R4C

WSPA STUDY OF THE

COST IMPACTS OF POTENTIAL

CARB PHASE 2 GASOLINE REGULATIONS

WSPA CONTRACT NO. DF 201-06
PHASES I, II AND III

DEPOSITION EXHIBIT
U.S. District Court (C.D. Ca.)
C.A. No. CV-95-2379 RG (JRx)
DX Exhibit 1360
Date 1/4/97 Stirewalt & Associates

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30046

Robert E. Cunningham
George W. Michalski
Charles L. Miller

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TURNER, MASON & COMPANY
Consulting Engineers

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I. INTRODUCTION

objective

The objective of our study for the Western States Petroleum Association (WSPA) was to determine the cost of potential California Air Resources Board (CARB) Phase 2 gasoline reformulations. These costs, along with calculated emissions benefits and macroeconomic impacts, could then be used to provide CARB with the cost-effectiveness and overall California economy impact of alternate Phase 2 gasoline proposals and assist them in establishing cost-effective regulations.

In order to improve the accuracy of these costs, we used a linear programming (LP) model approach to compare alternate reformulation costs. All reformulations explored were within real, practical refining limits. In addition to calculating base reformulation costs, we explored the cost impact of possible individual property limit changes.

study background

Prior to initiating this study, TM&C had performed a gasoline reformulation screening study for the American Petroleum Institute (API) in 1989 and economic analysis of possible gasoline reformulations for the Air Quality Industry Research Program (Auto/Oil) in 1990-91. In these studies, we significantly modified our refinery LP model to represent possible additional processing required to reformulate gasoline. These model changes permitted meeting reformulated criteria either singly or in combination.

capability of TM&C

TM&C has been well recognized as having the best refining industry modeling expertise and competence available in consulting firms over the past seven years. TM&C has conducted industry studies for DOE, EPA, National Petroleum Council (NPC), API, WSPA, Auto/Oil, Motor Vehicle Manufacturers Association (MVMA) and International Lead and Zinc Research Organization (ILZRO). Our LP model and/or input data with gasoline reformulation has been sold to several major oil companies. It has also been used in gasoline reformulation studies for other associations, groups and individual companies.

background of authors

TM&C used a very experienced team of LP model experts. This group is headed by Robert E. Cunningham and includes George W. Michalski and Charles L. Miller. Cunningham has managed studies for DOE, NPC, API and Auto/Oil, as well as this study for WSPA. He is highly regarded as the most competent LP industry modeler in the country with over 30 years of experience. He had almost fifteen years experience with Chevron before coming to TM&C in 1973. Michalski has over 35 years of experience, including significant experience with Ethyl Corporation as their LP modeling expert. He has developed LP models for numerous clients. Miller has over 20 years of experience, primarily with Texas City Refining (TCR). He has worked on several industry studies as a company expert for TCR, including the 1985 NPC study.

scope of report

This report presents our findings from 35 LP model cases that involved the federal Clean Air Act (FCAA), three separate CARB Phase 2 proposals and many alternatives. From the results of these cases, we calculated the costs and detailed refining industry impacts of meeting potential CARB Phase 2 regulations. We also developed estimates of the costs for incremental changes in the gasoline properties CARB plans to regulate. Our cost results were then used by two other WSPA contractors to evaluate cost-effectiveness and California macroeconomic effects of alternate Phase 2 proposals.

II. EXECUTIVE SUMMARY

- The most pertinent 1996 cases evaluated are:
  - Base – CARB Phase 1 regulations
  - FCAA – Federal Clean Air Act statewide – average limits
  - Flat – October 4 CARB 2 with flat limits and compliance margins
  - Average – October 4 CARB 2 modified to average limits at flat levels (no compliance margins)
  - Knees – Close to property cost curve break points – average limits

- The property control maximum limits for these five cases are listed below. All cases have the same binding octane limits (not listed).

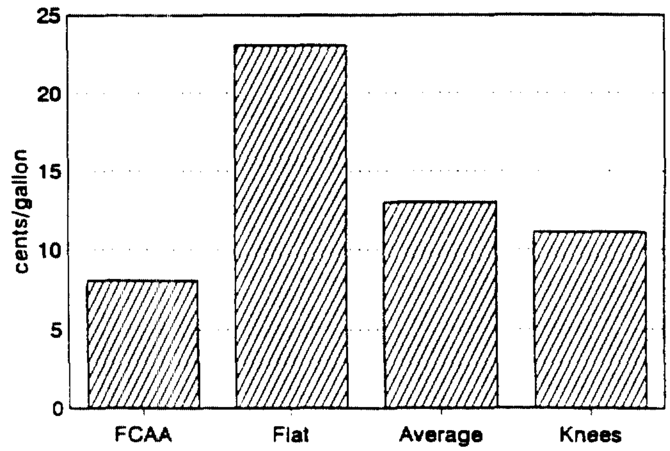
Case Name	A	OX (min)	OL	BZ	S	RVP	T90	T50
Base	-	0.4*	13*	-	210*	7.5	-	-
FCAA	25*	2.0	13*	0.95	163	7.1	328	-
Flat	20	2.0	3*	0.6	20	6.6	280	195*
Average	25	1.8	5	0.95	40	7.0	300	210*
Knees	25*	2.0	7	0.8	50	7.1	310	-

* LP results below limit.

- Calculated cost and cost range in cents per gallon (¢/G) as increases over the Base for the four CARB Phase 2 cases are as follows:

	FCAA	Flat	Average	Knees
Average, ¢/G	8	23	13	11
Range, ¢/G	6-11	20-28	11-16	9-14

- These average costs are graphically illustrated below:



The Knees case costs less than half as much as the most expensive flat limits case, whereas FCAA costs only 35% of Flat and the Average case costs almost 60% as much. The rough cost of a low C_8/C_9 aromatic case was estimated by hand at 50¢/G, or more than double the Flat case costs.

- Average total investment and investment range required in billions of dollars ($MMM) over the Base case are listed below. The Knees case saves $3 to $5 billion relative to the Flat case.

	FCAA	Flat	Average	Knees
Average, $MMM	3	7	4+	4-
Range, $MMM	2-4	6-10	3-6	3-5

- Average total investments and its MTBE and refining components are illustrated as follows:

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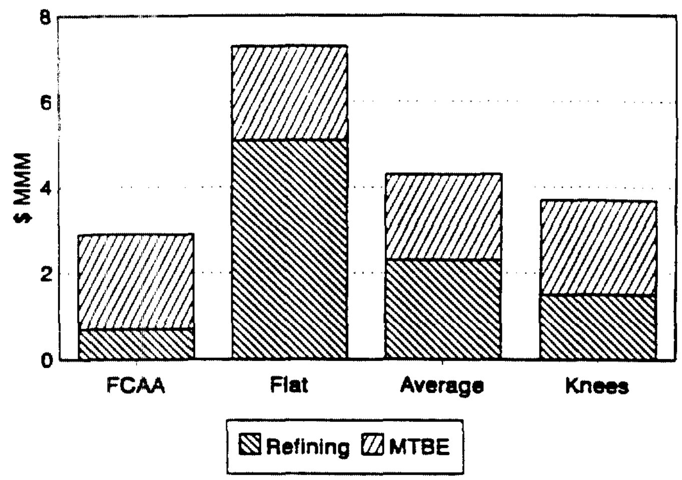
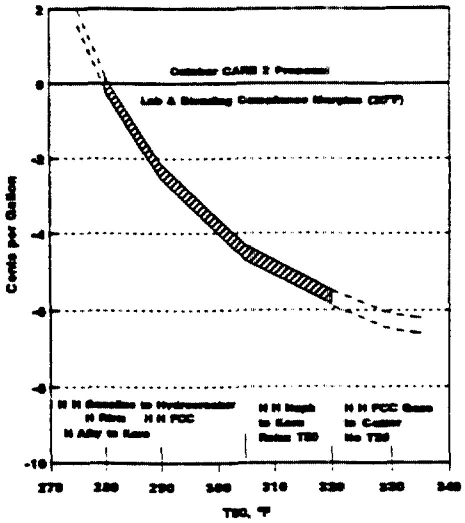
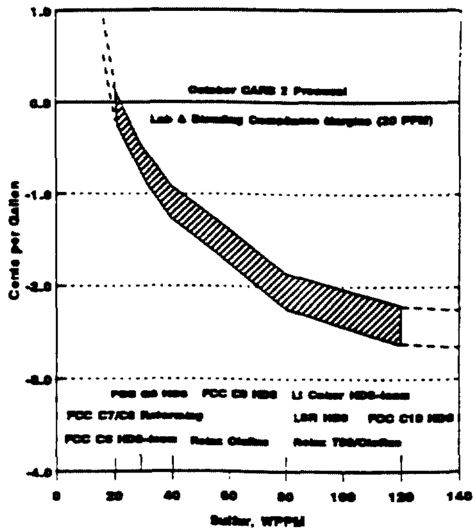


The foreign MTBE investments are almost the same in these four cases at $2 billion. The California refining investment for the Knees case would be only about 30% of the Flat case. The Average case would require about 45%, and the FCAA case requires only about 15% of the Flat case refinery investment.

- Additive individual property change cost curves were developed to help CARB optimize costs versus benefits for each regulated property. These curves are all shown as cost reductions from the Flat case. The Flat case limits proposed by CARB staff on October 4 were all more restrictive than the optimum break points, or knees, of the property change cost curves. This is illustrated by the following charts:





- The following table combines the impacts of these property changes to the knees, or optimum point, of the cost curves. Note that increasing from the Flat to these knees reduces combined cost by about 13¢/G.

	Flat 10/4 CARB – Comply	Knee Curve Optimum	Property Change	Cost Impact ¢/G
Property				
Aromatics, Vol. %	20	25	+5	(2.6)
Olefins, Vol. %	3.0	7.5	+4.5	(2.6)
Sulfur, ppm	20	80	+60	(2.0)
RVP, psi	6.6	7.1	+0.5	(1.7)
T90, °F	280	305	+25	(4.5)
Combined				(13.4)

- Flat limits would require large compliance margins to include the poor lab test reproducibility plus refinery blending margins for property variations and unit shutdowns, as shown below. Simple quarterly average limits would eliminate these compliance margins:

	Compliance Margins		
	Lab Testing	Blending	Lab Plus Blending
Property			
Aromatics, Vol. %	3	2	5
Oxygen, Wt. %	0.2	-	0.2
Olefins, Vol. %	1	1	2
Benzene, Vol. %	0.2	0.2	0.4
Sulfur, Wt. ppm	15	5	20
RVP, psi	0.3	0.1	0.4
T90, °F	10	10	20
T50, °F	10	5	15

- In the Flat case, physically blending gasoline would be extremely difficult due to loss of all flexibility, because binding property limits increase by 6, while components increase by only 4. In the Knees case, physical gasoline blending would be much less difficult, because averaging increases flexibility and components increase by 8. The Flat case would double required refinery gasoline tankage, while the Knees case would require only 1.4 times as much, as shown below:

	Base CARB 1	FCAA State	Flat 10/4	Average @ 10/4	Knees Curves
Flexibility	High	Mid	Nil	Low	Mid
Difficulty	Low	Mid	Wild	High	Mid
Tankage, % Base	100	140	200	150	140
Components					
Typical Pool	8	13	12	15	16
Property Limits					
Binding/Flat	3	2	9	2	2
Average	-	5#	-	6	6
Almost Binding	1	1	-	1	-
Non-Binding	11	9	8	8	9

2 of these are not very restrictive.

- The refining industry needs some oxygen content flexibility to meet octanes with limited aromatics. Because T50 is not controllable (in known commercial processing), CARB should exclude T50 from the Phase 2 regulations.

- Because of the increased processing required to reformulate gasoline, refinery emissions will increase. In the Flat case, emissions of NO_x, CO and PM increased moderately. CO_2 emissions increased by 22,000 tons per day (T/D) from about 300 new sources. In the Average case, SO_x emissions decreased moderately, while emissions of CO_2 increased by 8,600 T/D from about 200 new sources.

III. GASOLINE REFINING PRIMER

types of refineries

Each refinery is unique in its process units configuration and relative sizes, although refineries can be classified in broad categories. We divided the California refining industry for this study into conversion and simple refinery groups. There were seventeen conversion and twelve smaller, simple refineries operating in 1989. The conversion refineries differ from simple refineries in that they can upgrade residual fuel oil (heavier than diesel) into major light products – gasoline, jet and diesel. The conversion refineries produced 99% of the California gasoline output in 1989 and processed over 90% of the crude. The simple refineries also can be divided into specialty asphalt and/or lube plants, which do not make finished gasoline, and hydroskimming refineries, which make a low yield of finished gasoline.

finished product yields

Each refinery makes a different slate and yield of products. The California refining industry is highly oriented to maximize gasoline and kero jet and minimize residual fuel oil. Average California yields of major fuels products in 1989 were as follows:

- gasoline – 46%;
- kero/jet – 10%;
- No. 2 diesel – 15%; and
- residual fuel oils – 12%.

These major fuels products comprised 83% of total refinery output. Minor products, comprising 3 to 5% each of refinery output, include asphalt, coke, LPG and process gas. California conversion refineries gasoline ranges from about

40 to 65% of total output, whereas simple refineries gasoline make varies from 0 to about 20% of total output. Crude oil comprises about 96% of California refinery input. The remainder consists primarily of unfinished products, butanes and oxygenates.

gasoline composition

Gasoline is blended from many components yielded by refinery processing units. Typical California gasoline consists of about 40% cracked, 35% reformate and 25% minor components. The latter is made up of about 10% alkylate and up to 5% each of light straight run gasoline, butane, light hydrocrackate and ether. These gasoline components range from zero to twice these amounts in individual refineries. Most California conversion refineries make from seven to ten gasoline components, whereas the simple refineries make only two or three gasoline components.

finished gasoline properties

The following table shows California summer gasoline pool properties:

	Typical 1989	Individual Refinery Range
Octane, (R+M)/2	88.5	87-90
RVP, psi	8.5	7.5-9.0
Distilled, °F		
10%	130	120-140
50%	218	200-230
90%	328	310-360
Aromatics, %	35	25-45
Olefins, %	9.5	0-20
Benzene, %	2	1-4
Oxygen, %	0.2	0-3

	Typical 1989	Individual Refinery Range
Oxygenates, %	1	0-10
Sulfur, ppm	160	100-300

Most refineries blend the components in this pool into three finished gasolines: unleaded regular, midgrade and premium grades. Most refiners design their gasoline blends using a gasoline blending linear program (LP) to enable them to use all of their gasoline components while making on-test gasoline for each grade. Most refineries have in-line gasoline blenders to control recipes and continuously monitor limiting properties.

Octane and RVP have been blended very close to specifications. Other specifications (distillation, corrosion, gum, etc.) have not normally been binding. Reformulation will increase the number of components. However, it will require more precise blending to meet more specifications simultaneously (up to nine limits). This will require blending compliance margins or averaging due to minor variations in component properties and unit shutdowns. Averaging for the added limits would allow meeting the target property over a period of time (i.e., quarterly).

The following table shows typical California gasoline component properties:

gasoline component properties

	Octane (R+M)/2	RVP psi	90% Distilled °F	Benzene %	Aromatics %	Olefins %	Sulfur ppm
Light FCC Gasoline	87	9	240	2	9	37	100
Heavy FCC Gasoline	87	1	400	0	60	12	600
Reformate							
High ON (100 RONC)	95	3	340	2	69	0	0
Low ON (90 RONC)	86	2	340	1	50	0	0
Alkylate	91	5	280	0	0	0	20
Light Straight Run/Natural	72	13	160	1	2	0	150
Isomerate – C_5/C_6	90	18	140	0	0	0	0
Light Hydrocrackate	87	14	160	1	1	0	20
Light Coker	77	11	160	2	4	46	2,100
Poly Gasoline	86	9	350	0	0	100	80
MTBE	110	8	138	0	0	0	10
Normal Butane	97	61	33	0	0	0	20
Light Reformate	81	8	170	8	9	0	0
Toluene	104	1	231	0	100	0	0

Each component differs significantly in several key properties. Note that reformate has high aromatics and no olefins. FCC heavy gasoline also has high aromatics but contains about 12% olefins. Light FCC gasoline contains high olefins and only about 9% aromatics. The only other high aromatics stock is toluene, and the other high olefin stocks are poly gasoline and light coker gasoline. The other gasoline components are low in aromatics and olefins. Most of the sulfur in gasoline is contained in heavy FCC, light coker and light FCC gasoline. Prior to the Clean Air Act, the primary specified properties of gasoline were octane, RVP and distillation. These have been met by varying the reformate octane to meet blended gasoline octane, adding butane to meet RVP and blending a wide mixture of available components to meet nonbinding distillation temperature limits.

use of reformulation

Existing process unit flexibilities are insufficient to meet reformulated gasoline properties. Minimal reformulation will require production of ether inside of refineries and use of significantly more ether produced outside refineries. Ether consumes field butane, recovered from natural gas liquids, and methanol, which is produced from natural gas. Aromatics will be decreased by reducing reformer severity and feed rate concomitant with increasing ether. See the Model section of the report for a detailed discussion of refining changes.

IV. ANALYTICAL APPROACH

LP models

We used our refinery LP model for the aggregate group of conversion refineries in California. Aggregate modeling permits determination of refining industry capability and costs without revealing any specific refinery's confidential data. TM&C's California conversion refinery aggregate model was originally developed and extensively calibrated for prior studies. TM&C's model was already extensively modified to include gasoline reformulation capability. It had been calibrated to accurately predict aromatics, olefins, benzene, sulfur, RVP, 90% distilled temperature (T90) and driveability index (DI). It was extensively reviewed by WSPA LP experts. LP models will be more thoroughly discussed in a following report section.

assumptions and bases

We developed and agreed upon all of the assumptions and bases for this study with WSPA. Major assumptions included: supply and demand forecasts, fixed product requirements, investment costs, rate of return on investment, crude and product pricing outlook, refinery process unit capacities and utilization limits, new unit sizing, product grade ratios and properties, crude and minor product flexibilities, and MTBE supply sources. These assumptions will be covered in more detail in a major report section below.

WSPA determined that model runs producing gasoline to various property specifications should be made for 1996, allowing investment in additional refining facilities. In the

1996 base cases, all gasoline was produced to conventional specifications. We made LP model runs for summer and winter base cases, a Los Angeles only FCAA partial reformulation summer case, one winter CARB Phase 2 case and 31 complete CARB Phase 2 reformulation cases. It should not be inferred that the average/typical gasoline properties not specified by CARB and the compositions of any of the gasoline pools determined in this study would be produced and distributed by any specific California refiner. Each company in WSPA continues to conduct its separate research, planning, manufacturing, trading and marketing activities.

analysis of results

We compared the results of the reformulation cases to the base case, using a Lotus 1-2-3 program to generate pertinent tabular refining industry results. These results included the run basis, gasoline properties, the incremental cost of decreasing limiting gasoline properties, and detailed gasoline compositions. Tabular results also included material balance changes, reformulation costs and cost sensitivities, required new process unit rates, and investments. All process unit rate changes and absolute utilizations were also compared.

optimized reformulation costs

The LP technique systematically finds the least cost solution for any given case. Although there are hundreds of feasible solutions with the large number of variables that can be modified, the LP seeks the one mathematically optimal solution. The advantage of comparing a reformulation case LP run against a base case LP run is that both are optimized, and the difference in cost is the least cost for reformulation. This technique is much better than comparing simulation cases because it offers a consistent approach to least cost and not an arbitrary selection of alternate feasible solutions. This approach avoids significant under- or over-estimation of gasoline reformulation's economic impact.

cost variations

All of the calculated reformulation costs are based on our modeling aggregation of refineries and do not apply to any individual refinery. Actually, every refinery is unique in processing, raw materials, products and product properties. Although we calculated the average or typical reformulation cost for the group of all conversion refineries, cost results are low or conservative due to unavoidable over-optimization in our aggregate model. Our cost results are also reported as a range for each reformulation to cover reasonable changes in the major cost variables. The probable real range of individual refinery costs would be wider than indicated, especially higher, due to differences in refinery size, processing and initial gasoline properties.

relevant refining costs

Each LP run was optimized based on a combination of relevant refining costs in constant 1991 dollars. Each LP solution considers raw material cost, variable product prices, variable operating costs, incremental capital costs, and additional fixed operating costs. For each case, we made several iterative runs to optimize new process plant sizing and provide one new unit of each type for each refinery for more accurate capital cost. Numerous model limits were added to correspond with realistic refinery situations and to avoid over-optimization. However, the nature of refining industry LP models is such that their tendency to over-optimize cannot be totally eliminated. Off-line, we considered external effects, including MTBE investment costs, physical gasoline blending constraints and the impact of BTU content on mileage, to maintain constant total miles traveled.

critical review

The shadow values on each run were checked to make sure the model was not unreasonably constrained. We applied our well-seasoned judgment to ascertain that the solution was realistic and that there were no anomalies. In addition to utilizing our extensive judgment and internal cross-checking of the results for consistency, the results of this study were subjected to critical review by a group of WSPA refining industry experts. We also checked the strategies chosen by the model for realism and compared the results between different cases for consistent strategies and reformulation costs. Differences had to be understandable and reasonable.

V. ASSUMPTIONS

general and investment

The assumptions and bases for our study are outlined in detail on the A- tables attached. All of our work was done in constant 1991 dollars. We assumed that the base case (CARB Phase 1) investments required for 1996 were sunk. They could not be saved in CARB Phase 2, due to the fact that most of these investments are already committed.

capital charge

We based capital charges on a risk-free 15% discounted cash flow (DCF) rate of return on investment (ROI) hurdle rate in constant dollars. Use of a 15% ROI has been the common practice of the petroleum refining industry, WSPA and CARB in past studies. Due to risk factors, the risk-free 15% estimated DCF ROI rate for planning purposes typically turns out to be only an 8% DCF ROI rate on a post-audit basis. In the base cases, we utilized new plant sizes characteristic of California. In the Phase 2 cases, units are sized to provide one unit for each refinery. Detailed investment assumptions are shown in Tables A-1 and A-6.

flexibility

In making the refinery conversion to reformulated gasoline, product demands for finished motor gasoline and middle distillates, as well as most minor products, remained fixed for all reformulation cases. Only high-sulfur residual fuel oil, coke and C_5- products were allowed to vary. Alaska North Slope crude was allowed to vary, along with MTBE, methanol, natural gasoline, purchased butanes and natural gas feed to the H_2 plant. All other raw materials were fixed, as noted in Table A-2. Finished gasoline outturn was adjusted to maintain constant miles traveled when the BTU content shifted, based on the 0.8 R factor used by the EPA in their RVP reduction study. That is, 0.8 of the differences (up or down) in gasoline heat of combustion are reflected in vehicle fuel economy.

pricing

We based our major crude and product pricing outlook, shown in Table A-5, primarily on pricing in 1989-91. We provided the pricing for other crudes, low aromatic diesel and minor products and developed prices for both California and the Gulf Coast using TM&C location differentials.

supply and demand

We developed our summer supply and demand estimates from the consensus U.S. supply and demand estimate for major products and crudes that was published by the *Oil & Gas Journal* in early 1991. We obtained from DOE much more detailed actual supply and demand data for the summer quarters and the year 1989 for both crudes and products. Using the DOE data, we were able to develop our summer supply and demand outlook and to allocate part of the consensus supply and demand estimate first to PADD V and then to California conversion refineries. The DOE information also allowed us to express the consensus supply and demand estimate in greater detail. Our development of the U.S. supply and demand data is summarized in Tables A-7 through A-12. Our allocation to PADD V is detailed in Tables A1-1 through A1-4. Our allocation to

California conversion refineries can be found in Tables A1-6 through A1-12.

We classified forecasted crude inputs by the types used by the NPC and API in prior studies by TM&C, as shown in Table A-13. We allocated these crudes in detail to fit our specific PADD V refinery model groups, using the 1989 detailed crude run property and import data as well as production data supplied by DOE, as shown in Tables A1-8 through A1-10.

capacities and utilization

Our basis and initial unit capacities for the model are shown on Tables A-14 through A-17. We allowed the model to add refining capacity as required for all of the cases. We estimated maximum capacity utilization for major units using the DOE 1987-89 data, which are summarized in Tables A-14 and A-15.

MTBE

We allowed the conversion refineries to produce maximum MTBE from isobutylene in their cat-cracked and coker butylene/butane streams. (No ether production was permitted in refineries with less than 20 MBPSD of FCC capacity, because the small ether unit would be uneconomic.) We allowed the refineries to produce TAME from the FCC and coker isoamylenes in cases with low olefin gasoline limits. All other ether was assumed purchased in the form of MTBE from outside sources, with no butane dehydrogenation capacity included in the refineries. We estimated the investment for outside MTBE from the Middle East, as shown on Table A-18. Our estimated MTBE price and investment costs were very close to those made independently by other contractors. The price paid by refineries for purchased MTBE includes a 40¢/G capital charge to payout the very large outside investment in MTBE. These investments are summarized along with refinery investments to show total investments.

product grade ratios and properties

Our outlook for gasoline and residual fuel grade ratios is shown in Table A1-5. Estimated octanes are included in Table A-3. We assumed that all of the No. 2 diesel fuels would be 0.05% sulfur, 80% of it would meet a 10% aromatics limit and the rest of the diesel would be blended with no increase in cracked stocks. In the partial reformulation case, all gasoline aromatics, ether, olefins, sulfur and 90% distilled properties were capped at the 1989 survey level.

PADD V refinery groups rates

Detailed refinery raw material and product rates for each of our three groups of refineries in PADD V for 1989 are listed in Tables A1-6 and A1-7. Similar detailed crude rates are shown in Tables A1-8 through A1-10. Detailed refinery product rates and growth for the California conversion refineries are listed for 1989 and 1996 in Tables A1-11 and A1-12. As most of the detail tables focused on the summer quarters, the ratio of winter to annual refinery outturns are presented in Table A1-13.

VI. REFINERY LP MODEL DEVELOPMENT

Our LP model has been designed to represent the group of seventeen conversion refineries in California, which produce over 99% of the gasoline. We use the concept of an average refinery to more easily understand the results.

industry model

TM&C developed the composite California refining industry model originally for refining industry studies conducted for the Federal Energy Agency (FEA) and the Department of Energy (DOE) in the 1970s. It was upgraded, modified and very extensively validated using a 1985 industry survey for our National Petroleum Council (NPC) study of gasoline capability and cost. We then used the model in several multi-client subscription studies and a vapor pressure reduction cost study for the API in 1987.

gasoline reformulation model

Gasoline reformulation capability was developed and added in a 1989 gasoline reformulation screening study for API. Reformulation capability was further improved in 1990-91 for the Auto/Oil study. The model enhanced for that study was used for this WSPA study. We converted the LP model in 1990 to run on a personal computer instead of on a large mainframe computer. TM&C's reformulation capability LP model and/or data have been sold to several companies, and others are considering purchasing our LP model and/or these reformulation data. Adding gasoline reformulation with about 80 options doubled the size of our LP model by requiring over a dozen new refining processes and much more extensive gasoline properties on many narrow gasoline cuts.

model validation

The TM&C model has been extensively validated with historical data. Validation involved comparison of model results with industry data, then adjusting the model data until model outputs agreed with historic data. For the NPC validation, crude and major product volumes were matched exactly. After allowing residual fuels, butanes and lighter, cokes and gain to vary, DOE material balances for these products were matched within 0.3% of total input. Individual conversion units throughput was matched within 8% for a total conversion unit throughput match within 5%. Catalytic cracker conversion matched within 5%. Model utilities usage and individual fuel components were matched to DOE data within 4% of their absolute levels.

Gasoline RVP and octane numbers and distillate fuel sulfur levels were forced to survey levels. Component octane numbers were adjusted where necessary to match component NPC survey results. Then octane factors were adjusted until gasoline lead level was within 0.1 gram per gallon, reformer throughput was within 15% and reformer severity was within 0.5 octane number. The validation criteria used for the NPC study are listed on Table A2-1, and the validation results described above are detailed on Table A2-2.

model calibration

In our 1987 RVP study for API, gasoline RVP and butane content were calibrated against industry survey data to fit within 0.1 RVP and 0.1% butane. During our work for Auto/Oil, the gasoline sulfur, aromatics and olefins content, plus 90% distilled representation, were calibrated against the NPRA survey results conducted for Auto/Oil. Results of this calibration showed agreement on aromatic and olefin contents within 1.4% each. The 90% distilled temperature agreed within 3°F. Model sulfur content matched the survey and NIPER results within 40 ppm. During a 1990-91 study for WSPA/GM/CARB on RVP/DI impacts, benzene, T50, T10 and DI were calibrated in our LP model. The model predicted benzene fit within 0.2, T50 and T10 matched within 3°F and DI matched within 20°F of physical blends. These differences are all less than the test reproducibilities and most are significantly less. The details of these calibrations are presented on Tables A2-3 through A2-7.

The investment estimates for new processes were extensively reviewed by the engineering staff of each participating oil company in Auto/Oil. All of our investment estimates were within 20% of individual unit estimates provided by individual participating companies and within less than 5% of the composite estimate of all of the companies.

reformulation options

Primary options for reducing olefins include splitting light FCC gasoline into carbon number cuts and then processing the C_5 olefins via etherification and alkylation. Light coker

– olefins

gasoline and FCC C_6 olefins can be saturated then isomerized. Alternately, light coker gasoline can be desulfurized through chemical extraction, then split and processed like FCC C_5s and C_6s. Polymer and Dimersol plants can be shut down and their C_3= or C_3=/C_4= feeds alkylated. Very low olefin levels require saturation and reforming of FCC C_7 and C_8 cuts.

– aromatics and T90

Aromatics are reduced primarily by narrowing the catalytic reformer feed boiling range and reducing reforming severity, plus fractionating out the back end of the heavy cat-cracked gasoline and reformate. The heavy low aromatic hydrocracked and straight run naphtha are routed to treating and middle distillates. The heavy, highly aromatic gasoline fractions are routed preferentially to resid cutter, and finally, fed to hydrocracking to make lighter gasoline. The 90% distilled point is reduced in similar fashion, cutting the back end out of these same gasoline blending components and reformer feed and then blending or cracking it. In addition, heavy alkylate can be fractionated out and routed to middle distillates. Deep T90 reductions require hydrocracking heavy, heavy FCC gasoline and reformate.

– sulfur, benzene and RVP

Sulfur is initially reduced by hydrotreating heavy, cat-cracked gasoline, as well as hydrotreating FCC feed. Deeper sulfur reductions require extractive sulfur removal from light coker gasoline and hydrotreating light straight run gasoline. Very low sulfur levels require hydrotreating FCC C_6, C_7 and C_8

gasoline. Benzene is reduced by routing benzene precursors around the reformer to gasoline. Reformate feed prefractionation, BT reformate fractionation and benzene saturation are required. Benzene extraction would probably not be used in California due to strict toxic controls and lack of a market for benzene. RVP is reduced by butane fractionation and sale. Low RVP levels require FCC C_5 fractionation and C_5= processing to ether and alkylate. Very low RVP levels require saturated C_5 sales and light hydrocrackate fractionation with added C_5 sales.

– T50 and DI

T50 and DI cannot be controlled except by added ether use or further reductions in T90. Even T90 reductions have limited impact on T50 as they must be offset by T10 increases (C_5 sales) to maintain a constant RVP. The ranges of flexibility and product yields from these additional processing options, as well as the investment and operating costs, were extensively reviewed both by an API task force, the Auto/Oil Economics Subcommittee and WSPA.

VII. MODEL RUN MATRIX

base cases

We ran two 1996 base cases for this study – summer (Case 0) and winter (Case W-0) for California conversion refineries. The summer case served as the basis for all but one of the Phase 2 gasoline reformulation cases because summer reformulation presents the greatest challenge to the refining industry.

gasoline reformulation cases

We ran a total of 32 Phase 2 full reformulation cases and one partial reformulation case. We evaluated five major premises of what the Phase 2 reformulation might be and various sensitivities to these major scenarios. Our first set of runs evaluated the FCAA amendments applied statewide and only to Los Angeles and San Diego. Second, we ran cases on the initial June CARB staff proposal. Then, we evaluated the revised CARB staff proposal issued on August 5, 1991 and ARCO's EC-X properties. Next, we studied the detailed October 4, 1991 CARB staff proposal. Finally, we reviewed a series of alternate proposals that were close to the break points, or "knees", of our individual property change cost curves. Most of the sensitivity runs were made to develop these individual property change cost curves. The one winter case tested the FCAA using CARB's August 5 proposal.

case matrix

Cases 1 and 2 studied the impact of the FCAA. Cases 3 through 5 studied the June 1991 CARB Phase 2 proposal. Case 6 evaluated ARCO EC-X properties. Cases 7 through 22 studied the August 5 CARB staff proposal for Phase 2 reformulation and sensitivities. Cases 23 through 25, 31 and 32 evaluated the implications of the October 4 CARB staff proposal and sensitivities. Cases 26 through 29 evaluated various alternate "knee" proposals with more cost-effective potential Phase 2 regulations. Case W-1 evaluated the wintertime economics of the August 5 CARB staff proposal (Case 8 modified for winter gasoline specifications) to confirm that the summer case is more restrictive.

guide to tables

Base case results for both the summer and winter cases are reported in Tables B-. Tables C- contain the results of the FCAA cases, the June CARB Phase 2 cases and the ARCO EC-X case. The results of the August 5 CARB staff proposal and various sensitivity cases start with Case 7 on the C-tables and continue through Tables F-. The winter case results are reported on Tables G-. The H- and I- tables report the results the CARB staff October 4 proposal case and alternate "knee" and sensitivity cases.

format of tables

LP results are reported for each of the runs. These results include gasoline properties and compositions, costs, processing, raw materials and products. A uniform table matrix was used for all reformulation runs results. This format for Tables C- through I- is shown below:

Table	Description
-1	Run Basis and Gasoline Pool Properties
-2	Summary of Costs
-3	Raw Material and Product Rate Changes
-4	New Process Unit Rates

Table	Description
-5	New Process Unit Investment Costs
-6	Process Unit Rate Changes
-7	Process Unit Utilizations
-8	Gasoline Pool Compositions
-9	Incremental Costs for Gasoline Property Decrease

A few cases (Cases 27, 28 and 29) were run to obtain only costs instead of complete refinery industry impacts. These cases were reported only on Tables -1, -2, -5 and -9. Some additional tables are included for the partial reformulation Case 1 and several cases reported to DRI (Cases 7, 8, 17 and 25) to evaluate macroeconomic impacts on California.

VIII. BASE CASES HIGHLIGHTS AND DISCUSSION	The base case assumes no FCAA or CARB Phase 2 regulations. CARB Phase 1 gasoline regulations and diesel sulfur and aromatic limits are in place. We ran summer and winter base cases to determine the facilities required to meet forecasted 1996 demands with these product specifications.
raw materials	Table B-2 shows details of refinery raw material input rates. Crude oil provides about 94% of input requirements, while the rest is unfinished and other products. There is some transfer of vacuum gas oil from simple refineries, plus imports. Small amounts of imported naphtha and reformate are also used. Domestic and imported MTBE is used by the refining industry. Some methanol is required for production of MTBE within California refineries. Other raw materials are optimized and are largely derived from natural gas liquids.
products	Refinery product rates are shown in Table B-3. The models were required to exactly meet the demand for most products. Residual fuel, propane and marketable coke were allowed to seek their optimum levels. Optimized process gas and catalytic coke are consumed in the refinery as fuel. Reflecting the trend toward increased sales of the higher octane grades, the percentage of premium and midgrade gasolines has been increased over today's levels.
crude oil details	Tables B-4 through B-6 show details of the crude input represented in the model. Most of the crude oil rates are fixed at forecast levels based on projections from historic

rates. In our California conversion refinery model, only Alaska North Slope crude was allowed to optimize.

process capacity

New process capacity and investment required over 1991 is shown in Tables B-7 and B-8. Most of the investment is in diesel aromatics saturation and distillate hydrodesulfurization units required to meet the stringent California limits on diesel aromatics and sulfur. Added hydrogen plants are required to supply these units. There is some investment in octane-producing capacity in terms of new and revamped reformers and alkylation units. Investment in MTBE plants provides an economical source of oxygenate as well as octane numbers. We have included new and improved gasoline stabilizers and fractionators required to meet California Phase 1 RVP limits. Total process unit capacities are shown in Table B-8.

This is not all of the industry investment that will be required by 1996. It does not include capital for environmental requirements other than diesel aromatics and sulfur limits. It also does not include capital required to sustain ongoing operations.

process operations

Table B-9 shows process unit rates in terms of barrels per calendar day (BPCD) per refinery. Catalytic cracker conversion is about 74%. The high octane catalysts are minimized in California refineries because they produce a more olefinic gasoline that would result in violation of the current Bromine Number limits in Los Angeles (15% octane catalyst was the lowest allowed). Reformer severity was high at 99 Research octane number clear. Refinery process unit utilizations (calendar day rates divided by stream day capacities) are shown in Table B-10.

gasoline composition and quality

Gasoline pool compositions are shown in Table B-11. Components are grouped in four categories: FCC gasolines, other olefinic components, reformates and low aromatic saturated stocks. The compositions of base case gasolines are similar to those produced today.

Table B-12 shows gasoline pool properties and incremental costs. The (R+M)/2 octanes are limited at the specifications. Aromatic content of summer pool gasoline is about two percentage points lower than today's levels. Winter levels are slightly lower than summer levels due to the octane and dilution contributions of butane at the higher winter vapor pressure. Ethers are at 2% of the pool, as indicated by the projected availability of MTBE absent an oxygen mandate. The increased supply of MTBE has more than offset the need for more aromatics for the octane number increase required by the higher 1996 percentages of premium and midgrade gasoline. Olefin, benzene and sulfur levels are similar to historic levels. RVP has been reduced to 7.5 psi in the summer to meet CARB Phase 1 limits. Other measures of volatility are similar to current levels, except that T90 increased about 20°F. The heat of combustion is shown to provide a basis for estimating changes in demand due to reformulation at constant vehicle miles travelled.

Incremental octane costs are indicated to be in the range of 0.3-0.9¢ per octane number gallon. RVP marginal cost is 0.3-0.6¢ per psi gallon. In this case, a decrease in RVP would result in the higher cost. These costs are shadow values from the LP model and apply only to very small changes. They are not applicable to significant changes.

IX. INDIVIDUAL PROPERTY CHANGES

methodology

Our cost curves are based on the differences in refining margin between cases and the shadow values, or incremental costs, for the individual components. As shown in Table 3, by comparing the costs of different combinations of cases, we calculated the costs of changes in controlled properties at different levels. In some instances, we estimated the cost of changes in a controlled property from the cost of controlling a combined set of properties. For some of the extremes, we used shadow values to extrapolate the costs for the next increment of change in a controlled property. We avoided the synergism between properties to create additive curves for each property.

unit costs

Table 5 presents a summary of the cost changes for individual property changes. As detailed on Table 5 and as visually demonstrated on the cost impact curves, V-12 through V-16, the cost of compliance for each controlled property decreased as the restriction on the property was decreased.

knees

All of the cost impact curves have definite break points at which the cost of controlling the property changes significantly. We call these breakpoints the knees of the curves. The following table details the knees for the cost curves:

Viewgraph	Property	Curve Knee	Knees Case
V-12	Aromatics, %	25	25
V-13	Olefins, %	7.5	7
V-14	Benzene, %	1.0	0.8
V-15	Sulfur, wppm	80	50
V-16	RVP, psi	7.3	7.1
V-17	T90, °F	328	310

The RVP knee could not be attained because of federal mandate. For benzene, sulfur and T90, CARB staff seemed to be planning tighter limits than the knees. Our Knees case incorporated these concerns into realistic limits shown above. The overall cost for meeting the property limits in the Knees case was 11.1¢/G versus the 23.1¢/G cost for the Flat case. The curves knee level would cost only about 8¢/G.

cost slopes

The table below, which is taken from Table 5, shows how the cost of controlling the different properties increases dramatically as the property limits become more stringent:

Property Controlled	Control Level From To	Cost ¢/G[(1)]
Aromatics, %	34-33	0.2
	21-20	0.6
Olefins, %	11-10	0.1
	4-3	0.6
Benzene, 0.1%	2.2-2.1	0.1
	0.7-0.6	0.4
Sulfur, 10 wppm	206-196	0.03
	30-20	0.7
RVP, 0.1 psi	7.5-7.4	0.06
	6.7-6.6	0.5

Property Controlled	Control Level From To	Cost ¢/G[1]
T90, 10°F	348-338	0.2
	290-280	2.4

[1] ¢/G per unit change in the controlled property. Units for each property are noted.

cost savings

Viewgraphs V-12 through V-16 present the costs of controlling individual properties as cost savings from the flat limits case (the October 4 CARB staff proposal incorporating compliance margins). The savings are shown as a range to reflect the accuracy of the study.

aromatics reduction

As shown in V-12, aromatics were controlled down to 25% by reducing reformer severity and blending additional oxygenates. Dropping the level to 22% required reducing the T90 to 300°F by fractionating out the back end of the heavy FCC gasoline and hydrocracking it. Reducing the aromatics content below 22% required investment to fractionate and hydrocrack heavy FCC gasoline and heavy reformate. To maintain octane, the LP would alkylate C_5 olefins and isomerize pentanes and hexanes. Below 20% aromatics, additional ether was needed to maintain octane.

olefins reduction

As shown in V-13, olefins were controlled down to about 9% by hydrotreating and isomerizing the pentane/hexane stream from the coker. Reducing the olefins level further involved a complex arrangement of FCC gasoline splitters to first remove C_5 olefins, then the C_6 cut, and finally the C_7/C_8 stream. First, the C_5 olefins were converted to TAME and alkylated. Second, the C_6 stream was hydrotreated and isomerized. To drop the olefin content of finished gasoline below 5%, the FCC C_7/C_8 stream had to be hydrotreated and then reformed due to octane loss.

benzene reduction

As shown on V-14, benzene levels down to close to 1% were achieved in the gasoline pool by bypassing medium hydrocrackate around the reformer. This stream is normally reformed because of its low octane. Additionally, reformate fractionation and benzene saturation became necessary. Reducing the benzene level of the gasoline pool to 0.8% required fractionating the naphtha feed to the reformer to concentrate low octane benzene precursors, fractionating the BT reformate to light reformate and then saturating the benzene in it. Reducing the benzene level to 0.6% required splitting the C_6 stream out of FCC gasoline and hydrotreating and isomerizing it.

sulfur reduction

In V-15, we demonstrated that sulfur was removed from the gasoline pool by progressively treating the high sulfur components: light coker gasoline, heavy FCC gasoline, light FCC gasoline and light straight run gasoline. Fractionating the C_{10} portion of the FCC gasoline stream and hydrotreating it reduced the pool gasoline sulfur level to 120 wppm. Dropping the sulfur level to 80 wppm required hydrotreating and isomerizing the light coker gasoline and hydrotreating the light straight run gasoline. To drop the sulfur level below 80 wppm, the LP added FCC gasoline splitters, fractionated out the C_9 component and hydrotreated it. Continued sulfur reduction brought on the fractionation, hydrodesulfurization and reforming of the FCC gasoline C_8 cut. Dropping the sulfur level of the pool gasoline below 40 wppm required hydrotreating and reforming the C_7 fraction and hydrotreating and isomerizing the C_6 fraction of the FCC gasoline.

RVP reduction

As shown in V-16, RVP was initially reduced by fractionating butanes out of the gasoline pool and selling them. Reducing the RVP from 7.3 psi to 6.9 psi involved investment in FCC gasoline splitters to fractionate out the C_5 stream and using the C_5 olefins to produce TAME and alkylate. Reducing the RVP from 6.9 to 6.6 psi forced the sale of FCC pentanes. Reducing the RVP below 6.6 psi required selling the light hydrocrackate and light straight gasoline or fractionating them for added C_5 sales.

T90 reduction

As shown in V-17, the model reduced T90 by cutting the heavy components out of gasoline streams and blending the components into heavier oils or cracking them into lighter gasolines. Reducing the T90 to 320°F was achieved by fractionating the back end out of heavy FCC gasoline and using it as resid cutter. Fractionating reformer feed and blending the 300+°F heavy naphtha into kerosene jet reduced the T90 to 305°F. Reducing the T90 below 305°F involved cutting deeper into the FCC gasoline, fractionating heavy reformate and hydrocracking these heavy gasolines. Getting below 290°F also involved fractionating alkylate and blending the heavy alkylate to jet.

synergy

Controlling some properties synergistically controlls others. Reducing T90 significantly reduces aromatics because the heavy-heavy FCC gasoline and heavy reformate that are removed from the gasoline pool to drop T90 are rich in aromatics. Reducing T90 also reduces sulfur because heavy FCC gasoline has a high sulfur content. However, reducing T90 is antagonistic to controlling RVP because the heavy components cut out of the gasoline pool have a very low RVP. Reducing olefins also drops sulfur content of the gasoline pool as very high sulfur light coker gasoline is hydrotreated and isomerized, intermediate sulfur light FCC gasoline with C_5 olefins is etherified and alkylated, and the FCC C_6 cut is hydrotreated and isomerized. Processing C_5 olefin rich FCC gasoline to reduce olefins also reduces RVP. Blending ether to meet mandated oxygen content greatly reduces aromatics as the high octane ether backs out some of the need for aromatic octane.

X. REFORMULATION CASE RESULTS

The CARB staff proposed some mild reformulation limits in June that we studied in Cases 3 to 5. The more stringent CARB August proposal and ARCO EC-X proposal were studied in Cases 6 to 22. The CARB October 4 proposal, and our alternate cases are covered in Cases 23 to 30. Our discussion of reformulation case results will cite a few cases as examples. These are: the FCAA Case 2 as a relatively mild case; the Flat October 4 CARB proposed Case 25 as one of the more severe cases studied with flat limits and realistic compliance margins; and our alternate proposed Knees Case 30. Average Case 23, with the flat limits of Case 25 modified to averages at the flat level, will illustrate the advantage of averaging with less restrictive refinery property limits on the ultimate cost to the California motorist. While these cases are cited as examples, the points discussed apply to all of the cases.

cost of reformulated gasoline

The cost of reformulated gasoline ranges from 6-11¢/G for the FCAA Case 2 up to 20-28¢/G for the proposed CARB Case 25 with flat limits and compliance margins. Case 23 with average limits reduces the cost to 11-16¢/G. By investigating the cost curves for each property, we have arrived a more cost-effective set of specifications which are close to the knees in our Knees Case 30 with costs in the range of 9-14¢/G.

The California refinery investment required for the Flat Case 25 would be in the range of $4 to $7 billion. The

Knees case would require only about 30%, the Average case about 45% and the FCAA case only 14% as much refinery investment as the Flat case.

Foreign ether investment is about the same for all reformulation cases studied at about $2 to $3 billion.

material balance

All of the reformulation cases require a large increase of about 100 MBPCD of MTBE supplied to the refinery. This MTBE contribution to the gasoline pool means that less gasoline has to be made from crude oil for two reasons. First, MTBE directly reduces the need for hydrocarbon gasoline that is made from crude. Secondly, the octane contributed by MTBE is offset by lower reformer severity, which improves gasoline yield. This in turn reduces crude demand further. The net result in a relatively mild reformulation case, such as FCAA Case 2, is a 115 MBPCD reduction in crude requirement.

The addition of MTBE, reduction in aromatic content and reduction in T90 tend to reduce the heat of combustion of gasoline. To compensate for this and maintain constant total vehicle miles travelled (TVMT), gasoline production is increased by 2 to 3%.

Reductions in T90 are accomplished by heavy component fractionation and rejection from gasoline. One of the dispositions of the heavy, heavy aromatic gasoline cuts is to residual fuel. In severe reformulation cases such as Flat Case 25, this low value cutter results in a significant increase in residual fuel production from crude and increases the amount of crude required to make gasoline. In mild reformulation cases like the FCAA case, the crude oil reduction results in a decrease in residual fuel.

In order to meet low RVP limits below about 7.0 psi, it is necessary to remove saturated C_5s from gasoline. Pentanes, light straight run gasoline and light hydrocrackate are shipped to the Gulf Coast and sold as petrochemical feeds. Removal of C_5s requires more gasoline from crude oil with a concomitant increase in residual fuel.

process investment detail

In order to simultaneously meet all of the stringent specifications in Flat Case 25, it is necessary to completely fractionate many gasoline streams. These include a heavy naphtha splitter, FCC gasoline splitters, hydrocrackate fractionation, coker light gasoline splitter, reformer feed fractionator, reformate fractionator and an alkylate splitter. In addition to existing fractionation, this fractionation capacity corresponds to more than double the gasoline production, since some streams must be fractionated as unit feeds and multi-fractionated into cuts again as products. Fractionation equipment will cost about $1.4 billion, or nearly 30% of refinery investment in this case. In the alternate Knees Case 30, this added fractionation is reduced to about equal to gasoline production. This will cost only $0.3 billion, or 20% of total refinery investment.

There is a considerable amount of severe and mild hydrogen processing required in Flat Case 25. The severe part includes hydrocracking of heavy gasoline to reduce T90 and benzene saturation. The mild part includes FCC gasoline hydro-desulfurization to remove sulfur and hydrotreating of distillate. This would require either expansion or addition of hydrogen plants. In total, for the Flat Case 25, these hydrogen process facilities will cost about $2.3 billion, or 45% of total refinery investment. In the Knees Case 30, the amount of new hydrogen processing is reduced to primarily mild and benzene saturation so that existing hydrogen generation capacity is almost adequate. Hydrogen processing will require nearly one-third of total refinery investment, or $0.5 billion in Knees Case 30.

In FCAA Case 2, MTBE is produced from all available isobutylene. In Flat Case 25 and Knees Case 30, vapor pressure and olefin limits combine to make the addition of TAME plant capacity economical. In the severe Flat Case 25, alkylation capacity is also built to handle the production of amylene alkylate. This case also requires a great deal of isomerization capacity to improve the octane number of the olefin saturated FCC and coker C_6 streams. Alkylation and isomerization facilities will cost about

$1.3 billion, or 25% of total Flat Case 25 refinery investment. These steps are not necessary in the knees Case 30.

process unit utilization

The addition of MTBE to the gasoline pool reduces the need for other gasoline components. This is reflected in reductions in both FCC feed rate and conversion. The added octane from MTBE reduces the need for octane from reformate. Hence, reformer feed rate and severity are reduced. This reduced demand for gasoline from crude lowers crude unit utilization.

gasoline pool composition

One of the most notable changes in gasoline composition involves FCC gasoline. In the Base Case, FCC gasoline is about 37% of the gasoline pool and is mostly split into only light and heavy gasoline at a 255°F cut point. In the severe Flat Case 25, all of the FCC gasoline is split into individual carbon number cuts, and only 15% of the pool is FCC gasoline cuts. In the Knees Case 30, fractionation is less complete, but FCC gasoline cuts are 22% of the pool.

Reformate is not fractionated in the Base and mild FCAA Case 2 and comprises 35% and 25% of the pool, respectively. It is all fractionated in the severe Flat Case 25, and the heart cut contributes a little more than 20% to the pool. The Knees Case 30 has partial splitting, and 24% of the pool is reformate and its cuts.

These decreases in FCC gasoline and reformate are reflected in the increase in low aromatic, saturated components from 25% in the Base up to 40 to 64% for these reformulation cases. There is no light reformate in gasoline in the Base Case. It gets as high as 11% in the Flat Case 25 and must all be severely treated to saturate benzene. This is an expensive step and destroys octane by converting benzene into cyclohexane.

In most cases, conventional alkylate is 10 to 11% of the pool. However, in Flat Case 25 the low vapor pressure and olefin limits require removal of amylenes from the pool, which boosts the alkylate to nearly 18%, including nearly 4% amylene alkylate.

In order to reduce olefins and maintain octane number in Flat Case 25, much of the FCC C_6s must be hydrotreated and then isomerized. Isomerate becomes 7% of the pool in Flat Case 25, but is in the 1 to 2% range in the other cases being discussed.

Light and medium hydrocrackate get as high as 15% of the pool in Flat Case 25, reflecting the hydrocracking of heavy gasoline to reduce T90. In the Knees case, this component is about 12% and is in the 5 to 7% range in the Base and FCAA Case 2.

MTBE and TAME total just over 11% in all three of these cases. It must be emphasized that variability in this component on a blend-to-blend basis would add flexibility in controlling octane at the fixed aromatics levels required in reformulated CARB Phase 2 gasoline.

gasoline property incremental costs

The incremental costs shown in Table H-9 for Flat Case 25 point up the extreme difficulty in meeting the restrictions in this case. Octane, RVP, benzene, sulfur and T90 incremental costs are 2 to 17 times higher than the corresponding figures for the Knees Case 30 shown in Table I-9. While these shadow costs apply to only very small changes, they are a reflection of the high cost of meeting the onerous restrictions of Case 25.

winter case

We ran a winter base case and one Case W-1, which was similar to summer Case 8 adjusted for winter volatility constraints and the winter CO nonattainment area requirement for 2.7% minimum oxygen. This case verified that the summer case was generally more severe in terms of the cost of reformulated gasoline and investment requirements.

The winter case cost of reformulation was 12¢ to 19¢/G of gasoline, compared to 16¢ to 22¢/G for Case 8. Refinery investments at $1.5 to $2.3 billion were right at half of summer investments. Foreign investments for MTBE plants are $2.4 to $3.9 billion, about 30% higher than the summer case. This would indicate that foreign MTBE investment should be midway between the summer and winter requirements, with adequate storage to even out producton in face of the seasonal demand swing.

There were a few differences in the processes selected. There was a greater requirement for FCC gasoline hydrodesulfurization and alkylate splitting in the winter case. This indicates that each refiner will have to carefully study its winter operation before committing to summer investment requirements. All of the other summer process equipment is more than adequate to meet winter requirements.

low C_8/C_9 aromatics

Reduced C_8/C_9 aromatics in gasoline are purported to reduce reactivity of exhaust gases by a small amount. By extrapolation of our LP results, we made an approximate guesstimate by hand of the cost of a severe reduction in C_8/C_9 aromatics down to 1%. This evaluation could not be made using our refinery LP without extensive additional data to represent added processing options. Results were as follows:

	Case			Very Low C_8/C_9 Aromatics
	0	23	21	
C_8/C_9 Aromatics, %	24	17	12	1
Ether, %	2	10	15	24
T10, °F	125	132	149	155
T90, °F	348	300	270	240
Pentane Sales, % of Gasoline Pool	0	0	8	16

	Case			Very Low C_8/C_9 Aromatics
	0	23	21	
Cost Over Base Case				
Investment, $MMM	0	3-6	8-12	~16-22
Unit Gasoline Cost, ¢/G				
All Restrictions	0	11-16	26-36	~45-60
C_8/C_9 Restrictions	0	6-9	15-20	~35-45

With the exception of alkylate, the octane of the available refinery C_8+ streams after aromatics removal and olefins saturation is unacceptably low for blending into gasoline. Loss of these very low RVP C_8/C_9 components would necessitate C_5 rejection to maintain RVP. Therefore, the impacts of eliminating most of the C_8/C_9 aromatics would be to drastically narrow the composition of the summer gasoline from a primarily C_5/C_9 mix to an impractical C_6/C_7 mix. This would reduce the T10 to T90 boiling range to about 155 to 240°F, compared to the CARB 1 base of 125 to 348°F. It is questionable whether the existing automobile fleet could run well on such a narrow boiling fuel. Total aromatics would be reduced to about 12%, and ether content of the gasoline would have to be increased to about 24% (above the legal limit of 15%) to maintain octane. This would require unmanageable pentane sales of about 16% of the gasoline pool.

The total costs for these cases are higher than the C_8/C_9 aromatics reduction costs because they include costs for reductions in olefins, benzene, sulfur, RVP, T50 and DI. The wholesale elimination of most of the C_8/C_9 aromatics would have extremely high costs with apparently low emission benefits.

average vs. flat limits

CARB Phase 2 regulations with quarterly averaging of controlled properties at the flat limit level would make the cost of reformulating gasoline only about half as expensive as the proposed flat limits. Lab plus blending compliance margins increased the cost of reformulating gasoline by about 75% over averaging. Reformulation costs rose from 11-16¢/G to 20-28¢/G.

Flat limits effectively create a much more severe actual limit on regulated properties than the promulgated specification because refiners must always include a compliance margin to keep from exceeding the specifications. As we discuss later in the section on the need for compliance margins, the refining/blending/testing process is subject to inaccuracies and unplanned unit outages. To avoid the stiff penalties for exceeding the flat limits of the regulations, refiners will incorporate compliance margins to compensate for the inaccuracies of the properties associated with gasoline production. The compliance margins then become de facto extensions of the regulations, making the regulation more burdensome and expensive to meet.

Averaging controlled properties on a quarterly basis allows refineries to avoid large compliance margins and produce reformulated gasoline that meets the specifications intended in the regulations. Averaging has precedent; the Environmental Protection Agency, as part of its lead phasedown regulations, has used quarterly averaging to regulate the amount of lead allowed in leaded gasoline. Refiners have still blended conservatively to not exceed the allowed average and incur fines, but their compliance margin has been very small.

XI. NEED FOR COMPLIANCE MARGINS

flexibility

Because refineries have a limited number of blending stocks, they are limited in the number of specifications they can meet simultaneously. Current gasoline specifications are written loosely enough that a diligent refinery blender can usually optimize on two or three binding specifications and still easily be within specification on all other properties. The CARB Phase 2 proposed regulations require so many added tight property specifications that the refinery will have to meet as many as nine limitations simultaneously instead of the current two or three.

LP versus actual refinery

The refinery LP was able to concurrently meet all nine property specifications of the very restrictive CARB Phase 2 proposed regulations with a combination of investment in new processes and the availability of multiple narrow range components, neither of which will be available to all the refineries. To meet the proposed Phase 2 regulations, we allowed the LP almost unlimited new process opportunities, and the LP typically invested in twelve to fifteen new or expanded units. Individual refineries may not have the resources for such a massive construction program. To simulate the operation of a complex refinery, the LP portrays gasoline stocks as a collection of up to forty components with very narrow property ranges. Actual refinery production consists of about one-third to one-half as many components with broader property ranges. At times, unit shutdowns decrease the number of blending components even more, making blending to multiple property limits still more difficult.

Sampling inaccuracies add another degree of uncertainty to gasoline blending. Thus, the LP normally optimizes by blending components in ways not available to the refiner.

blending margins

First, the refiner does not have as many blending components as the refinery LP. Second, because of variation in feedstocks and unit operations, the refiner has only approximate knowledge of the properties of the blending components, while the refinery LP is based on exact properties. Because refining is a continuous process involving enormous volumes, samples often offer only approximations of the actual properties of the refinery streams. When the stream is blended, it may not behave as predicted. Because of these process limitations, the refinery is more limited on the number of specifications it can meet simultaneously. In actual practice, the refinery must give away (be below the limit) on some specifications in order to meet all specifications. On average, the give-aways are the blending margins shown on V-6.

lab compliance margins

When facing flat limits, the refiner must also compensate for lack of precision in laboratory testing. As shown in V-3, the inaccuracy in laboratory tests can be as high as 40%. If the definition of meeting a regulated property is the analysis of an outside laboratory and failure to meet the test carries serious economic consequences, the refiner must account for the reproducibility of the test in its blending and set its blending specifications to include lab compliance margins, as shown in V-6.

gasoline blending LP

Most of the discussion and our reporting has centered around gasoline pool properties. However, in all cases we produced at least three grades of gasoline: premium, intermediate and regular. The refinery LP blended each grade to specifications. We tested a refinery's ability to meet specifications on each gasoline grade by combining the refinery LP components into blending components refineries could produce. We then reblended to individual gasolines specifications with a gasoline blending LP. We evaluated Case 21, the case with the most stringent lab and blending compliance margins for the CARB staff August 5 proposal, and Case 8 with only lab compliance margins. We had a difficult time reblending Case 21 to specification, while reblending Case 8 was relatively easy.

Case 21 was such a severe reformulation case that the number of blending components decreased as added blending components from lower reformulation limits were processed out of existence. As shown in Table X-5, we combined the refinery LP components into refinery-producible components. As shown in Table X-1, we then blended the twelve components we produced to verify that we had properly combined properties. We then blended the individual gasoline streams according to the refinery LP recipes, as shown in Tables X-2 through X-4. For the three blends, all properties except octane were within reasonable tolerance. Premium octane was below specification by 0.8 octane number, a significant difference. Using a gasoline blending LP, we attempted to reblend all properties to specification. To blend premium octane to within 0.1 octane number of specification, we had to allow the aromatics and benzene contents and distillation to fluctuate. The reblend was difficult, requiring us to rerun the case seven times to maximize premium octane and stay within blending tolerance on aromatics and distillation.

Case 8, with much less severe reformulation limits, required very little reblending. As shown in Tables X-6 and X-10, 37 refinery LP blending components were combined to eighteen components available to the refineries. As shown in Tables X-7 through X-9, when we blended the refinery-producible components according to the refinery LP recipes, premium octane was down only 0.3 number, and regular benzene content was high by 0.1 volume %. Other properties were very close to specification. The gasoline LP blended to the tolerances we had established for the properties on the first pass, so we considered the problem solved.

The individual refinery would have even more difficulty than we did in blending to the proposed Phase 2 specifications. Our analysis represents the aggregate refinery. Because the individual refinery will not have as many process units, it will not have all the components available to the aggregate refinery model and will typically face blending problems similar to the ones we faced in reblending Case 21 for less restrictive property limits.

XII. REFINERY EMISSIONS IMPACTS

We calculated the impact the CARB staff October 4 proposal would have on refinery emissions for Case 25 with flat limits or Case 23 with average limits. Our analysis was limited to emissions from increased fuel consumption in low NO_x burners, sulfur plant emissions and FCC stack emissions. We did not calculate fugitive emissions from new units or new offsite facilities and tankage.

changes in refinery emissions

The estimated increase in total California refinery emissions to produce reformulated gasoline meeting the CARB staff October 4 proposal in tons per day is shown in the following table:

	Flat Limits Case 25	Average Limits Case 23
SO_x	0	(5)
NO_x	5	1
CO	7	1
PM	3	0
CO_2	22,000	8,600

new source permits

We calculated the number of new source permits required to construct new process heaters and fired boilers. We assumed that 450 psig steam would be available in the California conversion refineries for reboiling towers and supplying preheat for processes. Fired heaters would be required to reboil streams boiling above 300°F or to supply preheat above 300°F. Additional steam demand would come from gas-fired boilers with a capacity of 150M pounds/hour. Associated refinery added fuel consumed and estimated new furnaces and boilers (statewide total) are shown below:

	Flat Limits Case 25	Average Limits Case 23
Added Fuel Use, MMBTU/Hr.	15,000	5,900
Number of New Fired Heaters	260	180
Number of New Boilers	34	17

increased tankage

Although we did not calculate the fugitive emissions from new process units and new offsites, we did estimate the amount of new tankage that would be required for the CARB staff October 4 proposal. Naturally, we considered the number of new blending components required. More importantly, we considered the difficulty a refiner would have blending to meet the constraints of the flat limits case. We also incorporated the refiner's need to isolate and test components before blending and to provide for fluctuations in component qualities. We estimated that meeting the CARB staff October 4 proposed reformulations using averaging would increase gasoline tankage requirements 50% above the base case. Using flat limits would increase gasoline tankage requirements to double that of the base case.

XIII. MODELING ASSUMPTIONS AND CONSTRAINTS

aggregate model constraints

Our California refining industry model with seventeen conversion refineries could over-optimize relative to individual refinery models. Individual refineries do not contain the same average size process units, nor process the same average slate of raw materials, nor make the same products. Further, all LP models tend to over-optimize because they represent curves with straight line segments. We are extremely aware of these tendencies and have taken extraordinary steps to avoid over-optimization. We have added extra constraining equations and have extensively calibrated our model against aggregate industry results for the same group of refineries. On the other hand, individual refineries can exploit their own particular process capacity strengths to fill their own raw material and product niche, tending to make them nearly as efficient as the aggregate model.

cost ranges

We have provided ranges of cost results rather than individual refinery results. Each refinery is unique and will have different reformulation costs. We have limited new unit sizes to practical ranges and required added units in refineries without needed equipment. When the LP called for additional existing process unit capacity, we sized the capacity to be built in those refineries that did not already have the capacity. Thus, we have avoided implying that one refinery could utilize process capacity at another refinery.

gasoline grade optimization

In early cases, results could be over-optimized by gasoline grade. Our reformulation model contains up to about 100 gasoline components with about 25 to 40 active in each case. Physical reformulated gasoline components would be limited to around 12 to 15 in each refinery. To avoid this potential for over-optimization, we have included restrictive equations to limit over-distribution of theoretical LP components to grades. For Cases 23 and later, we added more restrictive component equations after calculating physical equivalent blends off-line, using our gasoline blending LP program.

investment cost accuracy

The TM&C LP models used investment costs that were estimated from curves based on actual unit construction costs. Individual process unit costs were reviewed by the industry experts from WSPA members and increased by 3% to account for increases in costs due to permitting and obtaining emissions offsets. It should be noted that curve type investment costs have an accuracy of only ±25%. Major equipment components would have to be costed out in a detailed engineering cost estimate to attain a better accuracy of ±10%.

construction load

These cost curves also reflect normal engineering construction industry load. At times of peak load or slack load, the cost could be significantly higher or lower. The next few years promise a fairly high overall load due to the required reduction in low sulfur diesel in the U.S. and low aromatic diesel in California, the FCAA requirements for ether and reformulated gasoline by 1995, other refining industry environmental improvements and the significant refinery rebuilding in the Middle East as a result of the recent war with Iraq. WSPA and TM&C decided that because of the significant engineering and construction activity load outlook, the normal range for estimating accuracy should be biased to the high side. Therefore, LP model calculated investment costs are expressed along with a cost range of -15/+35%. The model studies further assume full utilization from initial startup with no problems. All of these factors tend to understate the specific risks associated with each project and the buildup time and other risks related to uncertainties. That is the reason why the risk-free 15% DCF ROI hurdle rate was used.

process unit yields

Our LP model uses process unit yields that were initialized to match the last NPC survey (1985) and are typical for each group of refineries. These yields are based on existing technology and take into account the impact of major quality variables. However, each refinery has unique yields from each process based on specific design factors and secondary feed and product property considerations. We also assumed currently available catalyst and the ability to block out alternate operating modes perfectly.

Our model results were based on using 1989 NPRA average survey gasoline properties as the base line from which the *base line gasoline*

uncontrolled properties could not be downgraded. The appropriate legal limitation will be 1990 gasoline properties, measured more accurately than the 1989 survey data. These were not defined, so this substitute was used. Base line gasoline will not be fully defined until 1990 industry statistics are compiled. More stringent properties on base line gasoline would make the partial reformulation case more constrained. This was more than offset by assuming tighter caps on unreformulated than required.

product test accuracy

The level of aromatics and olefins in gasoline was indicated by the NPRA survey for Auto/Oil. Most respondents indicated a very limited amount of data in this area and based their responses on the FIA test. The FIA test indicates a reproducibility of only ±3% on aromatics and about ±5% on olefins. In addition, some respondents reported data from alternate test methods, such as mass spec, chromatograph or PIANO analysis. The lack of accuracy and method consistency was apparent from the standard deviations calculated from the survey results. Standard deviations for aromatics ranged from 8% to 9% for most of the major aromatic components and for finished gasoline. Standard deviations for olefins ranged from 6% to 8% for finished gasoline and reached as high as 11% for whole FCC gasoline. Test method accuracy for sulfur was similar, only worse. The xray method for sulfur testing has an accuracy of ±30 ppm at the 50 ppm level and ±90 ppm at the 300 ppm level. Relative test accuracy is ±100 ppm at the

1,000 ppm level. Finished gasoline standard deviation was in the 100 to 300 range. Sulfur accuracy was further compromised by numerous respondents reporting "less than" instead of specific sulfur results.

TVMT/BTU factor

We assumed the 0.8 total vehicle miles traveled/BTUs factor used by EPA in prior studies. We showed a possible range on this variable of 0.6 to 1.0. Preliminary test data from Auto/Oil indicate that this BTU factor may be in the 1.0 to 1.4 range. The cost of the BTU impact ranges from about 3¢ to 5¢/G for the 0.6 to 1.0 BTU factor range used. If the higher range were used, it could add another 1¢ to 2¢/G to reformulation costs.

LIST OF TABLES

WSPA STUDY OF CARB PHASE 2 GASOLINE

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WSPA STUDY OF CARB PHASE 2 GASOLINE

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WSPA STUDY OF CARB PHASE 2 GASOLINE

Table **Description**

VIEWGRAPH 1
WSPA/TM&C ECONOMIC STUDY

CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

MAJOR TM&C ASSUMPTIONS AND BASES

- Model – validated/calibrated – 17 California conversion refineries
- Investment – MTBE – Middle East basis – ROI 18%
- Investment – Refinery – ROI 15%, realistic, reviewed, optimized from unit curves
- Pricing – 1996 spot – $16.70 ANS, 65¢ gasoline, 96¢ MTBE, $13 bunker
  – 1988-91 spot – $16.90 ANS, 65.2¢ gasoline, 98.4¢ MTBE, $13.10 bunker
- Major light products – constant; adjust gasoline to constant vehicle miles traveled
- Flexibility – optimum ANS, MTBE, bunker, coke, C_5, C_4, C_3, gas
- 1996 supply and demand – summer – consensus outlook
- 1996 grades – 25% premium gasoline, 80% low aromatics diesel
- Capacities – Base plus required; summer utilizations; add to each refinery; 2 MBPSD minimum unit size; debottlenecking up to 20%
- Reformulation options (#) – aromatics (21), oxygen (4), olefins (12), benzene (8), sulfur (13), RVP (8), T90 (20)

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VIEWGRAPH 2
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

STRENGTHS AND LIMITATIONS

Strengths

- TM&C – Selected as modeling contractor by NPC, API, Auto/Oil, WSPA
- Recognized Refining Industry Experts – Cunningham, Michalski, others
- Best Refining Industry Models – critiqued by 5 industry task groups
- Validated, Accurate Models – unit/refinery yields and properties – reproduced history
- Flexible Models – over 50 different gasoline reformulation options
- Costs Results – conservative, optimized, unbiased
- Valid Basis – constant major light products/net margins; optimum minor products
- Realistic Investments, Valid Pricing Outlook, Calibrated Operating Costs
- Reasonable Supply and Demand – consensus outlook – seasonalized
- Optimized Capacities – 1 new unit of each type per refinery; realistic minimum sizes

Limitations (Compensation)

- Over-optimized – excess flexibility with 17 refineries in one model (calibrated)
- No individual refinery costs (proprietary/antitrust preclude)
- Over-optimized gasolines – meet 9-10 limits simultaneously (lab and blend margins)
- Marginal refineries obscured (cost and price impacts offset – conservative costs)
- Property cost curves interdependent (synergisms minimized – conservative costs)

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VIEWGRAPH 3
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

PRECISION OF ASSUMED LAB TEST METHODS

	Proposed Flat Limit	Repro-ducibility	Repeat-ability	Test Name	ASTM Method D-
Aromatics, Vol. %	25	±5-10%	±5%(1)	GC-PID/FID	Not std.
Oxygen, Wt. %	1.8-2.2	±22%	±10%	GC	4815-89
Olefins, Vol. %	5	±20%	±8%	Bromine No.(2)(3)	1159-89
Benzene, Vol. %	1.0	±28%	±15%(1)	GC	3606-87
Sulfur, Wt. PPM	40	±38%	±28%	Coulometry(3)	3120-87
RVP, PSI	7.0	±0.3	±0.2(1)	Grabner	13CRR-2262b
T90, °F	300	±12	±7	Distillation	86-90
T50, °F	210	±12	±7	Distillation	86-90

(1) Estimated.
(2) Results may be affected by oxygenates.
(3) Significantly more precise than method indicated in CARB proposal.

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VIEWGRAPH 4
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

INADEQUACIES OF ALTERNATE LAB TEST METHODS

	Proposed Flat Limit	Repro-ducibility	Repeat-ability	Test Name	ASTM Method D-
Aromatics, Vol. %	25	±3	±1.4	FIA[1]	1319-89
Olefins, Vol. %	5	±3.7[2]	±0.9	FIA[1][3]	1319-89
Sulfur, Wt. PPM	40	±60%[2]	±60%[2]	X-Ray[3]	2622-87
RVP, PSI	7.0	±0.9[2]	±0.3[2]	Dry[4]	4953-90
		±0.7[2]	±0.2	Reid[5]	323-90

(1) Results affected by oxygenates.
(2) Very poor precision.
(3) Method indicated in CARB proposal.
(4) Results not affected by any oxygenates.
(5) Results affected by alcohols.

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VIEWGRAPH 5
WSPA/TM&C ECONOMIC STUDY

CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

TYPICAL BLENDING FLEXIBILITY, DIFFICULTY AND TANKAGE

	Current/ CARB 1	Federal CAA	10/4 CARB 2 Proposal: Flat Limits	10/4 CARB 2 Proposal: Averaging*	CARB 2 Knees¤
Number of Components in Gasoline Pool					
LP Model Used	21	29	27	34	35
Real Equivalent	10	15	14	17	18
Typical Refinery	8	13	12	15	16
Number of Property Limits					
Binding/Flat	3	2	9	2	3
Average (with NB Caps)	-	5#	-	6	4
Almost Binding	1	1	-	1	1
Non-Binding (NB)	11	9	8	8	9
Level of Flexibility	High	Mid	Nil	Low	Mid
Level of Difficulty	Low	Mid	Extreme	High	Mid
Tankage Required	Base	1.4 Base	2 Base	1.5 Base	1.4 Base

* At flat limits. ¤ Close to property cost curve break points.
# 2 of these are not very restrictive.

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VIEWGRAPH 6
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

COMPLIANCE MARGINS WITH FLAT LIMITS

Property	Proposed Flat Limit	Compliance Margins: Lab Testing	Compliance Margins: Blending	Compliance Margins: Lab Plus Blending	Refinery Blend Target
Aromatics, Vol. %	25	3	2	5	20
Oxygen, Wt. %	1.8-2.2	0.2[1]	-[2]	0.2[2]	2.0-2.0
Olefins, Vol. %	5.0	1.0	1.0	2.0	3.0
Benzene, Vol. %	1.0	0.2[3]	0.2	0.4	0.6
Sulfur, Wt. PPM	40	15	5	20	20
RVP, PSI	7.0	0.3	0.1[2]	0.4[2]	6.6
T90, °F	300	10[3]	10	20	280
T50, °F	210	10[3]	5	15	195

(1) Repeatability.
(2) Conservative; need 0.1 higher margin.
(3) Average of reproducibility and repeatability.

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VIEWGRAPH 7
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

CASE DESCRIPTIONS

<u>Case</u>	
Base	CARB Phase 1 Regulations
2	Federal CAA – Statewide – No Compliance Margins (Average Limits)
6	EC-X – No Compliance Margins (Average Limits)
	<u>CARB Phase 2 Proposal</u>
23	October – With No Compliance Margins (Average Limits)
24	October – With Lab Testing (L) Compliance Margins
25	October – With Lab Testing Plus Blending (B) Compliance Margins
31	October – With L Plus B Compliance Margins (Average BZ, S)
	<u>Alternate for CARB 2</u>
30	C – Property Cost Curve Knees

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VIEWGRAPH 8
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

PROPERTY CONTROL MAXIMUM LIMITS

Case	Name	Comply Margins	A	OX (min)	OL	BZ	S	RVP	T90	T50
Base	CARB 1	Lab	-	0.4	13 #	-	210 *	7.5	-	-
2	CAA	No	25 *	2.0	13 #	0.95	163	7.1	328	-
6	EC-X	No	20	2.7	4	0.8	40	6.7	295	-
	CARB 2									
23	10/4	No	25	1.8	5	0.95	40	7.0	300	210 #
24	10/4	Lab	22	2.0	4	0.8	25	6.7	290	200 #
25	10/4	L + B	20	2.0	3 *	0.6	20	6.6	280	195 *
31	11/4	L + B(A)	20	2.0	3	0.8	30 *	6.6	280	195 *
	Alternate									
30	Knees	No	25 *	2.0	7	0.8	50	7.1	310	-

* LP results slightly below limit.

\# LP results significantly below limit – by blending compliance margin or more.

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VIEWGRAPH 9
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

INVESTMENTS REQUIRED OVER BASE

		Comply	Investments $MMM (Billions)			
Case	Name	Margins	Refining	MTBE*	Total	Range
2	CAA	No	0.7	2.2	2.9	2.2-3.7
6	EC-X	No	2.5	3.3	5.8	4.6-7.5
	CARB 2					
23	10/4	No	2.3	2.0	4.3	3.4-5.6
24	10/4	Lab	3.4	2.2	5.6	4.6-7.4
25	10/4	L + B	5.1	2.2	7.3	6.0-9.7
31	10/4	L + B(A)	4.7	2.2	6.4	5.7-9.1
	Alternate					
30	C	No (Knees)	1.5	2.2	3.7	2.9-4.7

* In Middle East/Far East

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VIEWGRAPH 10
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

COST RESULTS OVER BASE

Case	Name	Compliance Margins	Costs, ¢/G Typical	Costs, ¢/G Range
2	CAA	No (Averaging)	8.1	6.5-10.8
6	EC-X	No (Averaging)	17.0	14.3-21.8
	CARB 2			
23	10/4	No (Averaging)	13.0	11.2-16.4
24	10/4	Lab Testing	17.1	14.8-21.4
25	10/4	Lab + Blending	23.1	20.4-28.4
31	10/4	L + B(Avg. BZ, S)	21.1	18.5-26.1
	Alternate			
30	C	No (Knees)	11.1	9.3-14.2

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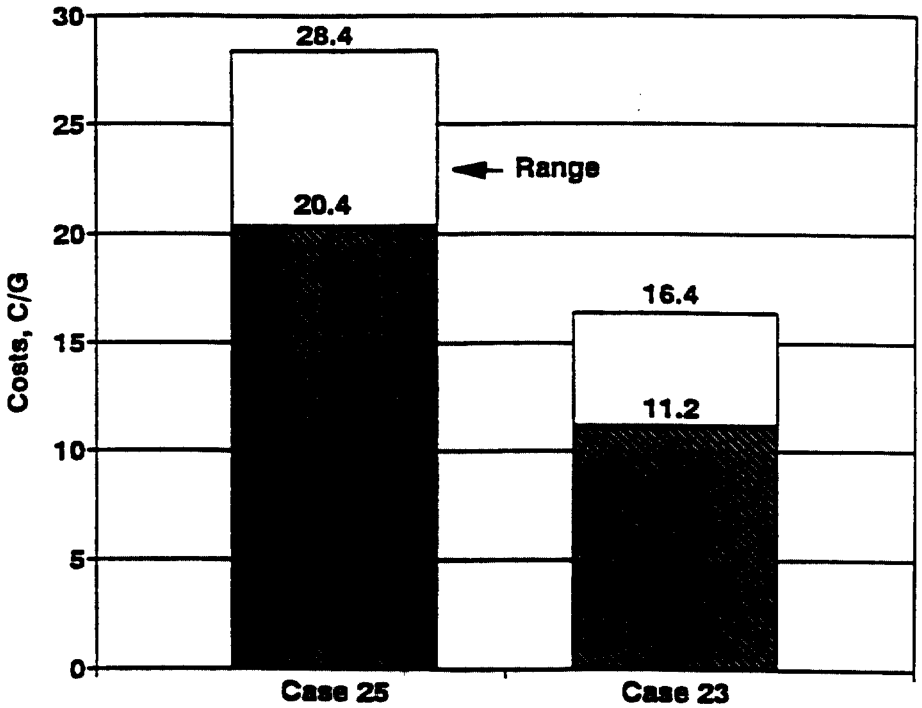
VIEWGRAPH 11
COST OF AVERAGE VS FLAT PROPERTY LIMITS FOR 10/4/91 CARB PHASE 2 PROPOSAL
WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



Property Limits:	Flat	Average
Compliance Margins:	Lab Testing & Blending	None
LP CONTROL LIMITS - MAX		
Aromatics, V%	20	25
Oxygen, W% Min	2.0	1.8
Max	2.0	2.2
Olefins, V%	3	5
Benzenes, V%	0.6	0.95
Sulfur, WPPM	20	40
RVP, PSI	6.6	7.0
T90, Deg F	280	300
T50, Deg F	195	210

REC/CLM 10/24/91

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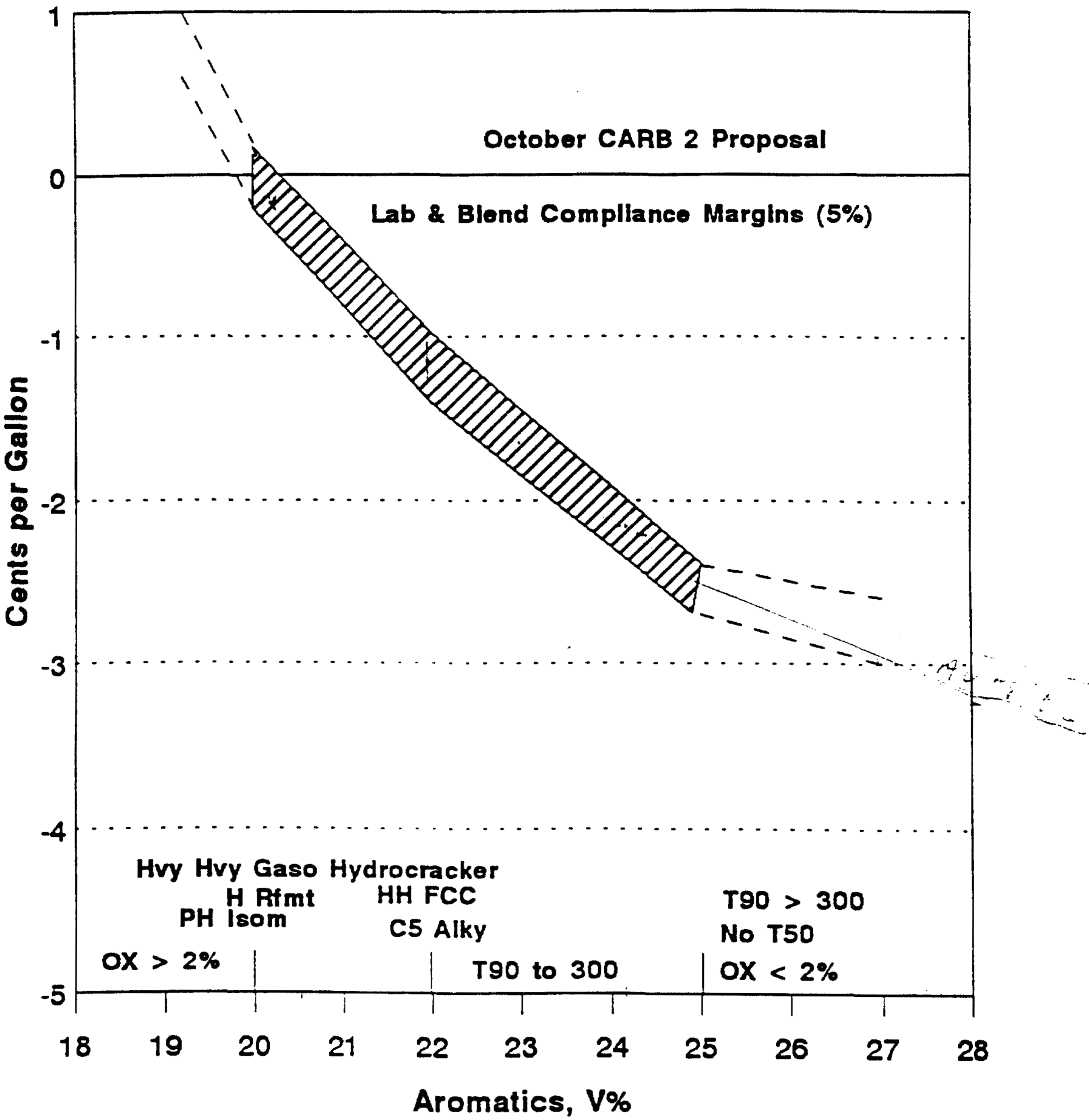
VIEWGRAPH 12

COST IMPACTS OF INCREASED AROMATICS

WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



REC/CLM 10/26/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30128

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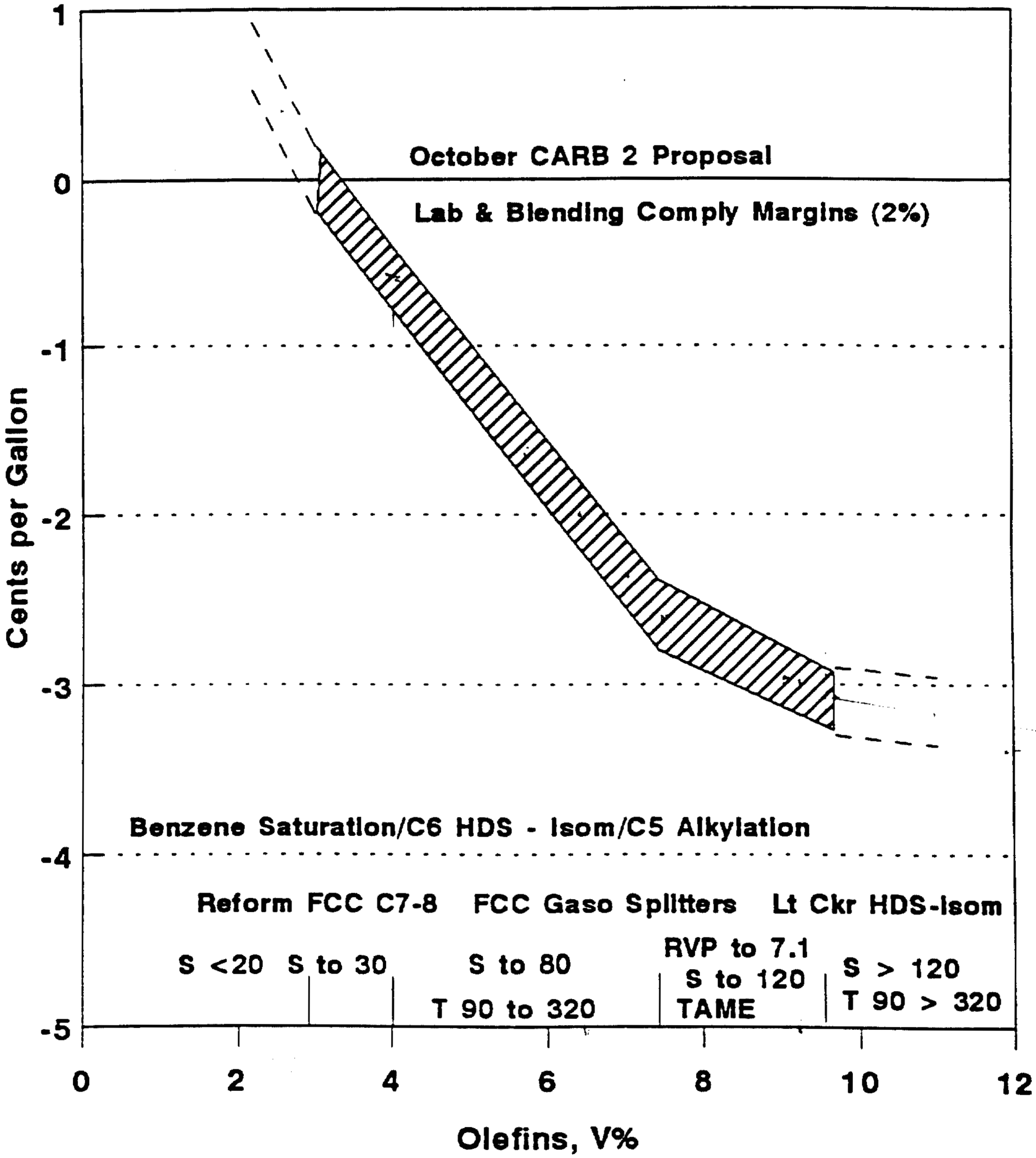
VIEWGRAPH 13

COST IMPACTS OF INCREASED OLEFINS

WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



REC/CLM 10/24/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
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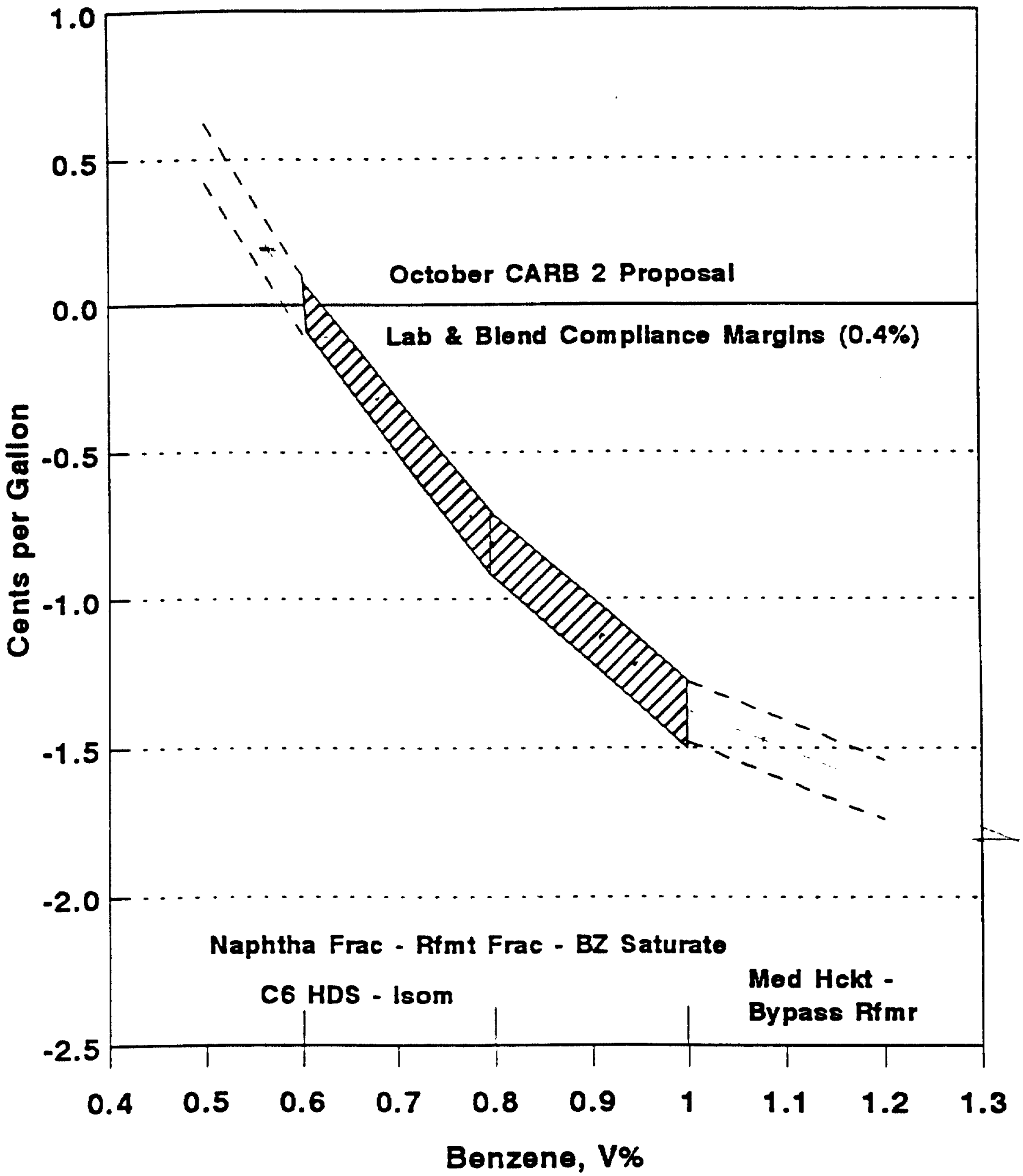
VIEWGRAPH 14

COST IMPACTS OF INCREASED BENZENE

WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



REC/CLM 10/26/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
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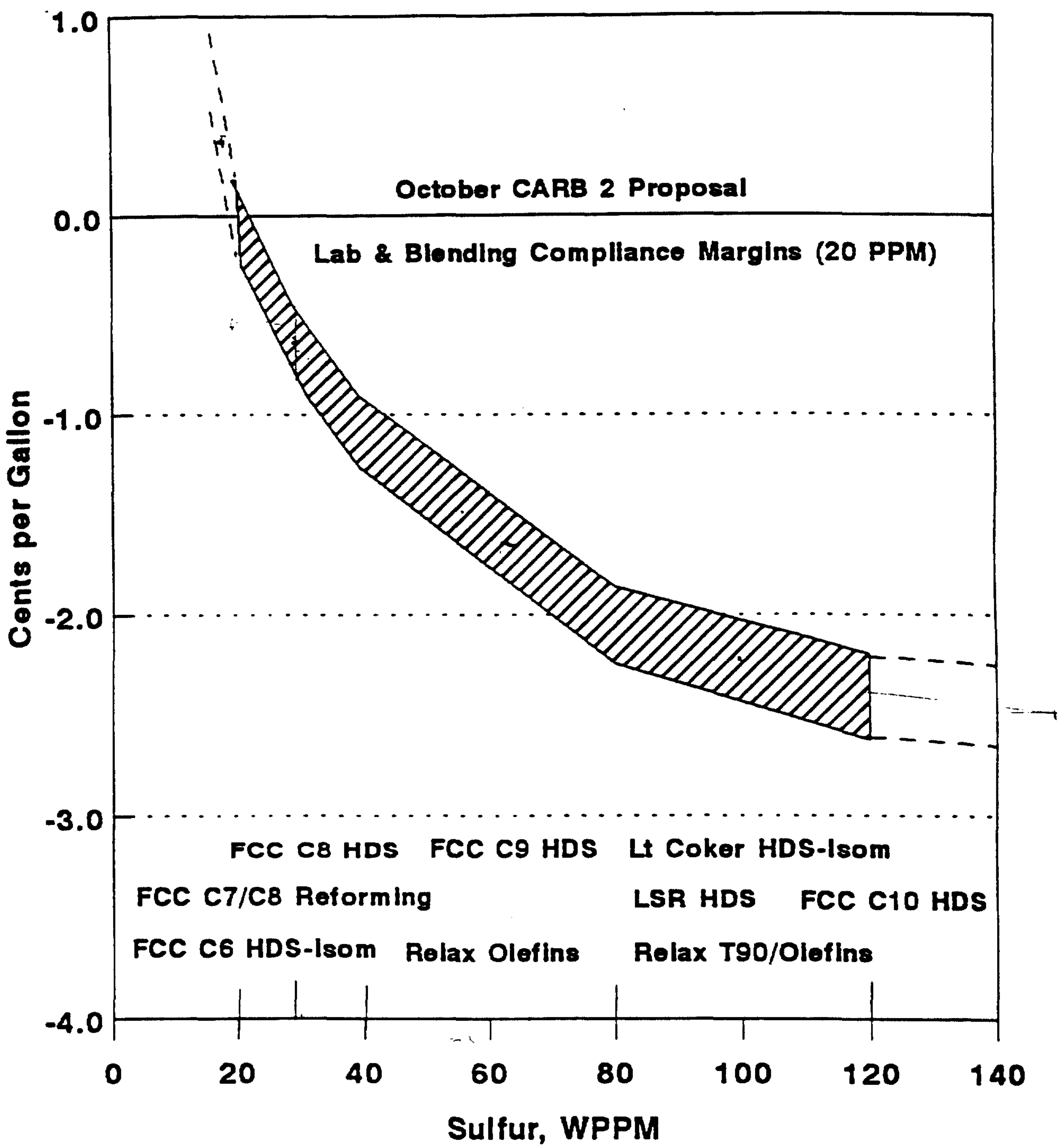
VIEWGRAPH 15

COST IMPACTS OF INCREASED SULFUR

WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



REC/CLM 11/4/91

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U.S. District Court (C.D. Ca.)
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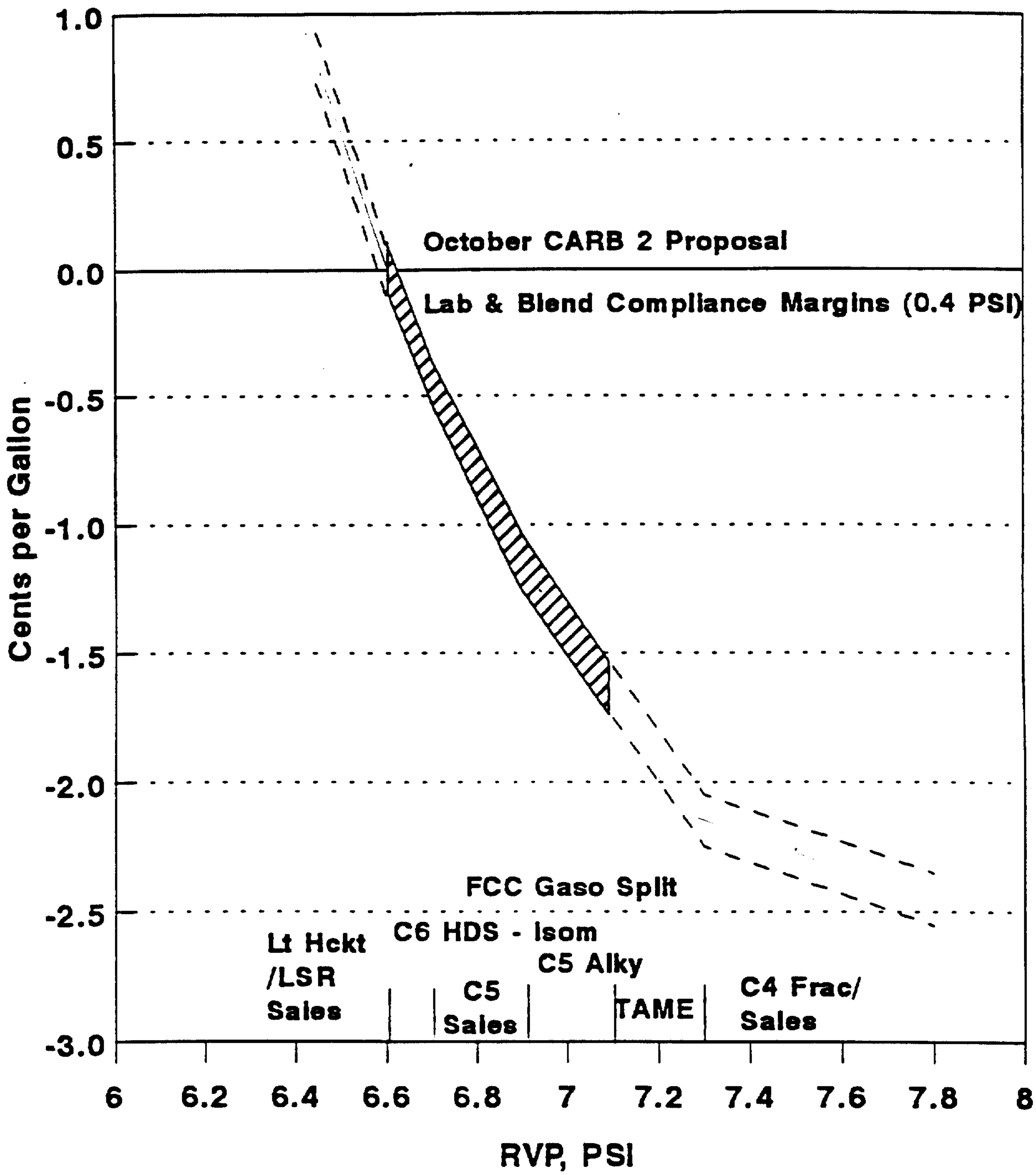
VIEWGRAPH 16

COST IMPACTS OF INCREASED RVP

WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



Based on 280-290 F T90. Curve shifts to left by 0.1 for 20 F T 90 increase.

GWM/REC/CLM 11/4/91

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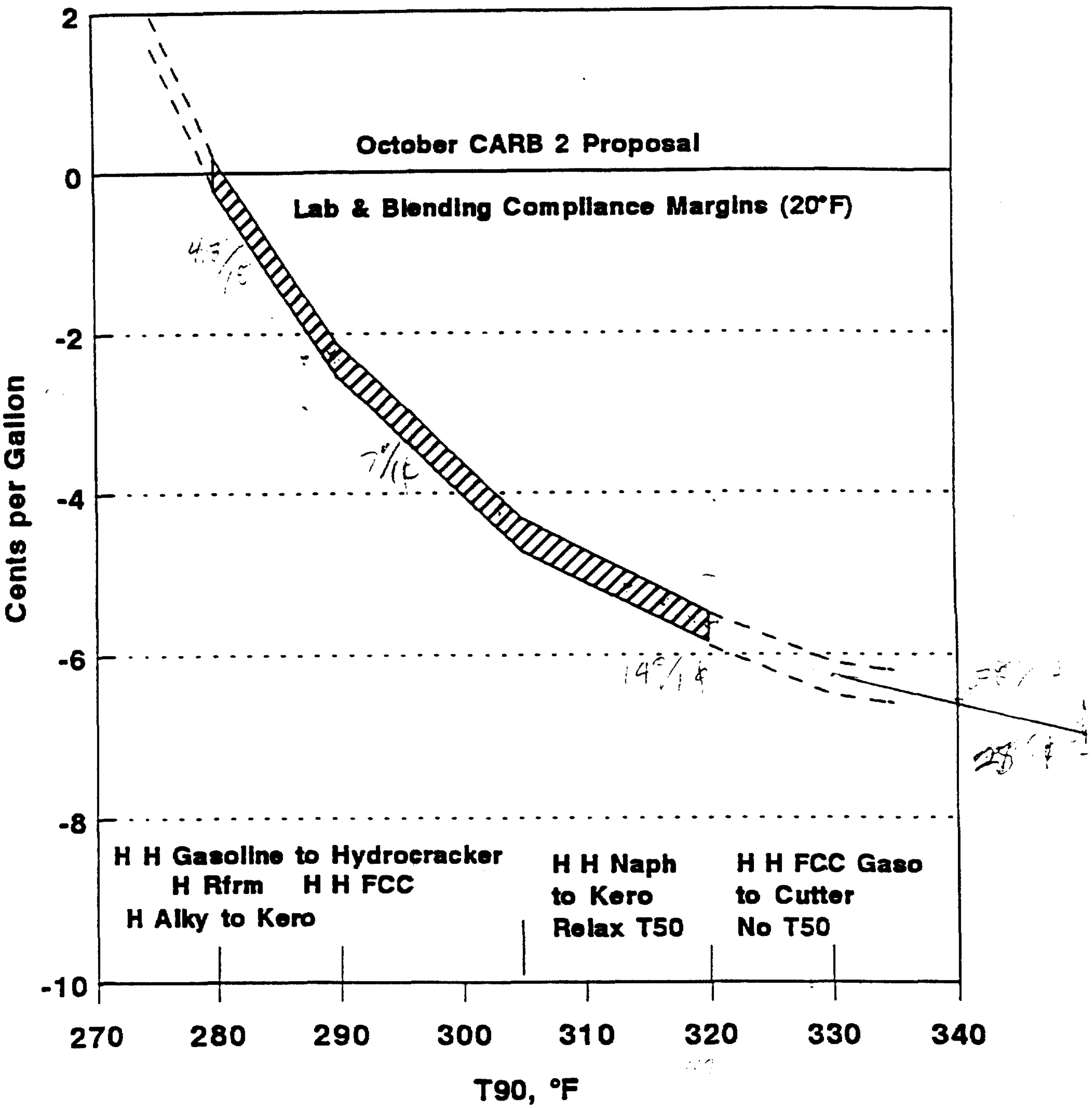
VIEWGRAPH 17

COST IMPACTS OF INCREASED T90

WSPA/TM&C STUDY OF CARB PHASE 2 GASOLINE



GWM/REC/CLM 10/26/91

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U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
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VIEWGRAPH 18
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

COST IMPACTS OF PROPERTY INCREASES

Property	10/4 CARB 2 Less Comply	Cost Curve Optimum	Property Change	Cost Impact, ¢/G
Aromatics, Vol. %	20	25	+5	(2.4)-(2.8)
Olefins, Vol. %	3.0	7.5	+4.5	(2.4)-(2.8)
Sulfur, PPM	20	80	+60	(1.8)-(2.2)
RVP, PSI	6.6	7.1 *	+0.5	(1.6)-(1.8)
T90, °F	280	305	+25	(4.3)-(4.7)
Combined				(12.5)-(14.3)

* Federal CAA limit (lower than optimum).

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VIEWGRAPH 19
WSPA/TM&C ECONOMIC STUDY
CARB/WSPA/TM&C ECONOMICS MEETING
CARB Phase 2 Gasoline Regulations

CONCLUSIONS SUMMARY

- Federal CAA (statewide) requires $2.2-3.7 MMM investment and costs 6-11¢/G
- CARB Phase 2 gasoline (October proposal) with compliance margins for lab testing plus blending requires investments of $6.0-9.7 MMM and costs 20-28¢/G
- Changing October CARB 2 proposal flat limits to average limits (system caps):
  - Reduces costs by 9-12¢/G to 11-16¢/G
  - Reduces required investments by $2.6-4.1 MMM to $3.4-5.6 MMM.
  - Drops required investments in California refineries by over 50%.
- Shifting to optimum on cost curves would change October CARB 2 proposal for:

  Aromatics by 5 to 25% | RVP by 0.5 to 7.1 PSI
  Olefins by 4.5 to 7.5% | T90 by 25°F to 305
  Sulfur by 60 to 80 PPM

  and reduce costs by 12-14¢/G based on additive cost curves.
- Alternate C (knees) requires $2.9-4.7 MMM investment and costs 9-14¢/G.
- Need flexibility of 1.5 to 2.7 Wt. % oxygen and no T50 limit (not controllable).

DAB/REC – 11/6/91

TURNER, MASON & COMPANY
Consulting Engineers

TABLE 1
SUMMARY OF UNIT COSTS
1996 CASE RESULTS – INCREASE OVER BASE CASE
WSPA STUDY OF CARB PHASE 2 GASOLINE
(¢/G of base gasoline - constant 1991 $)

		MAXIMUM PROPERTY CONTROL LIMITS (1)									SOURCE	CALCULATED COSTS	
CASE	DESCRIPTION	A	OX	OL	BZ	S	RVP	T90	T50	DI	TABLE	TYPICAL	RANGE
7/91 EPA CLEAN AIR ACT REGS 1													
1	EX. NORTH	25	2.0	13	0.95	163	7.1	328			C-2	8.8	7.3-11.5
2	+ NONE	25	2.0	13	0.95	163	7.1	328			C-2	8.1	6.5-10.8
7/91 MIN CARB 2 - LAB COMPLY MARGINS													
3	+ NONE	25	2.0	8	0.8	120	6.7	328			C-2	9.5	7.8-12.3
4	- 80 S	25	2.0	8	0.8	40	6.7	328			C-2	10.0	8.2-13.0
5	- 33 T90	25	2.0	8	0.8	120	6.7	295			C-2	13.5	11.6-17.0
ARCO PROPOSAL													
6	EC-X	20	2.7	4	0.8	40	6.7	295			C-2	17.0	14.3-21.7
8/5/91 CARB 2 - LAB COMPLY MARGINS													
7	+ 9 DI	22	2.1	4	0.8	20	6.7	290	195	1084	C-2	17.4	14.9-22.0
8	+ NONE	22	2.1	4	0.8	20	6.7	290	195	1075	D-2	18.0	15.5-22.4
9	+ .4 RVP	22	2.1	4	0.8	20	7.1	290	195	1075	D-2	16.7	14.3-21.0
10	+ 30 T90(2)	22	2.1	4	0.8	20	6.7	320			D-2	14.6	12.2-18.7
11	+ 15 T90(2)	22	2.1	4	0.8	20	6.7	305			D-2	15.8	13.3-20.1
12	+ 22 S	22	2.1	4	0.8	42	6.7	290	195	1075	D-2	17.2	14.8-21.5
13	+ 4 OL/100 S/30 T90(2)	22	2.1	8.1	0.8	120	6.7	320			D-2	11.2	9.3-14.7
14	+ 3 OL/60 S/30 T90(2)	22	2.1	7.4	0.8	80	6.7	320			E-2	11.3	9.4-14.7
15	+ 3 A/30 T90(2)	25	2.1	4	0.8	20	6.7	320			E-2	13.1	11.1-16.6
16	+ 3 OL/60 S/30 T90/NO C5 OL(2)	22	2.1	7.1	0.8	80	6.7	320			E-2	11.7	9.8-15.0
17	+ LAB COMPLY MARGINS	25	2.0	5	0.95	30	7.0	300	200	1100	E-2	13.5	11.5-17.0
18	+ 3 A/3 OL/30 S/.4 RVP/15 T90(2)	25	2.1	7.5	0.8	50	7.1	305			E-2	11.8	9.9-15.2
19	- BLEND COMPLY MARGINS(2)	20	2.5	2	0.8	10	6.5	280			F-2	23.5	20.4-29.2
20	+ 6 OL/100 S/.4 RVP/30 T90(2)	22	2.1	10	0.8	120	7.1	320			F-2	9.8	7.9-13.1
21	- BLEND COMPLY MARGINS	20	2.5	2	0.8	10	6.5	280	187	1055	F-2	26.9	23.6-23.2
22	+ .2 RVP	22	2.1	4	0.8	20	6.9	290	195	1075	F-2	17.1	14.7-21.4

(1) OX = Oxygen is the only minimum control limit.
(2) No T50/DI Limits.

REC - 11/13/91

TABLE 1–A
SUMMARY OF UNIT COSTS
1996 CASE RESULTS – INCREASE OVER BASE CASE
WSPA STUDY OF CARB PHASE 2 GASOLINE
(¢/G of base gasoline – constant 1991 $)

		MAXIMUM PROPERTY CONTROL LIMITS (1)									SOURCE	CALCULATED COSTS	
CASE	DESCRIPTION	A	OX	OL	BZ	S	RVP	T90	T50	DI	TABLE	TYPICAL	RANGE
10/4/91 CARB 2													
23	- NONE/(2.2 MAX OX)	25	1.8	5	0.95	40	7.0	300	210		H-2	13.0	11.2-16.4
24	- LAB COMPLY MARGINS(2)	22	2.0	4	0.8	25	6.7	290	200		H-2	17.1	14.8-21.4
25	- LAB/BLEND CMPL MGNS(2)	20	2	3	0.6	20	6.6	280	195		H-2	23.1	20.4-28.4
31	- LAB COMPLY MARGINS(3)	20	2	3	0.8	30	6.6	280	195		I-2	21.1	18.5-26.1
32	- LAB COMPLY MARGINS(4)	20	2	3	0.6	20	6.6	280	195		I-2	22.8	20.0-28.1
ALTERNATES													
26	- ALTERNATE A	25	1.8	7	0.8	30	7.1	295	195		H-2	13.8	11.9-17.3
27	- TEST FOR EMISSIONS(2)	20	2.0	5	0.8	30	7.0	300	200		H-2	15.9	13.5-20.1
28	- ALTERNATE B	25	1.8	8	0.8	80	7.1	320			I-2	9.2	7.7-12.0
29	- ALTERNATE B - 50S	25	1.8	7	0.8	30	7.1	320			I-2	11.0	9.2-14.1
30	- ALTERNATE C - KNEE	25	2	7	0.8	50	7.1	310			I-2	11.1	9.3-14.2

(1) OX = Oxygen is the only minimum control limit.
(2) Fixed OX (max = min).
(3) With averaging on benzene and sulfur limits, fixed OX Max = Min.
(4) Case 25 with Lt. Hydrocrackate split for added C5 sales.

REC - 11/12/91

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TABLE 2

COMPLIANCE MARGIN CHANGE COST REDUCTIONS

FROM 1996 CASE RESULTS COMPARISONS

WSPA STUDY OF CARB PHASE 2 GASOLINES

(¢/G of base gasoline - constant 1991 $)

CASES DELTA	CARB 2 PROPOSAL DATE	COMPLIANCE MARGINS INCREMENT / DECREMENT	CALCULATED COST REDUCTIONS TYPICAL	RANGE
		NO LAB TESTING / NO BLENDING		
21 - 17	8/5	+5 A, -0.5 OX, +3 OL, +0.15 BZ, +20 S, +0.5 RVP, +20 T90, +13 T50, +45 DI	16.1	14.5 - 19.4
25 - 23	10/4	+5 A, -0.2 OX, +2 OL, +0.35 BZ, +20 S, +0.4 RVP, +20 T90, +15 T50	10.1	9.2 - 12.0
32 - 23(1)	10/4	+5 A, -0.2 OX, +2 OL, +0.35 BZ, +20 S, +0.4 RVP, +20 T90, +15 T50	9.8	8.8-11.7
		NO BLENDING		
21 - 8	8/5	+2 A, -0.4 OX, +2 OL, +10 S, +.2 RVP, +10 T90, +8 T50, +20 DI	11.6	10.5 - 14.0
25 - 24	10/4	+2 A, +1 OL, +0.2 BZ, +5 S, +.1 RVP, +10 T90, +5 T50	6.0	5.6 - 7.0
32 - 24(1)	10/4	+2 A, +1 OL, +0.2 BZ, +5 S, +.1 RVP, +10 T90, +5 T50	5.7	5.2-6.7
		NO LAB TESTING		
8 - 17	8/5	+3 A, -0.1 OX, +1 OL, +0.15 BZ, +10 S, +0.3 RVP, +10 T90, +5 T50, +25 DI	4.5	4.0 - 5.4
24 - 23	10/4	+3 A, -0.2 OX, +1 OL, +0.15 BZ, +15 S, +0.3 RVP, +10 T90, +10 T50	4.1	3.6 - 5.0

(1) Case 32 is the same as case 25 with Lt. Hydrocrackate split for added C5 sales.

REC
11/12/91

TABLE 3

PROPERTY LIMIT CHANGE COST REDUCTIONS

FROM 1996 CASE RESULTS COMPARISONS

WSPA STUDY OF CARB PHASE 2 GASOLINES

(¢/G of base gasoline - constant 1991 $)

CASES DELTA	PROPERTY INCREMENT / DECREMENT	CALCULATED COST REDUCTIONS TYPICAL	RANGE
	RVP(PSI)		
8 - 9	+0.4 RVP: 6.7 to 7.1	1.3	1.2 - 1.4 *
8 - 22	+0.2 RVP: 6.7 to 6.9	0.9	0.8 - 1.0 *
22 - 9	+0.2 RVP: 6.9 to 7.1	0.4	0.3 - 0.5 *
	AROMATICS(%)		
15 - 10	+3 A: 22 to 25	1.5	1.1 - 2.1
	OLEFINS ESTIMATE(%)		
3/4/8/10/12/13/14	+3.4 OL: 4 to 7.4	2.1 #	1.9 - 2.5 #
8/9/13/14/20	+2.3 OL: 7.4 to 9.7	0.5 #	0.3 - 0.6 #
3/4/8/10/12/13/14/16	+3.1 OL (C5 OL = 0): 4 to 7.1	1.7 #	1.4 - 2.1 #
	SULFUR ESTIMATE(PPM)(1)		
28 - 29	+50 S: 30 to 80	1.4	1.2 - 1.6
	COMBINED T90(°F) & T50 / DI		
5 - 3	+33 T90: 295 to 328	4.0	3.8 - 4.7
8 - 10	+30 T90: 290 to 320, No T50/DI	3.4	3.3 - 3.7
8 - 11	+15 T90: 290 to 305, No T50/DI	2.2	2.1 - 2.3 *
11 - 10	+15 T90: 305 to 320, No T50/DI	1.2	1.1 - 1.4
	COMBINED T50(°F) & DI		
21 - 19	+6 T50, +28 DI	6.1	5.6 - 7.2
	COMBINED OLEFIN (%) & SULFUR (PPM)		
10 - 14	+3.4 OL, +60 S	3.3	2.8 - 4.0
28 - 29	+1.0 OL, +50 S	1.8	1.5 - 2.1
	COMBINED - ALL BUT OXYGEN		
8 - 18	+3 A, +3.4 OL, +30 S, +0.4 RVP, +15 T90, No T50/DI	6.2	5.6 - 7.2
3/4/8/9/10/11/12/13/14/15	Sum of Cost of Indiv. Property Changes from Cases 8 to 18	7.6 #	7.0 - 9.0 #

(1) Corrected by 0.4 ¢/G for Olefin change (7 to 8%) using Olefin cost curve.

* Adjusted for rounding to encompass typical.

Estimated costs calculated from multiple cases.

REC
11/6/91

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TABLE 4
SUMMARY OF CALCULATED COSTS
1996 CASE RESULTS – INCREASE OVER BASE CASE
WSPA STUDY OF CARB PHASE 2 GASOLINE
(Constant 1991 $)

CASE	DESCRIPTION	MAXIMUM PROPERTY CONTROL LIMITS (1)								CALCULATED COSTS	
		A	OX	OL	BZ	S	RVP	T90	T50	¢/G	MMM$/YR
	HAND CASES										
-	WSPA 1 (A +20S)	25	1.8	7	0.8	50	7.1	295	195	13.0	2.03
-	WSPA 2 (B −30S)	25	1.8	8	0.8	60	7.1	320	-	9.7	1.52
-	WSPA 3 (A +20S, +15 T90, +10 T50)	25	1.8	7	0.8	50	7.1	310	205	11.1	1.73
-	GM Target (1 % C8A+)	12	4.3	3	0.8	20	6.6	240	180	~50	~8

(1) OX = Oxygen is the only minimum control limit.

REC – 11/12/91

TABLE 5
SUMMARY OF CALCULATED COST CHANGES(1)
FOR PROPERTY CHANGES
WSPA STUDY OF CARB PHASE 2 GASOLINE
(Constant 1991 $)

PROPERTY	PROPERTY CHANGE From	To	CALCULATED COST INCREASE ¢/G	MMM$/YR
Aromatics, V%	34	32	0.4	0.06
	32	25	1.4	0.22
	25	22	1.5	0.23
	22	20	1.2	0.19
Olefins, V%	11	10	0.1	0.02 -
	10	8	0.2	0.03
	8	7	0.4	0.06
	7	5	1.2	0.19
	5	3	1.2	0.19
Sulfur, WPPM	206	150	0.3 +	0.05
	150	50	1.3 -	0.20 -
	50	30	0.7 -	0.10
	30	20	0.7 -	0.10
T90, °F	348	329	0.8 +	0.13
	329	310	1.4 -	0.21
	310	300	1.1	0.17
	300	295	0.7	0.11
	295	290	0.8 -	0.12
	290	280	2.3	0.36
RVP, psi	7.5	7.1	0.5	0.08
	7.1	6.9	0.5 +	0.08 +
	6.9	6.6	1.1	0.18
Benzene, V%	2.2	0.95	1.5	0.23 +
	0.95	0.8	0.4	0.06 +
	0.8	0.6	0.8	0.13

(1) Assuming property limits shift in combinations that allow all property limits to be met simultaneously.

REC - 11/12/91

TABLE A-1

INVESTMENT ASSUMPTIONS

WSPA STUDY OF CARB PHASE 2 GASOLINE

- Investment costs are the mid-1991 curve costs shown in LP model data Table I enclosed. Process code names are listed in LP model data Table CAP attached.
- The investment required to meet Base Case 0 demands without gasoline reformulation is sunk investment. Allow the LP models to add economic capacity as required, using fixed cost factors shown in Table A-6.
- Process facilities investment sized by model for each case based on one new unit per refinery. New unit minimum size is 2.0 MBPSD.
- Existing unit capacity can be expanded by up to 20%, based on an equal % of the current investment cost for the average size of the existing units.

REC
11/4/91

TABLE CAP
UNIT CAPACITIES AND INVESTMENT DATA
WSPA STUDY OF CARB PHASE 2 GASOLINE

* ALL PROCESS UNITS ARE IN MB/CD EXCEPT SULFUR WHICH IS MST/CD.
* ALL PROCESS CAPACITIES ARE BASED ON FEED RATE EXCEPT FOR
* ALKYLATION,HYDROGEN,SULFUR,AROMATICS,LUBE /WAX, WHICH ARE
* BASED UPON PRODUCT RATE.
* POWER GENERATION CAPACITY IS MKW*24
* STEAM PRODUCTION IS MLB/HR
*

UNIT NAME		COST OPTION	MB/SD	MB/CD	MB/CD	MB/CD	NO. REF.
COL 7	30	34	42	48	54	60	66

* PADD V CAL CONVERSION, FEBRUARY 1990
* 1/89 CAPACITIES+CAP UNDER CONSTRUCTION+NO CREEP
* TO 1/1995

UNIT NAME	SYMBOL				STD SIZE MBPD	CAPACITY BASE	MIN	MAX	NO OF REFIN
	H>	V	I	T	SCP	BAS	MIN	MAX	NRF
CRUDE DISTILLATION	ACU	1			70	119.6		119.6	17
HEAVY NAPHTHA SPLITTER	NFS		1		7.7	0		10	
BT NAPTHA SPLITTER	LNS		1		4	0		10	
COKER DELAYED	KRD	1			20	23.755		23.755	
COKER FLUID	KRF	1			20	5.3		5.3	
COKER NAP SPLITTER	KNS	1			2	0		0	
COKER L GASO DS/SPL	CGS		1		2.5	0		10	
VISBREAKER & THRM CRKR	VBR	1			20	2.3		2.3	
SOLVENT DEASPHALTER	SDA	1			20	2.59		2.59	
NAPHTHA HYDROTREATER	NDS	1			25	24.8		24.8	
DISTILLATE HDS	DDS		1		10.4	21.98		100	
FCC FEED HYDROFINER	FDS		1		36	31.8	31	100	
VAC RESID HYDROFINER	RDS	1			15	1.4		1.4	
ATM RESID HYDROFINER	ARD	1			30	0		0	
CAT REFORMER 450 PSI	RFH	1			20	8.85	6.6	8.85	
CAT REFORMER 200 PSI	RFL	1			20	16.6		16.6	
CAT REF(CONT)100 PSI	RFC	1			20	3.39	3.1	3.39	
REFORMATE FRACTIONAT	RFT		1		14.8	0		100	
AROMATIC EXTRACT/FRACT	AEF	1			2	0		0	
BENZENE SATURATION	BSU		1		4.8	0		10	
FLUID CAT CRACKER	FCC	1			35	36.8		36.8	
FCC GASO SPLITTER	FGS		1		21.9	0		100	
FCC GASO FRACT	FGF	1			22.2	17		17	
FCC GASO HDS	GDS		1		2	0		10	
GASO AROMATICS SATUR	GAS		1		2	0		10	
DIESEL AROMATICS SAT	DAS		1		13.3	11.72		100	
HYDROCRACKER-2 STAGE	HCR		1		19.2	16.9		100	
HYDROCRACKER-LOW CONV	HCL	1			15	4.2	3.2	4.2	
HYDROCRACKER-HVY GASO	LHC		1		4.6	0		10	
HYDROCRK H GASO TO C4	HC4		1		4.6	0		10	
HYDROCRACKATE SPLITTER	HCS		1		2	0		25	
RESID HYDROCONVERSION	RHC	1			18	0		0	
ALKYLATION PLANT	ALK		1		5.4	6.60		100	
ALKYLATE SPLITTER	AKS		1		5.3	0		100	
OLEFIN CAT POLY	PLM	1			2	0.50		0.50	
IC4 DEHYDROGENATION	C4D	1			15	0		0	
MTBE UNIT	BEU		1		1.63	0.85		10	
TOL DEALKYLATION	HDA	1			5	0		0	
LUBE/WAX PLANT	LUB	1			7	1.3		1.3	
PEN/HEX ISOMERIZATION	PHI		1		7	0		10	
TIP PEN/HEX ISOM	TIP		1		7	.38		10	
BUTANE ISOMERIZATION	C4I		1		2.	0.28		10	
HYDROGEN PLT MBPD FOE	H2P		1		2.6	3.36	2.7	10	
SULFUR PLANT, MLT/D	SUL	1			.10	.167		.167	
FUEL MIXING (FOE)	FUM	1			10	20		20	
STEAM PRODUCED,MLB/HR	STG	1			150	600		600	
POWER GENERATION,MKW	KWG	1			200	0		0	
PLANT FUEL ADJUSTMENT	PFA	1			2	10		10	
REFINERY LOSS	REL	1			2	10		10	

* V I T ARE USED TO SELECT WHETHER THE OBJECTIVE SEES ONLY VARIABLE
* COSTS (V), INCREMENTAL INVESTMENT COSTS (I) OR TOTAL
* INVESTMENT COSTS-INCLUDING LABOR (T)
* INVESTMENTS ARE CALCULATED FOR CAPACITY USED OVER BASE (BAS)
* (SCP) IS THE STANDARD SIZE FOR NEW CAPACITY
* (MAX)(MIN) LIMIT THE TOTAL CAPACITY USABLE IN A RUN (BASE , NEW)
* (NRF) IS THE NUMBER OF REFINERIES REPRESENTED BY THIS MODEL
* ASSUME 50% OF 450 PSI REFM UPGRADED
* TO 200 PSI @ 91% OF FORMER CAPACITY

TABLE I
BASIC INVESTMENT DATA
WSPA STUDY OF CARB PHASE 2 GASOLINE

* TABLE I IS A CONTINUATION OF TABLE CAP AND CONTAINS BASIC
* INVESTMENT DATA (MID 1991 GULF COAST, NII=1250)
* (CAP) IS THE BASIC UNIT SIZE FOR WHICH INVESTMENT DATA IS PROVIDED
* (STF) IS THE ON-STREAM FACTOR FOR CONVERTING FROM MB/SD TO MB/CD.
* (BLI) IS THE BATTERY LIMITS INVESTMENT ($MM) FOR A UNIT WITH THE
* SIZE INDICATED UNDER (CAP). BLI INCREASED TO 118% OF GULF
* COAST FOR VCC COSTS INCL. MORE STRINGENT ENVIRONMENTAL COST.
* (BLE) IS THE EXPONENT USED TO CALCULATE THE INVESTMENT FOR A UNIT
* IF THE SIZE (SCP IN TABLE CAP) DIFFERS FROM (CAP).
* (CAT) IS THE INITIAL CATALYST CHARGE ($MM) FOR A UNIT OF SIZE (CAP
* (PDR) IS THE PAID-UP-ROYALTY CHARGE ($MM) FOR A UNIT OF SIZE (CAP)
* (MAN) IS THE NUMBER OF SHIFT POSITIONS REQUIRED FOR NEW UNIT.
* (OFF) IS THE FRACTION OF BATTERY LIMITS INVESTMENT REQUIRED FOR
* OFF SITE FACILITIES.
* (CHG) (.242) IS THE CAPITAL CHARGE ON NEW FACILITY INVESTMENTS
* REQUIRED TO EARN A 15 PCT DCF ROR INCLUDING 2 YR CONST. PERIOD
* COL 7 18 24 30 36 42 48 54 60 66
*

	CAPACITY MBPD	OPER FACTOR	ON SITE INVEST $MM	EXP	CATALYST $MM	ROYALTY $MM	SHIFT MEN	FRACT OFF SITE	CAPIT CHARG
	CAP	STF	BLI	BLE	CAT	PDR	MAN	OFF	CHG
ACU	50	.96	41.5	.7			2	0.5	.242
NFS	15	.95	5.4	.7			.5	.4	.242
LNS	15	.95	5.4	.7			.5	.4	.242
KRD	25	.95	97.4	.6			4	0.6	.242
KRF	25	.95	121.5	.65			4	0.5	.242
KNS	15	.95	6.2	.7			.5	.4	.242
CGS	3	.95	3	.65		0.1	0.5	0.5	.242
VBR	30	.88	22.1	.65			1.5	0.5	.242
SDA	10	.88	10.6	.6	.06		1	0.4	.242
NDS	15	.88	13.6	.6	.09		.5	0.5	.242
DDS	15	.88	15.9	.65	.09		1	0.5	.242
FDS	20	.88	35.6	.65	.28		1	0.4	.242
ARD	40	.88	61.1	.65	2.3	2.0	2	0.5	.242
RDS	20	.88	57.2	.65	2.0	2.0	2	0.5	.242
RFH	15	.88	24.6	.65	.9	.8	1	0.5	.242
RFL	15	.88	27.5	.65	1.2	1.0	1	0.5	.242
RFC	15	.88	34.3	.65	1.2	1.0	1	0.5	.242
RFT	15	.88	10.2	.7			.5	.4	.242
AEF	6	.88	17.8	.6		.37	1	.4	.242
BSU	10	.83	13.5	.65	2	1.0	1	.4	.242
FCC	40	.95	114.5	.65	.8	3.9	3.5	0.4	.242
FGS	20	.95	19.7	.7			1	0.4	.242
FGF	15	.95	5.4	.7			.5	.4	.242
GDS	15	.88	14.6	.6	.2		.5	.4	.242
GAS	10	.88	36.6	.65	.5	.6	1.5	.4	.242
DAS	20	.88	47.6	.65	.5	.6	1.5	.4	.242
HCR	20	.88	82.1	.65	3.5	3.5	2	0.5	.242
HCL	20	.88	60.8	.65	2.5	2.5	2	.5	.242
LHC	10	.88	55.0	.65	1.6	1.8	2	.4	.242
HC4	10	.88	57.3	.65	1.2	2	2	.5	.242
HCS	15	.95	6.0	.7			.5	.4	.242
RHC	20	.88	249.5	.65	1.0	5	6	.253	.242
ALK	7	.83	24.3	.65			2	0.4	.242
AKS	15	.83	5.4	.7			.5	.4	.242
PLM	2	.83	5.4	.65	.2	.3	1	0.4	.242
C4D	13.6	.83	89.0	.65	14.9	7.0	2	0.35	.242
BEU	3	.83	8.1	.6	.1	.6	1	0.4	.242
HDA	3	.88	10.6	.65	.3	.6	.5	0.4	.242
LUB	2	.88	78.4	.65			3	0.6	.242
PHI	5	.88	14.6	.65	.7	1	1	0.4	.242
TIP	5	.88	25.7	.7	.9	2	1	0.4	.242
C4I	2	.83	6.7	.65	.2		1	0.4	.242
H2P	2.5	.83	49.3	.65	.9		1	0.4	.242
SUL	.08	.59	12.8	.6			1.5	0.4	.242
KWG	200	.86	8.9	.7			1	0	.242
STG	150	.86	4.6	.7			1	0	.242

* SULFUR INVESTMENT IS FOR ONE UNIT, INCLUDING TAILGAS.
* NO INVESTMENT DATA IS REQUIRED FOR (FUM,REL,PFA), IN TABLE CAP
* THE VALUE UNDER BAS AND UNDER MAX SHOULD BE THE SAME FOR
* EACH OF THESE PSEUDO UNITS
* 2.5 MB/D (FOE) HYDROGEN PLANT IS EQUIVALENT TO 49 MMSCF/D
* MAN POWER = 1988 SURVEY AVG X 0.7
* ALKY INCLUDES DIOLEFIN SELECTIVE HYDROGENATION UNIT COSTING $2 MM.
* PEN HEX ISOM & TIP DO NOT INCLUDE HDS UNIT INVESTMENT. NAPHTHA HDS
* CAPACITY IS USED FOR PEN/HEX ISOM & TIP FEED.

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TABLE A-2

ALLOCATION APPROACH AND FLEXIBILITY

BASE CASE 1996 LP MODEL RUNS

WSPA STUDY OF CARB PHASE 2 GASOLINE

- Start with (1) 1989 DOE U.S. supply and demands that have been sorted into our California conversion refinery model group, and (2) a supply and demand outlook for PADD V. Develop more detailed supply and demand forecasts for minor products for PADD V. Allocate the PADD V refinery raw materials and products to our three model groupings within PADD V.

- Meet forecasted PADD V refinery production for finished motor gasolines and diesel/No. 2 fuel, adjusted for BTU changes to maintain constant total vehicle miles traveled. Adjust refinery production outlook as required for kero jet, residual fuels and minor products. Allocate to our three models within PADD V (VCC – conversion in California, VCOC – conversion outside California and VS – simple).

- Fit the PADD V domestic and foreign crude runs, actual and forecast, into the types (sweet, light high sulfur and heavy high sulfur) used in the National Petroleum Council and API studies (see Table A-13). Allocate these crudes to our three model groups. Use the TM&C crude assay library and the 1989 detailed crude run property data supplied by DOE to develop the detailed crude run forecast from this allocation. Optimize rate of ANS swing crude in model VCC.

- Optimize marketable coke, catalytic coke, bunker residual fuel, C_5s, C_4s, C_3s, process gas and sulfur product rates in model runs.

- Optimize input rates for MTBE, natural gasoline, IC_4, NC_4, methanol and natural gas process feed to hydrogen plants in model runs.

- Use TM&C Gulf Coast major crude and product pricing outlook. Provide pricing for other crudes and minor products. Develop pricing for model VCC from Gulf Coast and Los Angeles values and location differentials (see Table A-5).

- Use base unit capacities in each model (see Tables A-14 and A-16). Allow models to add capacity (see Table A-1).

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TABLE A-3

PRODUCT GRADE RATIOS AND PROPERTIES

WSPA STUDY OF CARB PHASE 2 GASOLINE

- Set base future summer gasoline RVP (without compliance margin) at 7.8 psi maximum. Use 0.3 psi RVP compliance margin. Set base future winter (first and fourth quarters) gasoline RVP at 10.5 psi maximum.

	Base	CAA	CARB 2
Summer			
– Regulation Limit	7.8	7.5	7.0
– Maximum	7.5	7.1	6.7
Winter – Maximum	10.5	10.5	10.5

- The TM&C model was calibrated to 1988 and 1989 finished gasoline properties from 1989 NPRA survey for Auto/Oil and 1988 NIPER data by adjusting component data. Results fit adjusted 1989 average gasoline qualities from the NPRA survey data for aromatics and olefins within ±1.5%.

- Use outlook for gasoline grade ratios (Table A1-5) and match 1989 NPRA refinery survey octane results by grade.

Leaded Regular	88.2
Unleaded Regular	87.4
Unleaded Midgrade	89.3*
Unleaded Premium	92.0
Gasoline Pool – Clear	
1989	88.5
1996	89.0

* Estimated

- Assume 95% of diesel is 0.05% sulfur in California (100% in VCC model). Assume a 10% aromatic limit on 80% of diesel and no aromatic limit and no increase in high aromatic (cracked) components on the other 20% of diesel.

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TABLE A-4

TM&C MODEL PROCESSING OPTIONS

REFORMULATED GASOLINE STUDY

Improvement in Gasoline Quality

Sulfur

- High sulfur FCC gasoline to splitter columns
    - Heavy heavy FCC gasoline to HDS unit
    - Medium/heartcut FCC gasoline to HDS unit and cat reforming
    - Heavy heavy FCC gasoline to resid cutter
    - Heavy heavy FCC gasoline to aromatics saturation unit and distillate blending
    - C_6 FCC gasoline to naphtha HDS, fractionation and isomerization
    - C_5 FCC gasoline to TAME, alkylation, naphtha HDS, fractionation
- High sulfur FCC feed to HDS unit
- High sulfur atmospheric resid to ARDS unit and FCC feed
- Light coker gasoline to naphtha HDS, fractionation and isomerization
- Light coker gasoline to sulfur extraction (chemical), splitter; C_5s to TAME, alkylation; C_6 to naphtha HDS, fractionation and isomerization
- Light straight run/natural gasoline to naphtha HDS

Benzene

- Reformer feed to prefractionator to concentrate benzene precursors and reduce reformate splitting required
- Reformate to splitter columns
    - Light reformate to benzene saturation
- Light straight run to naphtha HDS, distillation and isomerization
- Light coker gasoline to naphtha HDS, distillation and isomerization
- Light hydrocrackate to benzene saturation
- Bypass reformer – benzene precursors
    - Increase cut point on light straight run gasoline to gasoline blending or isomerization
    - Fractionate medium hydrocrackate out of heavy hydrocrackate and blend to gasoline

Olefins/Bromine Number

- FCC gasoline to multiple splitter columns
    - FCC isoamylene to TAME
    - FCC C_5 olefins to alkylation
    - FCC C_6 olefins to naphtha HDS, distillation and isomerization
    - Medium FCC gasoline to naphtha HDS and cat reforming
    - Heartcut FCC gasoline to naphtha HDS and cat reforming
    - Heavy heavy FCC gasoline to gasoline HDS unit
    - Heavy heavy FCC gasoline to aromatics saturation and distillate blending

  - Heavy heavy FCC gasoline to resid cutter
  - Heavy heavy FCC gasoline to new gasoline hydrocracker to 300°F- or to C_4s
- Reduce FCC conversion level and feed rate
- Increase FCC feed hydrotreating
- Reduce FCC resid cracking
- Shut down polymer and dimersol unit and send C_3/C_4 olefins to alkylation
- Light coker gasoline to naphtha HDS, distillation and isomerization

Aromatics
- Reduce reformer severity
- Naphtha to splitter columns
  - Heavy heavy naphtha to distillate HDS and kero jet blending
  - Heavy heavy naphtha to new gasoline hydrocracker to 300°F- or to C_4s
- FCC gasoline to splitter columns
  - Heavy heavy FCC gasoline to resid cutter
  - Heavy heavy FCC gasoline to new gasoline hydrocracker to 300°F- or to C_4s
  - Heavy heavy FCC gasoline to aromatics saturation and distillate blending
- Reformate to splitter columns
  - Heavy reformate to resid cutter
  - Heavy reformate to new gasoline hydrocracker to 300°F- or to C_4s
  - Heavy reformate to aromatics saturation and distillate blending
- Reduce heavy hydrocrackate cut point to 300°F
  - Hydrocrack heavy hydrocrackate to 300°F- on gasoline operation
  - Switch to maximum jet operation
- Bypass reformer – higher cut point on light gasolines, lower cut point on kerosene
  - Medium (BT) naphtha to gasoline blending
  - Medium hydrocrackate to gasoline blending
  - Heavy heavy naphtha to distillate HDS and kero jet blending
  - Heavy heavy naphtha to new gasoline hydrocracker to 300°F- or to C_4s
- Coker naphtha to splitter column
  - Heavy heavy coker naphtha to resid cutter
  - Heavy heavy coker naphtha to aromatics saturation and distillate blending
  - Heavy heavy coker naphtha to new gasoline hydrocracker to 300°F- or to C_4s

90% Distilled
- Same as aromatics reduction options except no reformer severity reduction, no medium naphtha or medium hydrocrackate to gasoline blending
- Alkylate fractionation
  - Heavy alkylate to JP-4 blending
  - Heavy alkylate to distillate blending
  - Heavy alkylate to new gasoline hydrocracker to 300°F- or to C_4s

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TABLE A-5

AVERAGE TM&C SPOT PRICING OUTLOOK[1]

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Gulf Coast			California
	Annual		Second and Third Quarters	
	1989	1996	1996	1996
Major Products, ¢/G				
Unleaded Regular Gasoline	55.6	58.0	59.5	65.5
Unleaded Premium Gasoline	61.5	63.0	65.0	71.0
Jet Fuel A-Kero	55.1	57.0	55.5	60.0
Distillate Fuel (0.25% Sulfur)	51.8	53.5	52.0	56.5
Distillate Fuel (0.05% Sulfur)	-	-	55.0	59.5
Residual Fuel (1% Sulfur), $/B	16.21	15.80	15.00	15.30
Residual Fuel (3% Sulfur), $/B	13.30	13.00	12.60	13.00
Major Crudes, $/B[2]				
Domestic – West Texas Intermediate	19.64	20.00	19.80	-
– West Texas Sour	18.13	18.22	18.02	-
– Alaska North Slope	17.40	17.45	17.20	16.70
– California Kern River	-	-	-	12.80
Foreign – United Kingdom Brent	19.37	19.90	19.60	-
– Dubai	17.54	18.10	17.85	-
– Mexico Isthmus	18.07	17.82	17.62	-
– Mexico Maya	15.13	14.42	14.23	-
– Saudi Light	-	-	17.95	17.60
– Saudi Heavy	-	-	16.50	16.15
Other, ¢/G				
Natural Gasoline	41.2	48.0	49.5	50.0
Iso-Butane	36.4	43.0	43.0	55.0
Normal Butane	28.6	35.0	38.3[3]	33.1[4]
Propane	22.7	30.0	29.0	32.6
Natural Gas, $/MMBTU[2]	-	2.30	2.20	3.25
MTBE	89.0	89.5	93.0	96.0 –
Methanol	-	-	60.0	65.0

(1) Based on constant 1991 dollars.
(2) Delivered.
(3) To Petrochemicals
(4) To fuel.

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TABLE A-6

TM&C FIXED COSTS FACTORS

FOR ADDED PROCESS FACILITIES

WSPA STUDY OF CARB PHASE 2 GASOLINE

	% of Investment	
	Annual Cost	Initial
Initial Cost		
Investment – Gulf Coast	-	100
Investment – California[1]	-	118
Owner Engineering and Start-Up	-	10
Operating Costs		
Capital Charge[2]	24.2	-
Maintenance		
On-Site	4.0	-
Off-Site	2.0	-
Taxes and Insurance	1.5	-
Miscellaneous Fixed Costs	0.6	-
Operator Wages Average $16/hour		
Salaries and Wages of All Other Refinery Personnel[3] is 222% of Process Operators' Wages		
Benefits @ 36% of Salaries and Wages		

[1] Includes 3% premium for emissions offsets and extra permitting costs.

[2] Based on 15% DCF annual rate of return, fifteen-year project life, ten-year tax life, double declining balance tax depreciation (10% in first year), 39% income tax rate (including 5% state) and two-year construction time.

[3] All refinery personnel except process operators and maintenance. Includes off-site operators, supervisory, administrative, technical, laboratory and clerical.

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TABLE A-7

U.S. ANNUAL PRODUCT DEMAND GROWTH RATE

ACTUAL AND OUTLOOK

WSPA STUDY OF CARB PHASE 2 GASOLINE

(% change/year)

	Actual 1989 vs. 1984	Outlook 1996 vs. 1989
Motor Gasoline	1.8	0.4
Jet – Naphtha	(0.8)	0.7
Kero Jet/Kerosene	5.2	1.6
Diesel/No. 2 Fuel	1.8	1.2
Residual Fuel	(0.9)	0.0
Asphalt	3.3	1.7
Natural Gas Liquids	0.2	1.6
Other Products	(0.2)	1.1
Total Products	1.4	0.9
Crude Run	2.2	0.6
Domestic Crude Production	(2.8)	(1.3)

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TABLE A-8

U.S. ANNUAL PRODUCT DEMANDS

ACTUAL AND OUTLOOK

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPCD)

	Actual		Outlook
	1984	1989	1996
Motor Gasoline	6,692	7,319	7,524
Jet – Naphtha	223	214	224
Kero Jet/Kerosene	1,068	1,379	1,545
Diesel/No. 2 Fuel	2,844	3,103	3,370
Residual Fuel	1,369	1,306	1,306
Asphalt	408	479	538
Natural Gas Liquids	1,772	1,789	2,006
Other Products	1,650	1,630	1,715
Total Products	16,026	17,219	18,228
Crude Run	12,044	13,420	14,035
Domestic Crude Production	8,879	7,726	7,060

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TABLE A-9

U.S. 1989 ANNUAL SUPPLY AND DEMAND – ACTUAL

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPCD)

	Supply					Demand		
	Field Produc-tion	Imports	From Inven-tory	Net Receipts	Refinery Produc-tion	Refinery Input	Exports	Products Demand
Crudes								
Domestic	7,726		(14)	37		7,649	136	(36)
Foreign		5,808		(37)		5,771		1
[Total Crudes]	7,726	5,808	(14)			13,420	136	(35)
Products – NGL / Unfin.								
Natural Gasoline	313	7	(3)	(0)	0	185	7	125
Ethane	485	8	(27)		14	5		476
Propane	474	107	17	(0)	396	11	24	959
Normal Butane	155	52	12	5	142	149	11	207
Iso – Butane	150	8	4	(0)	15	146		31
[Sub-Total] *	1,577	182	5	5	568	497	42	1,789
Unfinished Oils								
Mogas Components								
Oxygenates and Other								
[Sub-Total] *								(158)
[Total – NGL / Unf & Other]*	1,577	795	(7)	0	568	1,101	111	1,631
Products – Finished								
Motor Gasoline		408	(5)		6,933		16	7,319
Aviation Gasolines			(1)		27			27
Naphtha Jet		3			212			214
Kero Jet		102	(7)	(0)	1,209		21	1,284
Kerosene		14	(2)		84		1	95
Diesel / No. 2		300	(22)		2,905		80	3,103
Residual Fuels		594	(3)		930		215	1,306
Petrochem Naphtha *					172			512
Lube and Wax *					193			172
Marketable Coke – 400 #B					335		231	104
Asphalt / Road Oil		34	1		445			479
Others *					518			279
Process Gas – FOE					683			683
[Total Products]	1,577	2,250	(45)	0	15,214	1,101	676	17,219
Total Crudes and Products	9,303	8,059	(59)	0	15,214	14,521	812	17,184
(Gain) / Loss					(694)			

* Individual rows do not balance due to incomplete data.

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TABLE A-10

U.S. 1996 ANNUAL SUPPLY AND DEMAND – OUTLOOK

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPCD)

	Supply					Demand		
	Field Production	Imports	From Inventory	Net Receipts	Refinery Production	Refinery Input	Exports	Products Demand
Crudes								
Domestic	7,060		(7)	(3)		7,052	101	(100)
Foreign		6,980		3		6,983		0
[Total Crudes]	7,060	6,980	(7)			14,035	101	(100)
Products - NGL / Unfin.								
Natural Gasoline	305							
Ethane	493							
Propane	492							
Normal Butane	149							
Iso - Butane	147							
[Sub-Total] *	1,586				512			2,006
Unfinished Oils								
Mogas Components								
Oxygenates and Other								
[Sub-Total] *	0							(158)
[Total - NGL / Unf & Other]*	1,586	1,078	(8)		512	1,137	100	1,848
Products - Finished								
Motor Gasoline		409	(2)		7,135		18	7,524
Aviation Gasolines					28			28
Naphtha Jet		3			221			224
Kero Jet		112	(2)		1,363		18	1,454
Kerosene		14			78		1	91
Diesel / No. 2		378	(5)		3,074		77	3,370
Residual Fuels		564	(3)		979		234	1,306
Petrochem Naphtha *					192			571
Lube and Wax *					216			176
Marketable Coke - 400 #B					348		246	101
Asphalt / Road Oil		37	(1)		502			538
Others *					560			304
Process Gas - FOE					691			691
[Total Products]	1,586	2,595	(21)	0	15,899	1,137	694	18,228
Total Crudes and Products	8,649	9,575	(28)		15,899	15,172	795	18,129
(Gain) / Loss					(727)			

* Individual rows do not balance due to incomplete outlook data. The sum of all * rows balances.

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TABLE A-11

U.S. 1989 SUMMER SUPPLY AND DEMAND – ACTUAL DOE

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPCD)

	Supply					Demand		
	Field Production	Imports	From Inventory	Net Receipts	Refinery Production	Refinery Input	Exports	Products Demand
Crudes								
Domestic	7,641		(45)	(2)		7,715	129	(250)
Foreign		6,011	(62)	4		5,953		0
[Total Crudes]	7,641	6,011	(107)	2		13,668	129	(250)
Products - NGL / Unfin.								
Natural Gasoline	319	7	(19)	0		148	7	152
Ethane	466	8	(38)	(1)	15	5		445
Propane	470	96	(153)	1	393	12	24	771
Normal Butane	153	45	(87)	(1)	182	62	13	218
Iso - Butane	150	8	(5)	0	17	155		15
[Sub - Total]	1,558	164	(302)	(1)	607	382	44	1,600
Unfinished Oils		372	7	1		550		(170)
Mogas Components		55		0		(6)		61
Oxygenates and Other	56		(1)	0		52		3
[Sub - Total]	56	427	6	1		596		(106)
[Total - NGL / Unf & Other]	1,614	591	(296)	0	607	978	44	1,494
Products - Finished								
Motor Gasoline		365	17	(1)	7,052		47	7,385
Aviation Gasolines				(1)	28			27
Naphtha Jet		4	(2)	0	212			214
Kero Jet		104	(21)	(1)	1,148		13	1,218
Kerosene		1	(8)	1	60		1	53
Diesel / No. 2		276	(141)	2	2,836		79	2,894
Residual Fuels		528	(39)	(1)	901		210	1,179
Petrochem Naphtha		64		(2)	116		5	173
P / Chem Gas Oil + C. Black		56		0	236		23	269
Special Naphtha / Misc.		6	(3)	0	61		14	50
Lube and Wax		12	(3)	1	181		20	171
Marketable Coke - 400 #B		1	(1)	0	336		240	96
Catalytic Coke - 400 #B					215			215
Asphalt / Road Oil		36	57	1	514		5	603
Others		2		0	66		2	67
Process Gas - FOE					703			703
[Total Products]	1,614	2,045	(440)	(1)	15,272	978	700	16,812
Total Crudes and Products	9,255	8,056	(547)	1	15,272	14,646	830	16,562
(Gain) / Loss					(626)			

Note: Rows and columns may not balance due to rounding.

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TABLE A-12

U.S. 1996 SUMMER SUPPLY AND DEMAND – OUTLOOK

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPCD)

	Supply					Demand		
	Field Production	Imports	From Inventory	Net Receipts	Refinery Production	Refinery Input	Exports	Products Demand
Crudes								
Domestic								
Foreign								
[Total Crudes]								
Products - NGL / Unfin.								
Natural Gasoline								
Ethane								
Propane								
Normal Butane								
Iso - Butane								
[Sub - Total]								
Unfinished Oils								
Mogas Components								
Oxygenates and Other								
[Sub - Total]								
[Total - NGL / Unf & Other]								
Products - Finished								
Motor Gasoline		426	23		7,271		17	7,702
Aviation Gasolines					32			33
Naphtha Jet		3	1		228			232
Kero Jet		113	(5)		1,324		9	1,422
Kerosene		7	(6)		58			59
Diesel / No. 2		337	(212)		3,036		71	3,089
Residual Fuels		498	(2)		929		215	1,210
Petrochem Naphtha								
P / Chem Gas Oil + C. Black								
Special Naphtha / Misc.								
Lube and Wax								
Marketable Coke - 400 #B			8		348		257	98
Catalytic Coke - 400 #B								
Asphalt / Road Oil		44	49		633			726
Others								
Process Gas - FOE								
[Total Products]		1,428	(143)		13,858		571	14,572
Total Crudes and Products								
(Gain) / Loss								

Note: Rows and columns may not balance due to rounding.

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TABLE A-13

U.S. CRUDE RUNS ACTUAL & OUTLOOK

TYPES OF DOMESTIC AND IMPORTED – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

		ACTUAL				OUTLOOK	
		1984(1)	1985	1988	1989(2)	1996	
TYPES							
Domestic	Sweet	4,728	4,663	3,740		2,900	
	Lt Hi Sulfur	818	812	731		630	
	Hvy Hi Sulfur	3,152	3,326	3,668		3,522	(3)
	Subtotal	8,698	8,801	8,139	7,715	7,052	
Imported	Sweet	1,583	1,580	2,051	2,322	2,300	+(4)
	Lt Hi Sulfur	418	384	935	1,090	1,100	+
	Hvy Hi Sulfur	1,345	1,237	2,121	2,541	2,500	+
	Subtotal	3,346	3,201	5,107	5,953	6,983	
Combined	Sweet	6,311	6,243	5,791		5,200	+
	Lt Hi Sulfur	1,236	1,196	1,666		1,730	+
	Hvy Hi Sulfur	4,497	4,563	5,789		6,022	+
	Total	12,044	12,002	13,246	13,668	14,035	

- Definition of crude types (NPC/TM&C): Sweet ≤0.50%s, Lt ≤15% vac resid @ 1050° F.

(1) From NPC survey and report.

(2) TM&C data from DOE for 2nd & 3rd qtrs.

(3) ANS (included in Heavy Hi Sulfur)rates are 1779, 1975, 1850 and 1872 MBPD in '85, '88, '89 and '96 respectively.

(4) Give LP flexibility to import up to 300 MBPCD more or less sweet than shown and to optimize import rates of various high sulfur Saudi Arabian crudes above minimums shown.

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TABLE A-14

REFINERY PROCESS CAPACITIES BASIS

WSPA STUDY OF CARB PHASE 2 GASOLINE

- Start with all operable refineries as of January 1, 1989, reported by DOE in the 1988 *PSA*.
- Add changes in process unit capacity from January 1, 1989 to January 1, 1991, reported by DOE in 1988 and 1990 PSAs.
- Add process unit capacity that is under construction and was not completed by January 1, 1991, according to *Hydrocarbon Processing* and *Oil & Gas Journal* through 4/91.
- Add some 1/1/90 unit capacities indicated in Auto/Oil survey not shown by published data.
- Exclude refineries that reported no inputs to DOE in 1988.
- Add refineries that have announced restarts and have actively begun the restart process.
- Delete refineries that have announced pending shutdowns. Deletion of some downstream equipment when indicated by announcement.
- Assume following maximum utilizations of stream day capacities:

	2nd and 3rd Qtrs.		1st and 4th Qtrs.	
	VCC	U.S. Average	VCC	U.S. Average
Crude	96	95	96	95
FCC/Coking	95	92	88	88
Hydrocracking	88	86	85	82
Dependent Downstream[1]	83	85	80	81
Other Downstream	88	91	85	87

[1] Units for which operation is dependent on simultaneous operation of other downstream units, i.e., alkylation, polymerization, C_4 isomerization, hydrogen and MTBE.

Sulfur recovery maximum utilization of stream day capacities is: 59% in model VCC.

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TABLE A-15

ACTUAL AVERAGE UTILIZATION DATA - %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	CAPACITY %	WINTER QUARTERS 1987	SUMMER QUARTERS 1988	WINTER QUARTERS 1988	SUMMER QUARTERS 1989	WINTER QUARTERS 1989	SUMMER QUARTERS 1990	WINTER QUARTERS 1990	ANNUAL AVERAGE 1987-90	SUMMER QUARTERS AVERAGE	WINTER QUARTERS AVERAGE
FCC											
US	100.0	81.8	87.2	84.9	91.8	80.7	87.0	83.8	85.3	88.7	82.8
PADD I	15.0	91.5	90.8	90.7	95.5				92.1 *		
PADD III	65.0	82.6	89.5	88.0	95.9	80.9	88.3	83.3	86.9	91.2	83.7
PADD V	20.0	81.6	85.5	80.5	93.0	79.2	85.9	87.8	84.8	88.1	82.3
HCKR											
US	100.0	77.4	79.1	75.9	78.4	71.0	74.4	71.0	75.3	77.3	73.8
PADD I	7.0	74.3	78.9	62.9	88.3				76.1 *		
PADD III	49.0	77.9	71.8	71.4	80.9	66.4	70.4	68.3	72.4	74.4	71.0
PADD V	44.0	81.6	86.9	85.9	76.2	81.6	78.7	76.1	81.0	80.6	81.3
COKER											
US	100.0	89.0	89.3	89.5	90.4	86.3	85.1	84.1	87.7	88.3	87.2
PADD I	7.0	89.9	85.0	88.1	74.5				84.4 *		
PADD III	51.0	95.2	90.9	93.5	95.8	90.9	86.9	85.2	91.2	91.2	91.2
PADD V	42.0	85.2	89.8	87.6	90.7	82.6	84.1	84.9	86.4	88.2	85.1
CRUDE											
US	100.0	79.5	83.4	82.1	84.9	84.8	86.7	89.5	84.4	85.0	84.0
PADD I	13.0	81.8	85.0	84.1	81.8				83.2 *		
PADD III	61.0	80.0	81.5	81.2	84.5	82.7	87.9	83.4	83.0	84.7	81.8
PADD V	26.0	75.2	82.5	81.4	85.5	86.2	87.7	88.1	83.8	85.3	82.7

* Annual average 1987-1989.

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TABLE A-16

REFINERY PROCESS UNIT CAPACITIES DETAIL

EXISITING[(1)] BEFORE REQUIRED ADDITIONS

WSPA STUDY OF CARB PHASE 2 GASOLINE

	VOCC	VCC	VS	Estimated U.S. Total
Number of Refineries	7	17	23	202
Feed Rate				
Crude – Atmospheric	657	2,119	428	16,216
Crude – Vacuum	262	1,231	169	7,058
Catalytic Cracking	128	659	-	5,392
Hydrocracking	61.5	327#	-	989
Hydrocracking (Low Conversion)	15.4	81.8#	-	247
Coking – Delayed	70.0	409	-	1,348
Coking – Fluid	-	94.5	-	200
Combined	70.0	504	-	1,548
Combined Coke, 400 Lb./B	17.5	102	-	351
Thermal Cracking/Visbreaking	13.0	44.8	5.0	182
Solvent Deasphalting	20.0	50.0	-	308
Catalytic Reforming				
100 psi	48.8	65.5	-	1,217
200 psi	70.0	123	6.0	700
450 psi	21.0	342	14.5	2,034
Total	140	530	20.5	3,951
Hydrotreating				
Naphtha	127#	479	20.5	3,951
Distillate	81.5	387	7.6	2,929
Heavy Gas Oil	7.5	615	13.8	1,830
Residuum	-	26.5	-	321
FCC Gasoline Fractionation#	54.0	304	-	1,501
Product Rate				
Alkylation	29.3	130	-	1,043
Polymerization	6.6	10.3	-	109
Isomerization – C_5/C_6	4.0	7.4	1.0	379
Isomerization – C_4	4.3	5.8	-	64.2
Hydrogen, MMSCFPSD	116	1,353#	-	2,994
Hydrogen, FOE	5.9	69.6#	-	155
Asphalt	1.3	35.8	102	800
Lube	-	25.1	6.0	229
MTBE	-	4.8	-	38.2
Sulfur, MLTPD	0.3	4.3	0.7	23.2

[(1)] 1/1/91 existing (DOE *PSA* 1990), plus under construction 4/91 *Hydrocarbon Processing* and *Oil & Gas Journal*.

Increased based on NPRA survey.

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TABLE A-17

REFINERY PROCESS UNIT COUNT[1] AND PERCENTAGE[2]

1995 BASE[3] BEFORE REQUIRED ADDITION – VCC

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Count	Percentage
Number of Refineries	17	100
Feed Rate		
Crude – Atmospheric	17	100
Crude – Vacuum	17	100
Catalytic Cracking	14	82
Hydrocracking	14	82
Coking – Delayed	9	53
Coking – Fluid	3	18
Combined	12	71
Combined Coke, 400 Lb./B	12	71
Thermal Cracking/Visbreaking	3	18
Solvent Deasphalting	1	6
Catalytic Reforming		
100 psi	3	18
200 psi	5	29
450 psi	14	82
Total	17	100
Hydrotreating		
Naphtha	16	94
Distillate	12	71
Heavy Gas Oil	13	76
Residuum	1	6
Product Rate		
Alkylation	14	82
Polymerization	4	24
Isomerization – C_5/C_6	1	6
Isomerization – C_4	2	12
Hydrogen	15	88
Asphalt	3	18
Lube	3	18
MTBE	2	12
Sulfur, MSTPD	16	94

(1) Number of refineries having each process.
(2) Percent of refineries having each process.
(3) 1/1/91 existing (DOE *PSA* 1990), plus under construction 4/91 *Hydrocarbon Processing* and *Oil & Gas Journal*.

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TABLE A-18

ASSUMED OXYGENATES INVESTMENT COSTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1989 $)

	Methanol	Field Butane Isomerization	Isobutane Dehydrogenation	MTBE	Combined MTBE Complex
Middle East					
Standard Size MBPSD	300 MMGPY	12.1 MBPSD	11.9 MBPSD	12.5 MBPSD	12.5
	(21.7 MBPSD)				
TM&C Estimates – Used					
Unit Investment, MM$[1]	375	35	140	25	275[2]
Unit Cost, MM$/MBPCD	19.2	2.8	13.5	2.2	24.3
Other Estimates (For Comparison)					
Unit Investment, MM$[3]	370	55	129	30	288[2]

[1] Includes 35% off-sites.
[2] Includes one-fifth of a standard size methanol plant, or $75 million.
[3] Made by another consulting firm; includes contingency, no working capital and 40% offsites.

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TABLE A1-1

PADD V

1989 SUMMER SUPPLY AND DEMAND – ACTUAL – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Supply					Demand		
	Field Produc- tion	Imports	From Inven- tory	Net Receipts	Refinery Produc- tion	Refinery Input	Exports	Products Demand
Crudes								
Domestic	2,878		(19)	(375)		2,402	124	(41)
Foreign		301				301		
[Total Crudes]	2,878	301	(19)	(375)		2,702	124	(41)
Products - NGL / Unfin.								
Natural Gasoline	43					4	1	39
Ethane					2			2
Propane	11	2	(4)		35		7	37
Normal Butane	21	1	(9)		26	9	4	26
Iso - Butane	7	1	(2)		3	8		1
[Sub - Total]	82	4	(15)		66	21	11	105
Unfinished Oils		5	13	6		37		(13)
Mogas Components		2	(1)			(9)		10
Oxygenates and Other	14					13		1
[Sub - Total]	14	6	12	6		41		(3)
[Total - NGL / Unf & Other]	96	10	(3)	6	66	62	11	102
Products - Finished								
Motor Gasoline		31	(13)	60	1,214		9	1,283
Aviation Gasolines					7			7
Naphtha Jet		1	(1)	10	55			65
Kero Jet		11	3	10	327		1	350
Kerosene					4			4
Diesel / No. 2		4	2	20	442		23	445
Residual Fuels		13	3		380		164	232
Petrochem Naphtha		1			7			8
P / Chem Gas Oil + C. Black					13		9	5
Special Naphtha / Misc.					3		2	1
Lube and Wax		1			22		4	19
Marketable Coke - 400 #B			(1)		101		92	8
Catalytic Coke - 400 #B					34			34
Asphalt / Road Oil			4		72		1	76
Others								
Process Gas - FOE					145			145
[Total Products]	96	73	(6)	106	2,892	62	317	2,782
Total Crudes and Products	2,974	373	(25)	(269)	2,892	2,764	440	2,741
(Gain) / Loss					(128)			

Note: Rows and columns may not balance due to rounding.

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TABLE A1-2
PADD V
1996 SUMMER SUPPLY AND DEMAND - OUTLOOK - MBPCD
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Supply					Demand		
	Field Produc-tion	Imports	From Inven-tory	Net Receipts	Refinery Produc-tion	Refinery Input	Exports	Products Demand
Crudes								
Domestic								
Foreign								
[Total Crudes]								
Products - NGL / Unfin.								
Natural Gasoline								
Ethane								
Propane								
Normal Butane								
Iso - Butane								
[Sub - Total]								
Unfinished Oils								
Mogas Components								
Oxygenates and Other								
[Sub - Total]								
[Total - NGL / Unf & Other]								
Products - Finished								
Motor Gasoline		26	(10)	69	1,323		4	1,405
Aviation Gasolines					8			8
Naphtha Jet				12	54			67
Kero Jet		30	2	8	372		2	410
Kerosene					5			5
Diesel / No. 2		4	(5)	30	490		43	476
Residual Fuels		5	5		402		165	247
Petrochem Naphtha								
P / Chem Gas Oil + C. Black								
Special Naphtha / Misc.								
Lube and Wax								
Marketable Coke - 400 #B					120		109	11
Catalytic Coke - 400 #B								
Asphalt / Road Oil		4	2		80			86
Others								
Process Gas - FOE								
[Total Products]		69	(5)	119	2,854		323	2,714
Total Crudes and Products								
(Gain) / Loss								

Note: Rows and coulmns may not balance due to rounding.

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TABLE A1-3

PADD V

1989 ANNUAL SUPPLY AND DEMAND – ACTUAL – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Supply					Demand		
	Field Produc-tion	Imports	From Inven-tory	Net Receipts	Refinery Produc-tion	Refinery Input	Exports	Products Demand
Crudes								
Domestic	2,959		(5)	(506)		2,326	125	(3)
Foreign		288		23		291		
[Total Crudes]	2,959	288	(5)	(483)		2,617	125	(3)
Products - NGL / Unfin.								
Natural Gasoline	42		0	(0)		27	1	14
Ethane	0				1			2
Propane	11	2	0		35	0	7	41
Normal Butane	21	2	0		19	27	3	13
Iso - Butane	7	1	0	(1)	3	11		(1)
[Sub-Total] *	81	5	1	(1)	59	65	11	68
Unfinished Oils								
Mogas Components								
Oxygenates and Other								
[Sub-Total] *								(10)
[Total - NGL / Unf & Other] *	81	12	0	3	59	80	26	58
Products - Finished								
Motor Gasoline		23	4	63	1,189		2	1,277
Aviation Gasolines		0	(0)		6			6
Naphtha Jet			(0)	12	52			63
Kero Jet		19	0	8	335		5	357
Kerosene			(0)		6			5
Diesel / No. 2		3	1	22	437		44	418
Residual Fuels		12	1		374		145	242
Petrochem Naphtha *					9			13
Lube and Wax *					21			18
Marketable Coke - 400 #B			(1)		104		90	13
Asphalt / Road Oil		3	0		61			65
Others *					50			35
Process Gas - FOE					143			143
[Total Products]	81	72	5	108	2,845	80	312	2,719
Total Crudes and Products	3,040	340	(0)	(375)	2,845	2,697	437	2,716
(Gain) / Loss					(148)			

* Individual rows do not balance due to incomplete data.

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TABLE A1-4

PADD V

1996 ANNUAL SUPPLY AND DEMAND - OUTLOOK - MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Supply					Demand		
	Field Produc-tion	Imports	From Inven-tory	Net Receipts	Refinery Produc-tion	Refinery Input	Exports	Products Demand
Crudes								
Domestic	3,105		(3)	(380)	0	2,676	46	0
Foreign		199		3		202		0
[Total Crudes]	3,105	199	(3)	(377)	0	2,878	46	0
Products - NGL / Unfin.								
Natural Gasoline	44							
Ethane	0							
Propane	12							
Normal Butane	22							
Iso - Butane	7							
[Sub-Total] *	85				70			76
Unfinished Oils								
Mogas Components								
Oxygenates and Other								
[Sub-Total] *								(10)
[Total - NGL / Unf & Other]*	85	(11)	(1)	4	70	83	14	66
Products - Finished								
Motor Gasoline		22	(1)	69	1,296		5	1,382
Aviation Gasolines		0	(0)	0	6		0	6
Naphtha Jet		0	(0)	12	53		0	65
Kero Jet		26	(0)	8	372		3	402
Kerosene		0	0	0	5		0	5
Diesel / No. 2		3	(1)	28	480		45	465
Residual Fuels		5	(0)	0	415		168	251
Petrochem Naphtha *					9			14
Lube and Wax *					22			19
Marketable Coke - 400 #B		0	(0)	0	116		102	14
Asphalt / Road Oil		3	(0)	0	63		0	67
Others *					60			42
Process Gas - FOE					156			156
[Total Products]	85	48	(4)	121	3,124	83	337	2,954
Total Crudes and Products	3,190	247	(7)	(256)	3,124	2,962	383	2,954
(Gain) / Loss					(162)			

* Individual rows do not balance due to incomplete outlook data. The sum of all * rows balance.

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TABLE A1-5

PRODUCT GRADE DISTRIBUTION

ANNUAL REFINERY OUTPUT

WSPA STUDY OF CARB PHASE 2 GASOLINE

	%		MBPCD	
	PADD V	U.S. TOTAL	PADD V	U.S. TOTAL
Residual Fuel				
1989 – Actual – DOE				
≤.30% S	8.4	10.1	32	91
0.31 – 1.00% S	9.2	18.3	35	165
>1.01% S	82.4	71.6	313	645
Total	100	100	380	901
1996				
≤.30% S	10.1	11.1	42	108
0.31 – 1.00% S	9.1	18.9	38	185
>1.01% S	80.9	70.0	335	686
Total	100.0	100.0	415	979
Motor Gasolines				
1989 – Actual				
Leaded Regular	21.8	10.8	272	786
Unleaded Regular	52.9	58.9	636	4,129
Unleaded Midgrade	1.5	6.8	18	479
Unleaded Premium	23.8	23.5	288	1,656
Total	100.0	100.0	1,214	7,050
1996				
Unleaded Regular	54.8	55.7	725	4,052
Unleaded Midgrade	20.2	19.0	268	1,378
Unleaded Premium	25.0	25.3	331	1,841
Total	100.0	100.0	1,323	7,271

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TABLE A1-6

REFINERY RAW MATERIALS INPUT RATES DETAIL

SUMMER 1989 ACTUAL - MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	VCOC	VCC	VS	U.S. TOTAL
DOMESTIC CRUDES	493	1,695	214	7,715
FOREIGN CRUDES	142	154	5	5,955
SUBTOTAL CRUDES	634	1,849	219	13,668
NATURAL GASOLINE / LSR		4		148
REFORMATE 100 RONC	(22)	15	(2)	(5)
NAPHTHA	2	7	(1)	114
VACUUM GAS OIL	(11)	45	(5)	423
VACUUM RESID				14
NORMAL BUTANE	3	6		62
ISO - BUTANE	2	6		154
MTBE		12	1	52
PROPANE				17
NAT. GAS FD. TO H2 FOE				
METHANOL				
TOTAL INPUT	608	1,944	212	14,647

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TABLE A1-7

REFINERY PRODUCT RATES DETAIL

SUMMER 1989 ACTUAL - MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	VCOC	VCC	VS	U.S. TOTAL
MOTOR GASOLINES				
LOW LEAD REGULAR	66	200	6	786
UNLEADED REGULAR	109	515	12	4,129
UNLEADED INTERMEDIATE	3	15		480
UNLEADED PREMIUM	48	240		1,656
SUB TOTAL	226	970	18	7,051
AVIATION GASOLINES		7		28
NAPHTHA JET	11	40	4	212
KERO JET / KEROSENE	107	198	27	1,209
DISTILLATE FUELS - 0.05% S		92		92
DISTILLATE FUELS - 0.25% S	115	185	50	2,745
RESIDUAL FUELS				
< 0.3% SULFUR	10	4	18	91
0.3 - 0.7% SULFUR				
0.7 - 1.0% SULFUR	22	9	4	165
1.0 - 2.0% SULFUR				
> 2.0% SULFUR	79	212	22	645
SUB TOTAL	111	225	44	901
ASPHALT / ROAD OIL		24	48	514
MARKETABLE COKE - 400#	12	89		336
CATALYTIC COKE - 400#	6	28		215
BENZENE				23
TOLUENE				33
XYLENE		1		45
SPCL. NAPH. / MISC.		4	2	130
PETROCHEM NAPHTHA		4	2	15
LUBES		13	6	166
WAX		3		15
PETROCHEM GAS OIL		7	4	196
CARBON BLACK FEED		2		40
PROPENE				104
BUTANES /BUTENES	3	26		202
PROPANE	9	26		296
PROCESS GAS / C2 / C2=	21	123	3	718
(GAIN) / LOSS	(14)	(123)	4	(639)
TOTAL PRODUCTS	607	1,944	212	14,647

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TABLE A1-8

REFINERY CRUDE INPUT SUMMARY

SUMMER 1989 ACTUAL

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Type	VCOC	VCC	VS	U.S. TOTAL
RATES - MBPD					
Domestic					
Low Sulfur	S	28	91	31	3,750
High Sulfur Light	HL	0	0	0	655
High Sulfur Heavy	HH	465	1,604	183	3,310
Subtotal		493	1,695	214	7,715
Foreign					
Low Sulfur	S	131	106	0	2,322
High Sulfur Light	HL	11	23	0	1,090
High Sulfur Heavy	HH	0	25	5	2,541
Subtotal		142	154	5	5,953
Combined					
Low Sulfur	S	159	196	32	6,072
High Sulfur Light	HL	11	23	0	1,746
High Sulfur Heavy	HH	465	1,630	187	5,851
Total		635	1,849	219	13,668
QUALITIES					
Calculated					
Domestic Gravity, Deg. API		27.3	23.8	24.2	31.7
Domestic Sulfur, % wt.		0.99	1.13	1.48	0.87
Foreign Gravity, Deg. API		42.0	39.2	22.9	31.9
Foreign Sulfur, % wt.		0.14	0.33	2.66	1.39
Combined Gravity, Deg. API		30.6	25.1	24.2	31.8
Combined Sulfur, % wt.		0.80	1.07	1.51	1.10
DOE Reported					
Combined Gravity, Deg. API		30.6	24.4	24.1	32.0
Combined Sulfur, % wt.		0.78	1.13	1.59	1.07

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TABLE A1-9

REFINERY DOMESTIC CRUDE INPUT RATES DETAIL

SUMMER 1989 ACTUAL

WSPA STUDY OF CARB PHASE 2 GASOLINE

LOCATION / NAME		LP Code	Type	GRAV. °API	SULF %	MBPCD VCOC	MBPCD VCC	MBPCD VS	MBPCD U.S. TOTAL
AK	COOK	AKC	S	34.0	0.11	28		10	39
	NORTH SLOPE	ANS	HH	27.5	1.05	442	908	105	1,840
CA	BETA	CBT	HH	15.1	3.70		16		16
	ELK HILLS	CEH	S	36.2	0.36		91	12	138
	HUNTINGTON BEACH	CHB	HH	19.6	1.56		21		21
	HONDO	CAH	HH	17.1	5.15		8	29	62
	LA BASIN LIGHT	CLL	HH	27.0	1.10		32		32
	SAN ARDO	CSA	HH	13.1	1.76		65		65
	SJV LIGHT	CJL	HH	26.0	1.20		95		95
	SJV KERN RIVER	CJH	HH	14.1	1.05		72	49	121
	SJV HEAVY	CVH	HH	13.8	0.98	22	245		273
	VENTURA	CCV	HH	30.9	1.12	1			49
	WILMINGTON HEAVY	CWH	HH	17.1	1.70		91		91
	WILMINGTON LIGHT	CWL	HH	22.2	1.35		51		51
NV	SWEET	NVS	S	37.0	0.30			9	9
Total						493	1,695	214	7,715

CLM/REC
6/28/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30171

TABLE A1-10

REFINERY FOREIGN CRUDE INPUT RATES DETAIL

SUMMER 1989 ACTUAL

WSPA STUDY OF CARB PHASE 2 GASOLINE

					MBPCD			
COUNTRY	NAME	TYPE	GRAV. °API	SULF %	VCOC	VCC	VS	U.S. TOTAL
Abu Dhabi/Dubai/Oman/UAE		HL	38.7	0.62		21		51
Canada	Heavy	HH	22.0	2.80			5	208
	Rangeland	HL	40.3	0.58	11			101
China	Daqing	S	32.4	0.09	9	21		92
Ecuador	Oriente	HH	30.0	0.90		25		100
Indonesia	Minas	S	35.0	0.09	44	32		88
	Attika	S	43.0	0.10	25	17		42
	Cond.	S	55.0	0.10	32	29		71
Iraq	Kirkuk	HL	35.9	1.95		3		428
Misc. Low Sulfur		S	41.1	0.16	21	8		88
Total					142	154	5	5,953

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6/28/91

TABLE A1-11

VCC CALIFORNIA REFINERY PRODUCTION RATES

SUMMER ACTUAL AND OUTLOOK

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPCD)

	Actual		Outlook[1]
	1984	1989	1996
Motor Gasoline	804	970	1,019
Jet – Naphtha	37	40	42
Kero Jet/Kerosene	165	198	235
Diesel/No. 2 Fuel	228	277	303
Residual Fuel	173	225	140
Asphalt	22	24	28
Propane and Butane	36	52	73
Other Products	120	158	202
Total Products	1,585	1,944	2,042
Crude Run	1,474	1,849	1,954
Crude Production			
California	1,106	1,014	1,180
Alaska	1,577	1,879	1,905

[1] Using a PADD V forecast, TM&C estimated California conversion refineries' production.

REC
11/11/91

TABLE A1-12

CALIFORNIA REFINERY PRODUCTION GROWTH RATES

VCC – SUMMER ACTUAL AND OUTLOOK

WSPA STUDY OF CARB PHASE 2 GASOLINE

(% change/year)

	Actual 1989 vs. 1984	Outlook 1996 vs. 1989
Motor Gasoline	3.8	0.7
Jet – Naphtha	1.6	0.7
Kero Jet/Kerosene	3.7	2.5
Diesel/No. 2 Fuel	4.0	1.3
Residual Fuel	5.4	(7.0)
Asphalt	1.8	2.2
Butane and Propane	7.6	5.0
Other Products	5.7	3.6
Total Products	4.2	0.7
Crude Run	4.6	0.8
PADD V Crude Production	1.5	0.9

REC
11/11/91

TABLE A1-13

PADD V REFINERY PRODUCTION RATIOS

WINTER QUARTERS vs. ANNUAL

WSPA STUDY OF CARB PHASE 2 GASOLINE

(% of Annual)

	1987	1988	1989	1990	1987-90 Average
LPG	90.3	90.2	84.5	81.2	86.5
Gasoline	97.0	100.1	97.0	99.3	98.3
Kerosene Jet Fuel	99.2	102.4	102.4	104.5	102.1
Distillate Fuel	98.8	97.9	97.4	99.9	98.5
Residual Fuel	101.5	105.2	101.7	98.2	101.6
Asphalt	54.6	78.7	83.5	82.4	74.8

REC/CLM
11/11/91

TABLE A2-1

1984 CALIBRATION CRITERIA

NPC STUDY

	Maximum Variance
• Match Material Balance from DOE	
Allow Residual Fuels, C4- and Gain to Vary	± 0.3% of Total Input
• Match Utilities from DOE	
Usage	± 3% of Target
Fuel Composition	± 4% of Total Fuel
• Match Major Product Primary Qualities(1)	
Mogas Octanes: (R+M)/2	+ 0.1
Mogas Lead, Gms./Gal.	- 0.1
Mogas RVP, psi	- 0.5
Distillate Fuels Sulfur, Wt.%	- 0.2(2)
• Match Unit Utilizations(1)	
Conversion Units by Type	± 8%
Composite of Conversion Units	± 5%
Catalytic Reformers	± 15%
• Match Unit Severities(1)	
Cat Cracking Conversion, %	± 5%
Reformate Octane, RONC	± 0.5
• Judgement Review of Shadow Values	
None Constraining Severely	± 20%

(1) From NPC survey data.
(2) Adjusted to zero on future runs by allowing high-sulfur diesel to by-pass distillate HDS unit.

REC
2/24/86

TABLE A2-2

1984 CALIBRATION RUN RESULTS

ACTUAL VARIANCES(1) COMPARED TO ACCEPTABLE VARIANCES

NPC STUDY

	Maximum Acceptable Variance	IC	IIDC	IILC	IIIDC	IIILC	IV	VCOC	VCC	VCLA
Material Balance, % Total Input										
Residual Fuels	± 0.3	0.05	-0.01	0.04	0.26	0.18	0.01	0.1	-0.1	0.05
Propane	± 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Produced Fuels (FOE)	± 0.3	-0.08	0.03	-0.02	-0.11	-0.25	-0.27	-0.12	0.07	-0.03
Gain	± 0.2	-0.01	0.01	0.03	0.15	-0.16	0.0	0.01	0.0	0.08
Utilities Usage, % Target										
Total Fuels (FOE)	± 2%	-0.1	0.4	0.3	-0.9	0.1	-1.1	-0.3	-0.7	-0.9
Purchased Fuels (FOE)(2)	± 4%	0.9	0.0	0.6	0.4	3.6	2.6	1.5	-1.4	-0.5
Produced Fuels (FOE)(2)	± 4%	-1.0	0.4	-0.3	-1.3	-3.5	-3.7	-1.8	0.7	-0.4
Power (KWH)	± 3%	0.4	0.2	0.5	-2.5	-0.2	-1.4	-0.2	0.0	-1.0
Product Qualities										
Motor Gasolines										
Octane - R+M/2										
Grade	+0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pool	+0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lead, Gms./Gal.										
Regular Leaded	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Premium Leaded	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RVP, psi										
Grade	-0.5	-0.46	-0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Pool	-0.2	-0.14	-0.17	-0.04	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuels, % S(3)	-0.2	-0.01	-0.17	-0.17	0.0	-0.15	0.0	0.0	-0.25	0.0
Capacity Utilization, %(4)										
Cat Cracking	± 8	1.8	4.9	2.5	-2.5	-6.7	4.9	7.7	-5.0	-0.5
Hydrocracking	± 8	2.2	7.3	*	8.3	*	*	*	4.0	0.4
Coking Combined	± 8	*	-1.1	-	7.1	-	*	*	-5.3	-5.2
Composite Conversion(5)	± 5	*	3.9	*	0.6	*	*	*	-1.8	-1.7
Cat Reforming Combined	± 15	-14.8	2.7	-5.4	-0.3	-1.3	-4.7	5.0	-6.2	3.4
Unit Severities										
Cat Cracking Conversion, %	± 5	3.2	-1.5	-4.3	0.0	1.3	-2.2	-1.9	3.1	-1.7
Reformate Octane, RONC	± 0.5	-0.1	0.1	0.2	-0.3	-0.3	0.1	0.0	0.0	-0.1

(1) LP run results minus target (from DOE or survey data).
(2) Variance expressed as % of total fuel.
(3) Forecast case runs changed to allow bypassing distillate HDS with high-sulfur distillate, hence forecast case runs variance from distillate fuels sulfur target is zero.
(4) Utilizations based on calendar day capacities and actual feed rates, ignoring severity effects.
(5) Utilizations for cat cracking, hydrocracking and coking combined on an actual feed basis, ignoring severity effects.
* Survey data excluded by NPC.

REC/JRW/GWM
3/26/86

TURNER, MASON & COMPANY
Consulting Engineers

TABLE A2-3

GASOLINE DISTILLATION CALIBRATION

1988 ANNUAL DATA FOR PADD III

WSPA STUDY OF CARB PHASE 2 GASOLINE

	TM&C LP Results[1][2] IIIC	NIPER Data Actual Production[3]	Difference	Reproduc-ibility
Distillation, % at				
170°F	38	38	-	-
212°F	53	53	-	-
257°F	69	69	-	-
300°F	82	82	-	-
356°F	93	93	-	-
50% Point, °F	203	203	-	15
90% Point, °F	336	336	-	16
Temperature @ V/L = 20, °F	122	122	-	2

(1) Based on weighted average model IIIC gasoline pool component composition from 1988 calibration runs for models IIILC and IIIDC in 1989 subscription study *U.S. Gasoline Outlook, 1989-94*.

(2) Based on adjusted LP model component gasoline distillations calibrated to match NIPER data on finished gasoline distillation.

(3) Calculated weighted average of summer and winter NIPER data for PADD III production based on PADD III plus shipments to PADDs I and II.

GWM
07/12/91

TABLE A2-4

COMPARISON OF MEASURED VS. PREDICTED GASOLINE DISTILLATION

90% DISTILLED TEMPERATURE FOR TEST FUELS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(°F)

		Predicted		Predicted – Measured	
	Measured Average	TBP Method	LP Model Method	TBP Method	LP Model Method
Fuel					
1	330	329	329	(1)	(1)
2	286	284	286	(2)	0
3	356	355	359	(1)	3
4	356	354	360	(2)	4
5	292	287	285	(5)	(7)
6	328	332	326	4	(2)
7	326	333	328	7	2
Average					
Net (Bias)				0	0
Absolute				3	3

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7/12/91

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TABLE A2-5

CALIBRATION OF GASOLINE POOL PROPERTIES

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Survey		TM&C Base Cases		
	Finished Gasoline	Pool Hydro-carbon Type	1995	Adjusted to 1989	Difference[1]
PADD V (California)					
Aromatics, %	35.8	35.2	34.0	33.8	(1.4)
Olefins, %	9.5	9.5	10.9	10.9	1.4
(R+M)/2 (Clear)	88.5	-	89.0	88.5	-
MTBE, %	-[2]	-	2.0	0	-
RVP, psi	8.5	-	7.7	8.5	-
90% Distilled, °F	328	-	348	-	-
Total U.S.					
Aromatics, %	31.6	31.8	32.0	31.6	(0.2)
Olefins, %	12.3	12.7	13.5	13.4	0.7
(R+M)/2 (Clear)	88.6	-	88.9	88.6	-
MTBE, %	0.9	0.8	2.2	0.8	-
RVP, psi	9.5	-	8.5	9.5	-
90% Distilled, °F	336	-	346	-	-

[1] Adjusted TM&C minus Survey Pool Hydrocarbon Type. Not adjusted to fit 90% distilled.

[2] Deleted by NPRA.

GWM
7/12/91

TABLE A2-6

CALIBRATION OF GASOLINE POOL PROPERTIES

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Survey		TM&C Base Cases		
	Finished Gasoline	Pool Hydro-carbon Type	1995	Adjusted to 1989	Difference[1]
PADD VCHA					
(High Aromatics)					
Aromatics, %	40.2	39.7	43.2	41.0	1.3
Olefins, %	0.2[2]	0.3[2]	2.7	2.6	2.3
(R+M)/2 (Clear)	87.8	-	88.8	87.8	-
MTBE, %	0.0	-	2.0	0.0	-
RVP, psi	9.8	-	8.2	9.8	-
90% Distilled, °F	316	-	319	319	3
PADD IIICHT					
(High 90% Point)					
Aromatics, %	27.9[3]	27.4[3]	31.1	31.4	4.0
Olefins, %	15.6	16.0	15.0	15.1	(0.9)
(R+M)/2 (Clear)	89.2	-	89.4	89.2	-
MTBE, %	0.6	0.7	2.5	0.7	-
RVP, psi	9.3	-	8.6	9.3	-
90% Distilled, °F	359	-	355	355	(4)

(1) Adjusted TM&C minus NPRA Survey Pool Hydrocarbon Type or Finished Gasoline 90% Point.
(2) Survey olefins level is too low for light coker gasoline content.
(3) Survey aromatics level is too low, and it is inconsistent with IIIC data.

GWM
07/12/91

TABLE A2-7

AVERAGE SUMMER GASOLINE PROPERTIES

AS PRODUCED

WSPA STUDY OF CARB PHASE 2 GASOLINE

	NPC[1] 1984	Actual: CARB[1] 1987	Actual: NIPER 1988	Actual: NIPER 1989	Actual: NPRA 1989	TM&C Model Base Case 1996
PADD V (California)						
Benzene, %	2.46	1.86	1.79	2.00	-	2.26
Sulfur, ppm	-	-	130	130	161	183
(R+M)/2, Clear	86.4	-	88.6	88.5	88.5	89.0
RVP, psi	10.0	-	8.7	8.5	8.5	7.7
PADD V (Excl. California)						
Benzene, %	1.67	-	2.13	2.58	-	2.84
Sulfur, ppm	-	-	470	370	389	284
(R+M)/2, Clear	86.3	-	88.1	87.9	87.7	88.7
RVP, psi	12.8	-	11.3	10.0	10.3	8.6
Total U.S.						
Benzene, %	1.96	-	1.58	1.75	-	2.02
Sulfur, ppm	-	-	290	301	321	306
(R+M)/2, Clear	86.2	-	88.4	88.4	88.6	88.9
RVP, psi	11.7	-	10.7	9.3	9.5	8.5

[1] Annual data.

GWM
7/12/91

TABLE B-2

REFINERY RAW MATERIALS INPUT RATES DETAIL

1996 BASE RESULTS – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
Domestic Crudes	1,733	1,630
Foreign Crudes	155	155
Sub Total Crudes	1,888	1,785
Natural Gasoline	4	4
Reformate, 100 RONC	2	2
Naphtha	3	5
Vacuum Gas Oil	45	45
Vac Resid		
Normal Butane		27
Iso–Butane	3	10
MTBE	6	6
Propane		
Nat. Gas Fd to H2, FOE	46	22
Methanol	5	5
Total Input	2,002	1,912

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10/02/91

TABLE B-3

REFINERY PRODUCT RATES DETAIL

1996 BASE RESULTS – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
Motor Gasolines		
Unleaded Regular	557	539
Unleaded Intermediate	207	200
Unleaded Premium	255	246
Sub Total	1,019	985
Aviation Gasolines	8	8
Naphtha Jet	42	42
Kero Jet / Kerosene	235	245
Distillate Fuels - 0.05% S	61	59
Distillate Fuels - 0.05% S, 10% Arom	242	235
Residual Fuels		
< 0.3% Sulfur	4	6
0.7 - 1.0% Sulfur	9	7
1.0 - 2.0% Sulfur		
> 2.0% Sulfur	38	65
Sub Total	51	78
Asphalt / Road Oil	28	17
Marketable Coke - 400#	138	128
Catalytic Coke - 400#	32	30
Benzene		
Toluene		
Xylene		
Spcl. Naph. / Misc.	4	4
Petrochem Naphtha	3	3
Lubes / Wax	22	22
Petrochem Gas Oil	7	7
Carbon Black Feed	2	2
Propene	13	10
Butanes / Butene	29	3
Propane	45	41
Process Gas / C2 / C2=, FOE	163	129
(Gain) / Loss	(142)	(136)
Total Products	2,002	1,912

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10/02/91

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TABLE B-4

REFINERY CRUDE INPUT SUMMARY

1996 BASE CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Type	Summer	Winter
RATES - MBPD			
Domestic			
Low Sulfur	S	91	91
High Sulfur Light	HL		
High Sulfur Heavy	HH	1,642	1,539
Subtotal		1,733	1,630
Foreign			
Low Sulfur	S	106	106
High Sulfur Light	HL	24	24
High Sulfur Heavy	HH	25	25
Subtotal		155	155
Combined			
Low Sulfur	S	197	197
High Sulfur Light	HL	24	24
High Sulfur Heavy	HH	1,667	1,564
Total		1,888	1,785
QUALITIES - Calculated			
Domestic Gravity, Deg. API		22.9	22.6
Domestic Sulfur, % wt.		1.40	1.41
Foreign Gravity, Deg. API		39.3	39.3
Foreign Sulfur, % wt.		0.33	0.33
Combined Gravity, Deg. API		24.1	23.9
Combined Sulfur, % wt.		1.32	1.32

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TABLE B-5

REFINERY DOMESTIC CRUDE INPUT RATES DETAIL

1996 BASE CASE RESULTS – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

LOCATION / NAME		Type	Summer	Winter
AK	COOK	S		
	NORTH SLOPE	HH	857	754
CA	BETA	HH	39	39
	ELK HILLS	S	91	91
	HUNTINGTON BEACH	HH	19	19
	HONDO	HH	71	71
	LA BASIN LIGHT	HH	29	29
	SAN ARDO	HH	72	72
	SJV LIGHT	HH	104	104
	SJV KERN RIVER	HH	84	84
	SJV HEAVY	HH	239	239
	VENTURA	HH		
	WILMINGTON HEAVY	HH	82	82
	WILMINGTON LIGHT	HH	46	46
NV	SWEET	S		
	TOTAL		1,733	1,630

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TABLE B-6

REFINERY FOREIGN CRUDE INPUT RATES DETAIL

1996 BASE CASE RESULTS – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

COUNTRY	NAME	TYPE	SUMMER/ WINTER
Abu Dhabi/Dubai/Oman/UAE		HL	21
China	Daqing	S	20
Ecuador	Oriente	HH	25
Indonesia	Minas	S	32
	Attaka	S	17
	Cond.	S	29
Iraq	Kirkuk	HL	3
Misc. Low Sulfur		S	8
Total			155

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10/02/91

TABLE B-7

NEW PROCESS CAPACITY AND INVESTMENT REQUIRED OVER 1991

1996 BASE CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
New Capacity, MBPSD		
Distillate HDS	38	49
Diesel Aromatics Saturation	226	226
Cat Reformer, 200 PSI	44	44
MTBE	13	13
Alkylation	5	5
Hydrogen, MMSCFPSD	24	24
Sulfur, MLTPD		
Fractionation(2)	44	44
Improvements, MBPSD		
Cat Reformers – Reduce Pressure	171	171
Gasoline Stabilizers – Fractionation(2)	180	180
Investment, MM$ (In Constant 1991 $)(3)		
New Capacity	1,310	1,330
New Fractionation(2)	10	10
Improve Cat Reformers – C5+ Yield	60	60
Improve Fractionation/C4 Handling(2)	10	10
Total Refinery	1,390	1,410

(1) Estimated.
(2) RVP reduction survey for API in 1987.
(3) This is not the complete industry investment required. It does not include capital for environmental restrictions other than diesel sulfur and aromatics restrictions. It also excludes sustaining capital.

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10/02/91

TABLE B–7A

NEW PROCESS INVESTMENTS DETAIL

1996 BASE CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM – in constant 1991 $)

	Summer	Winter
Distillate HDS	70	90
Diesel Aromatics Saturation	950	950
Cat Reformer, 200 PSI	130	130
MTBE	80	80
Alkylation	20	20
Hydrogen, MMSCFPSD	60	60
Total Refinery	1,310	1,330

CLM
10/02/91

TABLE B-8

REFINERY PROCESS UNIT CAPACITIES DETAIL

1996 BASE CASE RESULTS(1)(2)

WSPA STUDY OF CARB PHASE 2 GASOLINE

(MBPSD)

	Summer/ Winter	
Number of Refineries	17	
Feed Rate		
Crude - Atmospheric	2119	
Crude - Vacuum	1231	
Catalytic Cracking	659	
Hydrocracking - High Conversion	327	*
Hydrocracking - Low Conversion	81.8	*
Coking - Delayed	409	
Coking - Fluid	94.5	
Combined	504	
Combined Coke, 400 #B	102	
Thermal Cracking / Visbreaking	44.8	
Solvent Deasphalting	50.0	
Catalytic Reforming		
100 psi	65.5	
200 psi(3)	321	
450 psi(3)	171	
Total	557	
Hydrotreating		
Naphtha	479	
Distillate(4)	425	
Heavy Gas Oil	615	
Residuum - Vacuum	26.5	
Diesel Aromatics Saturation	226	
FCC Gasoline Fractionation	304	*
Product Rate		
Alkylation	135	
Polymerization	10.3	
MTBE	17.3	
Isomerization - C5/C6 with recycle	7.4	
- C4	5.8	
Hydrogen, MMSCFPSD	1378	*
Hydrogen, FOE	71.1	*
Asphalt	35.8	
Lube	25.1	
Sulfur, MLTPD	4.3	

* Increased based on NPRA survey.
(1) 1/1/91 existing (DOE-PSA 1990) plus under construction 4/91 Hydrocarbon Processing (Table A-19).
(2) Includes required and estimated additions to meet 1996 demands (Table B-7).
(3) Includes one-half of 450 psi reformers converted to 200 psi operation with 9% capacity reduction.
(4) Winter capacity is 11 MSPSD higher than indicated summer capacity.

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10/02/91

TABLE B-9

REFINERY PROCESS UNIT RATES

1996 BASE CASE RESULTS – MBPCD PER REFINERY

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
Crude - Atmospheric	111.1	105.0
Catalytic Cracking(1)	36.8	34.1
Catalytic Cracking(2)	37.3	34.6
Conversion, %	74.4	74.4
Octane Catalyst, %	15.0	15.0
FCC Gasoline Fractionation	15.2	14.1
Hydrocracking - High Conversion	16.9	16.3
Jet Yield, % of Maximum	96.7	100.0
Hydrocracking - Low Conversion	3.2	3.1
Hydrocracking - Combined	20.1	19.4
Coking - Delayed	22.9	21.2
- Fluid	5.3	4.9
Thermal Cracking, Visbreaking	2.3	2.2
Solvent Deasphalting	1.0	2.5
Catalytic Reforming - 100 PSI(1)	3.4	2.6
- 200 PSI(1)	16.6	14.6
- 450 PSI(1)	8.9	6.0
- Combined(2)	26.4	21.5
- RONC	99.2	99.3
Hydrotreating - Naphtha	18.8	15.6
- Distillate	22.0	21.8
- Heavy Gas Oil	31.0	30.0
- Residuum - Vac	1.4	1.4
Diesel Aromatics Saturation	11.7	11.1
Alkylation	6.6	6.3
Polymerization	0.0	0.0
Isomerization - C5/C6, Recycle	0.4	0.3
- C4	0.3	0.0
Hydrogen, MMSCFPCD	58.1	56.0
Lubes	1.3	1.3
MTBE	0.8	0.8
Sulfur, LTPCD	130	123

(1) Include effects of nonunitary capacity for some feedstocks and severities.
(2) Based on actual feed rates, ignoring severity effects.

GWM/CLM
10/02/91

TABLE B-10

REFINERY PROCESS UNIT UTILIZATIONS (1)

1996 BASE CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
Crude Distillation – Atmospheric	89.2	84.3
Catalytic Cracking (2)	95.0	88.0
Catalytic Cracking (3)	96.2	89.2
Catalytic Gasoline Fractionation	84.9	79.0
Hydrocracking – High Conversion	88.0	85.0
– Low Conversion	67.0	64.9
Coking – Delayed	95.0	88.0
– Fluid	95.0	88.0
Thermal Cracking, Visbreaking	88.0	85.0
Solvent Deasphalting	32.5	85.0
Catalytic Reforming – 100 PSI (2)	88.0	67.6
– 200 PSI (2)	88.0	77.7
– 450 PSI (2)	88.0	59.6
– Combined (3)	80.4	65.8
Hydrotreating – Naphtha	66.7	55.3
– Distillate	88.0	85.0
– Heavy Gas Oil	85.8	83.1
– Residuum, Vacuum	88.0	85.0
Diesel Aromatics Saturation	88.0	83.7
Alkylation	83.0	79.8
Polymerization	0.0	0.0
Isomerization – C5/C6, Recycle	88.0	78.1
– C4	83.0	0.0
Hydrogen	72.9	70.4
Lubes	87.6	84.6
MTBE	83.0	76.3
Sulfur	45.9	43.5
Dependent Downstream Unit Maximum	83.0	80.0
Other Downstream Unit Maximum	88.0	85.0

(1) Calendar day rates divided by stream day capacity.

(2) Include effects of nonunitary capacity factors for some feedstocks and severities.

(3) Based on actual feed rates, ignoring severity effects.

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11/12/91

TABLE B-11

GASOLINE POOL COMPOSITIONS

1996 BASE CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
FCC Gasoline	11.0	10.4
Lt FCC 255-	14.9	14.4
Hvy FCC 255+	10.4	10.0
Total FCC Gasoline	36.3	34.8
Butenes		
Poly Gasoline		
Lt Coker Gasoline (C5-180)	2.8	2.7
Total Olefinic	2.8	2.7
Reformate (220-350 Feed)	22.1	18.2
Reformate (220-300 Feed)	5.9	6.1
BT Reformate (150-220 Feed)	7.2	5.5
Total Reformate	35.2	29.8
Alkylate (C3/C4)	10.8	10.6
Butanes	3.0	8.4
Natural/LSR Gasoline	3.8	3.6
Lt Naphtha (150-220)		
Isomerate (C5-C6)	0.6	0.6
Lt Hydrocrackate (C5-180)	5.0	5.0
Medium Hydrocrackate (180-225)	0.5	2.5
MTBE	2.0	2.0
Total Low Aromatics, Saturated	25.7	32.7
Total	100.0	100.0

CLM
10/02/91

TABLE B–12

GASOLINE POOL PROPERTIES AND INCREMENTAL COSTS

1996 BASE CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Summer	Winter
Average Properties		
(R+M)/2 Octane, Clear	88.9 *	88.9 *
Aromatics, V%	34	31
Ethers, V%	2.0 *	2.0 *
Oxygen, W%	0.4 *	0.4 *
Olefins, V%	11	10
Benzene, V%	2.2	2.0
Sulfur, WPPM	206	169
Reid Vapor Pressure, PSI	7.5 *	10.5 *
Temperature at V/L = 20, °F	145	128
Distillation		
90°F, V%	12	17
130°F, V%	23	27
170°F, V%	33	37
212°F, V%	50	54
257°F, V%	67	70
300°F, V%	81	83
356°F, V%	91	92
10 V%, °F	125	102
50 V%, °F	212	203
90 V%, °F	348	342
Driveability Index	1171	1104
Heat Content, MBTU/G	114.4	113.0
Incremental Costs for Property Decrease(1)		
(¢/G Per Unit In Constant 1989 $)		
(R+M)/2 Octane, Clear	(0.9)	(0.3)
Reid Vapor Pressure, PSI	0.6	0.3
Ethers, V%	(0.1)	(0.4)

* Input limit.

(1) Shadow costs for very small changes.
Not applicable for significant changes.

REC/CLM
10/02/91

TURNER, MASON & COMPANY
Consulting Engineers

TABLE C–1

RUN BASIS AND GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

				MIN CARB 2 - LAB COMPLY + CHANGES			ARCO	
		Case 1(1)						Case 7
	Base	CAA/	Case 2	Case 3	Case 4	Case 5	Case 6	8 CARB 2
Reformulated Properties*	Case 0	LA	CAA	+ None	-80 S	-33 T90	EC-X	-L C +9 DI
Aromatics, Vol.%, Max. Avg.		25	25	25	25	25	20	22
Regulatory Cap		25	25	25	25	25	20	25
Ethers, Vol.%, Minimum	2.0	11	11	11	11	11	15	11.7
Bromine No., Maximum	26 (2)	26	26 (2)	16	16	16	8	8
Regulatory Cap	30 (2)	30	30 (2)	20	20	20	10	10
Benzene, Vol.%, Max. Avg.		0.95	0.95	0.8	0.8	0.8	0.8	0.8
Sulfur, Wt. PPM, Maximum	250	163 (3)	163 (3)	120	40	120	40	20
Regulatory Cap	300	300	300	150	50	150	50	30
Reid Vapor Pressure, PSI, Max	7.5	7.1	7.1	6.7	6.7	6.7	6.7	6.7
Regulatory Cap	7.8	7.5	7.5	7.0	7.0	7.0	7.0	7.0
T90, °F, Maximum		328 (3)	328 (3)	328 (3)	328 (3)	295	295	290
Regulatory Cap		328	328	328	328	305	305	300
Driveability Index, Maximum								1084
Regulatory Cap								1100
Ethers, Vol.% Pool								
Purchased	0.6	4.8	9.4	9.3	9.7	10.1	13.2	11.9
Manufactured	1.4	1.4	1.6	1.7	1.3	1.5	1.8	1.8
Gasoline Pool Properties								
(R+M)/2 Octane, Clear*	88.9	88.9	88.9	88.9	88.9	88.9	88.9	88.9
Aromatics, Vol.%	34	29	25	25 *	25 *	24	20 *	22 *
Ethers, Vol.%	2.0 *	6.2	11.0 *	11.0 *	11.0 *	11.6	15.0 *	13.7
Oxygen, Wt.%	0.4 *	1.1	2.0 *	2.0 *	2.0 *	2.1	2.7 *	2.5
Olefins, Vol.%	11	11	10	8 *	8 *	8	4 *	4 *
Bromine No.	22	22	21	16 *	16 *	16	8 *	8 *
Benzene, Vol.%	2.2	1.3 *	0.95 *	0.8 *	0.8 *	0.8 *	0.8 *	0.8 *
Sulfur, Wt. PPM	206	155	163 *	90	40 *	72	40 *	20 *
Reid Vapor Pressure, PSI*	7.5	7.3	7.1	6.7	6.7	6.7	6.7	6.7
Temperature at V/L = 20, °F	145	145	145	147	147	146	146	146
Distillation								
90°F, Vol.%	12	11	10	9	10	8	8	8
130°F, Vol.%	23	23	21	20	20	19	18	18
170°F, Vol.%	33	40	39	37	36	37	38	38
212°F, Vol.%	50	55	56	55	54	57	58	58
257°F, Vol.%	67	72	72	72	72	77	77	78
300°F, Vol.%	81	85	85	85	85	91	91	93
356°F, Vol.%	91	94	94	94	94	98	98	98
T10, °F	125	127	131	134	134	138	140	139
T50, °F	212	197	198	201	203	196	195	195 *
T90, °F	348	328 *	328 *	328 *	328 *	295 *	295 *	290 *
Driveability Index	1171	1109	1118	1132	1137	1090	1090	1084 *
Heat Content, MBTU/G	114.4	112.8	111.6	111.8	111.8	111.4	110.4	110.8

* Input limit.

(1) 55% reformulated, 100% in LA refineries. Reformulated properties apply to LA refineries. Gasoline pool properties are average for entire state.

(2) LA only.

(3) CAA requires no degradation from 1990 base.

CLM/REC
11/4/91

TURNER, MASON & COMPANY
Consulting Engineers

TABLE C-1A

RUN BASIS AND REFORMULATED GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

Reformulated Properties*	Base Case 0	Case 1(1) CAA/LA
Aromatics, Vol.%, Max. Avg.		25
Ethers, Vol.%, Minimum	2	11
Bromine No., Maximum	26 (2)	26
Regulatory Cap	30 (2)	30
Benzene, Vol.%, Max. Avg.		0.95
Sulfur, Wt. PPM, Maximum	250	163 (3)
Regulatory Cap	300	300
Reid Vapor Pressure, PSI, Max	7.5	7.1
Regulatory Cap	7.8	7.5
T90, °F, Maximum		328 (3)
Ethers, Vol.% Pool		
Purchased	0.6	8.5
Manufactured	1.4	2.5
Gasoline Pool Properties		
(R+M)/2 Octane, Clear*	88.9	88.9
Aromatics, Vol.%	34	24
Ethers, Vol.%	2.0	11.0
Oxygen, Wt.%	0.4	2.0
Olefins, Vol.%	11	10
Bromine No.	22	20
Benzene, Vol.%	2.2	0.95 *
Sulfur, Wt. PPM	206	163
Reid Vapor Pressure, PSI*	7.5	7.1
Temperature at V/L = 20, °F	145	145
Distillation		
90°F, Vol.%	12	11
130°F, Vol.%	23	20
170°F, Vol.%	33	36
212°F, Vol.%	50	56
257°F, Vol.%	67	73
300°F, Vol.%	81	85
356°F, Vol.%	91	94
T10, °F	125	130
T50, °F	212	200
T90, °F	348	328 *
Driveability Index	1171	1123
Heat Content, MBTU/G	114.4	111.5

* Input Limit
(1) 55% reformulated, 100% in LA refineries. Reformulated properties apply to LA refineries.
(2) LA only.
(3) CAA requires no degredation.

CLM
11/4/91

TURNER, MASON & COMPANY
Consulting Engineers

TABLE C–1B

RUN BASIS AND UNREFORMULATED GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

Unreformulated Properties*	Base Case 0		Case 1(1) CAA/LA	
Aromatics, Vol.%, Max. Avg.			34	(3)
Ethers, Vol.%, Minimum	2			
Bromine No., Maximum	26	(2)	22	(3)
Regulatory Cap	30	(2)		
Benzene, Vol.%, Max. Avg.			1.8	(3)
Sulfur, Wt. PPM, Maximum	250		163	(3)
Regulatory Cap	300		300	
Reid Vapor Pressure, PSI, Max	7.5		7.5	
Regulatory Cap	7.8		7.8	
T90, °F, Maximum			328	(3)
Ethers, Vol.% Pool				
Purchased	0.6		0.2	
Manufactured	1.4		0.1	
Gasoline Pool Properties				
(R+M)/2 Octane, Clear*	88.9		88.9	
Aromatics, Vol.%	34		34	
Ethers, Vol.%	2.0	*	0.3	
Oxygen, Wt.%	0.4	*	0.1	
Olefins, Vol.%	11		11	
Bromine No.	22		22	
Benzene, Vol.%	2.2		1.8	*
Sulfur, Wt. PPM	206		144	
Reid Vapor Pressure, PSI*	7.5		7.5	
Temperature at V/L = 20, °F	145		144	
Distillation				
90°F, Vol.%	12		12	
130°F, Vol.%	23		25	
170°F, Vol.%	33		36	
212°F, Vol.%	50		53	
257°F, Vol.%	67		70	
300°F, Vol.%	81		85	
356°F, Vol.%	91		94	
T10, °F	125		125	
T50, °F	212		204	
T90, °F	348		328	*
Driveability Index	1171		1127	
Heat Content, MBTU/G	114.4		114.3	

* Input limit.

(1) 55% reformulated, 100% in LA refineries. Unreformulated properties apply to refineries outside LA.

(2) LA only.

(3) CAA requires no degredation.

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11/4/91

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TABLE C-2

SUMMARY OF COSTS

1996 CASE RESULTS[1] – INCREASE OVER BASE CASE[2]

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

			Min. CARB 2 - Lab Comply + Changes			ARCO	Case 7
	Case 1[3] CAA/LA	Case 2 CAA	Case 3 + None	Case 4 -80 S	Case 5 -33 T90	Case 6 EC-X	8 CARB 2 -L C +9 DI
Investments, MM$							
Refinery	530	650	1,020	1,230	1,790	2,510	2,860
MTBE[4]	1,070	2,240	2,230	2,310	2,410	3,250	2,890
Total	1,600	2,890	3,250	3,540	4,200	5,760	5,750
Range, MMM$[5]	1.2-2.0	2.2-3.7	2.5-4.2	2.8-4.5	3.3-5.4	4.6-7.5	4.6-7.5
Daily Costs, M$/D							
Capital Charge[6]	350	434	676	818	1,186	1,663	1,896
Net Upgrading Costs[7]	981	1,931	2,078	2,173	2,586	3,269	2,992
Variable Operating Costs	58	(49)	144	78	547	352	672
Fixed Operating Cost[8]	155	201	279	312	456	621	681
Total Refinery	1,544	2,517	3,177	3,381	4,775	5,905	6,241
Annual Cost, MM$/Yr.							
Refinery	564	919	1,160	1,234	1,744	2,157	2,279
Other[9]	196	342	318	317	375	498	440
Total	760	1,261	1,478	1,551	2,119	2,655	2,719
Total Unit Cost, ¢/G of Base Gasoline							
Average	8.8[10]	8.1	9.5	10.0	13.5	17.0	17.4
Range[11]	7.3-11.5	6.5-10.8	7.8-12.3	8.2-13.0	11.6-17.0	14.3-21.7	14.9-22.0

TURNER, MASON & COMPANY
Consulting Engineers

TABLE C-2

SUMMARY OF COSTS

1996 CASE RESULTS[1] – INCREASE OVER BASE CASE[2]

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

(1) For reformulation runs, based on a composite model of conversion refineries. Individual refinery costs will differ from average.
(2) Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.
(3) 55% reformulation; 100% in LA refineries.
(4) For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).
(5) For variations from investment curves of -15/+35% for refining and ±25% for MTBE.
(6) Based on expected 15% DCF rate of return on new refining facilities investment.
(7) Raw material upgrading costs.
(8) For new refining facilities only.
(9) Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.
(10) For reformulation portion only.
(11) For variations in capital charge (-15/+35%), MTBE costs (-10/+20¢/G) and BTU mileage factor (±0.2).

REC
11/12/91

TABLE C–2A

COMPOSITE REFINERY MARGIN & COST INCREASE DETAIL

1996 CASE 7 OVER (UNDER) BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

	MBPD	C/GAL	$/B	M$/D
Products				
Motor Gasolines–Regular	13.9	65.5	27.51	383
Motor Gasolines–Intermediate	5.2	67.7	28.43	147
Motor Gasolines–Premium	6.4	71.0	29.82	190
No. 6 Bunker	30.0		13.00	390
Propane	(10.8)	32.6	13.69	(148)
Propane to Fuel	11.6		20.47	237
Propylene	(1.6)	29.6	12.43	(20)
Propylene to Fuel	(11.6)		20.47	(238)
Process Gas to Fuel	(14.2)		20.47	(290)
Pentanes to P/C	12.1	20.0	8.40	101
Normal Butane to Fuel	(2.9)		20.47	(59)
FCC Coke to Fuel	(5.3)		20.47	(109)
Loss(Gain)	14.1			
Subtotal	46.8			583
Sulfur(M L T; $/L T)	(0.2)		70.00	(13)
Total				570
Raw Materials				
Alaska North Slope Crude	(105.2)		16.70	(1,757)
Naphtha	3.5	52.5	22.05	78
MTBE	117.9	96.0	40.32	4,754
Methanol	1.3	65.0	27.30	35
NC4	20.0	34.1	14.32	286
Natural Gas to H2 plant	9.2		20.47	188
Total	46.7			3,585
Gross Margin				(3,015)
Variable Cost				
Natural Gas	45.3		20.47	928
Produced Fuels	(21.5)		20.47	(350)
Other				184
Total Variable Cost				762
Gross Margin after Variable Cost				(3,777)

RMA
11/12/91

TABLE C-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES

1996 CASE RESULTS

INCREASE OVER BASE CASE – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Case 1		MIN CARB 2 - LAB COMPLY + CHANGES			ARCO	Case 7
	CAA/ LA	Case 2 CAA	Case 3 + None	Case 4 -80 S	Case 5 -33 T90	Case 6 EC-X	8 CARB 2 -L C +9 DI
Raw Materials							
Alaska North Slope	(38)	(115)	(111)	(113)	(50)	(140)	(105)
Subtotal Crudes	(38)	(115)	(111)	(113)	(50)	(140)	(105)
Natural Gasoline							
Naphtha	3	(3)	4	(3)	4	4	4
MTBE	44	91	91	95	99	133	118
Methanol	0	1	1	(0)	0	1	1
Normal Butane			3	1	7	20	20
Isobutane							
Natural Gas to H2 Plant Feed	3	4	5	6	(19)	8	9
Total	12	(22)	(7)	(14)	40	26	47
Products							
Motor Gasolines	12	19	18	18	21	29	25
No. 6 Bunker	5	(12)	(8)	(13)	38	18	30
Normal Butane		0	(3)	(3)	(3)	(3)	(3)
Propane	1	(4)	(5)	(5)	1	(0)	1
Propylene, Low Value	(2)	(1)	1	(6)	(13)	(13)	(13)
Process Gas	(5)	(22)	(20)	(21)	(41)	(21)	(14)
Lt Coker Naphtha to P/C			8	14	28		
Pentanes to P/C					10	7	12
Isobutane							
Marketable Coke	0	0	0	(2)	(4)	(0)	0
FCC Coke		(0)	(1)	(2)	(1)	(7)	(5)
Loss(Gain)	0	(2)	1	4	6	15	14
Total	12	(22)	(7)	(14)	40	26	47
Crude Property Increase							
Gravity, °API	(0.1)	(0.2)	(0.2)	(0.2)	(0.1)	(0.3)	(0.2)
Sulfur, Wt%	0.00	0.01	0.01	0.01	0.00	0.01	0.01
Gasoline Demand Increase, %(1)							
Results	1.1 (2)	2.0	1.8	1.8	2.0	2.8	2.5
Target	1.1 (2)	1.9	1.8	1.8	2.1	2.8	2.5

(1) To maintain constant miles traveled with lower BTU content reformulated gasoline.

(2) Unreformulated: 0.1% Results, 0.1% Target

Reformulated: 2.0% Results, 2.0% Target

CLM

11/4/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30201

TABLE C-4

NEW PROCESS UNIT RATES

1996 CASE RESULTS

INCREASE OVER BASE CASE - MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Case 1	MIN CARB 2 - LAB COMPLY + CHANGES				ARCO	Case 7
	CAA/	Case 2	Case 3	Case 4	Case 5	Case 6	8 CARB 2
	LA	CAA	+ None	-80 S	-33 T90	EC-X	-L C +9 DI
Heavy Naphtha Splitter					132	121	128
FCC Gasoline Splitters	158	142	179	149	218	338	347
FCC Gasoline Fractionation				35	61		
Hydrocracking - Heavy Gasoline						8	
Hydrocrackate Fractionation	76	128	128	137	152	148	152
Hydrotreating - Distillate	72	9	25	52	118	91	103
Reformer Feed Fractionation	159	263	305	294	260	283	290
Reformate Fractionation	38	95	212	206	267	148	197
Benzene Saturation	22	47	75	74	87	58	73
FCC Gasoline Selective HDS				94		20	136
Gasoline Aromatics Saturation						10	6
Alkylation	3		6	1	43	56	65
Alkylate Splitter					171		189
MTBE /TAME		3	3		2	5	5
Isomerization - C5/C6	7		19	14		51	49
- C4		3	9	8	22	33	36
Hydrogen - MMSCFPSD	3	5	5	5	44	48	71

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11/4/91

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TABLE C-5

NEW PROCESS UNIT INVESTMENTS

1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	Case 1		MIN CARB 2 - LAB COMPLY + CHANGES			ARCO	Case 7
	CAA/ LA	Case 2 CAA	Case 3 + None	Case 4 -80 S	Case 5 -33 T90	Case 6 EC-X	8 CARB 2 -L C +9 DI
Heavy Naphtha Splitter					90	80	90
FCC Gasoline Splitters	80	80	90	140	180	470	520
FCC Gasoline Fractionation				10	30		
Hydrocracking - Heavy Gasoline						130	
Hydrocrackate Fractionation	90	90	90	90	100	100	100
Hydrotreating - Distillate	110	10	40	90	240	180	210
Reformer Feed Fractionation	80	140	160	160	140	150	150
Reformate Fractionation	30	70	130	120	150	100	120
Benzene Saturation	80	170	240	230	260	190	210
FCC Gasoline Selective HDS				210		70	270
Gasoline Aromatics Saturation						100	60
Alkylation	20		30		250	340	380
Alkylate Splitter					110		120
MTBE / TAME		20	20		10	30	30
Isomerization - C5/C6	40		120	90		290	270
- C4		20	50	40	120	170	170
Hydrogen	10	10	10	10	70	70	110
MTBE Storage & Blending	20	40	40	40	40	50	50
Total Refinery	530	650	1,020	1,230	1,790	2,510	2,860

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ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
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30203

TURNER, MASON & COMPANY
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TABLE C-6
PROCESS UNIT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE - MBPCD PER REFINERY
WSPA STUDY OF CARB PHASE 2 GASOLINE

		Case 1		MIN CARB 2 - LAB COMPLY + CHANGES			ARCO	Case 7
	Base Case 0	CAA/ LA	Case 2 CAA	Case 3 + None	Case 4 -80 S	Case 5 -33 T90	Case 6 EC-X	8 CARB 2 -L C +9 DI
Crude - Atmospheric	111.1	(2.3)	(6.8)	(6.5)	(6.6)	(3.0)	(8.2)	(6.2)
Heavy Naphtha Splitter						7.3	6.8	7.2
Catalytic Cracking (1)	36.8		(0.7)	(0.7)	(4.0)	(0.8)	(4.9)	(3.4)
Catalytic Cracking (2)	37.3		(0.7)	(0.7)	(4.0)	(0.8)	(5.4)	(3.9)
Conversion, %	74.4		(0.0)	(2.8)	(1.0)	(2.7)	(0.3)	(1.8)
Octane Catalyst, %	15.0		0.0	0.0	(0.0)			
FCC Gasoline Splitters		8.8	8.0	10.0	8.3	12.2	18.9	19.4
FCC Gasoline Fractionation	15.2	(2.7)	(5.2)	(5.2)	3.8	5.2	(15.2)	(15.2)
Hydrocracking - 2 Stage(1)	16.9							
Jet Yield, % of Max	96.7	(38.9)	(6.6)	(2.2)	(20.2)	(73.3)	(44.0)	(72.4)
300 - Gasoline Operation, %		38.1	9.9			66.1	38.7	58.2
Hydrocracking - Low Conversion	3.2				1.0	1.0	1.0	1.0
- Heavy Gasoline							0.4	
- Combined(2)	20.1	(1.1)	(0.3)		1.0	(0.9)	0.3	(0.6)
Hydrocrackate Fractionation		7.1	6.6	6.6	7.1	7.9	7.7	7.9
Coking - Delayed	22.9						(0.1)	
- Fluid	5.3				(0.5)	(0.8)		
Thermal Cracking, Visbreaking	2.3	(2.1)	(2.1)	(2.1)	(2.1)		(1.8)	(0.3)
Solvent Deasphalting	1.0	1.6	0.6	0.7	1.2	0.2	1.5	0.2
Catalytic Reforming - 100 PSI (1)	3.4	(1.1)	(1.4)	(0.9)	(0.9)	(0.9)	(0.9)	(0.5)
- 200 PSI (1)	16.6		(2.4)	(2.2)	(1.6)	(2.4)	(2.7)	(2.0)
- 450 PSI (1)	8.9	(4.4)	(4.4)	(4.4)	(4.4)	(4.4)	(4.4)	(3.1)
- Combined (2)	26.4	(4.4)	(5.8)	(5.4)	(4.6)	(5.2)	(4.9)	(3.5)
- RONC	99.2	(0.2)	(5.2)	(4.7)	(5.2)	(4.2)	(7.9)	(6.3)
Hydrotreating - Naphtha	18.8	(3.0)	(4.7)	(1.0)	0.2	(3.1)	0.7	1.0
- Distillate	22.0	3.7	0.5	1.3	2.7	6.1	4.7	5.3
- Heavy Gas Oil	31.0			0.8		0.8		
- Residuum - Vac	1.4						(1.4)	(1.3)
Reformer Feed Fractionation		8.2	13.6	15.8	15.2	13.5	14.6	15.0
Reformate Fractionation		2.0	4.9	11.0	10.7	13.8	7.6	10.2
Benzene Saturation		1.1	2.4	3.9	3.6	4.5	2.8	3.5
FCC Gasoline Selective HDS					4.8		1.1	7.1
Gasoline Aromatics Saturation							0.5	0.3
Diesel Aromatics Saturation	11.7		(0.4)	(0.3)	(0.0)	(0.4)	(0.0)	(0.3)
Alkylation	6.6	0.2		0.3	0.0	2.1	2.7	3.2
Alkylate Splitter						8.3		9.2
Polymerization								
MTBE / TAME	0.8	0.1	0.2	0.2	(0.1)	0.1	0.2	0.3
Lubes	1.3							
Isomerization - C5/C6		0.3		1.0	0.7		2.7	2.5
- C5/C6, Recycle	0.4							
- C4	0.3		0.2	0.5	0.4	1.1	1.6	1.8
Hydrogen - MMSCFPCD	58.1	3.2	5.1	6.4	7.6	9.9	10.1	11.5
Sulfur, LTPCD	130.0	1.0	(5.0)	(7.0)	(5.0)	(7.0)	(9.0)	(11.0)

(1) Include effects of nonunitary capacity for some feedstocks and severities.
(2) Based on actual feed rates, ignoring severity effects.

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11/4/91

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TABLE C-7

PROCESS UNIT UTILIZATIONS (1)

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base	Case 1		MIN CARB 2 – LAB COMPLY + CHANGES			ARCO	Case 7
	Case	CAA/	Case 2	Case 3	Case 4	Case 5	Case 6	8 CARB 2
	0(2)	LA	CAA	+ None	–80 S	–33 T90	EC–X	–L C +9 DI
Crude Distillation - Atmospheric	89.2	87.4	83.7	83.9	83.8	86.8	82.6	84.2
Heavy Naphtha Splitter						95.0	95.0	95.0
Catalytic Cracking (3)	95.0	95.0	93.3	93.2	84.6	93.0	82.3	86.1
Catalytic Cracking (4)	96.2	96.2	94.5	94.4	85.8	94.2	82.3	86.2
FCC Gasoline Splitters		95.0	95.0	95.0	95.0	95.0	95.0	95.0
FCC Gasoline Fractionation	84.9	69.9	55.9	55.9	95.0	95.0		
Hydrocracking - 2 Stage(3)	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0
- Low Conversion	67.0	67.0	67.0	67.0	88.0	88.0	88.0	88.0
- Heavy Gasoline							88.0	
- Combined(4)	83.8	79.4	82.7	83.8	88.0	80.2	85.3	81.2
Hydrocrackate Fractionation		88.0	88.0	88.0	88.0	88.0	88.0	88.0
Coking - Delayed	95.0	95.0	95.0	95.0	95.0	95.0	94.6	95.0
- Fluid	95.0	95.0	95.0	95.0	86.1	80.3	95.0	95.0
Thermal Cracking, Visbreaking	88.0	7.0	7.0	7.0	7.0	88.0	17.5	78.0
Solvent Deasphalting	32.5	87.7	53.9	55.8	71.9	38.2	84.4	38.9
Catalytic Reforming - 100 PSI (3)	88.0	59.0	51.9	64.9	64.9	64.9	64.9	75.3
- 200 PSI (3)	88.0	88.0	75.2	76.5	79.8	75.3	73.9	77.4
- 450 PSI (3)	88.0	43.8	43.8	43.8	43.8	43.8	43.8	57.7
- Combined (4)	80.4	67.2	62.9	63.9	66.3	64.6	65.4	69.7
Hydrotreating - Naphtha	66.7	56.1	50.1	63.0	67.3	55.5	69.1	70.1
- Distillate	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0
- Heavy Gas Oil	85.8	85.8	85.8	88.0	85.8	88.0	85.8	85.8
- Residuum, Vac	88.0	88.0	88.0	88.0	88.0	88.0	0.0	7.0
Reformer Feed Fractionation		88.0	88.0	88.0	88.0	88.0	88.0	88.0
Reformate Fractionation		88.0	88.0	88.0	88.0	88.0	88.0	88.0
Benzene Saturation		83.0	83.0	83.0	83.0	83.0	83.0	83.0
FCC Gasoline Selective HDS					88.0		88.0	88.0
Gasoline Aromatics Saturation							88.0	88.0
Diesel Aromatics Saturation	88.0	88.0	85.2	85.5	88.0	85.0	88.0	86.0
Alkylation	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Alkylate Splitter						83.0		83.0
Polymerization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MTBE / TAME	83.0	83.0	83.0	83.0	79.2	83.0	83.0	83.0
Lubes	87.6	87.6	87.6	87.6	87.6	87.6	87.6	87.6
Isomerization - C5/C6		88.0		88.0	88.0		88.0	88.0
- C5/C6, Recycle	88.0	88.0	88.0	88.0	88.0	88.0	88.0	88.0
- C4	83.0	76.2	83.0	83.0	83.0	83.0	83.0	83.0
Hydrogen	72.9	76.9	79.3	81.0	82.5	83.0	83.0	83.0
Sulfur	45.9	46.3	44.2	43.5	44.2	43.5	42.7	42.0

(1) Calendar day rates divided by stream day capacity.

(2) Includes idle 450 psi reformer, reformate fractionation, aromatics extraction, alkylation and polymerization capacity that was assumed not available in reformulation runs.

(3) Include effects of nonunitary capacity factors for some feedstocks and severities.

(4) Based on actual feed rates, ignoring severity effects.

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11/12/91

TABLE C-8

GASOLINE POOL COMPOSITIONS

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		Case 1		MIN CARB 2 - LAB COMPLY + CHANGES			ARCO	Case 7
	Base Case 0	CAA/ LA	Case 2 CAA	Case 3 + None	Case 4 -80 S	Case 5 -33 T90	Case 6 EC-X	8 CARB 2 -L C +9 DI
FCC Gasoline	11.1	4.7	5.7	1.2				
Lt. FCC 255-	15.0	12.3	9.7	9.7	17.5	13.6		
Hvy FCC 255+	10.5	10.6	11.1	11.9				
Hvy FCC 255+ Desul					8.0		1.8	11.5
FCC Gaso (100-255)		2.6	3.9	6.4				
FCC Gaso (100-180)					0.3	2.1	4.2	4.6
FCC Gaso (180-225)					0.2	1.3	3.7	2.8
FCC Gaso (225-300)					4.0	6.0	5.8	
FCC Gaso (300-375)						5.0	1.4	
Total FCC Gasoline	36.6	30.2	30.4	29.2	30.0	28.0	16.9	18.9
Pentenes		1.0	0.9	0.5				
Poly Gasoline								
Lt. Coker Gasoline	2.8	3.9	3.8					
Total Olefinic	2.8	4.9	4.7	0.5	—	—	—	—
Reformate	22.2	17.5	14.2	10.9	7.7			0.6
Reformate (220-300 Feed)	5.9	7.9	6.5	0.4	5.2	6.2	17.4	14.5
BT Reformate	7.2	0.9						
HC Reformate (210-300)		1.5	3.6	9.1	8.0	12.0	5.6	8.1
Heavy Reformate (300+)			0.4	2.6	3.8	3.3	2.2	1.9
Total Reformates(1)	35.3	27.8	24.7	23.0	24.7	21.5	25.2	25.1
Lt. Reformate (Benzene Saturated)		1.8	4.2	6.5	6.1	7.5	4.8	5.9
Alkylate/Lt Alkylate (C3/C4)	10.9	11.1	10.7	10.0	10.5	10.8	11.0	10.0
Alkylate/Lt Alkylate (C5)				1.1	0.2	0.9	3.4	2.8
Butane	2.5	1.8	1.5	1.5	1.5	1.5	1.5	1.5
Natural/LSR Gaso	3.8	3.7	3.4	2.6	2.7	2.9	2.5	2.7
BT Naphtha (150-220)						1.9	0.1	
Iso Pentane		0.9	1.0	1.4	0.1		1.9	1.6
Normal Pentane		0.2	0.2	0.3			0.4	0.3
Isomerate (C5-C6)	0.6	1.2	0.5	1.9	1.8	0.6	2.7	2.8
Isomerate (C6)			0.1	0.3			2.2	1.9
Lt. Hydrocrackate	5.0	5.7	5.1	5.0	5.4	6.5	6.2	6.5
Hydrocrackate (175-225)	0.5	4.5	2.4	5.7	6.0	6.2	6.1	6.3
MTBE	2.0	6.2	10.8	10.6	11.0	11.5	14.4	13.0
TAME		0.0	0.3	0.4		0.2	0.7	0.7
Total Low Arom., Saturated	25.3	37.1	40.2	47.3	45.3	50.5	57.9	56.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(1) Excluding light reformate.

CLM/REC
10/31/91

TABLE C–9

GASOLINE PROPERTY DECREASE – INCREMENTAL COSTS(1)

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

	Base Case 0	Case 1 CAA/ LA	Case 2 CAA	MIN CARB 2 - LAB COMPLY + CHANGES Case 3 + None	Case 4 -80 S	Case 5 -33 T90	ARCO Case 6 EC–X	Case 7 8 CARB 2 -L C +9 DI
(R+M)/2 Octane, Clear	(0.9)	(1.0)	(0.6)	(1.2)	(1.1)	(1.0)	(1.2)	(1.5)
Reid Vapor Pressure, PSI	0.6	0.7	0.6	2.3	2.5	4.2	4.0	3.6
Butane, Vol.%		0.0	0.0	0.8	1.0	1.8	1.6	1.5
Aromatics, Vol.%				0.2	0.3		0.2	0.2
Ethers, Vol.%	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)		0.1	
Olefins, Vol.%				0.0	0.2		0.5	0.5
Benzene, Vol.%		1.3	2.8	2.0	3.0	2.5	2.3	2.0
Sulfur, 100 Wt. PPM		0.2	0.0		3.5		2.3	3.0
T90, 10°F		0.6	1.4	1.2	0.3	3.2	2.3	2.5

(1) Shadow costs for very small changes.
Not applicable for significant changes.

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11/4/91

TABLE D-1

RUN BASIS AND GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES					
Reformulated Properties*	Base Case 0	Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(1)	Case 11 +15 T90(1)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(1)
Aromatics, Vol.%, Maximum		22	22	22	22	22	22
Regulatory Cap		25	25	25	25	25	25
Oxygen, Wt.%, Minimum Avg	0.4	2.1	2.1	2.1	2.1	2.1	2.1
Bromine No., Maximum	26 (2)	8	8	8	8	8	17
Regulatory Cap	30 (2)	10	10	10	10	10	20
Benzene, Vol.%, Maximum Avg		0.8	0.8	0.8	0.8	0.8	0.8
Sulfur, Wt. PPM, Maximum	250	20	20	20	20	50	120
Regulatory Cap	300	30	30	30	30	65	150
Reid Vapor Pressure, PSI, Max	7.5	6.7	7.1	6.7	6.7	6.7	6.7
Regulatory Cap	7.8	7.0	7.4	7.0	7.0	7.0	7.0
T90, °F, Maximum		290	290	320	305	290	320
Regulatory Cap		300	300	330	315	300	330
Driveability Index, Maximum		1075	1075			1075	
Regulatory Cap		1100	1100			1100	
Ethers, Vol.% Pool							
Purchased	0.6	9.9	9.9	11.8	12.0	9.9	10.8
Manufactured	1.4	1.8	1.8	1.8	1.8	1.9	1.7
Gasoline Pool Properties							
(R+M)/2 Octane, Clear*	88.9	88.9	88.9	88.9	88.9	88.9	88.9
Aromatics, Vol.%	34	22 *	22 *	22 *	22 *	22 *	22 *
Ethers, Vol.%	2.0 *	11.7 *	11.7 *	13.6	13.8	11.8	12.5
Oxygen, Wt.%	0.4 *	2.1 *	2.1 *	2.5	2.5	2.1	2.2
Olefins, Vol.%	11	4	4 *	4	4	4 *	8
Bromine No.	22	8	8 *	8	7	8 *	16
Benzene, Vol.%	2.2	0.8 *	0.8 *	0.8 *	0.8 *	0.8 *	0.8 *
Sulfur, Wt. PPM	206	20 *	20 *	20 *	20 *	42	120 *
Reid Vapor Pressure, PSI*	7.5	6.7	7.1	6.7	6.7	6.7	6.7
Temperature at V/L = 20, °F	145	144	142	146	146	145	147
Distillation							
90°F, Vol.%	12	8	10	9	9	8	9
130°F, Vol.%	23	20	22	19	19	19	19
170°F, Vol.%	33	39	41	39	39	38	38
212°F, Vol.%	50	60	61	58	59	60	56
257°F, Vol.%	67	79	79	74	77	79	74
300°F, Vol.%	81	92	92	86	89	92	86
356°F, Vol.%	91	98	98	96	97	98	95
T10, °F	125	139	133	136	137	139	142
T50, °F	212	192	190	195	194	192	198
T90, °F	348	290 *	290 *	320 *	305 *	290 *	320 *
Driveability Index	1171	1075 *	1060	1109	1093	1075 *	1127
Heat Content, MBTU/G	114.4	110.9	110.8	110.9	110.8	111.0	111.2

(1) No T50/DI Limits
(2) L.A. only
* Input limit.

CLM/REC 11/13/91

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Consulting Engineers

TABLE D-2

SUMMARY OF COSTS

1996 CASE RESULTS[1] – INCREASE OVER BASE CASE[2]

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

	8/5/91 CARB 2 Proposal - Lab Comply Margins + Changes					
	Case 8 + None	Case 9 + 0.4 RVP	Case 10 + 30 T90[3]	Case 11 + 15 T90[3]	Case 12 + 30 S	Case 13 + 5 OL/100S 30 T90[3]
Investments, MM$						
Refinery	3,430	3,130	2,120	2,350	3,200	1,320
MTBE[4]	2,390	2,400	2,890	2,940	2,410	2,610
Total	5,820	5,530	5,010	5,290	5,610	3,930
Range, MMM$[5]	4.7-7.6	4.5-7.2	4.0-6.5	4.2-6.8	4.5-7.3	3.1-5.0
Daily Costs, M$/D						
Capital Charge[6]	2,277	2,076	1,404	1,559	2,124	876
Net Upgrading Costs[7]	2,442	2,271	2,726	2,889	2,424	2,400
Variable Operating Costs	980	842	407	513	879	97
Fixed Operating Cost[8]	812	731	512	569	777	357
Total Refinery	6,511	5,920	5,049	5,530	6,204	3,730
Annual Cost, MM$/Yr.						
Refinery	2,377	2,162	1,843	2,019	2,265	1,362
Other[9]	426	451	428	448	425	398
Total	2,803	2,613	2,271	2,467	2,690	1,760
Total Unit Cost, ¢/G of Base Gasoline						
Average	18.0	16.7	14.6	15.8	17.2	11.2
Range[10]	15.5-22.4	14.3-21.0	12.2-18.7	13.3-20.1	14.8-21.5	9.3-14.7

TABLE D-2

SUMMARY OF COSTS

1996 CASE RESULTS[2] – INCREASE OVER BASE CASE[3]

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

[1] For reformulation runs, based on a composite model of conversion refineries. Individual refinery costs will differ from average.

[2] Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.

[3] No T50/DI Limits.

[4] For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).

[5] For variations from investment curves of -15/+35% for refining and ±25% for MTBE.

[6] Based on expected 15% DCF rate of return on new refining facilities investment.

[7] Raw material upgrading costs.

[8] For new refining facilities only.

[9] Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.

[10] For variations in capital charge (-15/+35%), MTBE costs (-10/+20¢/G) and BTU mileage factor (±0.2).

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TABLE D-2A

COMPOSITE REFINERY MARGIN & COST INCREASE DETAIL

1996 CASE 8 OVER(UNDER) BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

	MBPD	C/GAL	$/B	M$/D
Products				
Motor Gasolines–Regular	13.2	65.5	27.51	363
Motor Gasolines–Intermediate	4.9	67.7	28.43	139
Motor Gasolines–Premium	6.0	71.0	29.82	180
No. 6 Bunker	31.8		13.00	413
Propane	(8.6)	32.6	13.69	(117)
Propane to Fuel	11.6		20.47	237
Propylene	(1.6)	29.6	12.43	(20)
Propylene to Fuel	(11.6)		20.47	(238)
Process Gas to Fuel	(3.5)		20.47	(72)
Pentanes to P/C	18.0	20.0	8.40	151
Normal Butane to Fuel	(2.9)		20.47	(59)
FCC Coke to Fuel	(3.8)	48.7	20.47	(78)
Loss(Gain)	5.2			
Subtotal	58.6			899
Sulfur(M L T; $/L T)	(0.1)		70.00	(8)
Total				891
Raw Materials				
Alaska North Slope Crude	(66.5)		16.70	(1,110)
Naphtha	3.5	52.5	22.05	78
Normal Butane	9.1	34.1	14.32	131
MTBE	97.2	96.0	40.32	3,918
Methanol	1.4	65.0	27.30	39
Natural Gas to H2 Plant	13.8		20.47	283
Total	58.6			3,338
Gross Margin				(2,448)
Variable Cost				
Natural Gas	43.9		20.47	899
Produced Fuels	(10.3)		20.47	(210)
Other				291
Total Variable Cost				980
Gross Margin after Variable Cost				(3,424)

RMA
11/12/91

TABLE D-2B

ADDED MANPOWER AND FIXED COSTS

1996 CASE 8 INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Number of Employees
Manpower	
Direct Process Operating Labor	800
Off-Site Operators, Administrative, Technical and Staff	1,400
Maintenance Employees	900
Total Employees	3,100
Contract Maintenance	300
Total Manpower	3,400
Fixed Costs	
Total Fixed Operating Costs, $MM/Year[1]	285
Salaries and Wages, %	55
Maintenance Costs, $MM/Year[1]	111

[1] Includes manpower.

GWM
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TABLE D-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD
WSPA STUDY OF CARB PHASE 2 GASOLINE

	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES					
	Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(1)	Case 11 +15 T90(1)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(1)
Raw Materials						
Alaska North Slope	(66)	(79)	(165)	(136)	(79)	(170)
Subtotal Crudes	(66)	(79)	(165)	(136)	(79)	(170)
Naphtha	4	4	(2)	4	4	(3)
MTBE	97	97	117	120	98	106
Methanol	1	1	2	1	2	1
Normal Butane	9	1	20	20	17	20
Isobutane			6			6
Natural Gas to H2 Plant Feed	14	13	(20)	(19)	12	(21)
Total	58	38	(42)	(11)	52	(61)
Products						
Motor Gasolines	24	25	24	25	24	23
No. 6 Bunker	32	31	(13)	8	34	(13)
Normal Butane	(3)	(3)	(3)	(3)	(3)	(3)
Propane	3	2	(5)	(2)	0	(6)
Propylene, Low Value	(13)	(12)	(10)	(7)	(13)	(13)
Process Gas	(5)	(6)	(47)	(43)	(9)	(53)
Pentanes to P/C	18				16	
Marketable Coke	0	0	(1)	0	(5)	(6)
FCC Coke	(4)	(4)	(2)	(4)	(1)	(2)
Loss(Gain)	6	4	15	15	10	12
Total	59	38	(42)	(11)	52	(61)
Crude Property Increase						
Gravity, °API	(0.1)	(0.2)	(0.3)	(0.3)	(0.2)	(0.3)
Sulfur, Wt%	0.00	0.00	0.01	0.01	0.00	0.01
Gasoline Demand Increase, %(2)						
Results	2.4	2.5	2.3	2.5	2.3	2.2
Target	2.4	2.5	2.4	2.5	2.4	2.2

(1) No T50/DI Limits
(2) To maintain constant miles traveled with lower BTU content reformulated gasoline.

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TABLE D-4

NEW PROCESS UNIT RATES

1996 CASE RESULTS

INCREASE OVER BASE CASE – MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	8/5/91 CARB 2 PROPOSAL – LAB COMPLY MARGINS + CHANGES					
	Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(1)	Case 11 +15 T90(1)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(1)
Heavy Naphtha Splitter	128	127		99	129	2
FCC Gasoline Splitters	349	348	346	346	353	234
Hydrocracking – Heavy Gasoline	45	38			35	
Hydrocrackate Fractionation	179	175	134	141	171	130
Hydrotreating – Distillate	100	85	35	75	87	13
Reformer Feed Fractionation	343	335	348	350	316	255
Reformate Fractionation	347	312	273	246	310	170
Benzene Saturation	114	107	73	87	101	67
FCC Gasoline HDS	27	44	57	57		
Gasoline Aromatics Saturation	8	0				
Alkylation	65	46	48	49	72	51
Alkylate Splitter					69	
MTBE /TAME	6	6	6	6	7	4
Isomerization – C5/C6	30	30	28	28	39	1
– C4	25	15	29	32	34	29
Hydrogen – MMSCFPSD	191	172	22	52	131	1

(1) No T50/DI Limits

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TABLE D-5

NEW PROCESS UNIT INVESTMENTS

1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES					
	Case 8 +None	Case 9 +0.4 RVP	Case 10 +30 T90(1)	Case 11 +15 T90(1)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(1)
Heavy Naphtha Splitter	90	90		70	90	0
FCC Gasoline Splitters	530	520	520	520	530	210
Hydrocracking - Heavy Gasoline	620	610			530	
Hydrocrackate Fractionation	110	110	90	90	110	90
Hydrotreating - Distillate	200	170	60	150	170	20
Reformer Feed Fractionation	160	160	170	170	160	130
Reformate Fractionation	180	160	150	140	160	110
Benzene Saturation	310	290	230	250	280	210
FCC Gasoline HDS	90	140	160	160		
Gasoline Aromatics Saturation	80	0				
Alkylation	390	270	290	290	440	310
Alkylate Splitter					60	
MTBE / TAME	30	30	40	30	40	30
Isomerization - C5/C6	200	190	180	180	240	0
- C4	130	80	150	160	170	150
Hydrogen	280	250	40	70	190	10
MTBE Storage & Blending	40	40	50	50	40	40
Total Refinery	3,430	3,130	2,120	2,350	3,200	1,320

(1) No T50/DI Limits

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TABLE D-6

PROCESS UNIT RATE CHANGES

1996 CASE RESULTS

INCREASE OVER BASE CASE - MBPCD PER REFINERY

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES					
	Base Case 0	Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(1)	Case 11 +15 T90(1)	Case 12 +30 S	Case 13 +5 OL/100 S 30 T90(1)
Crude - Atmospheric	111.1	(3.9)	(4.6)	(9.7)	(8.0)	(4.7)	(10.0)
Heavy Naphtha Splitter		7.1	7.1		5.5	7.2	0.1
Catalytic Cracking (2)	36.8	(3.1)	(3.3)	(3.9)	(3.7)	(2.7)	(1.2)
Catalytic Cracking (3)	37.3	(3.4)	(3.6)	(3.9)	(4.0)	(2.7)	(1.2)
Conversion, %	74.4	(2.0)	(1.9)	(1.1)	(1.5)	(2.3)	(2.5)
Octane Catalyst, %	15.0						
FCC Gasoline Splitters		19.5	19.4	19.3	19.3	19.7	13.1
FCC Gasoline Fractionation	15.2	(15.2)	(15.2)	(15.2)	(15.2)	(15.2)	(8.2)
Hydrocracking - 2 Stage(2)	16.9						
Jet Yield, % of Max	96.7	(56.9)	(46.8)	(19.5)	(34.3)	(53.8)	(11.2)
300 - Gasoline Operation, %					16.5	9.9	14.5
Hydrocracking - Low Conversion	3.2	1.0	1.0		1.0	1.0	
- Heavy Gasoline		2.3	2.3			1.8	
- Combined(3)	20.1	3.3	3.3		0.5	2.5	(0.4)
Hydrocrackate Fractionation		9.3	9.1	6.9	7.3	8.9	6.7
Coking - Delayed	22.9			(0.3)		(1.0)	
- Fluid	5.3						(1.3)
Thermal Cracking, Visbreaking	2.3			(1.3)	(2.1)		(2.1)
Solvent Deasphalting	1.0	(0.0)	(0.0)	(0.5)	1.3		1.2
Catalytic Reforming - 100 PSI (2)	3.4			(0.5)	(0.5)	(0.5)	(1.0)
- 200 PSI (2)	16.6			(1.0)	(1.0)	(0.7)	(4.4)
- 450 PSI (2)	8.9	(2.3)	(2.3)	(2.9)	(2.9)	(2.3)	(4.4)
- Combined (3)	26.4	0.6	(0.3)	(1.9)	(1.2)	(1.4)	(7.7)
- RONC	99.2	(4.9)	(4.5)	(7.1)	(7.1)	(4.6)	(6.0)
Hydrotreating - Naphtha	18.8	2.8	2.4	3.3	3.1	0.2	(3.4)
- Distillate	22.0	5.2	4.4	1.8	3.9	4.5	0.7
- Heavy Gas Oil	31.0						0.8
- Residuum - Vac	1.4	(0.8)	(1.0)		(0.9)		
Reformer Feed Fractionation		17.8	17.3	18.0	18.1	16.4	13.2
Reformate Fractionation		18.0	16.2	14.1	12.7	16.1	8.8
Benzene Saturation		5.6	5.2	3.6	4.3	4.9	3.3
FCC Gasoline HDS		1.4	2.6	3.0	2.9		
Gasoline Aromatics Saturation		0.4					
Diesel Aromatics Saturation	11.7	(0.1)	(0.1)			(0.3)	
Alkylation	6.6	3.2	2.2	2.4	2.4	3.5	2.5
Alkylate Splitter						3.4	
Polymerization							0.1
MTBE / TAME	0.8	0.3	0.3	0.4	0.3	0.4	0.2
Lubes	1.3						
Isomerization - C5/C6		1.5	1.5	1.5	1.5	2.0	0.0
- C5/C6, Recycle	0.4						
- C4	0.3	1.2	0.7	1.4	1.5	1.6	1.4
Hydrogen - MMSCFPCD	58.1	17.2	16.4	9.0	10.5	14.4	6.5
Sulfur, LTPCD	130.0	(7.0)	(8.0)	(7.0)	(8.0)	(7.0)	(12.0)

(1) No T50/DI Limits
(2) Include effects of nonunitary capacity for some feedstocks and severities.
(3) Based on actual feed rates, ignoring severity effects.

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TABLE D–7

PROCESS UNIT UTILIZATIONS (1)

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base Case 0	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(2)	Case 11 +15 T90(2)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(2)
Crude Distillation - Atmospheric	89.2	86.0	85.5	81.4	82.7	85.4	81.1
Heavy Naphtha Splitter		95.0	95.0		95.0	95.0	95.0
Catalytic Cracking (3)	95.0	86.9	86.4	85.0	85.5	88.1	91.8
Catalytic Cracking (4)	96.2	87.4	86.8	86.2	85.9	89.3	93.1
FCC Gasoline Splitters		95.0	95.0	95.0	95.0	95.0	95.0
FCC Gasoline Fractionation	84.9						39.3
Hydrocracking - 2 Stage(3)	88.0	88.0	88.0	88.0	88.0	88.0	88.0
- Low Conversion	67.0	88.0	88.0	67.0	88.0	88.0	67.0
- Heavy Gasoline		88.0	88.0			88.0	
- Combined(3)	83.8	88.0	88.0	83.8	86.1	86.9	82.1
Hydrocrackate Fractionation		88.0	88.0	88.0	88.0	88.0	88.0
Coking - Delayed	95.0	95.0	95.0	93.9	95.0	90.7	95.0
- Fluid	95.0	95.0	95.0	95.0	95.0	95.0	71.3
Thermal Cracking, Visbreaking	88.0	88.0	88.0	37.3	7.3	88.0	7.0
Solvent Deasphalting	32.5	31.8	31.3	14.5	76.3	33.0	74.7
Catalytic Reforming - 100 PSI (3)	88.0	88.0	88.0	75.3	75.3	75.3	62.3
- 200 PSI (3)	88.0	88.0	88.0	82.7	82.4	84.4	64.7
- 450 PSI (3)	88.0	65.6	65.6	58.7	58.7	65.6	43.8
- Combined (4)	80.4	82.4	79.7	74.8	76.8	76.4	57.1
Hydrotreating - Naphtha	66.7	76.8	75.0	78.4	77.6	67.3	54.7
- Distillate	88.0	88.0	88.0	88.0	88.0	88.0	88.0
- Heavy Gas Oil	85.8	85.8	85.8	85.8	85.8	85.8	88.0
- Residuum, Vac	88.0	35.3	26.4	88.0	28.9	88.0	88.0
Reformer Feed Fractionation		88.0	88.0	88.0	88.0	88.0	88.0
Reformate Fractionation		88.0	88.0	88.0	88.0	88.0	88.0
Benzene Saturation		83.0	83.0	83.0	83.0	83.0	83.0
FCC Gasoline HDS		88.0	88.0	88.0	88.0		
Gasoline Aromatics Saturation		88.0	88.0				
Diesel Aromatics Saturation	88.0	87.3	87.0	88.0	88.0	85.7	88.0
Alkylation	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Alkylate Splitter						83.0	
Polymerization	0.0	0.0	0.0	8.1	0.0	0.0	20.3
MTBE / TAME	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Lubes	87.6	87.6	87.6	87.6	87.6	87.6	87.6
Isomerization - C5/C6		88.0	88.0	88.0	88.0	88.0	88.0
- C5/C6, Recycle	88.0	88.0	88.0	88.0	88.0	88.0	88.0
- C4	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Hydrogen	72.9	83.0	83.0	83.0	83.0	83.0	81.1
Sulfur	45.9	43.5	43.1	43.5	43.1	43.5	41.7

(1) Calendar day rates divided by stream day capacity.
(2) No T50/DI Limits
(3) Include effects of nonunitary capacity factors for some feedstocks and severities.
(4) Based on actual feed rates, ignoring severity effects.

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TABLE D-8

GASOLINE POOL COMPOSITIONS

1996 CASE RESULTS - %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES					
	Case 0	Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(1)	Case 11 +15 T90(1)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(1)
FCC Gasoline	11.1						
Lt. FCC 255-	15.0						6.9
Hvy FCC 255+	10.5						4.7
Hvy FCC 255+ Desul		2.3	4.2	4.9	4.9		
FCC Gaso (100-255)							
FCC Gaso (100-180)		6.2	6.3	6.3	6.2	5.6	4.4
FCC Gaso (180-225)		3.8	2.8	3.7	3.7	3.8	2.5
FCC Gaso (225-300)		0.2	0.4		0.1	3.2	5.1
FCC Gaso (300-375)						1.8	3.5
Total FCC Gasoline	36.6	12.5	13.7	14.9	14.9	14.4	27.1
Pentenes			0.7	0.4			
Poly Gasoline				0.1			0.2
Lt. Coker Gasoline	2.8						2.5
Total Olefinic	2.8	0.0	0.7	0.5	0.0	0.0	2.7
Reformate	22.2			0.5			7.7
Reformate (220-300 Feed)	5.9	7.9	9.4	11.3	14.2	8.2	4.1
BT Reformate	7.2						
HC Reformate (210-300)		14.8	13.0	11.1	10.0	13.3	6.8
Heavy Reformate (300+)		4.6	4.0	6.1	3.8	4.0	2.1
Total Reformates(2)	35.3	27.3	26.4	29.0	28.0	25.5	20.7
Lt. Reformate (Benzene Saturated)		9.3	8.8	6.1	7.2	8.3	5.5
Alkylate/Lt Alkylate (C3/C4)	10.9	11.7	11.3	11.1	10.5	11.9	11.9
Alkylate/Lt Alkylate (C5)		3.6	2.5	2.9	3.5	2.9	2.3
Butane	2.5	1.5	1.5	1.5	1.5	1.5	1.5
Natural/LSR Gaso	3.8	2.8	2.7	3.0	2.5	2.8	2.7
BT Naphtha (150-220)						1.1	
Iso Pentane		1.2	2.6	2.6	2.6	1.4	1.8
Normal Pentane		0.2	0.5	0.5	0.5	0.2	0.3
Isomerate (C5-C6)	0.6	2.8	2.8	2.7	2.7	2.7	0.7
Isomerate (C6)		0.3	0.3	0.3	0.3	1.1	
Lt. Hydrocrackate	5.0	7.7	7.6	5.4	5.8	7.4	5.3
Hydrocrackate (175-225)	0.5	7.3	6.8	5.8	6.1	6.9	5.0
MTBE	2.0	11.1	11.1	13.0	13.2	11.2	12.1
TAME		0.7	0.7	0.7	0.7	0.7	0.4
Total Low Arom., Saturated	25.3	60.2	59.2	55.6	57.1	60.1	49.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(1) No T50/DI Limits
(2) Excluding light reformate.

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TABLE D-9

GASOLINE PROPERTY DECREASE – INCREMENTAL COSTS(1)

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES					
	Base Case 0	Case 8 + None	Case 9 +0.4 RVP	Case 10 +30 T90(2)	Case 11 +15 T90(2)	Case 12 +30 S	Case 13 +5 OL/100S 30 T90(2)
(R+M)/2 Octane, Clear	(0.9)	(1.3)	(1.2)	(1.4)	(1.3)	(1.3)	(1.5)
Reid Vapor Pressure, PSI	0.6	3.5	2.5	2.4	2.8	4.1	2.5
Butane, Vol.%		1.4	0.8	0.9	1.0	1.6	0.9
Aromatics, Vol.%		0.2	0.2	0.5	0.3	0.2	0.6
Ethers, Vol.%	(0.1)	(0.0)	(0.0)				
Olefins, Vol.%			0.1			0.6	
Benzene, Vol.%		3.3	3.3	3.5	3.5	2.5	3.6
Sulfur, 100 Wt. PPM		9.1	7.7	8.4	8.7		0.8
T90, 10°F		2.0	1.8	0.3	0.8	3.6	0.5

(1) Shadow costs for very small changes.
Not applicable for significant changes.
(2) No T50/DI Limits

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11/4/91

TABLE E-1

RUN BASIS AND GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

Reformulated Properties*	Base Case 0	Case 14 +5 OL/60S 30 T90(1)	Case 15 +3A 30 T90(1)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(1)
		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES				
Aromatics, Vol.%, Maximum		22	25	22	25	25
Regulatory Cap		25	28	25	25	28
Oxygen, Wt.%, Minimum Avg	0.4	2.1	2.1	2.1	2.0	2.1
Bromine No., Maximum	26 (2)	17	8	15	10	15
Regulatory Cap	30 (2)	20	10	18	10	18
Benzene, Vol.%, Maximum Avg		0.8	0.8	0.8	1.0	0.8
Sulfur, Wt. PPM, Maximum	250	80	20	80	30	50
Regulatory Cap	300	100	30	100	30	65
Reid Vapor Pressure, PSI, Max	7.5	6.7	6.7	6.7	7.0	7.1
Regulatory Cap	7.8	7.0	7.0	7.0	7.0	7.4
T90, °F, Maximum		320	320	320	300	305
Regulatory Cap		330	330	330	300	315
Driveability Index, Reg. Cap					1100	
Ethers, Vol.% Pool						
Purchased	0.6	10.1	9.8	9.9	9.1	9.8
Manufactured	1.4	1.8	1.9	2.0	1.9	1.9
Gasoline Pool Properties						
(R+M)/2 Octane, Clear*	88.9	88.9	88.9	88.9	88.9	88.9
Aromatics, Vol.%	34	22 *	25 *	22 *	25 *	24
Ethers, Vol.%	2.0 *	11.9	11.7 *	11.9	11.0 *	11.7 *
Oxygen, Wt.%	0.4 *	2.1	2.1 *	2.1	2.0 *	2.1 *
Olefins, Vol.%	11	7	4 *	7	5 *	7 *
Bromine No.	22	15	8 *	14	10 *	15 *
Benzene, Vol.%	2.2	0.8 *	0.8 *	0.8 *	1.0 *	0.8 *
Sulfur, Wt. PPM	206	80 *	20 *	80 *	30 *	50 *
Reid Vapor Pressure, PSI*	7.5	6.7	6.7	6.7	7.0	7.1
Temperature at V/L = 20, °F	145	147	146	146	145	144
Distillation						
90°F, Vol.%	12	9	9	9	10	10
130°F, Vol.%	23	19	20	19	21	22
170°F, Vol.%	33	37	38	37	39	40
212°F, Vol.%	50	56	57	55	57	58
257°F, Vol.%	67	73	74	73	76	76
300°F, Vol.%	81	86	86	86	90	89
356°F, Vol.%	91	95	96	96	97	97
T10, °F	125	136	135	137	133	133
T50, °F	212	199	197	200	195	193
T90, °F	348	320 *	320 *	318	300 *	305 *
Driveability Index	1171	1121	1114	1124	1085	1084
Heat Content, MBTU/G	114.4	111.3	111.6	111.4	111.5	111.2

(1) No T50/DI Limits
(2) L.A. Only
* Input limit.

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TABLE E-2

SUMMARY OF COSTS

1996 CASE RESULTS[1] – INCREASE OVER BASE CASE[2]

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

	8/5/91 CARB 2 Proposal - Lab Comply Margins + Changes				
	Case 14 + 5 OL/60 S 30 T90[3]	Case 15 + 3 A 30 T90[3]	Case 16 = Case 14 With No C_5 O	Case 17 + Lab Comply Margin	Case 18 + 3A/4 OL/30 S .4 RVP/15 T90[3]
Investments, MM$					
Refinery	1,500	2,080	1,510	2,270	1,490
MTBE[4]	2,440	2,370	2,400	2,200	2,370
Total	3,940	4,450	3,910	4,470	3,860
Range, MMM$[5]	3.1-5.1	3.5-5.8	3.1-5.0	3.6-5.8	3.0-5.0
Daily Costs, M$/D					
Capital Charge[6]	997	1,376	998	1,508	987
Net Upgrading Costs[7]	2,260	2,231	2,260	2,108	2,206
Variable Operating Costs	142	555	321	624	409
Fixed Operating Cost[8]	406	491	399	557	387
Total Refinery	3,805	4,653	3,978	4,797	3,989
Annual Cost, MM$/Yr.					
Refinery	1,389	1,699	1,453	1,751	1,457
Other[9]	386	353	373	361	398
Total	1,775	2,052	1,826	2,112	1,855
Total Unit Cost, ¢/G of Base Gasoline					
Average	11.3	13.1	11.7	13.5	11.8
Range[10]	9.4-14.7	11.1-16.6	9.8-15.0	11.5-17.0	9.9-15.2

TABLE E-2

SUMMARY OF COSTS

1996 CASE RESULTS[2] – INCREASE OVER BASE CASE[3]

WSPA STUDY OF CARB PHASE 2 GASOLINE

(In constant 1991 $)

(1) For reformulation runs, based on a composite model of conversion refineries. Individual refinery costs will differ from average.

(2) Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.

(3) No T50/DI Limits.

(4) For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).

(5) For variations from investment curves of -15/+35% for refining and ±25% for MTBE.

(6) Based on expected 15% DCF rate of return on new refining facilities investment.

(7) Raw material upgrading costs.

(8) For new refining facilities only.

(9) Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.

(10) For variations in capital charge (-15/+35%), MTBE costs (-10/+20¢/G) and BTU mileage factor (±0.2).

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TABLE E-2A
COMPOSITE REFINERY MARGIN & COST INCREASE DETAIL
1996 CASE 17 OVER(UNDER) BASE CASE
WSPA STUDY OF CARB PHASE 2 GASOLINE

	MBPD	C/GAL	$/B	M$/D
Products				
Motor Gasolines–Regular	11.0	65.5		303
Motor Gasolines–Intermediate	4.1	67.7		116
Motor Gasolines–Premium	5.0	71.0		150
No. 6 Bunker	19.6		13.00	254
Normal Butane to Fuel	0.8		20.47	16
Propane	(1.4)	32.6		(20)
Propane to Fuel	1.3		20.47	27
Propylene	(1.6)	29.6		(20)
Propylene to Fuel	(1.3)		20.47	(27)
Process Gas to Fuel	(33.5)		20.47	(686)
Coke – Low Sulfur	3.9		7.00	27
Coke – High Sulfur	(3.9)		5.00	(20)
FCC Coke to Fuel	(1.9)		20.47	(39)
Loss(Gain)	5.0			
Subtotal	7.0			82
Sulfur(M L T; $/L T)	(0.12)		70.00	(8)
Total				74
Raw Materials				
Alaska North Slope Crude	(68.7)		16.70	(1,148)
Naphtha	3.5	52.5		78
MTBE	88.9	96.0		3,583
Methanol	1.7	65.0		46
Natural Gas to H2 Plant	(18.4)		20.47	(376)
Total	7.0			2,184
Gross Margin				(2,110)
Variable Cost				
Natural Gas	56.8		20.47	1,163
Produced Fuels	(34.6)		20.47	(708)
Other				170
Total Variable Cost				625
Gross Margin after Variable Cost				(2,734)

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TABLE E-2B

ADDED MANPOWER AND FIXED COSTS

1996 CASE 17 INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Number of Employees
Manpower	
Direct Process Operating Labor	500
Off-Site Operators, Administrative, Technical and Staff	1,000
Maintenance Employees	600
Total Employees	2,100
Contract Maintenance	200
Total Manpower	2,300
Fixed Costs	
Total Fixed Operating Costs, $MM/Year[1]	193
Salaries and Wages, %	55
Maintenance Costs, $MM/Year[1]	72

[1] Includes manpower.

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TABLE E-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE - MBPCD
WSPA STUDY OF CARB PHASE 2 GASOLINE

	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES				
	Case 14 +5 OL/60S 30 T90(1)	Case 15 +3A 30 T90(1)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(1)
Raw Materials					
Alaska North Slope	(162)	(110)	(151)	(69)	(89)
Subtotal Crudes	(162)	(110)	(151)	(69)	(89)
Natural Gasoline					
Naphtha	(3)	4	(3)	4	4
MTBE	99	96	97	89	96
Methanol	1	2	2	2	2
Normal Butane	20	7	20		
Isobutane	6		6		
Natural Gas to H2 Plant Feed	(21)	(19)	(21)	(18)	6
Total	(60)	(20)	(50)	7	18
Products					
Motor Gasolines	22	20	21	20	23
No. 6 Bunker	(13)	(5)	(13)	20	16
Normal Butane	(3)	(3)	(3)	1	(0)
Propane	(6)	(2)	(5)	(0)	(3)
Propylene, Low Value	(13)	0	(13)	(3)	(5)
Process Gas	(53)	(37)	(49)	(33)	(12)
Lt Coker Naphtha to P/C					
Pentanes to P/C					
Isobutane					
Marketable Coke	(6)	0	(0)	0	0
FCC Coke	(2)	(1)	(1)	(2)	(2)
Loss(Gain)	13	8	13	5	3
Total	(60)	(20)	(50)	7	18
Crude Property Increase					
Gravity, °API	(0.3)	(0.2)	(0.3)	(0.2)	(0.2)
Sulfur, Wt%	0.01	0.01	0.01	0.00	0.00
Gasoline Demand Increase, %(2)					
Results	2.1	1.9	2.1	2.0	2.2
Target	2.2	2.0	2.1	2.0	2.2

(1) No T50/DI Limits.
(2) To maintain constant miles traveled with lower BTU content reformulated gasoline.

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TABLE E-4

NEW PROCESS UNIT RATES

1996 CASE RESULTS

INCREASE OVER BASE CASE - MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGE				
	Case 14 +5 OL/60S 30 T90(1)	Case 15 +3A 30 T90(1)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(1)
Heavy Naphtha Splitter	1			125	80
FCC Gasoline Splitters	237	348	366	346	347
FCC Gasoline Fractionation					
Hydrocrackate Fractionation	130	141	132	156	143
Coker Lt Gasoline DS/Splitter	27		28	29	29
Hydrotreating - Distillate	20	60	21	110	80
Reformer Feed Fractionation	259	367	253	324	285
Reformate Fractionation	190	271	163	151	221
Benzene Saturation	66	87	69	71	88
FCC Gasoline HDS		66		54	27
Gasoline Aromatics Saturation					
Alkylation	52	23	55	18	
Alkylate Splitter				22	
MTBE /TAME	5	7	8	7	7
Isomerization - C5/C6	15	29		20	14
- C4	30	17	28	8	4
Hydrogen - MMSCFPSD	1	54	1	84	1

(1) No T50/DI Limits

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TABLE E-5

NEW PROCESS UNIT INVESTMENTS

1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES				
	Case 14 +5 OL/60S 30 T90(1)	Case 15 +3A 30 T90(1)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(1)
Heavy Naphtha Splitter	0			90	60
Coker Lt. Gasoline DS/Splitter	50		50	50	50
FCC Gasoline Splitters	210	520	290	520	280
FCC Gasoline Fractionation					
Hydrocracking - Heavy Gasoline				140	
Hydrocrackate Fractionation	90	90	90	100	90
Hydrotreating - Distillate	30	120	40	220	160
Reformer Feed Fractionation	140	170	140	170	150
Reformate Fractionation	110	150	100	100	130
Benzene Saturation	210	260	220	220	260
FCC Gasoline HDS		170		150	90
Gasoline Aromatics Saturation					
Alkylation	310	150	330	110	
Alkylate Splitter				20	
MTBE / TAME	30	40	50	40	40
Isomerization - C5/C6	100	190		130	90
- C4	150	90	150	40	20
Hydrogen	10	90	10	130	20
MTBE Storage & Blending	40	40	40	40	40
Total Refinery	1,500	2,080	1,510	2,270	1,490

(1) No T50/DI Limits.

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ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30227

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TABLE E-6
PROCESS UNIT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD PER REFINERY
WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES				
	Base Case 0	Case 14 +5 OL/60S 30 T90(1)	Case 15 +3A 30 T90(1)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(1)
Crude - Atmospheric	111.1	(9.5)	(6.5)	(8.9)	(4.0)	(5.3)
Heavy Naphtha Splitter		0.1			7.0	4.5
Catalytic Cracking (2)	36.8	(1.3)	(3.4)	(0.9)	(2.7)	(2.7)
Catalytic Cracking (3)	37.3	(1.3)	(3.4)	(0.9)	(2.8)	(2.8)
Conversion, %	74.4	(2.5)	(1.6)	(2.7)	(2.3)	(2.3)
Octane Catalyst, %	15.0					
FCC Gasoline Splitters		13.2	19.5	20.4	19.4	19.4
FCC Gasoline Fractionation	15.2	(8.3)	(15.2)	(15.2)	(15.2)	(15.2)
Hydrocracking - 2 Stage(2)	16.9					
Jet Yield, % of Max	96.7	(13.7)	(31.9)	(17.0)	(58.6)	(37.1)
300 - Gasoline Operation, %		17.0		12.1	5.1	
Hydrocracking - Low Conversion	3.2		1.0	0.0	1.0	1.0
- Heavy Gasoline					0.5	
- Combined(3)	20.1	(0.5)	1.0	(0.3)	1.3	1.0
Hydrocrackate Fractionation		6.8	7.3	6.8	8.1	7.4
Coking - Delayed	22.9					
- Fluid	5.3	(1.2)		(0.1)		
Coker Lt Gasoline DS/Splitter		1.5		1.6	1.6	1.6
Thermal Cracking, Visbreaking	2.3	(2.1)	(0.8)	(2.1)		
Solvent Deasphalting	1.0	1.2	(0.7)	0.2	(0.6)	(0.6)
Catalytic Reforming - 100 PSI (1)	3.4	(1.0)		(1.0)		
- 200 PSI (1)	16.6	(4.4)		(2.9)		(1.4)
- 450 PSI (1)	8.9	(4.4)	(2.3)	(4.4)	(2.3)	(2.9)
- Combined (2)	28.4	(7.7)	0.1	(6.1)	(0.7)	(2.4)
- RONC	99.2	(5.9)	(4.9)	(6.4)	(4.1)	(5.1)
Hydrotreating - Naphtha	18.8	(2.4)	4.4	(5.2)	1.5	(0.4)
- Distillate	22.0	1.0	3.1	1.1	5.7	4.2
- Heavy Gas Oil	31.0	0.8		0.8		0.0
- Residuum - Vac	1.4				(0.3)	(0.3)
Reformer Feed Fractionation		13.4	19.0	13.1	16.8	14.8
Reformate Fractionation		9.8	14.0	8.5	7.8	11.4
Benzene Saturation		3.2	4.3	3.4	3.5	4.3
FCC Gasoline HDS			3.4		2.8	1.4
Gasoline Aromatics Saturation						
Diesel Aromatics Saturation	11.7				(0.1)	(0.1)
Alkylation	6.6	2.6	1.1	2.7	0.9	
Alkylate Splitter					1.1	
Polymerization		0.1		0.5		
MTBE / TAME	0.8	0.3	0.3	0.5	0.4	0.4
Lubes	1.3					
Isomerization - C5/C6		0.8	1.5		1.0	0.7
- C5/C6, Recycle	0.4					
- C4	0.3	1.4	0.8	1.4	0.4	0.5
Hydrogen - MMSCFPCD	58.1	6.7	10.7	6.7	12.1	8.0
Sulfur, LTPCD	130.0	(11.0)	(5.0)	(9.0)	(7.0)	(8.0)

(1) No T50/DI Limits
(2) Include effects of nonunitary capacity for some feedstocks and severities.
(3) Based on actual feed rates, ignoring severity effects.

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TABLE E-7

PROCESS UNIT UTILIZATIONS (1)

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/5/91 CARB 2 PROPOSAL – LAB COMPLY MARGINS + CHANGES				
	Base Case 0	Case 14 +5 OL/60S 30 T90(2)	Case 15 +3A 30 T90(2)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(2)
Crude Distillation – Atmospheric	89.2	81.5	84.0	82.0	85.9	84.9
Heavy Naphtha Splitter		95.0			95.0	95.0
Catalytic Cracking (3)	95.0	91.7	86.2	92.7	87.9	88.1
Catalytic Cracking (4)	96.2	92.9	87.5	94.0	88.9	89.0
FCC Gasoline Splitters		95.0	95.0	95.0	95.0	95.0
FCC Gasoline Fractionation	84.9	38.3				
Hydrocracking – 2 Stage(3)	88.0	88.0	88.0	88.0	88.0	88.0
– Low Conversion	67.0	67.0	88.0	67.4	88.0	88.0
– Heavy Gasoline					88.0	
– Combined(4)	83.8	81.8	88.0	82.5	87.4	88.0
Hydrocrackate Fractionation		88.0	88.0	88.0	88.0	88.0
Coking – Delayed	95.0	95.0	95.0	95.0	95.0	95.0
– Fluid	95.0	73.8	95.0	93.9	95.0	95.0
Coker Lt Gasoline DS/Splitter		95.0		95.0	95.0	95.0
Thermal Cracking, Visbreaking	88.0	7.0	59.0	7.0	88.0	88.0
Solvent Deasphalting	32.5	73.2	10.1	40.1	12.5	10.5
Catalytic Reforming – 100 PSI (3)	88.0	62.3	88.0	62.3	88.0	88.0
– 200 PSI (3)	88.0	64.7	88.0	72.5	88.0	80.8
– 450 PSI (3)	88.0	43.8	65.6	43.8	65.6	58.7
– Combined (4)	80.4	56.9	80.7	61.8	78.6	73.1
Hydrotreating – Naphtha	66.7	58.0	82.4	48.4	72.0	65.3
– Distillate	88.0	88.0	88.0	88.0	88.0	88.0
– Heavy Gas Oil	85.8	88.0	85.8	88.0	85.8	85.9
– Residuum, Vac	88.0	88.0	88.0	88.0	69.1	67.3
Reformer Feed Fractionation		88.0	88.0	88.0	88.0	88.0
Reformate Fractionation		88.0	88.0	88.0	88.0	88.0
Benzene Saturation		83.0	83.0	83.0	83.0	83.0
FCC Gasoline HDS			88.0		88.0	88.0
Gasoline Aromatics Saturation						
Diesel Aromatics Saturation	88.0	88.0	88.0	88.0	87.1	87.5
Alkylation	83.0	83.0	83.0	83.0	83.0	83.0
Alkylate Splitter					83.0	
Polymerization	0.0	14.4	0.0	83.0	0.0	0.0
MTBE / TAME	83.0	83.0	83.0	83.0	83.0	83.0
Lubes	87.6	87.6	87.6	87.6	87.6	87.6
Isomerization – C5/C6		88.0	88.0		88.0	88.0
– C5/C6, Recycle	88.0	88.0	88.0	88.0	88.0	88.0
– C4	83.0	83.0	83.0	83.0	83.0	83.0
Hydrogen	72.9	81.3	83.0	81.3	83.0	83.0
Sulfur	45.9	42.0	44.2	42.7	43.5	43.1

(1) Calendar day rates divided by stream day capacity.
(2) No T50/DI Limits.
(3) Include effects of nonunitary capacity factors for some feedstocks and severities.
(4) Based on actual feed rates, ignoring severity effects.

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TABLE E-8

GASOLINE POOL COMPOSITIONS

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGE				
	Base Case 0	Case 14 +5 OL/60S 30 T90(1)	Case 15 +3A 30 T90(1)	Case 16 = Case 14 With No C5 O	Case 17 + Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(1)
FCC Gasoline	11.1					
Lt. FCC 255-	15.0	6.7				
Hvy FCC 255+	10.5	4.6				
Hvy FCC 255+ Desul			5.7		4.6	2.4
FCC Gaso (100-180)		4.7	6.3	7.1	6.5	6.4
FCC Gaso (180-225)		2.6	3.1	4.0	6.1	3.8
FCC Gaso (225-300)		5.2	0.5	8.0		7.6
FCC Gaso (300-375)		3.5		5.5		1.7
Total FCC Gasoline	36.6	27.3	15.6	24.6	17.2	21.9
Pentenes		0.3	0.6		1.4	2.2
Poly Gasoline		0.1		0.8		
Lt. Coker Gasoline	2.8	0.2		1.4		0.5
Total Olefinic	2.8	0.6	0.6	2.2	1.4	2.7
Reformate	22.2	2.7	3.3	11.5	10.1	4.4
Reformate (220-300 Feed)	5.9	7.3	10.5	2.9	12.0	9.8
BT Reformate	7.2					
HC Reformate (210-300)		7.4	10.3	6.7	5.8	8.3
Heavy Reformate (300+)		3.3	5.6	1.5	1.3	3.3
Total Reformates(2)	35.3	20.7	29.7	22.6	29.2	25.8
Lt. Reformate (Benzene Saturated)		5.5	7.2	5.8	6.0	7.3
Alkylate/Lt Alkylate (C3/C4)	10.9	12.2	9.6	10.6	10.1	10.5
Alkylate/Lt Alkylate (C5)		2.3	2.7	4.2	1.4	
Butane	2.5	1.5	1.5	1.7	1.5	1.5
Natural/LSR Gaso	3.8	2.6	3.3	3.3	3.0	3.5
BT Naphtha (150-220)						
Iso Pentane		2.1	2.6	3.2	3.1	3.1
Normal Pentane		0.4	0.5	0.6	0.6	1.0
Isomerate (C5-C6)	0.6	0.6	2.8	0.6	0.6	0.6
Isomerate (C6)		1.4	0.3		1.7	1.2
Lt. Hydrocrackate	5.0	5.3	5.6	5.4	6.5	5.8
Hydrocrackate (175-225)	0.5	5.6	6.2	3.2	6.7	3.4
MTBE	2.0	11.4	11.1	11.2	10.3	11.0
TAME		0.5	0.7	0.8	0.7	0.7
Total Low Arom., Saturated	25.3	51.4	54.1	50.6	52.2	49.6
Total	100.0	100.0	100.0	100.0	100.0	100.0

(1) No T50/DI Limits.
(2) Excluding light reformate.

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TABLE E-9

GASOLINE PROPERTY DECREASE – INCREMENTAL COSTS(1)

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

		8/5/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES				
	Base Case 0	Case 14 +5 OL/60S 30 T90(2)	Case 15 +3A 30 T90(2)	Case 16 = Case 14 With No C5 O	Case 17 +Lab Comply Margins	Case 18 +3A/4 OL/30S .4RVP/15 T90(2)
(R+M)/2 Octane, Clear	(0.9)	(1.5)	(1.0)	(1.4)	(1.0)	(0.6)
Reid Vapor Pressure, PSI	0.6	2.5	1.8	0.8	1.3	0.9
Butane, Vol.%		0.9	0.5		0.2	0.1
Aromatics, Vol.%		0.5	0.2	0.6	0.1	
Ethers, Vol.%	(0.1)		(0.1)		(0.1)	(0.2)
Olefins, Vol.%			0.1		0.3	0.1
Benzene, Vol.%		3.3	3.2	3.2	2.5	2.7
Sulfur, 100 Wt. PPM		1.4	6.2	0.7	5.2	2.8
T90, 10°F		0.4	0.6		1.9	1.4

(1) Shadow costs for very small changes.
Not applicable for significant changes.
(2) No T50/DI Limits.

CLM
11/4/91

TURNER, MASON & COMPANY
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TABLE F-1

RUN BASIS AND GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES			
Reformulated Properties*	Base Case 0	Case 19 - Blend Comply Margins(1)	Case 20 + 6 OL/100 S 0.4 RVP/30 T90(1)	Case 21 - Blend Comply Margins(2)	Case 22 +0.2 RVP
Aromatics, Vol.%, Maximum		20	22	20	22
Regulatory Cap		25	25	25	25
Oxygen, Wt.%, Minimum	0.4	2.5	2.1	2.5	2.1
Regulatory Bottom		2.0	2.0	2.0	2.0
Bromine No., Maximum	26 (3)	4	20	4	8
Regulatory Cap	30 (3)	10	24	10	10
Benzene, Vol.%, Maximum Avg		0.8	0.8	0.6	0.8
Sulfur, Wt. PPM, Maximum	250	10	120	10	20
Regulatory Cap	300	30	150	30	30
Reid Vapor Pressure, PSI, Max	7.5	6.5	7.1	6.5	6.9
Regulatory Cap	7.8	7.0	7.4	7.0	7.2
T90, °F, Maximum		280	320	280	290
Regulatory Cap		300	330	300	300
Driveability Index, Maximum				1055	1075
Regulatory Cap				1100	1100
Ethers, Vol.% Pool					
Purchased	0.6	13.0	10.4	12.1	9.8
Manufactured	1.4	2.0	1.3	2.0	1.9
Gasoline Pool Properties					
(R+M)/2 Octane, Clear*	88.9	88.9	88.9	88.9	88.9
Aromatics, Vol.%	34	20 *	22 *	20 *	22 *
Ethers, Vol.%	2.0 *	15.0 *	11.7	14.1	11.7 *
Oxygen, Wt.%	0.4 *	2.7 *	2.1	2.5	2.1 *
Olefins, Vol.%	11	1	10	1	4 *
Bromine No.	22	2	19	1	8 *
Benzene, Vol.%	2.2	0.8 *	0.8 *	0.6 *	0.8 *
Sulfur, Wt. PPM	206	10 *	120 *	10 *	20 *
Reid Vapor Pressure, PSI*	7.5	6.5	7.1	6.5	6.9
Temperature at V/L = 20, °F	145	147	144	144	144
Distillation					
90°F, Vol.%	12	6	10	6	9
130°F, Vol.%	23	16	21	16	21
170°F, Vol.%	33	39	40	41	40
212°F, Vol.%	50	59	56	64	60
257°F, Vol.%	67	80	74	84	79
300°F, Vol.%	81	96	86	98	92
356°F, Vol.%	91	99	96	100	98
T10, °F	125	149	131	149	135
T50, °F	212	193	197	187 *	191
T90, °F	348	280 *	320 *	271 *	290 *
Driveability Index	1171	1083	1108	1054 *	1086
Heat Content, MBTU/G	114.4	110.4	111.1	110.1	110.9

* Input limit.

(1) No T50/DI Limits.

(2) Revised to correct coker and add it hydrocrackate splitter for added C5 sales.

(3) L.A. only.

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11/12/91

TURNER, MASON & COMPANY
Consulting Engineers

TABLE F-2

SUMMARY OF COSTS

1996 CASE RESULTS(1) – INCREASE OVER BASE CASE(2)

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

	8/91 CARB 2 PROPOSAL – LAB COMPLY MARGINS + CHANGES			
	Case 19 – Blend Comply Margins(3)	Case 20 +6 OL/100 S 0.4 RVP/30 T90(3)	Case 21 – Blend Comply Margins	Case 22 +0.2 RVP
Investment, MM$				
Refinery	4,330	1,030	5,650	3,230
MTBE(4)	3,220	2,500	2,980	2,370
Total	7,540	3,520	8,640	5,600
Range, MMM$(5)	6.1–9.9	2.7–4.5	7.0–11.4	4.5–7.3
Daily Costs, M$/D				
Capital Charge(6)	2,873	682	3,747	2,138
Net Upgrading Costs(7)	3,416	2,116	3,095	2,312
Variable Operating Costs	1,423	3	2,062	907
Fixed Operating Costs(8)	982	294	1,179	771
Total Refinery	8,694	3,095	10,083	6,129
Annual Cost, MM$/Yr.				
Refinery	3,173	1,130	3,680	2,237
Other(9)	492	406	529	431
Total	3,665	1,536	4,209	2,668
Total Unit Cost, ¢/G of Base Gasoline				
Average	23.5	9.8	26.9	17.1
Range(10)	20.4–29.2	7.9–13.1	23.6–33.2	14.7–21.4

(1) For reformulation runs, based on a composite model of conversion refineries. Individual refinery costs will differ from average.
(2) Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.
(3) No T50/DI Limits.
(4) For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).
(5) For variations from investment curves of −15/+35% for refining and ±25% for MTBE.
(6) Based on expected 15% DCF rate of return on new refining facilities investment.
(7) Raw material upgrading costs.
(8) For new refining facilities only.
(9) Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.
(10) For variations in capital charge (−15/+35%), MTBE costs (−10/+20¢/G) and BTU mileage factor (±0.2).

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TABLE F-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES

1996 CASE RESULTS

INCREASE OVER BASE CASE – MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES		
	Case 19 - Blend Comply Margins(1)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
Raw Materials			
Alaska North Slope	(35)	(9)	(88)
Subtotal Crudes	(35)	(9)	(88)
Natural Gasoline	(4)	(4)	
Naphtha	4	4	4
MTBE	130	121	96
Methanol	2	2	2
Normal Butane	4		16
Isobutane			
Natural Gas to H2 Plant Feed	20	(9)	(16)
Total	121	104	13
Products			
Motor Gasolines	28	30	24
No. 6 Bunker	29	32	34
Normal Butane	(3)	11	(3)
Propane	11	11	1
Propylene, Low Value	(13)	(13)	(13)
Process Gas	5	(24)	(36)
Lt St Run Naphtha to P/C	19		
Lt Hydrocrackate to P/C			
Pentanes to P/C	38	37	
Iso Pentane to P/C		33	
Isobutane			
Marketable Coke	8	0	(5)
FCC Coke	(0)	0	(2)
Loss(Gain)	(1)	(13)	13
Total	121	104	13
Crude Property Increase			
Gravity, °API	(0.1)	0.0	(0.2)
Sulfur, Wt%	0.00	0.00	0.00
Gasoline Demand Increase, %(2)			
Results	2.8	2.9	2.4
Target	2.8	3.0	2.4

(1) No T50/DI Limits.
(2) To maintain constant miles traveled with lower BTU content reformulated gasoline.

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TABLE F-4

NEW PROCESS UNIT RATES

1996 CASE RESULTS

INCREASE OVER BASE CASE - MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES		
	Case 19 - Blend Comply Margins(1)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
Heavy Naphtha Splitter	135	135	74
FCC Gasoline Splitters	364	371	347
FCC Gasoline Fractionation			
Hydrocracking - Heavy Gasoline	59	120	
Hydrocrackate - Fractionation	149	236	156
Lt Hydrocrackate Splitter		76	
Coker Lt Gasoline DS/Splitter	33	30	29
FCC Gasoline HDS	48		31
Hydrotreating - Naphtha	4	79	
- Distillate	102	109	155
- Heavy Gas Oil		13	
Reformer Feed Fractionation	389	419	352
Reforming - 200 PSI		61	
Reformate Fractionation	174	465	302
Benzene Saturation	75	140	106
Gasoline Aromatics Saturation			47
Alkylation	93	90	63
Alkylate Splitter	164	214	2
MTBE /TAME	9	9	7
Isomerization - C5/C6	48	100	20
- C5/C6, Recycle	24		
- C4	30	10	33
Hydrogen - MMSCFPSD	339	551	184

(1) No T50/DI Limits.

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TABLE F-5

NEW PROCESS UNIT INVESTMENTS

1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES			
	Case 19 - Blend Comply Margins(1)	Case 20 +6 OL/100 S 0.4 RVP/30 T90(1)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
Heavy Naphtha Splitter	90		90	80
FCC Gasoline Splitters	540	60	550	520
FCC Gasoline Fractionation		30		
Hydrocracking - Heavy Gasoline	750		1,190	
Hydrocrackate - Fractionation	100	90	130	100
Lt Hydrocrackate Splitter			70	
Coker Lt. Gasoline DS/Splitter	60	20	50	50
FCC Gasoline HDS	140			110
Hydrotreating - Naphtha	10		100	
- Distillate	200	0	220	310
- Heavy Gas Oil			30	
Reformer Feed Fractionation	190	140	200	180
Reforming - 200 PSI			170	
Reformate Fractionation	200	100	410	180
Benzene Saturation	230	220	350	290
Gasoline Aromatics Saturation				420
Alkylation	540	180	530	380
Alkylate Splitter	100		120	0
MTBE / TAME	50		50	40
Isomerization - C5/C6	240		450	130
- C5/C6, Recycle	210			
- C4	150	130	50	170
Hydrogen	480	10	830	270
MTBE Storage & Blending	50	50	50	40
Total Refinery	4,330	1,030	5,650	3,230

(1) No T50/DI Limits.

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11/12/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30236

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TABLE F-6
PROCESS UNIT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD PER REFINERY
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base Case 0	8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES Case 19 - Blend Comply Margins(1)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
Crude - Atmospheric	111.1	(2.0)	(0.5)	(5.2)
Heavy Naphtha Splitter		7.5	7.6	4.1
Catalytic Cracking (2)	36.8	(0.7)		(2.6)
Catalytic Cracking (3)	37.3	(0.7)		(2.6)
Conversion, %	74.4	(2.9)	(2.8)	(2.3)
Octane Catalyst, %	15.0			0.0
FCC Gasoline Splitters		20.3	20.8	19.4
FCC Gasoline Fractionation	15.2	(15.2)	(15.2)	(15.2)
Hydrocracking - 2 Stage(2)	16.9			
Jet Yield, % of Max	96.7	(68.2)	(77.3)	(84.3)
300 - Gasoline Operation, %		71.1	0.0	66.6
Hydrocracking - Low Conversion	3.2	1.0	1.0	1.0
- Heavy Gasoline		3.1	6.2	
- Combined(3)	20.1	2.1	7.2	(0.9)
Hydrocrackate Fractionation		7.7	12.2	8.1
Lt Hydrocrackate Splitter			3.9	
Coking - Delayed	22.9		0.9	
- Fluid	5.3			(1.2)
Coker Lt Gasoline DS/Splitter		1.9	1.7	1.6
Thermal Cracking, Visbreaking	2.3			
Solvent Deasphalting	1.0	(0.2)	(0.1)	0.0
Catalytic Reforming - 100 PSI (2)	3.4			
- 200 PSI (2)	16.6	0.0	3.1	0.0
- 450 PSI (2)	8.9	(1.5)		(2.3)
- Combined (3)	26.4	1.6	6.2	0.3
- RONC	99.2	(8.3)	(5.7)	(5.2)
Hydrotreating - Naphtha	18.8	6.2	10.1	2.7
- Distillate	22.0	5.3	5.7	8.0
- Heavy Gas Oil	31.0	0.8	1.5	
- Residuum - Vac	1.4			
Reformer Feed Fractionation		20.1	21.7	18.2
Reformate Fractionation		9.0	24.1	15.6
Benzene Saturation		3.7	6.8	5.2
FCC Gasoline HDS		2.5		1.6
Gasoline Aromatics Saturation				2.4
Diesel Aromatics Saturation	11.7	(0.2)	(0.3)	(0.0)
Alkylation	6.6	4.5	4.4	3.1
Alkylate Splitter		8.0	10.4	0.1
Polymerization				
MTBE / TAME	0.8	0.4	0.4	0.4
Lubes	1.3			
Isomerization - C5/C6		2.5	5.2	1.0
- C5/C6, Recycle	0.4	1.3		
- C4	0.3	1.4	0.5	1.6
Hydrogen - MMSCFPCD	58.1	24.6	34.9	17.0
Sulfur, LTPCD	130.0	(3.0)		(8.0)

(1) No T50/DI Limits.

(2) Include effects of nonunitary capacity for some feedstocks and severities.

(3) Based on actual feed rates, ignoring severity effects.

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TABLE F-7

PROCESS UNIT UTILIZATIONS (1)

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES		
	Base Case 0	Case 19 - Blend Comply Margins(2)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
Crude Distillation - Atmospheric	89.2	87.5	88.7	85.0
Heavy Naphtha Splitter		95.0	95.0	95.0
Catalytic Cracking (3)	95.0	93.2	95.0	88.3
Catalytic Cracking (4)	96.2	94.4	96.2	89.5
FCC Gasoline Splitters		95.0	95.0	95.0
FCC Gasoline Fractionation	84.9			
Hydrocracking - 2 Stage(3)	88.0	88.0	88.0	88.0
- Low Conversion	67.0	88.0	88.0	88.0
- Heavy Gasoline		88.0	88.0	
- Combined(4)	83.8	80.7	88.0	80.2
Hydrocrackate Fractionation		88.0	88.0	88.0
Lt Hydrocrackate Splitter			88.0	
Coking - Delayed	95.0	95.0	95.0	95.0
- Fluid	95.0	95.0	95.0	74.3
Coker Lt Gasoline DS/Splitter		95.0	95.0	95.0
Thermal Cracking, Visbreaking	88.0	88.0	88.0	88.0
Solvent Deasphalting	32.5	25.2	28.5	33.2
Catalytic Reforming - 100 PSI (3)	88.0	88.0	88.0	88.0
- 200 PSI (3)	88.0	88.0	88.0	88.0
- 450 PSI (3)	88.0	73.4	88.0	65.6
- Combined (4)	80.4	85.4	89.6	81.5
Hydrotreating - Naphtha	66.7	88.0	88.0	76.3
- Distillate	88.0	88.0	88.0	88.0
- Heavy Gas Oil	85.8	88.0	88.0	85.8
- Residuum, Vac	88.0	88.0	88.0	88.0
Reformer Feed Fractionation		88.0	88.0	88.0
Reformate Fractionation		88.0	88.0	88.0
Benzene Saturation		83.0	83.0	83.0
FCC Gasoline HDS		88.0		88.0
Gasoline Aromatics Saturation				88.0
Diesel Aromatics Saturation	88.0	86.5	85.7	88.0
Alkylation	83.0	83.0	83.0	83.0
Alkylate Splitter		83.0	83.0	83.0
Polymerization	0.0	0.0	0.0	0.0
MTBE / TAME	83.0	83.0	83.0	83.0
Lubes	87.6	87.6	87.6	87.6
Isomerization - C5/C6		88.0	88.0	88.0
- C5/C6, Recycle	88.0	88.0	88.0	88.0
- C4	83.0	83.0	83.0	83.0
Hydrogen	72.9	83.0	83.0	83.0
Sulfur	45.9	44.9	45.9	43.1

(1) Calendar day rates divided by stream day capacity.
(2) No T50/DI Limits.
(3) Include effects of nonunitary capacity factors for some feedstocks and severities.
(4) Based on actual feed rates, ignoring severity effects.

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TABLE F-8

GASOLINE POOL COMPOSITIONS

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES		
	Base Case 0	Case 19 - Blend Comply Margins(1)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
FCC Gasoline	11.1			
Lt. FCC 255-	15.0			
Hvy FCC 255+	10.5			
Hvy FCC 255+ Desul		4.1		2.6
FCC Gaso (100-180)		2.6		6.4
FCC Gaso (180-225)			1.5	3.3
FCC Gaso (225-300)				
FCC Gaso (300-375)				
Total FCC Gasoline	36.6	6.7	1.5	12.3
Pentenes				0.6
Poly Gasoline				
Lt. Coker Gasoline	2.8			
Total Olefinic	2.8	0.0	0.0	0.6
Reformate	22.2	1.1		
Reformate (220-300 Feed)	5.9	23.0	6.0	11.2
BT Reformate	7.2			
HC Reformate (210-300)		6.8	20.6	12.5
Heavy Reformate (300+)		1.1	1.6	4.7
Total Reformates(2)	35.3	32.0	28.2	28.4
Lt. Reformate (Benzene Saturated)		6.2	11.5	8.6
Lt. Raffinate				
Alkylate/Lt Alkylate (C3/C4)	10.9	11.9	11.1	12.1
Alkylate/Lt Alkylate (C5)		3.3	3.4	3.1
Butane	2.5	1.5	1.5	1.5
Natural/LSR Gaso	3.8	0.6	3.4	2.6
BT Naphtha (150-220)				
Iso Pentane		0.2		3.0
Normal Pentane				0.6
Isomerate (C5-C6)	0.6	0.5	0.4	0.7
Isomerate (C6)		6.1	11.5	1.8
Lt. Hydrocrackate	5.0	8.7	4.6	6.7
Hydrocrackate (175-225)	0.5	7.2	8.7	6.3
MTBE	2.0	14.3	13.4	11.0
TAME		0.8	0.8	0.7
Total Low Arom., Saturated	25.3	61.3	70.3	58.7
Total	100.0	100.0	100.0	100.0

(1) No T50/DI Limits.

(2) Excluding light reformate.

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ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
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TABLE F-9

GASOLINE PROPERTY DECREASE – INCREMENTAL COSTS(1)

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

		8/91 CARB 2 PROPOSAL - LAB COMPLY MARGINS + CHANGES			
	Base Case 0	Case 19 - Blend Comply Margins(2)	Case 20 +6 OL/100 S 0.4 RVP/30 T90(2)	Case 21 - Blend Comply Margins	Case 22 +0.2 RVP
(R+M)/2 Octane, Clear	(0.9)	(2.2)	(1.4)	(1.3)	(1.3)
Reid Vapor Pressure, PSI	0.6	6.4	1.0	6.6	2.6
Butane, Vol.%		2.7		5.2	0.9
Aromatics, Vol.%		0.5	0.6	0.3	0.2
Ethers, Vol.%	(0.1)	0.1		0.4 (3)	(0.0)
Olefins, Vol.%					0.0
Benzene, Vol.%		2.3	3.3	4.4	3.2
Sulfur, 100 Wt. PPM		29.1	0.0	40.4	11.0
T90, 10°F		3.6	0.1	3.9	2.0

(1) Shadow costs for very small changes.
Not applicable for significant changes.
(2) No T50/DI Limits.
(3) Premium only.

CLM
11/12/91

TABLE G-1

RUN BASIS AND GASOLINE POOL PROPERTIES

WINTER 1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

Reformulated Properties*	Base Case W-0		Case W-1(1)	
Aromatics, Vol.%, Maximum			22	
Regulatory Cap			25	
Oxygen, Wt.%, Minimum	0.4		2.7	
Regulatory Bottom/Cap			2.7	
Bromine No., Maximum	26	(2)	8	
Regulatory Cap	30	(2)	10	
Benzene, Vol.%, Maximum Avg			0.8	
Sulfur, Wt. PPM, Maximum	250		20	
Regulatory Cap	300		30	
Reid Vapor Pressure, PSI, Max	10.5		10.5	
Regulatory Cap	10.8		10.8	
T90, °F, Maximum			290	
Regulatory Cap			300	
Driveability Index, Maximum			1075	
Regulatory Cap			1100	
Ethers, Vol.% Pool				
Purchased	0.6		13.2	
Manufactured	1.4		1.8	
Gasoline Pool Properties				
(R+M)/2 Octane, Clear*	88.9		88.9	
Aromatics, Vol..%	31		20	
Ethers, Vol.%	2.0	*	15.0	*
Oxygen, Wt.%	0.4	*	2.7	*
Olefins, Vol.%	10		4	*
Bromine No.	21		8	*
Benzene, Vol.%	2.0		0.8	*
Sulfur, Wt. PPM	169		20	*
Reid Vapor Pressure, PSI*	10.5		10.5	
Temperature at V/L = 20, °F	128		125	
Distillation				
90°F, Vol.%	17		15	
130°F, Vol.%	27		26	
170°F, Vol.%	37		47	
212°F, Vol.%	54		63	
257°F, Vol.%	70		80	
300°F, Vol.%	83		92	
356°F, Vol.%	92		98	
T10, °F	102		115	
T50, °F	203		177	
T90, °F	342		290	*
Driveability Index	1104		994	
Heat Content, MBTU/G	113.0		109.0	

(1) 8/91 Carb proposal with lab compliance margins, 2.7% oxygen and 10.5 RVP.
(2) L.A. only.
* Input limit.

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11/4/91

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TABLE G-2

SUMMARY OF COSTS

WINTER 1996 CASE RESULTS(1)

INCREASE OVER BASE CASE(2)

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

	Case W-1(3)
Investment, MM$	
Refinery	1,710
MTBE(4)	3,140
Total	4,850
Range, MMM$(5)	3.8-6.2
Daily Costs, M$/D	
Capital Charge(6)	1,136
Net Upgrading Costs(7)	2,825
Variable Operating Costs	445
Fixed Operating Costs(8)	431
Total Refinery	4,838
Annual Cost, MM$/Yr.	
Refinery	1,766
Other(9)	466
Total	2,232
Total Unit Cost, ¢/G of Base Gasoline	
Average	14.8
Range(10)	12.3-19.1

(1) For reformulation run, based on a composite model of conversion refineries. Individual refinery costs will differ from average.

(2) Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.

(3) 8/91 Carb proposal with lab compliance margins, 2.7% oxygen and 10.5 RVP.

(4) For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).

(5) For variations from investment curves of -15/+35% for refining and ±25% for MTBE.

(6) Based on expected 15% DCF rate of return on new refining facilities investment.

(7) Raw material upgrading costs.

(8) For new refining facilities only.

(9) Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.

(10) For variations in capital charge (-15/+35%), MTBE costs (-10/+20¢/G) and BTU mileage factor (±0.2).

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TABLE G-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES

WINTER 1996 CASE RESULTS

INCREASE OVER BASE CASE - MBPCD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Case W-1
Raw Materials	
Alaska North Slope	(128)
Subtotal Crudes	(128)
Natural Gasoline	
Naphtha	2
MTBE	128
Methanol	1
Normal Butane	1
Isobutane	
Natural Gas to H2 Plant Feed	4
Total	8
Products	
Motor Gasolines	28
No. 6 Bunker	(5)
Normal Butane	
Propane	0
Propylene, Low Value	(6)
Process Gas	(14)
Lt St Run Naphtha to P/C	
Lt Hydrocrackate to P/C	
Pentanes to P/C	
Isobutane	
Marketable Coke	
FCC Coke	(1)
Loss(Gain)	5
Total	8
Crude Property Increase	
Gravity, °API	(0.3)
Sulfur, Wt%	0.01
Gasoline Demand Increase, %(1)	
Results	2.8
Target	2.8

(1) To maintain constant miles traveled with lower BTU content reformulated gasoline.

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TABLE G–4

NEW PROCESS UNIT RATES

WINTER 1996 CASE RESULTS

INCREASE OVER BASE CASE – MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Case W–1
Heavy Naphtha Splitter	74
BT Naphtha Splitter	1
FCC Gasoline Splitters	335
FCC Gasoline Fractionation	
Hydrocracking – 2 stage	
– Heavy Gasoline	
Hydrocrackate Fractionation	121
Coker Lt Gasoline DS/Splitter	30
FCC Gasoline HDS	95
Hydrotreating – Naphtha	
– Distillate	59
Reformer Feed Fractionation	300
Reforming – 200 PSIG	
Reformate Fractionation	114
Benzene Saturation	59
Gasoline Aromatics Saturation	
Alkylation	
Alkylate Splitter	130
MTBE /TAME	6
Isomerization – C5/C6	18
– C5/C6, Recycle	
– C4	
Hydrogen – MMSCFPSD	57

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TABLE G-5

NEW PROCESS UNIT INVESTMENTS

WINTER 1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	Case W-1
Heavy Naphtha Splitter	60
BT Naphtha Splitter	0
FCC Gasoline Splitters	390
FCC Gasoline Fractionation	
Hydrocracking - 2 Stage	
- Heavy Gasoline	
Hydrocrackate Fractionation	80
Coker Lt. Gasoline DS/Splitter	50
FCC Gasoline HDS	210
Hydrotreating - Naphtha	
- Distillate	100
Reformer Feed Fractionation	160
Reforming - 200 PSIG	
Reformate Fractionation	80
Benzene Saturation	200
Gasoline Aromatics Saturation	
Alkylation	
Alkylate Splitter	90
MTBE / TAME	30
Isomerization - C5/C6	120
- C5/C6, Recycle	
- C4	
Hydrogen	90
MTBE Storage & Blending	50
Total Refinery	1,710

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ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30245

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TABLE G-6
PROCESS UNIT RATE CHANGES
WINTER 1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD PER REFINERY
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base Case W-0	Case W-1
Crude - Atmospheric	105.0	(7.6)
Heavy Naphtha Splitter		4.0
BT Naphtha Splitter		0.0
Catalytic Cracking (1)	34.1	(4.0)
Catalytic Cracking (2)	34.6	(4.0)
Conversion, %	74.4	(1.0)
Octane Catalyst, %	15.0	
FCC Gasoline Splitters		17.3
FCC Gasoline Fractionation	14.1	(14.1)
Hydrocracking - 2 Stage(1)	16.3	
Jet Yield, % of Max	100.0	(45.3)
300 - Gasoline Operation, %		45.3
Hydrocracking - Low Conversion	3.1	
- Heavy Gasoline		
- Combined(2)	19.4	(1.2)
Hydrocrackate Fractionation		6.3
Coking - Delayed	21.2	
- Fluid	4.9	
Coker Lt Gasoline DS/Splitter		1.5
Thermal Cracking, Visbreaking	2.2	
Solvent Deasphalting	2.5	(1.6)
Catalytic Reforming - 100 PSI (1)	2.6	
- 200 PSI (1)	14.6	(1.5)
- 450 PSI (1)	6.0	(0.9)
- Combined (2)	21.5	(0.6)
- RONC	99.3	(7.9)
Hydrotreating - Naphtha	15.6	3.7
- Distillate	21.8	3.0
- Heavy Gas Oil	30.0	(2.7)
- Residuum - Vac	1.4	
Reformer Feed Fractionation		15.0
Reformate Fractionation		5.7
Benzene Saturation		2.8
FCC Gasoline HDS		4.7
Gasoline Aromatics Saturation		
Diesel Aromatics Saturation	11.1	0.2
Alkylation	6.3	0.0
Alkylate Splitter		6.1
Polymerization		
MTBE / TAME	0.8	0.3
Lubes	1.3	
Isomerization - C5/C6		0.9
- C5/C6, Recycle	0.3	0.1
- C4		0.1
Hydrogen - MMSCFPCD	56.0	10.3
Sulfur, LTPCD	123.0	(4.0)

(1) Include effects of nonunitary capacity for some feedstocks and severities.
(2) Based on actual feed rates, ignoring severity effects.

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ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER

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TABLE G-7
PROCESS UNIT UTILIZATIONS (1)
WINTER 1996 CASE RESULTS – %
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base Case W-0	Case W-1
Crude Distillation – Atmospheric	84.3	78.2
Heavy Naphtha Splitter		93.0
BT Naphtha Splitter		93.0
Catalytic Cracking (2)	88.0	77.7
Catalytic Cracking (3)	89.2	78.9
FCC Gasoline Splitters		88.0
FCC Gasoline Fractionation	79.0	
Hydrocracking – 2 Stage(2)	85.0	85.0
– Low Conversion	64.9	64.9
– Heavy Gasoline		
– Combined(3)	81.0	75.9
Hydrocrackate Fractionation		88.0
Coking – Delayed	88.0	88.0
– Fluid	88.0	88.0
Coker Lt Gasoilne DS/Splitter		88.0
Thermal Cracking, Visbreaking	85.0	85.0
Solvent Deasphalting	85.0	29.9
Catalytic Reforming – 100 PSI (2)	67.6	67.6
– 200 PSI (2)	77.7	69.8
– 450 PSI (2)	59.6	50.7
– Combined (3)	65.8	63.9
Hydrotreating – Naphtha	55.3	68.4
– Distillate	85.0	85.0
– Heavy Gas Oil	83.1	75.6
– Residuum, Vac	85.0	85.0
Reformer Feed Fractionation		85.0
Reformate Fractionation		85.0
Benzene Saturation		80.0
FCC Gasoline HDS		85.0
Gasoline Aromatics Saturation		
Diesel Aromatics Saturation	83.7	85.0
Alkylation	79.8	80.0
Alkylate Splitter		80.0
Polymerization	0.0	0.0
MTBE / TAME	76.3	80.0
Lubes	84.6	84.6
Isomerization – C5/C6		85.0
– C5/C6, Recycle	78.1	85.0
– C4	0.0	23.7
Hydrogen	70.4	80.0
Sulfur	43.5	42.0

(1) Calendar day rates divided by stream day capacity.
(2) Include effects of nonunitary capacity factors for some feedstocks and severities.
(3) Based on actual feed rates, ignoring severity effects.

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TABLE G-8

GASOLINE POOL COMPOSITIONS

WINTER 1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base Case W-0	Case W-1
FCC Gasoline	10.4	
Lt. FCC 255-	14.4	
Hvy FCC 255+	10.0	
Hvy FCC 255+ Desul		8.1
FCC Gaso (100-180)		6.1
FCC Gaso (180-225)		0.2
FCC Gaso (225-300)		1.8
FCC Gaso (300-375)		
Total FCC Gasoline	34.8	16.2
Pentenes		1.3
Poly Gasoline		
Lt. Coker Gasoline	2.7	
Total Olefinic	2.7	1.3
Reformate	18.2	4.4
Reformate (220-300 Feed)	6.1	15.7
BT Reformate	5.5	
HC Reformate (210-300)		4.3
Heavy Reformate (300+)		0.6
Total Reformates(1)	29.8	25.0
Lt. Reformate (Benzene Saturated)		4.8
Alkylate/Lt Alkylate (C3/C4)	10.6	8.9
Alkylate/Lt Alkylate (C5)		
Butane	8.4	7.8
Natural/LSR Gaso	3.6	3.1
BT Naphtha (150-220)		
Iso Pentane		2.7
Normal Pentane		1.6
Isomerate (C5-C6)	0.6	0.6
Isomerate (C6)		1.5
Lt. Hydrocrackate	5.0	5.7
Hydrocrackate (175-225)	2.5	5.7
MTBE	2.0	14.4
TAME		0.7
Total Low Arom., Saturated	32.7	57.5
Total	100.0	100.0

(1) Excluding light reformate.

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TABLE G-9

GASOLINE PROPERTY DECREASE - INCREMENTAL COSTS(1)

WINTER 1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

	Base Case W-0	Case W-1
(R+M)/2 Octane, Clear	(0.3)	(0.4)
Reid Vapor Pressure, PSI	0.3	0.4
Butane, Vol.%		
Aromatics, Vol.%		
Ethers, Vol.%	(0.4)	(0.2)
Olefins, Vol.%		0.2
Benzene, Vol.%		3.2
Sulfur, 100 Wt. PPM		4.0
T90, 10°F		1.3

(1) Shadow costs for very small changes.
Not applicable for significant changes.

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TABLE H-1

RUN BASIS AND GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

		10/4 CARB 2 PROPOSAL + CHANGES				
Reformulated Properties*	**Base Case 0**	**Case 23 No Comply Margins**	**Case 24 Lab Comply Margins**	**Case 25 Lab & Blend Comply Margins**	**Case 26 Alternate A**	**Case 27 CARB Emissions**
Aromatics, Vol.%, Maximum		25	22	20	25	20
Regulatory Cap		25	25	25	25	25
Oxygen, Wt.%, Minimum	0.4	1.8	2.0	2.0	1.8	2.0
Regulatory Bottom		1.8	1.8	1.8	1.8	1.8
Bromine No., Maximum	26 (1)	10	8	6	14	10
Regulatory Cap	30 (1)	10	10	10	18	14
Benzene, Vol.%, Maximum Avg		0.95	0.8	0.6	0.8	0.8
Sulfur, Wt. PPM, Maximum	250	40	25	20	30	30
Regulatory Cap	300	40	40	40	50	50
Reid Vapor Pressure, PSI, Max	7.5	7.0	6.7	6.6	7.1	7.0
Regulatory Cap	7.8	7.0	7.0	7.0	7.4	7.3
90 Vol.% Point, °F, Maximum		300	290	280	295	300
Regulatory Cap		300	300	300	315	320
50 Vol.% Point, °F, Maximum		210	200	195	195	200
Regulatory Cap		210	210	210	210	210
Ethers, Vol.% Pool						
Purchased	0.6	8.1	9.2	9.3	8.4	9.8
Manufactured	1.4	1.9	1.9	1.8	1.6	1.3
Gasoline Pool Properties						
(R+M)/2 Octane, Clear*	88.9	88.9	88.9	88.9	88.9	88.9
Aromatics, Vol.%	34	25 *	22 *	20 *	25 *	20 *
Ethers, Vol.%*	2.0	10.0	11.1	11.1	10.0	11.1
Oxygen, Wt.%*	0.4	1.8	2.0	2.0	1.8	2.0
Olefins, Vol.%	11	5 *	4 *	3	7	5
Bromine No.	22	10 *	8 *	6	13	10
Benzene, Vol.%	2.2	0.95 *	0.8 *	0.6 *	0.8 *	0.8 *
Sulfur, Wt. PPM	206	40 *	25 *	20 *	30 *	30 *
Reid Vapor Pressure, PSI*	7.5	7.0	6.7	6.6	7.1	7.0
Temperature at V/L = 20, °F	145	145	145	144	143	143
Distillation						
90°F, Vol.%	12	9	8	6	10	10
130°F, Vol.%	23	21	20	18	23	21
170°F, Vol.%	33	38	39	39	40	39
212°F, Vol.%	50	58	60	59	60	60
257°F, Vol.%	67	76	79	80	78	78
300°F, Vol.%	81	90	92	96	91	90
356°F, Vol.%	91	97	98	99	98	97
T10, °F	125	132	139	144	131	132
T50, °F	212	196	192	193	191	192
T90, °F	348	300 *	290 *	280 *	295 *	300 *
Driveability Index	1171	1086	1075	1075	1065	1074
Heat Content, MBTU/G	114.4	111.7	111.0	110.9	111.4	110.8

(1) L.A. only.

* Input limit.

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TABLE H-2

SUMMARY OF COSTS

1996 CASE RESULTS(1) – INCREASE OVER BASE CASE(2)

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

	10/4 CARB 2 PROPOSAL + CHANGES				
	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A	Case 27 CARB Emissions
Investment, MM$					
Refinery	2,340	3,410	5,090	2,480	3,020
MTBE(3)	1,940	2,230	2,240	1,990	2,330
Total	4,280	5,640	7,330	4,470	5,350
Range, MMM$(4)	3.4–5.6	4.6–7.4	6.0–9.7	3.6–5.8	4.3–7.0
Daily Costs, M$/D					
Capital Charge(5)	1,549	2,263	3,377	1,644	1,999
Net Upgrading Costs(6)	1,897	2,129	2,556	1,862	2,098
Variable Operating Costs	655	996	1,677	790	753
Fixed Operating Costs(7)	573	815	1,103	605	728
Total Refinery	4,674	6,203	8,713	4,901	5,578
Annual Cost, MM$/Yr.					
Refinery	1,706	2,264	3,180	1,789	2,036
Other(8)	332	415	433	370	445
Total	2,038	2,679	3,613	2,159	2,481
Total Unit Cost, ¢/G of Base Gasoline					
Average	13.0	17.1	23.1	13.8	15.9
Range(9)	11.2–16.4	14.8–21.4	20.4–28.4	11.9–17.3	13.5–20.1

(1) For reformulation runs, based on a composite model of conversion refineries. Individual refinery costs will differ from average.

(2) Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.

(3) For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).

(4) For variations from investment curves of −15/+35% for refining and ±25% for MTBE.

(5) Based on expected 15% DCF rate of return on new refining facilities investment.

(6) Raw material upgrading costs.

(7) For new refining facilities only.

(8) Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.

(9) For variations in capital charge (−15/+35%), MTBE costs (−10/+20¢/G) and BTU mileage factor (±0.2).

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TABLE H-2A

COMPOSITE REFINERY MARGIN & COST INCREASE DETAIL

1996 CASE 25 OVER(UNDER) BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

	MBPD	C/GAL	$/B	M$/D
Products				
Motor Gasolines-Regular	13.0	65.5		358
Motor Gasolines-Intermediate	4.8	67.7		137
Motor Gasolines-Premium	6.0	71.0		177
No. 6 Bunker	45.1		13.00	586
Propane	4.0	32.6		55
Propane to Fuel	11.6		20.47	237
Propylene	(1.6)	29.7		(20)
Propylene to Fuel	(11.6)		20.47	(238)
Process Gas to Fuel	(19.5)		20.47	(400)
LSR Naphtha to P/C	10.1	25.0		107
Pentanes to P/C	40.1	20.0		337
Normal Butane to Fuel	(2.9)		20.47	(59)
Marketable Coke(All Grades)	18.0		5.85	105
Loss(Gain)	(7.8)			
Subtotal	109.3			1,383
Sulfur(M L T; $/L T)	(0.03)		70	(2)
Total				1,380
Raw Materials				
Alaska North Slope Crude	30.2		16.70	505
Natural Gasoline	(4.0)	50.0		(84)
Naphtha	3.5	52.5		78
MTBE	90.6	96.0		3,653
Methanol	1.6	65.0		45
Natural Gas to H2 Plant	(12.7)		20.47	(260)
Total	109.3			3,937
Gross Margin				(2,557)
Variable Cost				
Natural Gas	80.4		20.47	1,645
Produced Fuels	(22.5)		20.47	(460)
Other				493
Total Variable Cost				1,678
Gross Margin after Variable Cost				(4,235)

RMA
11/12/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30252

TURNER, MASON & COMPANY
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TABLE H-2B

ADDED MANPOWER AND FIXED COSTS

1996 CASE 25 INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Number of Employees
Manpower	
Direct Process Operating Labor	900
Off-Site Operators, Administrative, Technical and Staff	1,700
Maintenance Employees	1,400
Total Employees	4,000
Contract Maintenance	400
Total Manpower	4,400
Fixed Costs	
Total Fixed Operating Costs, \$MM/Year[1]	400
Salaries and Wages, %	52
Maintenance Costs, \$MM/Year[1]	170

[1] Includes manpower.

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11/12/91

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TABLE H-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD
WSPA STUDY OF CARB PHASE 2 GASOLINE

	10/4 CARB 2 PROPOSAL • CHANGES			
	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A
Raw Materials				
Alaska North Slope	(51)	(84)	30	(73)
Subtotal Crudes	(51)	(84)	30	(73)
Natural Gasoline		(4)	(4)	
Naphtha	4	4	4	4
MTBE	78	90	91	81
Methanol	2	2	2	1
Normal Butane		15		
Natural Gas to H2 Plant Feed	(19)	13	(13)	(18)
Total	14	36	109	(6)
Products				
Motor Gasolines	19	23	24	21
No. 6 Bunker	22	20	45	20
Normal Butane	(3)	(3)	(3)	(3)
Propane	(0)	1	16	0
Propylene, Low Value	7	(13)	(13)	(13)
Process Gas	(33)	(6)	(21)	(33)
Lt St Run Naphtha to P/C			10	
Pentanes to P/C		9	40	
Marketable Coke		(2)	18	0
FCC Coke	(2)	(2)	0	(2)
Loss(Gain)	4	8	(7)	4
Total	14	36	109	(6)
Crude Property Increase				
Gravity, °API	(0.1)	(0.2)	0.0	(0.2)
Sulfur, Wt%	0.00	0.00	(0.01)	0.00
Gasoline Demand Increase, %(1)				
Results	1.9	2.3	2.3	2.0
Target	1.9	2.4	2.4	2.1

(1) To maintain constant miles traveled with lower BTU content reformulated gasoline.

CLM
11/6/91

ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30254

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TABLE H-4

NEW PROCESS UNIT RATES

1996 CASE RESULTS

INCREASE OVER BASE CASE – MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	10/4 CARB 2 PROPOSAL + CHANGES			
	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A
Heavy Naphtha Splitter	121	125	137	129
FCC Gasoline Splitters	347	347	366	346
Hydrocracking – Heavy Gasoline	9	47	87	12
Hydrocrackate Fractionation	161	179	200	161
Coker Lt Gasoline DS/Splitter	29	29	38	29
FCC Gasoline HDS	23		69	50
Hydrotreating – Distillate	128	98	104	108
Reformer Feed Fractionation	293	343	346	314
Reformate Fractionation	210	326	424	321
Benzene Saturation	80	111	134	109
Gasoline Aromatics Saturation	9			3
Alkylation	20	77	103	26
Alkylate Splitter	15	27	41	153
MTBE /TAME	7	7	7	4
Isomerization – C5/C6	20	19	24	20
– C5/C6, Recycle			50	
– C4	6	33	30	13
Hydrogen – MMSCFPSD	75	174	375	80

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TABLE H-5

NEW PROCESS UNIT INVESTMENTS

1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	10/4 CARB 2 PROPOSAL + CHANGES				
	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A	Case 27 CARB Emissions
Heavy Naphtha Splitter	80	90	90	90	
BT Naphtha Splitter					0
FCC Gasoline Splitters	520	390	540	390	410
Hydrocracking - Heavy Gasoline	140	640	960	190	490
Hydrocrackate Fractionation	100	110	120	100	100
Coker Lt. Gasoline DS/Splitter	50	50	60	50	50
FCC Gasoline HDS	80		170	140	80
Hydrotreating - Distillate	260	200	210	220	50
Reformer Feed Fractionation	160	170	180	160	160
Reformate Fractionation	120	320	380	170	140
Benzene Saturation	240	300	340	300	250
Gasoline Aromatics Saturation	90			30	
Alkylation	120	480	580	150	510
Alkylate Splitter	10	30	40	100	
MTBE / TAME	40	40	40	20	
Isomerization - C5/C6	130	130	120	130	330
- C5/C6, Recycle			440		
- C4	30	160	170	70	180
Hydrogen	120	260	610	130	210
MTBE Storage & Blending	40	40	40	40	40
Total Refinery	2,340	3,410	5,090	2,480	3,020

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TABLE H-6
PROCESS UNIT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD PER REFINERY
WSPA STUDY OF CARB PHASE 2 GASOLINE

		10/4 CARB 2 PROPOSAL + CHANGES			
	Base Case 0	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A
Crude - Atmospheric	111.1	(3.0)	(4.9)	1.8	(4.3)
Heavy Naphtha Splitter		6.8	7.0	7.6	7.2
Catalytic Cracking (1)	36.8	(2.7)	(2.7)	(0.5)	(2.8)
Catalytic Cracking (2)	37.3	(2.7)	(2.7)	(0.5)	(2.9)
Conversion, %	74.4	(2.3)	(2.2)	(3.1)	(2.2)
Octane Catalyst, %	15.0				
FCC Gasoline Splitters		19.4	19.4	20.4	19.3
FCC Gasoline Fractionation	15.2	(15.2)	(15.2)	(15.2)	(15.2)
Hydrocracking - 2 Stage(1)	16.9				
Jet Yield, % of Max	96.7	(68.8)	(51.0)	(57.4)	(65.6)
300 - Gasoline Operation, %				60.7	
Hydrocracking - Low Conversion	3.2	1.0	1.0		1.0
- Heavy Gasoline		0.5	2.5	4.5	0.6
- Combined(2)	20.1	1.5	3.5	2.8	1.6
Hydrocrackate Fractionation		8.3	9.3	10.4	8.3
Coking - Delayed	22.9				
- Fluid	5.3		(0.5)		
Coker Lt Gasoline DS/Splitter		1.6	1.6	2.1	1.6
Thermal Cracking, Visbreaking	2.3				
Solvent Deasphalting	1.0	(0.5)	(0.6)	0.9	(0.6)
Catalytic Reforming - 100 PSI (1)	3.4		(0.3)	(0.3)	(0.2)
- 200 PSI (1)	16.6	(0.8)	(0.0)	(0.6)	
- 450 PSI (1)	8.9	(1.8)	(2.3)	(2.3)	(1.8)
- Combined (2)	26.4	(1.7)	0.0	(0.4)	(0.7)
- RONC	99.2	(2.7)	(5.0)	(5.4)	(3.0)
Hydrotreating - Naphtha	18.8	0.0	3.1	3.3	0.6
- Distillate	22.0	6.6	5.1	5.4	5.6
- Heavy Gas Oil	31.0			0.8	
- Residuum - Vac	1.4	(0.2)			(0.4)
Reformer Feed Fractionation		15.2	17.6	17.9	16.2
Reformate Fractionation		10.9	16.9	21.9	16.6
Benzene Saturation		3.9	5.4	6.5	5.3
FCC Gasoline HDS		1.2		3.6	2.6
Gasoline Aromatics Saturation		0.5			0.1
Diesel Aromatics Saturation	11.7	(0.0)	(0.2)	(0.2)	(0.3)
Alkylation	6.6	1.0	3.8	5.1	1.2
Alkylate Splitter		0.7	1.3	2.0	7.5
Polymerization					
MTBE / TAME	0.8	0.4	0.4	0.3	0.2
Lubes	1.3				
Isomerization - C5/C6		1.0	1.0	1.3	1.0
- C5/C6, Recycle	0.4			2.6	
- C4	0.3	0.3	1.6	1.5	0.6
Hydrogen - MMSCFPCD	58.1	11.7	16.5	26.3	11.9
Sulfur, LTPCD	130.0	(6.0)	(6.0)	(2.0)	(7.0)

(1) Include effects of nonunitary capacity for some feedstocks and severities.
(2) Based on actual feed rates, ignoring severity effects.

ARCO et al. v. UNOCAL et al.
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TABLE H-7

PROCESS UNIT UTILIZATIONS (1)

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		10/4 CARB 2 PROPOSAL + CHANGES			
	Base Case 0	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A
Crude Distillation - Atmospheric	89.2	86.8	85.2	90.6	85.7
Heavy Naphtha Splitter		95.0	95.0	95.0	95.0
Catalytic Cracking (2)	95.0	88.1	88.0	93.8	87.8
Catalytic Cracking (3)	96.2	89.1	89.2	95.0	88.8
FCC Gasoline Splitters		95.0	95.0	95.0	95.0
FCC Gasoline Fractionation	84.9				
Hydrocracking - 2 Stage(2)	88.0	88.0	88.0	88.0	88.0
- Low Conversion	67.0	88.0	88.0	67.0	88.0
- Heavy Gasoline		88.0	88.0	88.0	88.0
- Combined(3)	83.8	88.0	88.0	78.7	88.0
Hydrocrackate Fractionation		88.0	88.0	88.0	88.0
Coking - Delayed	95.0	95.0	95.0	95.0	95.0
- Fluid	95.0	95.0	85.9	95.0	95.0
Coker Lt Gasoline DS/Splitter		95.0	95.0	95.0	95.0
Thermal Cracking, Visbreaking	88.0	88.0	88.0	88.0	88.0
Solvent Deasphalting	32.5	16.8	12.9	62.5	12.5
Catalytic Reforming - 100 PSI (2)	88.0	88.0	80.5	80.5	83.9
- 200 PSI (2)	88.0	83.7	87.9	84.8	88.0
- 450 PSI (2)	88.0	70.6	65.6	65.6	70.6
- Combined (3)	80.4	75.3	80.6	79.3	78.2
Hydrotreating - Naphtha	66.7	66.7	77.7	78.4	68.6
- Distillate	88.0	88.0	88.0	88.0	88.0
- Heavy Gas Oil	85.8	85.8	85.8	88.0	85.8
- Residuum, Vac	88.0	75.8	88.0	88.0	65.9
Reformer Feed Fractionation		88.0	88.0	88.0	88.0
Reformate Fractionation		88.0	88.0	88.0	88.0
Benzene Saturation		83.0	83.0	83.0	83.0
FCC Gasoline HDS		88.0		88.0	88.0
Gasoline Aromatics Saturation		88.0			88.0
Diesel Aromatics Saturation	88.0	88.0	86.4	86.2	85.8
Alkylation	83.0	83.0	83.0	83.0	83.0
Alkylate Splitter		83.0	83.0	83.0	83.0
Polymerization	0.0	0.0	0.0	0.0	0.0
MTBE / TAME	83.0	83.0	83.0	83.0	83.0
Lubes	87.6	87.6	87.6	87.6	87.6
Isomerization - C5/C6		88.0	88.0	88.0	88.0
- C5/C6, Recycle	88.0	88.0	88.0	88.0	88.0
- C4	83.0	83.0	83.0	83.0	83.0
Hydrogen	72.9	83.0	83.0	83.0	83.0
Sulfur	45.9	43.8	43.8	45.2	43.5

(1) Calendar day rates divided by stream day capacity.
(2) Include effects of nonunitary capacity factors for some feedstocks and severities.
(3) Based on actual feed rates, ignoring severity effects.

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TABLE H-8

GASOLINE POOL COMPOSITIONS

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		10/4 CARB 2 PROPOSAL + CHANGES			
	Base Case 0	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A
FCC Gasoline	11.1				
Lt. FCC 255-	15.0				
Hvy FCC 255+	10.5				
Hvy FCC 255+ Desul		2.0		5.9	4.3
FCC Gaso (100-180)		6.5	6.4	4.5	6.4
FCC Gaso (180-225)		2.6	3.8	2.4	3.8
FCC Gaso (225-300)		7.6	2.3	1.8	3.7
FCC Gaso (300-375)		0.5			
Total FCC Gasoline	36.6	19.2	12.5	14.6	18.2
Pentenes		0.2			2.3
Lt. Coker Gasoline	2.8				
Total Olefinic	2.8	0.2	—	—	2.3
Reformate	22.2	5.0			
Reformate (220-300 Feed)	5.9	10.5	8.8		7.6
BT Reformate	7.2				
HC Reformate (210-300)		8.0	13.6	20.5	13.0
Heavy Reformate (300+)		3.4	5.1	1.3	5.4
Total Reformates(1)	35.3	26.9	27.5	21.8	26.0
Lt. Reformate (Benzene Saturated)		6.6	9.2	11.1	9.0
Alkylate/Lt Alkylate (C3/C4)	10.9	8.3	12.2	14.0	10.2
Alkylate/Lt Alkylate (C5)		3.4	3.4	3.6	0.5
Butane	2.5	2.4	1.5	1.5	1.5
Natural/LSR Gaso	3.8	3.7	2.9		2.8
Iso Pentane		3.0	2.3		3.1
Normal Pentane		0.6	0.1		0.6
Isomerate (C5-C6)	0.6	0.6	0.6	2.4	0.7
Isomerate (C6)		1.6	1.7	4.5	1.6
Lt. Hydrocrackate	5.0	6.6	7.8	9.4	6.8
Hydrocrackate (175-225)	0.5	6.9	7.2	5.9	6.6
MTBE	2.0	9.3	10.4	10.4	9.6
TAME		0.7	0.7	0.8	0.5
Total Low Arom., Saturated	25.3	53.7	60.0	63.6	53.5
Total	100.0	100.0	100.0	100.0	100.0

(1) Excluding light reformate.

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TABLE H-9

GASOLINE PROPERTY DECREASE – INCREMENTAL COSTS(1)

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

		10/4 CARB 2 PROPOSAL + CHANGES				
	Base Case 0	Case 23 No Comply Margins	Case 24 Lab Comply Margins	Case 25 Lab & Blend Comply Margins	Case 26 Alternate A	Case 27 CARB Emissions
(R+M)/2 Octane, Clear	(0.9)	(1.0)	(1.2)	(2.6)	(1.1)	(2.2)
Reid Vapor Pressure, PSI	0.6	0.9	3.9	5.2	1.9	1.9
Butane, Vol.%			1.6	2.1	0.5	0.4
Aromatics, Vol.%		0.1	0.2	0.7	0.2	0.9
Ethers, Vol.%	(0.1)	(0.1)	(0.1)	0.2	(0.1)	0.4
Olefins, Vol.%		0.3	0.5			
Benzene, Vol.%		2.5	3.2	5.2	3.2	3.3
Sulfur, 100 Wt. PPM		2.8	2.6	12.4	7.4	7.9
T90, 10°F		1.8	2.3	3.7	1.8	0.5

(1) Shadow costs for very small changes.
Not applicable for significant changes.

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TABLE I-1

RUN BASIS AND GASOLINE POOL PROPERTIES

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

		ALTERNATE B + CHANGES		ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+ (2)	
Reformulated Properties*	Base Case 0	Case 28 + None	Case 29 - 50 S	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
Aromatics, Vol.%, Maximum Avg		25	25	25	20	20
Regulatory Cap		28	28	28	25	25
Oxygen, Wt.%, Minimum Avg	0.4	1.8	1.8	2.0	2.0	2.0
Regulatory Bottom		1.8	1.8	2.0	1.8	1.8
Bromine No., Maximum Avg	26 (1)	16	16	14	6	6
Regulatory Cap	30 (1)	20	20	18	10	10
Benzene, Vol.%, Maximum Avg		0.8	0.8	0.8	0.8	0.6
Sulfur, Wt. PPM, Maximum Avg	250	80	30	50	30	20
Regulatory Cap	300	130	50	80	40	40
Reid Vapor Pressure, PSI, Max Avg	7.5	7.1	7.1	7.1	6.6	6.6
Regulatory Cap	7.8	7.4	7.4	7.4	7.0	7.0
90 Vol.% Point, °F, Maximum Avg		320	320	310	280	280
Regulatory Cap		330	330	320	300	300
50 Vol.% Point, °F, Maximum Avg					195	195
Regulatory Cap					210	210
Ethers, Vol.% Pool						
Purchased	0.6	8.1	8.6	9.2	9.1	9.4
Manufactured	1.4	1.9	1.4	1.9	2.0	1.7
Gasoline Pool Properties						
(R+M)/2 Octane, Clear*	88.9	88.9	88.9	88.9	88.9	88.9
Aromatics, Vol.%	34	25 *	25 *	25	20 *	20 *
Ethers, Vol.%*	2.0	10.0	10.0	11.1	11.1	11.1
Oxygen, Wt.%*	0.4	1.8	1.8	2.0	2.0	2.0
Olefins, Vol.%	11	8 *	7	7 *	3 *	2
Bromine No.	22	16 *	14	14 *	6 *	5
Benzene, Vol.%	2.2	0.8 *	0.8 *	0.8 *	0.8 *	0.6 *
Sulfur, Wt. PPM	206	80 *	30 *	50 *	30	20 *
Reid Vapor Pressure, PSI*	7.5	7.1	7.1	7.1	6.6	6.6
Temperature at V/L = 20, °F	145	144	143	144	146	145
Distillation						
90°F, Vol.%	12	11	11	10	7	7
130°F, Vol.%	23	22	23	22	17	18
170°F, Vol.%	33	38	39	39	37	38
212°F, Vol.%	50	56	58	58	60	60
257°F, Vol.%	67	73	74	75	81	81
300°F, Vol.%	81	85	85	88	96	96
356°F, Vol.%	91	95	96	96	99	99
T10, °F	125	130	130	133	145	145
T50, °F	212	197	194	194	194	193
T90, °F	348	320 *	320 *	310 *	280 *	280 *
Driveability Index	1171	1106	1097	1092	1080	1077
Heat Content, MBTU/G	114.4	111.7	111.6	111.4	110.8	110.8

(1) L.A. only.

(2) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.

* Input limit.

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U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER

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TABLE I–2

SUMMARY OF COSTS

1996 CASE RESULTS(1) – INCREASE OVER BASE CASE(2)

WSPA STUDY OF CARB PHASE 2 GASOLINE

(in constant 1991 $)

	ALTERNATE B + CHANGES		ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+ (3)	
	Case 28 + None	Case 29 – 50 S	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
Investment, MM$					
Refinery	1,250	1,730	1,460	4,720	5,170
MTBE(4)	1,930	2,030	2,220	2,210	2,260
Total	3,180	3,760	3,680	6,930	7,420
Range, MMM$(5)	2.5–4.1	3.0–4.9	2.9–4.7	5.7–9.1	6.1–9.8
Daily Costs, M$/D					
Capital Charge(6)	827	1,147	966	3,128	3,425
Net Upgrading Costs(7)	1,636	1,767	2,025	2,256	2,466
Variable Operating Costs	257	417	376	1,439	1,556
Fixed Operating Costs(8)	332	428	367	1,028	1,111
Total Refinery	3,052	3,759	3,734	7,852	8,558
Annual Cost, MM$/Yr.					
Refinery	1,115	1,372	1,363	2,865	3,124
Other(9)	329	343	369	438	443
Total	1,444	1,715	1,732	3,303	3,567
Total Unit Cost, ¢/G of Base Gasoline					
Average	9.2	11.0	11.1	21.1	22.8
Range(10)	7.7–12.0	9.2–14.1	9.3–14.2	18.5–26.1	20.0–28.1

(1) For reformulation runs, based on a composite model of conversion refineries. Individual refinery costs will differ from average.

(2) Based on normal investment costs, capital charge, fixed costs, net upgrading and variable costs over base case.

(3) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.

(4) For MTBE, methanol and butane isom plus dehydro plants outside of refineries, their capital and fixed cost are included in refinery raw material costs (net upgrading costs).

(5) For variations from investment curves of –15/+35% for refining and ±25% for MTBE.

(6) Based on expected 15% DCF rate of return on new refining facilities investment.

(7) Raw material upgrading costs.

(8) For new refining facilities only.

(9) Added consumer costs for extra gasoline used due to lower BTU content: retail price less 10¢/G refining margin included in refinery costs.

(10) For variations in capital charge (–15/+35%), MTBE costs (–10/+20¢/G) and BTU mileage factor (±0.2).

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TABLE I-3

REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD
WSPA STUDY OF CARB PHASE 2 GASOLINE

	ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+ (1)	
	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
Raw Materials			
Alaska North Slope	(97)	(27)	1
Subtotal Crudes	(97)	(27)	1
Natural Gasoline		(4)	(4)
Naphtha	4	4	4
MTBE	90	89	92
Methanol	2	2	1
Normal Butane		2	4
Natural Gas to H2 Plant Feed	6	(13)	(13)
Total	4	53	86
Products			
Motor Gasolines	21	25	25
No. 6 Bunker	4	35	58
Normal Butane	(2)	(3)	(3)
Propane	(3)	8	10
Propylene, Low Value	(7)	(13)	(13)
Process Gas	(12)	(34)	(31)
Lt St Run Naphtha to P/C			
Pentanes to P/C		39	40
Iso Pentane to P/C		1	2
Marketable Coke	0	(0)	(1)
FCC Coke	(1)	0	0
Loss(Gain)	3	(5)	(2)
Total	4	53	85
Crude Property Increase			
Gravity, °API	(0.2)	(0.1)	0.0
Sulfur, Wt%	0.01	0.00	0.00
Gasoline Demand Increase, %(2)			
Results	2.0	2.4	2.4
Target	2.1	2.5	2.5

(1) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.
(2) To maintain constant miles traveled with lower BTU content reformulated gasoline.

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TABLE I-4

NEW PROCESS UNIT RATES

1996 CASE RESULTS

INCREASE OVER BASE CASE – MBPSD

WSPA STUDY OF CARB PHASE 2 GASOLINE

	ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPLY MGNS+ (1)	
	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
Heavy Naphtha Splitter		132	134
FCC Gasoline Splitters	346	372	372
Hydrocracking – Heavy Gasoline		80	78
Hydrocrackate Fractionation	141	203	201
Lt. Hydrocrackate Splitter		4	6
Coker Lt Gasoline DS/Splitter	30	30	31
FCC Gasoline HDS	25		75
Hydrotreating – Distillate	63	106	109
– Hvy. Gas Oil		16	16
Reformer Feed Fractionation	309	319	298
Reformate Fractionation	248	264	373
Benzene Saturation	83	84	117
Gasoline Aromatics Saturation			
Alkylation		91	98
Alkylate Splitter		93	55
MTBE /TAME	7	9	6
Isomerization – C5/C6	19	51	35
– C5/C6, Recycle		61	77
– C4	5	25	29
Hydrogen – MMSCFPSD	1	342	381

(1) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.

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TABLE I-5

NEW PROCESS UNIT INVESTMENTS

1996 CASE RESULTS

INCREASE OVER BASE CASE

WSPA STUDY OF CARB PHASE 2 GASOLINE

($MM - in constant 1991 $)

	ALTERNATE B + CHANGES		ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+(1)	
	Case 28 + None	Case 29 - 50 S	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
Heavy Naphtha Splitter	0			90	90
BT Naphtha Splitter					
FCC Gasoline Splitters	190	320	320	550	550
Hydrocracking – Heavy Gasoline				910	890
Hydrocrackate Fractionation	90	90	90	120	120
Lt. Hydrocrackate Splitter				0	10
Coker Lt. Gasoline DS/Splitter			50	50	60
FCC Gasoline HDS	0	170	80		180
Hydrotreating – Distillate	60	70	120	210	220
– Hvy. Gas Oil				40	40
Reformer Feed Fractionation	140	170	160	170	160
Reformate Fractionation	120	140	140	270	350
Benzene Saturation	220	250	250	250	310
Gasoline Aromatics Saturation					
Alkylation	70	140		530	560
Alkylate Splitter				70	50
MTBE / TAME	40		40	50	30
Isomerization – C5/C6	180	200	120	220	150
– C5/C6, Recycle				470	590
– C4	70	110	20	130	150
Hydrogen	10	30	10	540	620
MTBE Storage & Blending	40	40	40	40	40
Total Refinery	1,250	1,730	1,460	4,720	5,170

(1) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.

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TABLE I-6
PROCESS UNIT RATE CHANGES
1996 CASE RESULTS
INCREASE OVER BASE CASE – MBPCD PER REFINERY
WSPA STUDY OF CARB PHASE 2 GASOLINE

		ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+ (1)	
	Base Case 0	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
Crude - Atmospheric	111.1	(5.7)	(1.6)	0.1
Heavy Naphtha Splitter			7.4	7.5
Catalytic Cracking (2)	36.8	(2.9)		
Catalytic Cracking (3)	37.3	(2.9)		
Conversion, %	74.4	(2.1)	(2.7)	(2.6)
Octane Catalyst, %	15.0			
FCC Gasoline Splitters		19.3	20.8	20.8
FCC Gasoline Fractionation	15.2	(15.2)	(15.2)	(15.2)
Hydrocracking - 2 Stage(2)	16.9			
Jet Yield, % of Max	96.7	(31.5)	(67.6)	(67.3)
300 - Gasoline Operation, %			37.8	57.4
Hydrocracking - Low Conversion	3.2	1.0	1.0	1.0
- Heavy Gasoline			4.1	4.0
- Combined(3)	20.1	1.0	4.1	3.4
Hydrocrackate Fractionation		8.3	10.5	10.4
Lt. Hydrocrackate Splitter			0.2	0.3
Coking - Delayed	22.9			
- Fluid	5.3			
Coker Lt Gasoline DS/Splitter		1.7	1.7	1.7
Thermal Cracking, Visbreaking	2.3	(0.5)		
Solvent Deasphalting	1.0	(0.7)	(0.0)	1.6
Catalytic Reforming - 100 PSI (2)	3.4	(0.3)	(0.3)	
- 200 PSI (2)	16.6	(2.0)	(1.0)	(3.1)
- 450 PSI (2)	8.9	(2.9)	(2.3)	(2.3)
- Combined (3)	26.4	(3.7)	(1.3)	(3.1)
- RONC	99.2	(2.9)	(5.7)	(4.1)
Hydrotreating - Naphtha	18.8	1.1	3.8	2.7
- Distillate	22.0	3.3	5.5	5.7
- Heavy Gas Oil	31.0		1.6	1.7
- Residuum - Vac	1.4	(0.1)		
Reformer Feed Fractionation		16.0	16.5	15.4
Reformate Fractionation		12.8	13.7	19.3
Benzene Saturation		4.1	4.1	5.7
FCC Gasoline HDS		1.3		3.9
Gasoline Aromatics Saturation				
Diesel Aromatics Saturation	11.7		(0.3)	(0.2)
Alkylation	6.6		4.4	5.1
Alkylate Splitter			4.5	2.7
Polymerization		0.1		
MTBE / TAME	0.8	0.4	0.4	0.3
Lubes	1.3			
Isomerization - C5/C6		1.0	2.7	1.8
- C5/C6, Recycle	0.4		3.2	4.0
- C4	0.3	0.2	1.2	1.4
Hydrogen - MMSCFPCD	58.1	8.0	24.7	26.6
Sulfur, LTPCD	130.0	(7.0)	(3.0)	(4.0)

(1) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.
(2) Include effects of nonunitary capacity for some feedstocks and severities.
(3) Based on actual feed rates, ignoring severity effects.

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TABLE I-7

PROCESS UNIT UTILIZATIONS (1)

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

	Base	ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+ (2)	
	Case 0	Case 30	Case 31	Case 32
Crude Distillation - Atmospheric	89.2	84.6	87.9	89.2
Heavy Naphtha Splitter			95.0	95.0
Catalytic Cracking (3)	95.0	87.5	95.0	95.0
Catalytic Cracking (4)	96.2	88.7	96.2	96.2
FCC Gasoline Splitters		95.0	95.0	95.0
FCC Gasoline Fractionation	84.9			
Hydrocracking - 2 Stage(3)	88.0	88.0	88.0	88.0
- Low Conversion	67.0	88.0	88.0	88.0
- Heavy Gasoline			88.0	88.0
- Combined(4)	83.8	88.0	84.3	82.3
Hydrocrackate Fractionation		88.0	88.0	88.0
Lt. Hydrocrackate Splitter			88.0	88.0
Coking - Delayed	95.0	95.0	95.0	95.0
- Fluid	95.0	95.0	95.0	95.0
Coker Lt Gasoline DS/Splitter		95.0	95.0	95.0
Thermal Cracking, Visbreaking	88.0	69.6	88.0	88.0
Solvent Deasphalting	32.5	8.0	32.3	88.0
Catalytic Reforming - 100 PSI (3)	88.0	80.5	80.5	88.0
- 200 PSI (3)	88.0	77.3	82.7	71.7
- 450 PSI (3)	88.0	58.7	65.6	65.6
- Combined (4)	80.4	69.2	76.6	71.0
Hydrotreating - Naphtha	66.7	70.6	80.2	76.1
- Distillate	88.0	88.0	88.0	88.0
- Heavy Gas Oil	85.8	85.8	88.0	88.0
- Residuum, Vac	88.0	84.4	88.0	88.0
Reformer Feed Fractionation		88.0	88.0	88.0
Reformate Fractionation		88.0	88.0	88.0
Benzene Saturation		83.0	83.0	83.0
FCC Gasoline HDS		88.0		88.0
Gasoline Aromatics Saturation				
Diesel Aromatics Saturation	88.0	88.0	86.0	86.1
Alkylation	83.0	83.0	83.0	83.0
Alkylate Splitter			83.0	83.0
Polymerization	0.0	12.8	0.0	0.0
MTBE / TAME	83.0	83.0	83.0	83.0
Lubes	87.6	87.6	87.6	87.6
Isomerization - C5/C6		88.0	88.0	88.0
- C5/C6, Recycle	88.0	88.0	88.0	88.0
- C4	83.0	83.0	83.0	83.0
Hydrogen	72.9	83.0	83.0	83.0
Sulfur	45.9	43.5	44.9	44.5

(1) Calendar day rates divided by stream day capacity.
(2) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.
(3) Include effects of nonunitary capacity factors for some feedstocks and severities.
(4) Based on actual feed rates, ignoring severity effects.

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TABLE I-8

GASOLINE POOL COMPOSITIONS

1996 CASE RESULTS – %

WSPA STUDY OF CARB PHASE 2 GASOLINE

		ALTERNATE C	10/4/91 CARB 2 PROPOSAL +L/B CMPL MGNS+ (1)	
	Base Case 0	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
FCC Gasoline	11.1			
Lt. FCC 255-	15.0			
Hvy FCC 255+	10.5			
Hvy FCC 255+ Desul		2.1		6.4
FCC Gaso (100-180)		6.4	1.8	2.0
FCC Gaso (180-225)		3.4	4.0	4.0
FCC Gaso (225-300)		7.6	5.8	1.8
FCC Gaso (300-375)		2.2		
Total FCC Gasoline	36.6	21.7	11.6	14.2
Pentenes		1.8		
Poly Gasoline		0.1		
Lt. Coker Gasoline	2.8			
Total Olefinic	2.8	1.9	0.0	0.0
Reformate	22.2	4.4		
Reformate (220-300 Feed)	5.9	5.3	12.6	0.3
BT Reformate	7.2			
HC Reformate (210-300)		9.4	11.3	17.7
Heavy Reformate (300+)		4.9	1.8	2.0
Total Reformates(2)	35.3	24.0	25.7	20.0
Lt. Reformate (Benzene Saturated)		6.8	6.9	9.6
Alkylate/Lt Alkylate (C3/C4)	10.9	10.5	12.6	13.6
Alkylate/Lt Alkylate (C5)			3.4	3.4
Butane	2.5	2.2	1.5	1.5
Natural/LSR Gaso	3.8	4.2		
Iso Pentane		3.0	0.1	
Normal Pentane		0.6		
Isomerate (C5-C6)	0.6	0.5	3.2	3.3
Isomerate (C6)		1.7	7.1	6.9
Lt. Hydrocrackate	5.0	5.6	9.1	8.9
Hydrocrackate (175-225)	0.5	6.1	7.6	7.4
MTBE	2.0	10.4	10.4	10.4
TAME		0.7	0.8	0.8
Total Low Arom., Saturated	25.3	52.3	62.7	65.8
Total	102.8	100.0	100.0	100.0

(1) Like Case 25 except added Lt. hydrocrackate splitter for added C5 sales.
(2) Excluding light reformate.

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TABLE I-9

GASOLINE PROPERTY DECREASE – INCREMENTAL COSTS(1)

1996 CASE RESULTS

WSPA STUDY OF CARB PHASE 2 GASOLINE

(¢/G per unit in constant 1991 $)

		ALTERNATE B + CHANGES		ALTERNATE C	10/4 CARB 2 PROPOSAL +L/B CMPL MGNS+ (2)	
	Base Case 0	Case 28 + None	Case 29 - 50 S	Case 30 Knees	Case 31 +.2 B/10 S	Case 32 + None
(R+M)/2 Octane, Clear	(0.9)	(1.2)	(1.2)	(0.5)	(2.0)	(2.2)
Reid Vapor Pressure, PSI	0.6	0.8	0.9	0.7	5.6	5.6
Butane, Vol.%					2.2	2.3
Aromatics, Vol.%		0.3	0.4		0.5	0.5
Ethers, Vol.%	(0.1)	(0.1)	(0.1)	(0.3)	0.1	0.1
Olefins, Vol.%		0.2		0.2	0.5	
Benzene, Vol.%		2.2	3.0	2.6	2.5	5.6
Sulfur, 100 Wt. PPM		1.0	5.8	2.5	2.4	11.0
T90, 10°F		0.1	0.2	0.6	3.7	3.4

(1) Shadow costs for very small changes.
Not applicable for significant changes.

(2) Like Case 25 except added Lt. Hydrocrackate splitter for added C5 sales.

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TABLE X-1
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 21 GASOLINE POOL
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS % OF BLEND						
Normal Butane		2.0	2.0		(0.0)	
Reformate LF-Low Oct		7.6	7.6		0.0	
Lt Reformate (C5-210)		0.7	0.7		(0.0)	
HC Reformate-Low Oct		5.8	5.8		(0.0)	
HC Reformate-Hi Oct		14.3	14.3		0.0	
FCC Gaso (180-225)		1.7	1.7		(0.0)	
Lt Hydrocrackate		8.1	8.1		0.0	
Med Hydrocrackate		10.0	10.0		(0.0)	
Lt Alkylate		14.3	14.3		(0.0)	
Isomerate C5/C6		8.6	8.6		(0.0)	
Lt Reformate Bz Sat		12.0	12.0		(0.0)	
MTBE/TAME		15.1	15.1		(0.0)	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	88.9	88.9	88.9	0.0	0.0	0.0
Aromatics, V%	20	20	20	0	0	0
Ethers, V%	15.0	15.0	15.0	0.0	0.0	0.0
Oxygen, W%	2.7	2.7	2.7	0.0	0.0	0.0
Olefins, V%	1	1	1	0	0	0
Bromine No.	1	1	1	0	0.0	0
Benzene, V%	0.60	0.60	0.60	0.00	0.00	0.00
Sulfur, WPPM	10	10	10	0	0	0
RVP, PSI	6.5	6.5	6.5	0.0	0.0	0.0
Temp. @ V/L = 20, Deg. F	145	145	145	0	0	0
Distillation: 10V%, Deg.F	149	149	149	0	0	0
50V%, Deg.F	187	187	187	0	0	0
90V%, Deg.F	270	270	270	0	0	0
Driveability Index	1,055	1,055	1,055	0	0	0
Heat Content, MBTU/Gal	110.0	110.0	110.0	0.0	0.0	0.0

(1) Adjusted to physically available components.
(2) Seventh pass.
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TABLE X-2
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 21 REFORMULATED UNLEADED REGULAR
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	2.0		(0.0)	
Reformate LF-Low Oct		9.6	13.5		3.9	
Lt Reformate (C5-210)		0.0	0.0		0.0	
HC Reformate-Low Oct		4.2	7.7		3.5	
HC Reformate-Hi Oct		15.1	11.4		(3.7)	
FCC Gaso (180-225)		1.5	2.7		1.2	
Lt Hydrocrackate		11.2	9.4		(1.8)	
Med Hydrocrackate		16.4	9.2		(7.1)	
Lt Alkylate		8.6	5.8		(2.7)	
Isomerate C5/C6		2.7	6.6		3.9	
Lt Reformate Bz Sat		13.7	16.4		2.7	
MTBE/TAME		15.0	15.1		0.1	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	87.4	87.9	87.5	0.5	(0.4)	0.1
Aromatics, Vol. %	20	21	21	1	0	1
Ethers, Vol. %	15	14.9	15.0	(0.1)	0.1	0.0
Oxygen, Wt. %	2.7	2.7	2.7	(0.0)	0.0	0.0
Olefins, Vol. %	0.5	0	1	(0)	0	0
Bromine No.	1	1	2	(0)	0.8	1
Benzene, Vol. %	0.8	0.79	0.68	(0.01)	(0.11)	(0.12)
Sulfur, Wt. ppm	10	10	10	0	(0)	(0)
RVP, psi	6.5	6.5	6.5	0.0	(0.0)	(0.0)
Temp. @ V/L = 20, Deg. F	145	145	145	0	(0)	(0)
Distillation: T10, Deg.F	146	145	146	(1)	1	0
T50, Deg.F	189	189	187	(0)	(2)	(2)
T90, Deg.F	270	269	271	(1)	2	1
Driveability Index	1056	1,053	1,051	(3)	(2)	(5)
Heat Content, MBTU/Gal	109.7	109.9	109.9	0.2	(0.0)	0.2

(1) Adjusted to physically available components.
(2) Seventh Pass.
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TABLE X-3
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 21 REFORMULATED UNLEADED INTERMEDIATE
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	2.0		0.0	
Reformate LF-Low Oct		6.7	0.7		(5.9)	
Lt Reformate (C5-210)		3.4	0.0		(3.4)	
HC Reformate-Low Oct		17.1	7.6		(9.5)	
HC Reformate-Hi Oct		4.8	15.2		10.4	
FCC Gaso (180-225)		1.8	0.5		(1.3)	
Lt Hydrocrackate		9.6	10.8		1.2	
Med Hydrocrackate		4.3	17.8		13.4	
Lt Alkylate		16.3	15.5		(0.8)	
Isomerate C5/C6		13.6	7.9		(5.7)	
Lt Reformate Bz Sat		4.9	6.9		2.0	
MTBE/TAME		15.4	15.1		(0.3)	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	89.3	89.0	89.2	(0.3)	0.2	(0.1)
Aromatics, Vol. %	20	18	20	(2)	2	(0)
Ethers, Vol. %	15	15.3	15.0	0.3	(0.3)	0.0
Oxygen, Wt. %	2.7	2.8	2.7	0.1	(0.1)	0.0
Olefins, Vol. %	0.5	1	0	0	(0)	(0)
Bromine No.	1	1	0	0	(0.7)	(1)
Benzene, Vol. %	0.8	0.80	0.74	0.00	(0.06)	(0.06)
Sulfur, Wt. ppm	10	10	10	0	(0)	(0)
RVP, psi	6.5	6.5	6.5	0.0	(0.0)	(0.0)
Temp. @ V/L = 20, Deg. F	144	145	145	1	(0)	1
Distillation: T10, Deg.F	153	157	152	4	(5)	(1)
T50, Deg.F	192	190	189	(2)	(1)	(3)
T90, Deg.F	269	269	265	0	(4)	(4)
Driveability Index	1,075	1,074	1,060	(1)	(14)	(14)
Heat Content, MBTU/Gal	109.7	109.9	110.0	0.2	0.1	0.3

(1) Adjusted to physically available components.
(2) Seventh pass.
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TABLE X-4
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 21 REFORMULATED UNLEADED PREMIUM
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	2.0		0.0	
Reformate LF-Low Oct		3.7	0.0		(3.7)	
Lt Reformate (C5-210)		0.0	2.8		2.8	
HC Reformate-Low Oct		0.0	0.0		0.0	
HC Reformate-Hi Oct		20.2	19.8		(0.4)	
FCC Gaso (180-225)		2.0	0.3		(1.7)	
Lt Hydrocrackate		0.2	3.1		2.9	
Med Hydrocrackate		0.6	5.3		4.7	
Lt Alkylate		25.1	31.8		6.7	
Isomerate C5/C6		17.2	13.4		(3.8)	
Lt Reformate Bz Sat		14.0	6.5		(7.6)	
MTBE/TAME		15.0	15.1		0.1	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	92.0	91.2	91.9	(0.8)	0.7	(0.1)
Aromatics, Vol. %	20	19	18	(1)	(1)	(2)
Ethers, Vol. %	15	14.9	15.0	(0.1)	0.1	0.0
Oxygen, Wt. %	2.7	2.7	2.7	(0.0)	0.0	0.0
Olefins, Vol. %	1	1	0	(0)	(0)	(1)
Bromine No.	1	1	0	(0)	(1.0)	(1)
Benzene, Vol. %	0.2	0.19	0.48	(0.01)	0.29	0.28
Sulfur, Wt. ppm	10	10	10	0	0	0
RVP, psi	6.5	6.5	6.5	(0.0)	0.0	(0.0)
Temp. @ V/L = 20, Deg. F	143	143	144	0	1	1
Distillation: T10, Deg.F	154	155	158	1	3	4
T50, Deg.F	181	184	188	3	4	7
T90, Deg.F	269	271	269	2	(2)	0
Driveability Index	1,043	1,054	1,070	11	16	27
Heat Content, MBTU/Gal	110.3	110.2	110.2	(0.1)	0.1	(0.1)

(1) Adjusted to physically available components.
(2) Seventh pass.
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TABLE X-5
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENT USAGE - MBPCD
THEORETICAL TO PHYSICAL COMBINATIONS - CASE 21
WSPA STUDY OF CARB PHASE 2 GASOLINE

	TOTAL	RUR	RUI	RUP
NORMAL BUTANE	1,235	676	251	309
REFORMATE LF (80 RON)	4,546	3,136	838	571
REFORMATE LF (90 RON)	121	121		
LT REFORMATE(C5-210)	429		429	
HC REFORMATE(210-300)9	1,420	1,420		
HC REFORMATE(210-300)B	2,148		2,148	
HC REFORMATE(210-300)0	4,441	3,840	600	
HC RFMTE LT(210-300)0	4,377	1,263		3,114
FCC (180-225) LO ON/LS	483	236	105	142
FCC (180-225) HI ON/LS	555	271	121	163
LIGHT HYDROCRACKATE	5,018	3,781	1,202	34
MED HYDROCRK CRFD	4,096	3,555	541	
MED HYDROCRK VRFD	2,062	1,975		87
LT ALKY (PROPYLENE)	3,290	2,895		395
LT ALKY (BUTYLENE)	3,502		19	3,483
LT ALKY (AMYLENE)	2,027		2,027	
ISOMERATE PEN/HEX	8	3		5
ISOMERATE-C6	4,920	922	1,711	2,287
TIPATE-C6	370			370
LT REFORMATE B(C5-210)	7,391	4,617	611	2,163
MTBE	8,849	5,071	1,461	2,318
TAME	473		473	
	61,761	33,782	12,537	15,441

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TABLE X-6
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 8 GASOLINE POOL
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	2.0		0.0	
Desulfurized C5s		1.4	1.4		-0.0	
Natural Gasoline		0.4	0.4		-0.0	
LSR Gasoline		2.4	2.4		-0.0	
Reformate-Low Oct		7.9	7.9		-0.0	
HC Reformate-Low Oct		3.9	3.9		-0.0	
HC Reformate-Hi Oct		10.8	10.8		-0.0	
Hvy Reformate		4.7	4.7		-0.0	
FCC Gaso (100-180)		6.3	6.3		-0.0	
FCC Gaso (180-225)		3.8	3.8		-0.0	
FCC Gaso (225-300)		0.2	0.2		-0.0	
FCC Gaso (225-375) Desul		2.3	2.3		-0.0	
Lt Hydrocrackate		7.7	7.7		-0.0	
Med Hydrocrackate		7.2	7.2		-0.0	
Alkylate		15.1	15.1		-0.0	
Isomerate C5/C6		3.1	3.1		-0.0	
Lt Reformate Bz Sat		9.3	9.3		-0.0	
MTBE/TAME		11.7	11.7		-0.0	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	88.9	88.9	88.9	0	0	0
Aromatics, Vol. %	22	22	22	0	(0)	0
Ethers, Vol. %	11.7	11.7	11.7	(0)	(0)	(0)
Oxygen, Wt. %	2.1	2.1	2.1	0	(0)	0
Olefins, Vol. %	4	4	4	(0)	(0)	(0)
Bromine No.	7	7	7	(0)	(0)	(0)
Benzene, Vol. %	0.8	0.8	0.8	0	(0.0)	0
Sulfur, Wt. ppm	20	20	20	0	(0)	0
RVP, psi	6.7	6.7	6.7	(0)	0	0
Temp. @ V/L = 20, Deg. F	144	144	144	0	(0)	0
Distillation: T10, Deg.F	139	139	139	(0)	(0)	(0)
T50, Deg.F	192	192	192	(0)	(0)	(0)
T90, Deg.F	292	292	292	(0)	(0)	(0)
Driveability Index	1076	1,076	1,076	(0)	(0)	(0)
Heat Content, MBTU/Gal	110.9	110.9	110.9	0	(0)	0

(1) Adjusted to physically available components.
(2) First pass.
CLM 11/13/91

TABLE X-7
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 8 REFORMULATED UNLEADED REGULAR
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	2.1		0.1	
Desulfurized C5s		0.6	2.3		1.7	
Natural Gasoline		0.7	0.7		(0.0)	
LSR Gasoline		0.0	2.1		2.1	
Reformate-Low Oct		14.4	8.1		(6.3)	
HC Reformate-Low Oct		4.6	7.1		2.5	
HC Reformate-Hi Oct		5.5	5.2		(0.4)	
Hvy Reformate		6.0	6.6		0.7	
FCC Gaso (100-180)		3.3	5.0		1.7	
FCC Gaso (180-225)		6.9	4.3		(2.6)	
FCC Gaso (225-300)		0.2	0.0		(0.2)	
FCC Gaso (225-375) Desul		2.9	4.1		1.2	
Lt Hydrocrackate		10.6	2.2		(8.4)	
Med Hydrocrackate		7.2	9.2		2.0	
Alkylate		7.4	7.2		(0.3)	
Isomerate C5/C6		4.0	5.6		1.6	
Lt Reformate Bz Sat		12.0	16.5		4.5	
MTBE/TAME		11.7	11.7		(0.0)	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	87.4	87.6	87.3	0.2	(0.2)	(0.1)
Aromatics, Vol. %	22	22	22	0	(0)	0
Ethers, Vol. %	11.7	11.6	11.6	(0.1)	(0.0)	(0.1)
Oxygen, Wt. %	2.1	2.1	2.1	(0.0)	(0.0)	(0.0)
Olefins, Vol. %	3	3	3	(0)	(0)	(0)
Bromine No.	7	7	6	(0)	(0)	(0)
Benzene, Vol. %	0.80	0.90	0.79	0.10	(0.11)	(0.01)
Sulfur, Wt. ppm	20	20	17	0	(3)	(3)
RVP, psi	6.7	6.6	6.7	(0.1)	0.1	0.0
Temp. @ V/L = 20, Deg. F	145	146	144	1	(1)	(1)
Distillation: T10, Deg.F	139	139	134	(0)	(5)	(5)
T50, Deg.F	192	193	189	1	(4)	(3)
T90, Deg.F	292	293	294	1	1	2
Driveability Index	1,077	1,080	1,062	3	(18)	(15)
Heat Content, MBTU/Gal	110.6	110.8	110.7	0.2	(0.1)	0.1

(1) Adjusted to physically available components.
(2) First pass.
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TABLE X-8
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 8 REFORMULATED UNLEADED INTERMEDIATE
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	1.8		(0.2)	
Desulfurized C5s		5.2	0.5		(4.7)	
Natural Gasoline		0.0	0.0		0.0	
LSR Gasoline		6.5	6.2		(0.3)	
Reformate-Low Oct		0.0	16.9		16.9	
HC Reformate-Low Oct		6.7	0.0		(6.7)	
HC Reformate-Hi Oct		12.5	16.8		4.4	
Hvy Reformate		2.9	0.0		(2.9)	
FCC Gaso (100-180)		9.0	4.6		(4.4)	
FCC Gaso (180-225)		0.0	6.7		6.7	
FCC Gaso (225-300)		0.6	1.1		0.5	
FCC Gaso (225-375) Desul		2.7	0.0		(2.7)	
Lt Hydrocrackate		0.0	13.1		13.1	
Med Hydrocrackate		8.3	0.0		(8.3)	
Alkylate		19.2	18.9		(0.3)	
Isomerate C5/C6		1.5	0.0		(1.5)	
Lt Reformate Bz Sat		11.0	1.5		(9.5)	
MTBE/TAME		11.9	11.9		0.0	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	89.3	89.2	89.6	(0.1)	0.3	0.3
Aromatics, Vol. %	22	20	23	(2)	3	1
Ethers, Vol. %	11.7	11.8	11.8	0.1	0.0	0.1
Oxygen, Wt. %	2.1	2.1	2.1	0.0	0.0	0.0
Olefins, Vol. %	4	4	4	(0)	0	0
Bromine No.	7	7	8	(0)	1	1
Benzene, Vol. %	0.80	0.66	0.85	(0.14)	0.19	0.05
Sulfur, Wt. ppm	20	20	25	(0)	5	5
RVP, psi	6.7	7.0	6.8	0.3	(0.2)	0.1
Temp. @ V/L = 20, Deg. F	143	141	144	(2)	3	1
Distillation: T10, Deg.F	131	131	142	0	10	11
T50, Deg.F	192	187	200	(5)	13	8
T90, Deg.F	292	286	284	(6)	(2)	(8)
Driveability Index	1,063	1,043	1,095	(20)	52	32
Heat Content, MBTU/Gal	111.3	110.6	111.3	(0.7)	0.7	(0.0)

(1) Adjusted to physically available components.
(2) First pass.
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ARCO et al. v. UNOCAL et al.
U.S. District Court (C.D. Ca.)
C.A. No. 95-2379 KMW (JRx)
SUBJECT TO PROTECTIVE ORDER
30277

TABLE X-9
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENTS COMBINED
CASE 8 REFORMULATED UNLEADED PREMIUM
WSPA STUDY OF CARB PHASE 2 GASOLINE

	Refinery LP	Adjusted Refinery LP(1)	Gaso. Blending LP(2)	ARLP Minus RLP	GBLP Minus ARLP	GBLP Minus RLP
COMPONENTS, % OF BLEND						
Normal Butane		2.0	1.9		(0.1)	
Desulfurized C5s		0.0	0.0		0.0	
Natural Gasoline		0.0	0.0		0.0	
LSR Gasoline		4.2	0.0		(4.2)	
Reformate-Low Oct		0.0	0.0		0.0	
HC Reformate-Low Oct		0.0	0.0		0.0	
HC Reformate-Hi Oct		21.0	18.2		(2.8)	
Hvy Reformate		3.1	4.1		0.9	
FCC Gaso (100-180)		10.4	10.3		(0.1)	
FCC Gaso (180-225)		0.0	0.2		0.2	
FCC Gaso (225-300)		0.0	0.0		(0.0)	
FCC Gaso (225-375) Desul		0.4	0.0		(0.4)	
Lt Hydrocrackate		7.8	15.5		7.7	
Med Hydrocrackate		6.4	8.8		2.4	
Alkylate		28.4	29.2		0.8	
Isomerate C5/C6		2.2	0.0		(2.2)	
Lt Reformate Bz Sat		2.2	0.0		(2.2)	
MTBE/TAME		11.8	11.8		0.0	
		100.0	100.0			
GASOLINE PROPERTIES						
(R+M)/2 Octane, Clear	92.0	91.7	91.9	(0.3)	0.3	(0.1)
Aromatics, Vol. %	22	22	21	0	(1)	(1)
Ethers, Vol. %	11.7	11.7	11.7	0.0	0.0	0.0
Oxygen, Wt. %	2.1	2.1	2.1	0.0	0.0	0.0
Olefins, Vol. %	4	4	4	(0)	0	(0)
Bromine No.	8	8	8	(0)	0	(0)
Benzene, Vol. %	0.8	0.70	0.79	(0.10)	0.09	(0.01)
Sulfur, Wt. ppm	20	20	22	(0)	2	2
RVP, psi	6.7	6.6	6.6	(0.1)	(0.0)	(0.1)
Temp. @ V/L = 20, Deg. F	144	145	145	1	1	1
Distillation: T10, Deg.F	142	144	146	2	2	4
T50, Deg.F	193	194	194	1	(1)	1
T90, Deg.F	292	292	295	0	3	3
Driveability Index	1084	1,092	1,095	8	3	11
Heat Content, MBTU/Gal	111.5	111.5	111.3	0.0	(0.2)	(0.2)

(1) Adjusted to physically available components.
(2) First pass.
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TABLE X-10
GASOLINE BLENDS USING REFINERY PRODUCIBLE COMPONENTS
REFINERY LP COMPONENT USAGE
THEORETICAL TO PHYSICAL COMBINATIONS - CASE 8
WSPA STUDY OF CARB PHASE 2 GASOLINE

	TOTAL	RUR	RUI	RUP
NORMAL BUTANE	1,227	671	249	307
HT NAT GASO VLS	235	235		
HT LSR(C5-150)ION/VLS	807		807	
HT LSR(C5-150)HON/VLS	649			649
REFORMATE LF (80 RON)	3,517	3,517		
REFORMATE LF (90 RON)	1,327	1,327		
HC REFORMATE(210-300)9	865	865		
HC REFORMATE(210-300)B	1,517	682	835	
HC REFORMATE(210-300)0	3,457		241	3,216
HC RFMTE LT(210-300)0	3,163	1,853	1,310	
HVY RFMTE(300+)100	2,336	2,010		326
HVY RFMTE LT(300+)100	521		365	156
NORMAL PENTANE LS	121	121		
ISO PENTANE LS	644		644	
HT NORMAL PENTANE VLS	15	15		
HT ISO PENTANE VLS	53	53		
FCC (100-180) LO ON/LS	1,796	517	534	745
FCC (100-180) HI ON/LS	2,043	595	591	857
FCC (180-225) LO ON/LS	1,078	1,078		
FCC (180-225) HI ON/LS	1,226	1,226		
FCC (225-300) HI ON/LS	140	57	77	6
FCC GS ST(225-300)LOLS	619	485	129	5
FCC GS ST(225-300)HOLS	573	501	72	
FCC GS ST(300-375)LOLS	93		64	29
FCC GS ST(300-375)HOLS	107		74	33
LIGHT HYDROCRACKATE	4,750	3,554		1,196
MED HYDROCRK CRFD	2,190	167	1,036	987
MED HYDROCRK VRFD	2,247	2,247		
PROPYLENE ALKYLATE	3,415	2,499	216	700
BUTYLENE ALKYLATE	3,655			3,655
ALKYLATE (AMYLENE)	2,180		2,180	
ISOMERATE PEN/HEX	1,342	1,342		
TIPATE	371	15	19	337
ISOMERATE-C6	165		165	
LT REFORMATE B(C5-210)	5,710	4,016	1,364	330
MTBE	6,789	3,917	1,212	1,660
TAME	418		271	147
	61,361	33,565	12,455	15,341

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TABLE Y-1
REDUCE C8/C9 AROMATICS IN GASOLINE
1996 CASE RESULTS COMPARISONS
WSPA STUDY OF CARB PHASE 2 GASOLINE

	CARB 1	CARB 2 PROPOSALS			
Gasoline Properties*	Case 0 Base	Case 23 10/4 AVG No Comply Margins	Case 25 10/4 Flat Limits	Case 21 8/5 Flat Limits	Rough Estimate GM Target
Aromatics, %	34	25	20	20	12
Benzene	2.2	0.95	0.6	0.6	0.8
Toluene	8	7	7	7	10
C8 Aromatics (DI)	10	10	11	11	1
C9 + Aromatics (TRI)	14	7	2	1	0
Ether, %	2	10	11	15	24
Low Arom., Saturated, % (1)	25	54	64	71	88
Distillation					
@ 257 °F, %	67	76	80	86	96
@ 300 °F, %	87	90	96	100	100
T10, °F	125	132	144	149	155
T50, °F	212	196	193	187	180
T90, °F	348	300	280	270	240
Driveability Index	1,171	1,086	1,075	1,055	1,010
Sales, % of Gasoline Pool					
Pentanes	0	0	4	8	16
C8 Aromatics	0	0	0	0	4
Cost Over Base Case					
Investment ($MMM)	0	3–6	6–10	8–12	~16–22 (2)
Unit Gasoline Pool (¢/G)	0	11–16	20–28	26–36	~45–60 (2)

(1) Components in gasoline pool.
(2) Conservative ballpark guesstimate.

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