications used for those products modeled to meet quality restrictions are shown in Table C-1. In addition, LPG was modeled to compositional specification of maximum 5 volume-percent olefins and 2.5 percent butanes. All other produts, such as lubes, asphalts, and specialty naphthas were modeled as recipe blends.

The specifications, with the exception of those enumerated below are those in the Refinery and Petrochemical Modeling System (RPMS) library. These RPMS specifications are routinely reviewed and updated to be representative of current industry requirements. The specifications were not varied by PADD nor varied for seasonality.

The Road Octane specification, (R+M)/2, for leaded regular and unleaded regular gasolines are ASTM D 439 specifications. The unleaded premium (R+M)/2 is an average from recent announcements by various marketers[1].

Gasoline volatility specification for percent distilled at 160°, 210°, 230° and 330° Fahrenheit were derived from considerations involving historical gasoline quality surveys[2] and from ASTM D 439 standards using the average of B and C volatility classes. It should be noted that ASTM D 439 schedules for various volatility classes describe distillation controls in terms of minimum and maximum temperatures at specified percents distilled. Representing such limits in mathematical models is usually done by transposing temperature limits at specified distillation points to distillation limits at specified temperatures. Blending data

TABLE C-1

PRODUCT SPECIFICATIONS

(Sheet 1 of 2)

GASOLINES	Leaded Regular Min	Leaded Regular Max	Unleaded Regular Min	Unleaded Regular Max	Unleaded Premium Min	Unleaded Premium Max
RVP		*		*		*
(R+M)/2	89.0		87.0		93.0	
Motor Octane	83.5		82.0		87.5	
% at 160° F.		35.0		35.0		35.0
% at 210° F.	35.0	57.0	35.0	57.0	35.0	54.0
% at 230° F.	44.0		44.0		44.0	
% at 330° F.	81.0	98.0	81.0	98.0	81.0	98.0
Wt. % Sulfur		0.15		0.10		0.10

JET FUELS	JP-4 Min	JP-4 Max	JTA Min	JTA Max
Specific Gravity	0.75	0.80	0.77	0.84
% at 400° F.	60.0		10.0	
% Aromatics		25.0		25.0
Wt. % Sulfur		0.3		0.3
Smoke Point, MM	20.0		18.0	
H_2 Treat Req. (%)			50.0	
Flash, Degrees F.			100.0	

---

*See later discussion

TABLE C-1

PRODUCT SPECIFICATIONS

(Sheet 2 of 2)

NO. 2 FUEL OIL	No. 2 Fuel Oil Min	No. 2 Fuel Oil Max
Specific Gravity		0.88
% at 400°F.	10.0	
Wt. % Sulfur		0.30
H_2 Treat Req. %	50.0	
Flash, Degrees F.	125.0	

NO. 6 FUEL OILS	Low Sulfur Min	Low Sulfur Max	Medium Sulfur Min	Medium Sulfur Max	High Sulfur Min	High Sulfur Max
Specific Gravity	0.00		0.00			1.0
Wt. % Sulfur		0.30		0.7		2.8
Flash, Degrees F.	150.0		150.0		150.0	
Viscosity, SSF/122		300.0		300.0		300.0

in RPMS and the corresponding distillation specifications are based on temperatures covering normally expected 10, 50 and 90 percentage points, namely, 160°, 210°, 230° and 330°F. The 160°F temperature was chosen because it is approximately equal to 158°F (70°C) which is frequently used to control "front-end" volatility and as part of the relationship termed Vapor Lock Index (VLI), also termed Front-End Volatility Index (FEVI). The expression for this relationship is:

$$VLI = RVP + 0.13\ (\%\ @\ 158°F)$$

It is used by some refiners to approximate control of 20 V/L temperature, a test which relates to vapor lock tendency. It is not, however, certain that all gasolines are produced to a 20 V/L temperature limit. In the absence of a VLI limitation, a maximum if 35 percent was imposed at 160°F to prevent excessively high percentages.

Reid Vapor Pressure (RVP) specification, being the subject specification of the study, was varied by PADD. Table C-2 shows the RVP specifications used for base and reduced volatility. Base-case RVP specification were derived using the volatility classes from ASTM D 439 for the months of June, July and August. The ASTM standard defines permitted volatility classes by State, by month. Class A is a maximum RVP of 9, Class B is a maximum of 10, and Class C is a maximum of 11.5. Based on the gasoline volumes to each location, a weighted average was developed of the RVP specification for refinery production in each PADD by accounting for the inter-PADD movements of gasoline.

TABLE C-2

RVP SPECIFICATIONS

(psi)

	Base RVP	RVP-1	RVP-2
PADD 1	11.50	10.50	9.50
PADD 2	11.46	10.46	9.46
PADD 3	11.12	10.12	9.12

Weight-percent-sulfur specifications for No. 6 Fuel Oils were set to represent the fuel oil production grouping in the DOE "Petroleum Annual Statement." Low-sulfur fuel oil with a specification of 0.3 weight percent sulfur, represents the 0-to-.3 weight-percent grouping. Medium-sulfur fuel oil, with a weight percent sulfur of 0.7 represents the .3-to-1.0 weight-percent grouping. The 0.7 level was used rather than 1.0 since most of the fuel oil in this group is produced at 0.5 and 0.7 sulfur levels. High-sulfur fuel oil was given a specification of 2.8 weight-percent sulfur.

APPENDIX C BIBLIOGRAPHY

[1] The Oil & Gas Journal, "More Higher Octane Unleaded Offered", June 25, 1984, pg. 36.

APPENDIX D

ECONOMIC AND FINANCIAL FACTORS

APPENDIX D

ECONOMIC AND FINANCIAL FACTORS

All costs and prices employed in this study were set at current 1984 values. No inflation to 1990 was employed, i.e., a constant dollar value was assumed. This assumption is not material to the results since results are based on comparisons between cases.

Prices for major products and the base crude slate were not needed since the quantities were fixed at forecast levels. Prices for swing crudes, normal and iso-butane, natural gasoline, LPG, coke and sulfur were, however, required and the values used are displayed in Table D-1.

Swing crude prices are based on current posted prices, FOB Ras Tanura, plus transportation costs to New York, Chicago and Houston representing PADDs 1, 2 and 3, respectively, Normal butane, iso-butane and natural gasoline prices for PADD 3 were based on the average of spot Mont Belvieu prices quoted in Platt's Oilgram, for the first quarter of 1984. Prices for PADDs 1 and 2 were determined using transportation cost estimates to Philadelphia and Chicago, respectively. LPG prices were similarly developed but adjusted higher by $0.80/barrel to be consistent with fuel oil costs derived from the swing crude. Coke prices were taken from the study of vapor pressure reduction in California[1] and assumed to be constant for all PADDs. Sulfur prices were obtained from the Chemical Marketing Reporter. for Houston and Tampa Bay, through the first quarter of 1984.

TABLE D-1

RAW MATERIAL COSTS AND BY-PRODUCT PRICES

	PADD 1	PADD 2	PADD 3
RAW MATERIALS ($/BBL)			
Swing Crudes			
Arabian Light	30.86	31.59	30.99
Arabian Heavy	27.94	28.67	28.07
Normal Butane	27.15	23.75	23.30
Iso-Butane	28.15	24.75	23.30
12# Natural Gasoline	32.52	29.12	28.67
BY-PRODUCT PRICES			
LPG ($/BBL)	23.85	20.45	20.00
Coke ($/FOEB)	4.23	4.23	4.23
Sulfur ($/ST)	94.00	80.00	94.00
PURCHASED UTILITY COSTS			
Electrical Power (¢/KWH)	6.24	6.69	5.99

The Refinery and Petrochemical Modeling System (RPMS), a proprietary Bonner & Moore system, generates process operating costs based on utility consumption factors multiplied by utility costs. Fuel and steam costs to all processes are based on crude costs plus investment and operating costs for utility supply facilities. Cooling water costs are based on zero-cost raw water plus the investment and operating costs of cooling and pumping facilities. Electric power was assumed to be purchased in all cases rather than internally generated. Power costs were obtained from Electric Power Monthly using regional quotations representing each PADD.

RPMS process data include 1982 catalyst and chemical costs for each process. These 1982 costs were converted to 1984 values using the Nelson Cost Index for chemicals of 1.026.

Capital requirements for new and expanded capacity were derived from investment-versus-capacity relationships* for each process using process sizes consistent with recent industry activities. Thus capacity costs are based on typical process capacities.

The cost of supporting investments for typical facilities was determined by applying a capital recovery factor derived from the factors shown in Table D-2.

----

*Part of RPMS proprietary data.

TABLE D-2

FINANCIAL AND CAPITAL-RELATED FACTORS

	FACTOR
Economic Life, yrs.	13
Depreciation Life, yrs.	13
Federal Income Tax Rate, percent	48
After tax Cost of Capital, percent	15
Capital Recovery Factor*	0.262
Local Taxes, Insurance and Overhead, % per year	2
Maintenance, % per year	4

Adding maintenance and local taxes, insurance and overhead to capital recovery, the total cost of supporting one dollar of investment becomes 0.322 dollars per year.

---

*Using double-declining-balance depreciation tax credit.

APPENDIX D

APPENDIX D BIBLIOGRAPHY

[1]Bonner & Moore Management Science, "Impact Assessment of Reducing Gasoline Volatility," study report prepared for the California Air Resources Board under State of California Contract No. A2-051-32, 30 November 1983.

APPENDIX E

BASE CONFIGURATION

APPENDIX E

BASE CONFIGURATION

The capacities of major processes used in models for each PADD's refinery capability are displayed in Table E-1. These data are based on the Oil & Gas Journal "Annual Refining Survey" and represent reported capacities as of January 1, 1984. Base capacities in each model were allowed to be expanded, as required, at cost typical of the sizes installed in recent years.

Auxiliary processes, including utility supply facilities, were allowed to take any required capacity at costs representing typical equipment sizes and construction costs.

TABLE E-1

REFINING PROCESS UNIT CAPACITIES

(Thousands of Barrels Per Calendar Day)

UNITS	PADD 1	PADD 2	PADD 3
Atmospheric crude dist.	1,437.1	3,379.5	7,295.6
Vacuum distillation	722.5	1,239.0	2,844.6
Naphtha hydrotreating	428.7	881.3	1,770.4
Reforming	400.3	877.3	1,679.6
Cat cracking (Total Feed)	622.8	1,405.6	2,528.9
Hydrocracking	51.7	160.1	261.1
Alkylation	62.6	245.1	410.6
Catalytic polymerizaton	11.3	17.3	35.6
Coking	74.8	257.7	437.4
Visbreaking	12.2	6.4	64.3
Light oil hydrotreating	320.0	451.6	1,147.7
Gasoil hydrotreating	244.4	253.2	862.0
Residual desulfurization	18.8	0.0	317.7
Butane isomerization	0.0	15.4	37.7
C_5 - C_6 isomerization	23.5	36.2	64.6
H_2 steam reforming (MMCFD)	162.3	188.5	637.6
H_2 purification (MMCFD)	0.0	0.0	89.3

APPENDIX F

ALCOHOL BLENDING VALUES

APPENDIX F

ALCOHOL BLENDING VALUES

Aziotropes formed by blends of alcohols and hydrocarbons result in non-linear blending characteristics for predicting quality of such blends. In this study, alcohol addition was fixed at predetermined concentrations for each alcohol mix. It is, therefore, possible to define the apparent linear blending values for each alcohol mix and to avoid the problems of non-linear representation.

Table F-1 presents the blending values employed for each of the three alcohol mixes included in this study. These values were derived from data in several literature sources[1,7] as well as unpublished laboratory results supplied by Southwest Research Institute.

TABLE F-1

BLENDING VALUES FOR ALCOHOLS

	METHANOL-TBA 50/50	METHANOL-TBA 2/1	ETHANOL
Fixed Concentration, Volume percent	5.0	7.5	10.0
Property			
Reid Vapor Pressure, psia	54.0	40.0	15.0
Percent Distilled at:			
160°F	115.0	175.0	220.0
210°F	110.0	105.0	137.0
230°F	100.0	100.0	108.0
330°F	100.0	100.0	100.0
Research Octane	120.65	124.7	133.4
Motor Octane	96.55	97.3	101.8
(R+M)/2	108.6	111.0	117.6
Specific Gravity	0.8	0.8	0.8

APPENDIX F BIBLIOGRPAHY

[1]ARCO Chemical Company, Technical Bulletin, OXINOL50.

[2] E.I.DuPont De Nemours & Co., E.N. Cantwell and W. E. Smith, IV, "Volatility Characteristics of Alcohol/Gasoline Blends and Automotive Emmissions." VI International Symposium on Alcohol Fuels Technology, May 21-25, 1984, Ottawa, Canada.

[3]Hinkamp, Oil & Gas Journal, 12 Sept. '83

[4]B.H. Eccleston and F. W. Cox, "Physical Properties of Gasoline/Methanol Mixtures," Bartlesville Energy Research Center, January, 1977.

[5]Sun Tech, Inc. "Assessment of Ether and Alcohol Fuels from Coal," Technical Report, March 1983, under DOE Contract No. DE-AC04-78CS 54045.

[6]Chevron Research Company, private communication re Contra Costa County Oxinol 50 Test, March 15 over December 13, 1983, to John D. Tosh, Southwest Research Institute.

[7]Mueller Associates, Inc., "Status of Alcohol Fuels Utilization Technology for Highway Transportation," June 1978 under DOE Contract No. EX-77-X-01-2923.